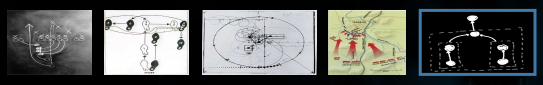
Building a Better Battle

The Halo 3 AI Objectives System



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Building A Better Battle

Designer tools

AI is an integral part of it

An interesting *Next-Gen* problem

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"Big Battle" Technology
Precombat
Combat dialogue
Ambient sound
Scalable perception
Flocking
Encounter logic
Effects
Targeting groups
In-game cinematics
Scalable AI
Mission dialogue
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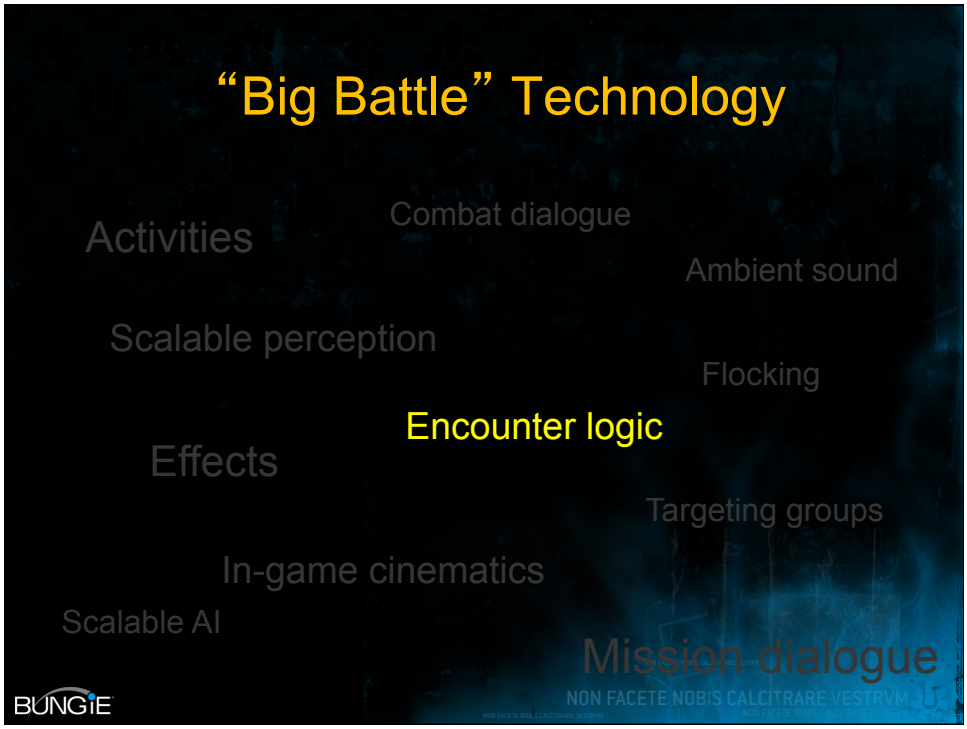
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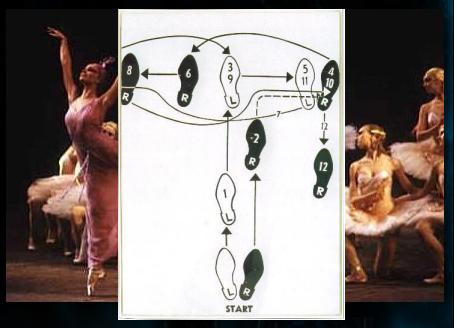
Encounter Design

- Encounters are *systems*
- Lots of guys
- Lots of things to do
- The system reacts in interesting ways
- The system collapses in interesting ways



An encounter is a complicated dance with lots of dancers

How is this dance choreographed?

