Lecture 23

Strategic AI
Role of AI in Games

- **Autonomous Characters** (NPCs)
  - Mimics the “personality” of the character
  - May be opponent or support character

- **Strategic Opponents**
  - AI at the “player level”
  - Closest to classical AI

- **Character Dialog**
  - Intelligent commentary
  - Narrative management (e.g. Façade)
If $X$ is true, Then do $Y$

Three-Step Process

- **Match**
  - For each rule, check if
  - Return *all* matches

- **Resolve**
  - Can only use one rule
  - Use metarule to pick one

- **Act**
  - Do *then*-part
Example: Tic-Tac-Toe

- Next move for player O?
  - If have a winning move, make it
  - If opponent can win, block it
  - Take the center if available
  - Corners are better than edges
- Very easy to program
  - Just check the board state
  - Tricky part is prioritization
Example: Real Time Strategy

• Example from Microsoft’s *Age of Kings*
  ; The AI will attack once at 1100 seconds and then again
  ; every 1400 sec, provided it has enough defense soldiers.

(defrule
  (game-time > 1100)
  =>
  (attack-now)
  (enable-timer ? 1100))
)
(defrule
  (timer-triggered ?) (defend-soldier-count >= 12)
  =>
  (attack-now)
  (disable-timer ?)
  (enable-timer ? 1400)
)
The Problems with Rules

- Rules only do one step
  - May not be best move
  - Could lose long term
- Next move for player O?
  - If can win, then do it
  - If X can win, then block it
  - Take the center if possible
  - Corners > edges
- Need to **look ahead**
The Problems with Rules

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Multiple Steps: Planning

• **Plan**: actions necessary to reach a **goal**
  - Goal is a (pseudo) specific game state
  - Actions change game state (e.g. verbs)

• **Planning**: steps to generate a plan
  - **Initial State**: state the game is currently in
  - **Goal Test**: determines if state meets goal
  - **Operators**: action the NPC can perform
What Should We Do?

Slide courtesy of John Laird
**Simplification: No Opponent**

- Identify desired goal
  - **Ex:** Kill enemy, get gold
  - Design appropriate test
- List all relevant actions
  - **Ex:** Build, send troops
- **Look-ahead Search**
  - Start with initial state
  - Try all actions (look-ahead)
  - Stop if reached goal
  - Continue if not at goal
Planning Issues

- **Exponential** choices
  - Search action *sequences*
  - How far are we searching?
  - Cannot do this in real life!

- Game state is **complex**
  - Do we look at entire state?
  - Faster to “do” than to plan

- Must **limit** search
  - Reduce actions examined
  - Simplify game state
Internal State Representation

<table>
<thead>
<tr>
<th>Simplified World Model</th>
<th>Uses of Internal State</th>
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# Internal State Representation

## Simplified World Model
- Includes primary resources
  - **Example**: ammo, health
- Rough notion of position
  - **Example**: in/outside
- Both characters
  - **Example**: respawn rate
- Game mechanics
  - **Example**: damage
- Allows tactical decisions

## Uses of Internal State
- Notice changes
- Health
  - Health is dropping
- Enemy
  - Enemy has left the room
- Recent events
  - Remember older events
  - Chase after fleeing enemy
  - Picked up health 30 sec ago

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**Similar to Non-Digital Prototype**
Internal State and Memory

- Each NPC has own state
  - Represents NPC memory
  - Might not be consistent

- Useful for character AI
  - Models sensory data
  - Models communication

- Isolates planning
  - Each NPC plans separately
  - Coordinate planning with a strategic manager
Strategy versus Tactics

Slide courtesy of Dave Mark
Internal State for Quake II

- Self
  - Current-health
  - Last-health
  - Current-weapon
    - Ammo-left
  - Current-room
    - Last-room
  - Current-armor
    - Last-armor
  - Available-weapons

- Enemy
  - Current-weapon
  - Current-room
  - Last-seen-time
  - Estimated-health
  - Current-time

- Random-number

- Powerup
  - Type
  - Room
  - Available
  - Estimated-spawn-time

- Map
  - Rooms
  - Halls
  - Paths

- Parameters
  - Full-health
  - Health-powerup-amount
  - Ammo-powerup-amount
  - Respawn-rate
## Internal Action Representation

