Lecture 22

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
  - If the center is available, take it
  - Corners are better than edges

- Very easy to program
  - Just check the board state
  - Tricky part is prioritization
Example: 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 7 1100))
)

(defrule
  (timer-triggered 7) (defend-soldier-count >= 12)
  =>
  (attack-now)
  (disable-timer 7)
  (enable-timer 7 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

- Rules only do one step
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- Next move for player O?
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- Need to **look ahead**
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

Tree Search
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

Simplified World Model

• Includes primary resources
  • Example: ammo, health

• Rough notion of position
  • Example: in/outside room

• Both characters and items

• Game mechanic details
  • Example: respawn rate

• Allows tactical decisions

Uses of Internal State

• Notice changes
  • Health is dropping

• Enemy must be nearby

• Remember recent events
  • Enemy has left the room

• Chase after fleeing enemy

• Remember older events
  • Picked up health 30 sec ago
### Internal State Representation

#### Simplified World Model
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  - **Example**: ammo, health
- Rough notion of position
  - **Example**
- Both characters and items
- Game mechanic details
  - **Example**: respawn rate
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#### Uses of Internal State
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  - Enemy has left the room
- Remember recent events
  - Enemy has left the room
  - Chase after fleeing enemy
- Remember older events
  - Picked up health 30 sec ago

**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
Simplified Action Model

Internal Actions = operators

Pre-conditions
- Operators alter internal state
- Just mathematical functions
- Often resource requirement

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

Deterministic NPC behavior
- Or pick worse case scenario
- "Average" random results

Extrapolate from gameplay
- Start with an internal state

Like Gameplay Specification,
- actions, interactions combined
- remove any uncertainty

Designing Actions
- Pick "canonical" game state
- Apply game action to state
- Back to internal state
- Remove any uncertainty
- Deterministic NPC behavior

Strategic AI

Internal Action Representation

gamedesigninitiative
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  Enemy.estimated-health = 50  Powerup.type = health-pak
Self.current-weapon = blaster  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

\begin{align*}
\text{Self.current-health} &= 80 \\
\text{Self.current-weapon} &= \text{blaster} \\
\text{Enemy.estimated-health} &= 40 \\
\text{Powerup.type} &= \text{health-pak} \\
\text{Powerup.available} &= \text{no} \\
\text{Powerup.type} &= \text{Railgun} \\
\text{Powerup.available} &= \text{yes}
\end{align*}
Three Step Look-Ahead

Slide courtesy of John Laird

Self.current-health = 100
Self.current-weapon = railgun

Enemy.estimated-health = 0

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

Powerup.type = Railgun
Powerup.available = no
Look-Ahead Search

One-Step Lookahead

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

Multistep Tree Search

```plaintext
[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

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

- **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

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
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
- AI Manager

- Check for request
- Compute answer
- Store in buffer

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

Game Thread:
- Update
- Draw

AI Manager:
- Initialize
- Update
- Result
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