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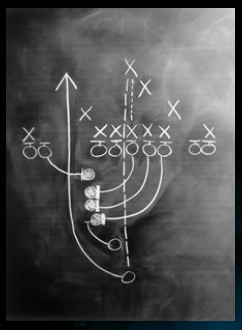
Choreography 101

- The dance is about the illusion of strategic intelligence
- Strategy is environment- story- and pacing-dependent

Designer provides the strategic intelligence



AI acts smart within the confines of the plan provided by the designer

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The Canonical Encounter

Two-stage fallback

- Enemies occupy a territory
- Pushed to *"fallback"* point
- Pushed to *"last-stand"* point
- Player "breaks" them
- Player finishes them off

... plus a little "spice"

- snipers
- turrets
- dropships

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Task

The *mission designers'* language for telling the AI what it should be doing

Halo:

- Territory
- Behavior
  - aggressiveness
  - rules of engagement
  - player following

Changing task moves AI around the encounter space

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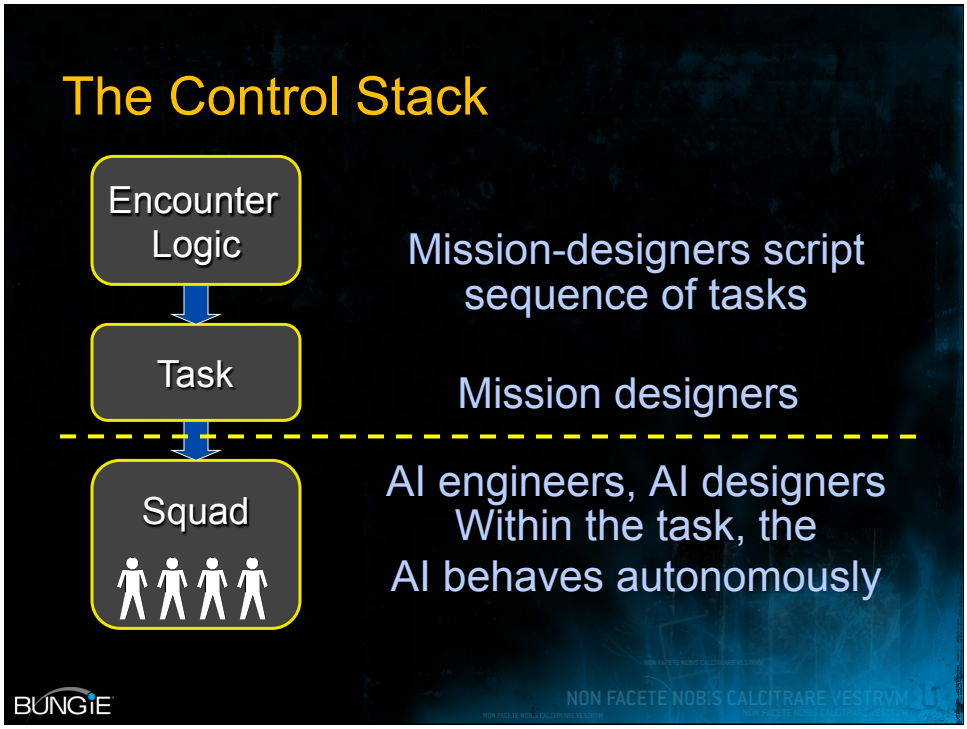
The Control Stack
Encounter Logic
Task
Squad
Mission-designers script sequence of tasks
Mission designers
AI engineers, AI designers
Within the task, the
AI behaves autonomously
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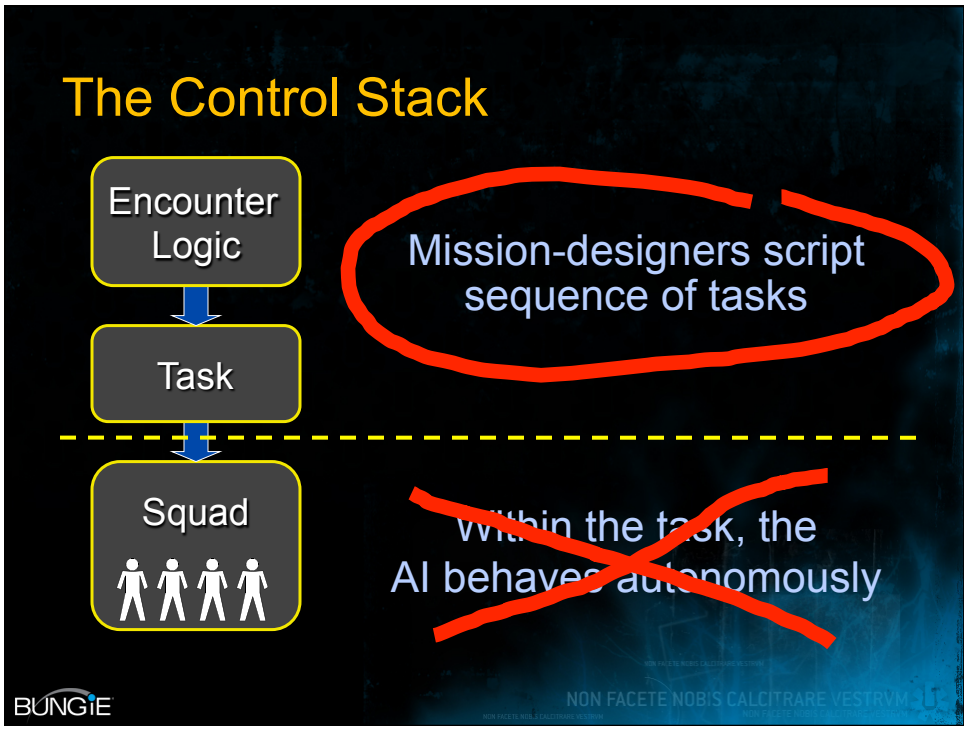
The Control Stack
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Mission-designers script sequence of tasks
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Halo 2: The Imperative Method