### Simplified Action Model
- **Internal Actions** = *operators*
  - Just mathematical functions
  - Operators alter internal state

- **Pre-conditions**
  - What is required for action
  - Often resource requirement

- **Effects**
  - How action changes state
  - Both global and for NPC

### Designing Actions
- Extrapolate from gameplay
- Start with an internal state
- Pick “canonical” game state
- Apply game action to state
- Back to internal state

- Remove any uncertainty
  - Deterministic NPC behavior
  - “Average” random results
  - Or pick worse case scenario
Internal Action Representation

**Simplified Action Model**

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**Designing Actions**

- Extrapolate from gameplay
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- Design action to state
  - Remove any uncertainty
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  - “Average” random results
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Like Gameplay Specification, but actions, interactions combined
Example: Pick-Up Health Op

• **Preconditions:**
  - Self.current-room = Powerup.current-room
  - Self.current-health < full-health
  - Powerup.type = health
  - Powerup.available = yes

• **Effects:**
  - Self.last-health = self.current-health
  - Self.current-health = current-health + health-powerup-amount
  - Powerup.available = no
  - Powerup.estimated-spawn-time = current-time + respawn-rate
Building Internal Models

• Planning is only as accurate as model
  • Bad models \(\rightarrow\) bad plans
  • But complex models \(\rightarrow\) slow planning

• Look at your nondigital prototype!
  • Heavily simplified for playability
  • Resources determine internal state
  • Nondigital verbs are internal actions

• One of many reasons for this exercise
What Should We Do?

Slide courtesy of John Laird

Self.current-health = 20
Self.current-weapon = blaster

Enemy.estimated-health = 50

Powerup.type = health-pak
Powerup.available = yes

Powerup.type = Railgun
Powerup.available = yes
One Step: Pick-up Railgun

Slide courtesy of John Laird

Self.current-health = 10
Self.current-weapon = railgun

Enemy.estimated-health = 50

Powerup.type = health-pak
Powerup.available = yes
Powerup.type = Railgun
Powerup.available = no
One Step: Shoot Enemy

Slide courtesy of John Laird

**Self.current-health = 10**
Self.current-weapon = blaster

**Enemy.estimated-health = 40**

Powerup.type = health-pak
Powerup.available = yes
Powerup.type = Railgun
Powerup.available = yes
One Step: Pick-up Health-Pak

Slide courtesy of John Laird

**Self.current-health = 90**
Self.current-weapon = blaster

Enemy.estimated-health = 50

Powerup.type = health-pak
Powerup.available = no

Powerup.type = Railgun
Powerup.available = yes
State Evaluation Function

- Need to **compare** states
  - Is either state better?
  - How far away is goal?

- Might be **partial order**
  - Some states incomparable
  - If not goal, just continue

- Purpose of planning
  - Find good states
  - Avoid bad states
State Evaluation: Quake II

• **Example 1**: Prefer higher `self.current-health`
  • Always pick up health powerup
  • **Counter example**:
    • `Self.current-health = 99%`
    • `Enemy.current-health = 1%`

• **Example 2**: Prefer lower `enemy.current-health`
  • Always shoot enemy
  • **Counter example**:
    • `Self.current-health = 1%`
    • `Enemy.current-health = 99%`
State Evaluation: Quake II

• **Example 3**: Prefer higher self.health – enemy.health
  - Shoot enemy if I have health to spare
  - Otherwise pick up a health pack
  - Counter examples?

• Examples of more complex evaluations
  - If self.health > 50% prefer lower enemy.health
    - Otherwise, want higher self.health
  - If self.health > low-health prefer lower enemy.health
    - Otherwise, want higher self.health
Two Step Look-Ahead

Slide courtesy of John Laird

Self.current-health = 80
Self.current-weapon = blaster

Enemy.estimated-health = 40

Powerup.type = health-pak
Powerup.available = no
Powerup.type = Railgun
Powerup.available = yes

Shoot

Pickup
Three Step Look-Ahead

Slide courtesy of John Laird

Self.current-health = 100      Enemy.estimated-health = 0
Self.current-weapon = railgun  Powerup.type = health-pak
Powerup.available = no
Powerup.type = Railgun
Powerup.available = no
# Look-Ahead Search