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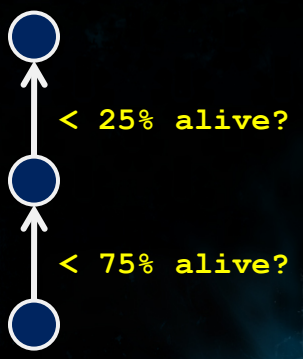
The Imperative Method

Give the designers an FSM construction tool



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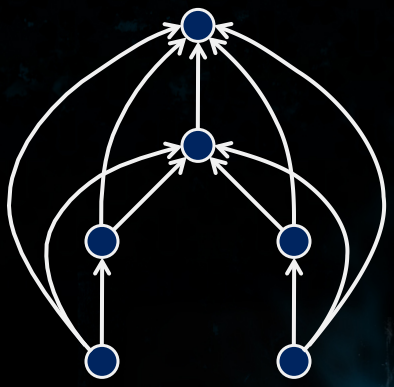
Problems with the Imperative Method



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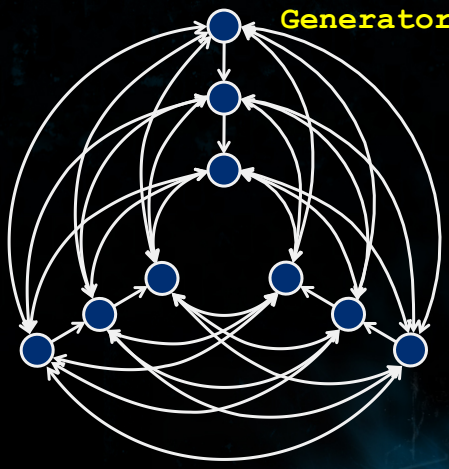
Problems with the Imperative Method



Explicit transitions → n^2 complexity

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Problems with the Imperative Method

For Halo 3:

- Larger encounters
- More characters
- More open spaces
- More avenues of attack

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Halo 3: The Declarative Method

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The Declarative Method

The new approach:

Enumerate “tasks that need doing” in the environment

Let the system figure out who should perform them

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The Declarative Method

Not without precedent

Similar to “affordances”

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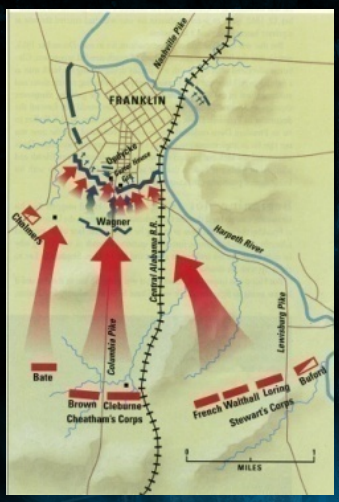
The Declarative Method

Tasks have *structure*

- Relative priorities
  - "The *most important* thing is to guard the door, but if you can, also guard the hallway"
- Are made up of sub-tasks
  - "Guarding the hallway means guarding the front, the middle and the rear of the hallway."



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Behavior Trees

(*Handling Complexity in the Halo 2 AI*, GDC 2005)

Takeaways:

1. Prioritized-list decision scheme
2. Behaviors are self-describing

We are not making a *single* choice.
We are finding a *distribution* across *all* choices.

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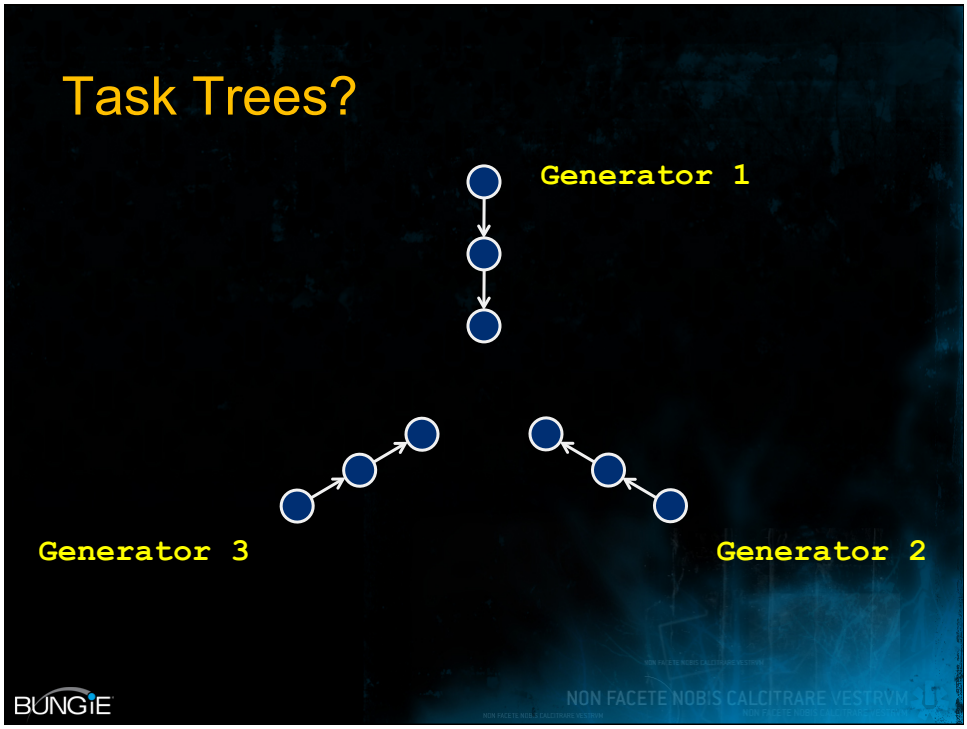
Task Trees?
Generator 1
Generator 3
Generator 2
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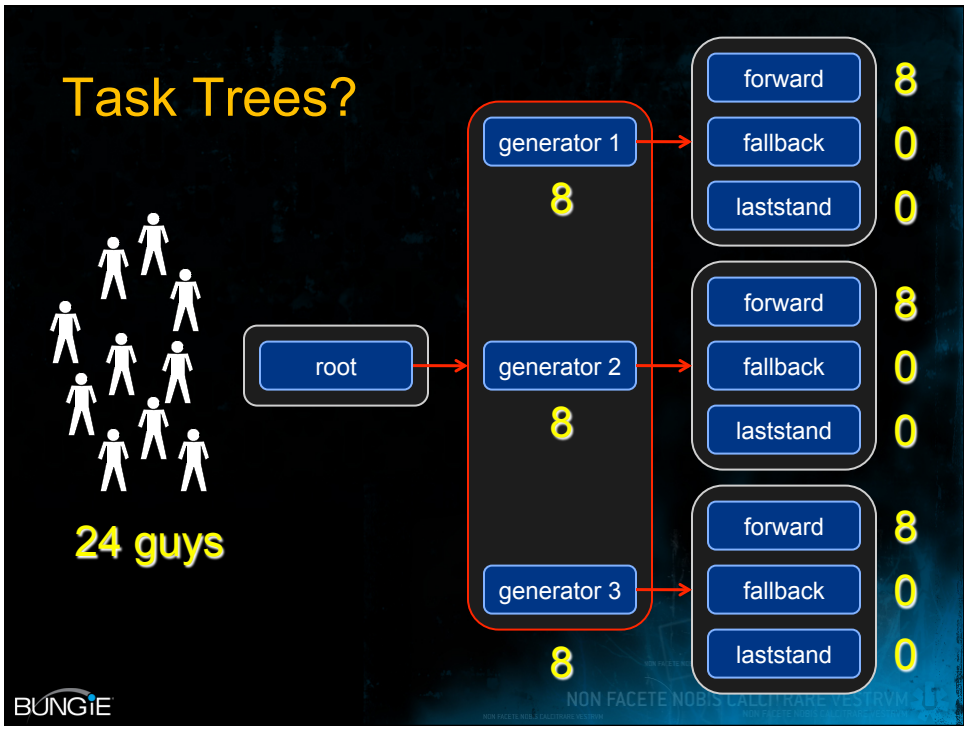
Task Trees?
24 guys
root
generator 1
8
generator 2
8
generator 3
8
forward
fallback
laststand
8
0
0
forward
fallback
laststand
8
0
0
forward
fallback
laststand
8
0
0
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Halo 3 AI Objectives System