## One-Step Lookahead

```c
op pickBest(state) {
    foreach op satisfying precond {
        newstate = op(state)
        evaluate newstate
    }
    return op with best evaluation
}
```

## Multistep Tree Search

```c
[op] bestPath(&state, depth) {
    if depth == 0 { return [] }
    foreach op satisfying precond {
        newstate = op(state)
        [nop]=bestPath(newstate, depth-1)
        evaluate newstate
    }
    pick op+[nop] with best state
    modify state to reflect op+[nop]
    return op+[nop]
}
```
Look-Ahead Search

- Are more steps better?
  - Longer, more elaborate plans
  - More time & space consuming
  - Opponent or environment can mess up plan
  - Simplicity of internal model causes problems

- In this class, limit three or four steps
  - Anything more, and AI is too complicated
  - Purpose is to be challenging, not to win
Recall: LibGDX Behavior Trees

- **Selector** rules
  - Tests each subtask for success
  - Tasks are tried independently
  - Chooses first one to succeed

- **Sequence** rules
  - Tests each subtask for success
  - Tasks are tried in order
  - Does all if succeeds; else none

- **Parallel** rules
  - Tests each subtask for success
  - Tasks are tried simultaneously
  - Does all if succeeds; else none
Recall: LibGDX Behavior Trees

- **Sequence** rules
  - Tests each subtask for success
  - Tasks are tried in order
  - Does all if succeeds; else none

Lookahead search, but only checks if plan is *acceptable*
Opponent: New Problems

Self.current-health = 20
Self.current-weapon = blaster

Enemy.estimated-health = 50

Powerup.type = health-pak
Powerup.available = yes

Powerup.type = Railgun
Powerup.available = yes

Slide courtesy of John Laird
Opponent Model

- **Solution 1**: Assume the worst
  - Opponent does what would be worst for you
  - Full game tree search; exponential

- **Solution 2**: What would I do?
  - Opponent does what you would in same situation

- **Solution 3**: Internal opponent model
  - Remember what did last time
  - Or remember what they like to do
Opponent Interference

- Opponent actions may prevent yours
  - **Example**: Opponent grabs railgun first
  - Need to take into account in your plan

- **Solution**: Iteration
  - Plan once with no interference
  - Run again, assuming best plans of the opponent
  - Keep iterating until happy (or run out of time)

- Planning is very **expensive**!
Asynchronous AI

Game Thread

- Update
- Draw

Second Thread

- Request Plan
- AI Manager
  - Check for request
  - Compute answer
  - Store in buffer
Alternative: Iterative AI

Game Thread

- Update
- Draw

AI Manager

- Initialize
- Update
- Result

Game Architecture
Alternative: Iterative AI

Game Thread

- Update
- Draw

AI Manager

- Initialize
- Update
- Result

Looks like asset management
Using Asynchronous AI

- Give AI a **time budget**
  - If planning takes too long, abort it
  - Use counter in update loop to track time

- Beware of **stale plans**
  - Actual game state has probably changed
  - When find a plan, make sure it is still good
  - Evaluate (quickly) with new internal state
  - Make sure result is “close” to what thought
Planning: Optimization

- **Backwards Planning**
  - **Idea**: few operators achieve goal conditions
  - **Implementation**:
    - For each operator, reverse the effect
    - Check reversed effect satisfies pre-conditions

- Possible to use backwards **and** forwards
  - Start on each end, and check for meets
  - Does not work well with numerical resources
To Plan or Not to Plan

• **Advantages**
  - Less predictable behavior
  - Can handle unexpected situations
  - More accurate than rule-based AI

• **Disadvantages**
  - Less predictable behavior (harder to debug)
  - Planning takes a lot of processor time
  - Planning takes memory
  - Need simple but accurate internal representations
Other Possibilities

- There are many more options available
  - Neural nets
  - Decision trees
  - General machine learning
  - Take **CS 4700** if want to learn more

- Quality is a matter of heated debate
  - Better to spend time on internal state design
  - Most AI is focused on perception modeling
Summary

- Rule-based AI is simplest form of strategic AI
  - Only limited to one-step at a time
  - Can easily make decisions that lose in long term
- More complicated behavior requires planning
  - Simplify the game to turn-based format
  - Use classic AI search techniques
- Planning has advantages and disadvantages
  - Remember, the desire is to challenge, not to win