The structure:

- A Tree of Prioritized *Tasks*
- Tasks are self-describing
  - priority
  - activation script-fragments
  - capacities

The Algorithm:

- Pour squads in at the top
- Allow them to filter down to the most important tasks to be filling RIGHT NOW

Basically, it's a plinko machine.

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The *Dynamic* Plinko Machine

- Tasks turn themselves on and off
- Squads pulled UP, on activation of a higher-priority task
- Squads pushed DOWN, on deactivation of the task they're in

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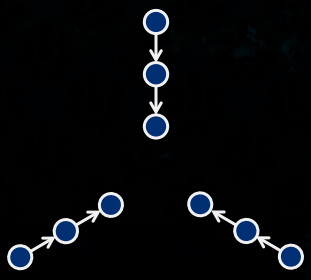
3 Generators Revisited



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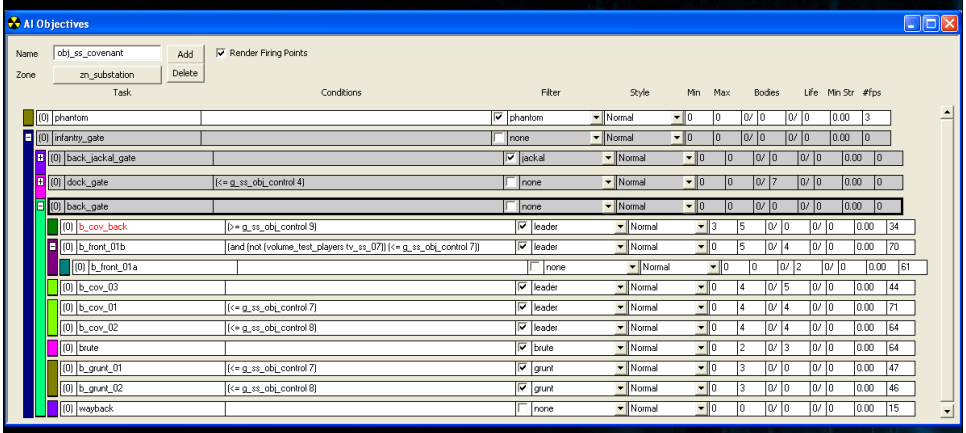
Designer UI



- Integration with HaloScript
- Run-time feedback

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The Algorithm

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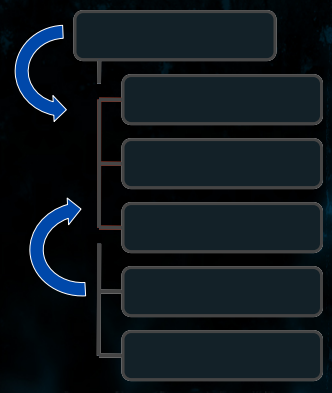
The Algorithm

- Consider a subtree fragment
- Determine which children are active
  - Squads in inactive tasks assigned back up to parent
- Consider top priority group
- Collect squads to attempt to distribute
  - Squads currently in parent
  - Squads in lower-priority tasks
- Distribute Squads
- Recurse for children in top priority-group
- Iterate to next “priority group”



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Squad Distribution

Formally, we have
- set ***S*** of ***n*** squads
- set ***T*** of ***m*** tasks

Now, find a mapping *F : S ➔ T*

Two parts:
1. Respect Task-Capacity Constraints
2. Minimize cost function *H(F)*

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Squad Distribution

1. Respect Task-Capacity Constraints

 # guys assigned to task t ≤ capacity(t)

... but remember, we're bucketing by squads.

This is called ***bin-packing***. And it's NP-Hard.

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Squad Distribution

1. Respect Task-Capacity Constraints

Fortunately

a) there's always Wikipedia
b) we can live with sub-optimal
c) we're optimizing not for *m*, but for ***H(F)***

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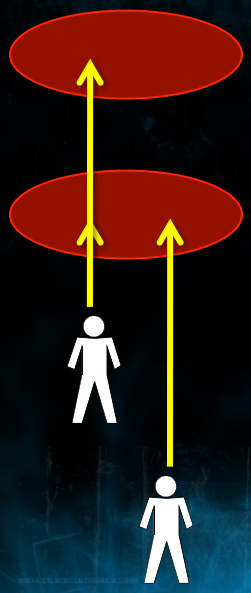
Squad Distribution

2. Minimize cost function *H(F)*

Why a cost function?

- Gives us a basis for choosing one distribution over another
- Weigh different concerns
  - *don't want* to travel far
  - *want* to act coordinated
  - *want* to balance the tree
  - *want* to get near to the player



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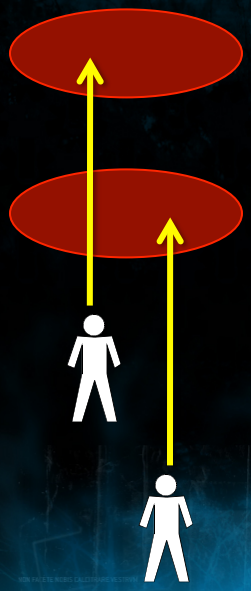
Squad Distribution

2. Minimize cost function *H(F)*

DANGER: AI can look really stupid with wrong H(F)

OPPORTUNITY: Designer has abdicated his decision-making authority



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Squad Distribution

2. Minimize cost function *H(F)*

A class of local cost functions:

$$H(F) = \sum_{s \in S} H\left(s, F(s)\right)$$

We use

$$H(F) = \sum_{s \in S} \text{distance}\left(s, F(s)\right)$$

A Greedy Approach

```
while (S is not empty)

  find pair (s,t) that give the minimum H(s,t)
  for all S x T (where adding s to t would not
  exceed t's capacity)

  if (s,t)
     assign(s, t)
     capacity(t) = capacity(t) - size(s)
     S = S - s
  else
     end
```

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A note on Performance

Our algorithm may be $O(n^2m)$, but we are redeemed by the fact that n and m are small

Other performance improvements

- Cache H(s,t) results
- Timeslice entire trees ← Halo3
- Timeslice nodes within trees

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Filters

Particular tasks only available to particular *kinds* of guys

E.g.

- Must be of character type X
- Must be in vehicles
- Must NOT be in vehicles
- Snipers

"Filters"

- Specify *occupation* conditions (as opposed to *activation* conditions)
- "Trivially" implemented as an inf return value from H(s, t)
- Helpful for the "spice"

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Further Task Refinements

Activation behavior
- Latch on
- Latch off / exhaustion

Exhaustion behavior
- Death count
- Living count

Assignment behavior
- One-time assignment

All of these were designer requests

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Case Studies

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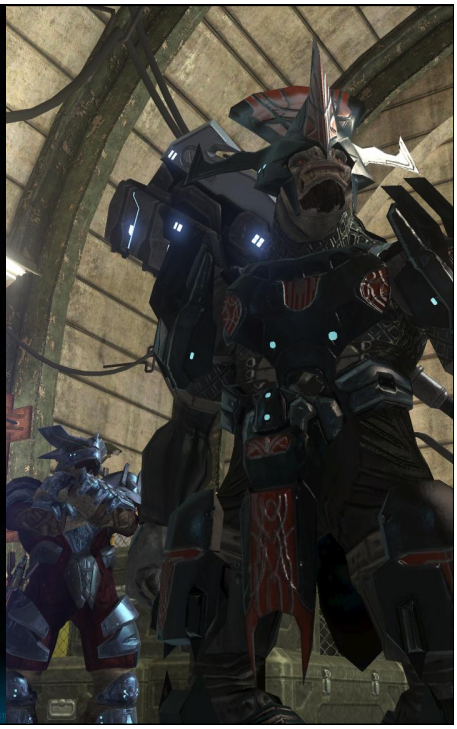
Case Study #1: Leadership

Want to have leaders and followers

- Brute and three grunts
- Brute Chieftan and brute pack

Gameplay

- Leaders provide structure to encounter
- Leader death "breaks" followers



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Case Study #1: Leadership

Two Parts:

1. Leadership-based filters
   - Core task: "leader" filter
   - Peripheral tasks: "NO leader" filter
2. Task "broken" state (leader dead)
   - Task does not allow redistribution in or out while broken
   - NPCs have "broken" behaviors

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Case Study #2: Player pickup

Vehicle encounters are not fun without a vehicle

Gameplay

- When the player needs a vehicle, allies go pick him up

Case Study #2: Player pickup

Implementation: one dedicated player-pickup task per encounter (high priority)

Four parts:

1. vehicle filter
2. player_needs_vehicle() script function
3. “follow player” task option
4. driver player_pickup behavior

And that’s it!


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Summaries
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Badness Summary

- Requires designer training
- Sometimes awkward relationship between scripting system and Objectives
- Tying together allied and enemy “fronts” was complicated.
- The squad wasn’t always the best level at which to do the bucketing
  - e.g. give a guy a sniper rifle ... shouldn’t he then be allowed to occupy a “sniper” task?

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Technique Summary

- Declarative approaches are great
  - less direct control, more manageability
- Hierarchies are great
  - more modular
  - better scalability
- Self-describing tasks makes this whole thing O(n) complexity rather than $O(n^2)$ (conceptually)

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Production Summary

- The Goal: provide a powerful tool for designers to control strategy-level decision-making for a large group of characters
- Flexible enough to incorporate plenty of designer-requested features / modifications
- Great for Prototyping
  - became much more complicated as we neared shippable encounter state
- One-stop-shop for encounter construction

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Summary Summary

Not a problem isolated to Halo

As number of NPCs grows, these kinds of techniques will become more and more important

All you need ...

... is *H(s,t)*

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