the gamedesigninitiative at cornell university

Lecture 23

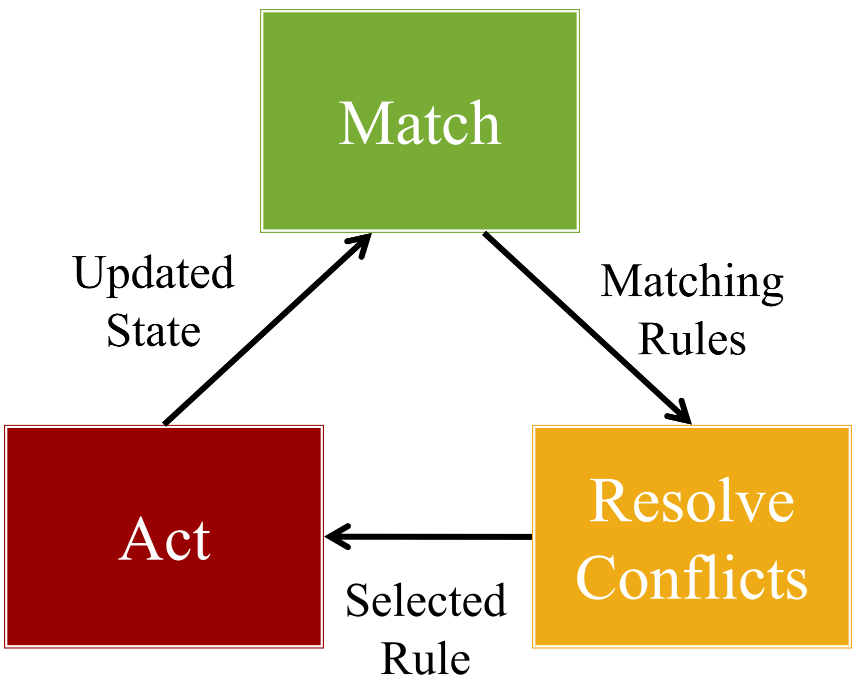
Strategic AI

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)

Rule-Based AI

If *X* is true, Then do *Y*

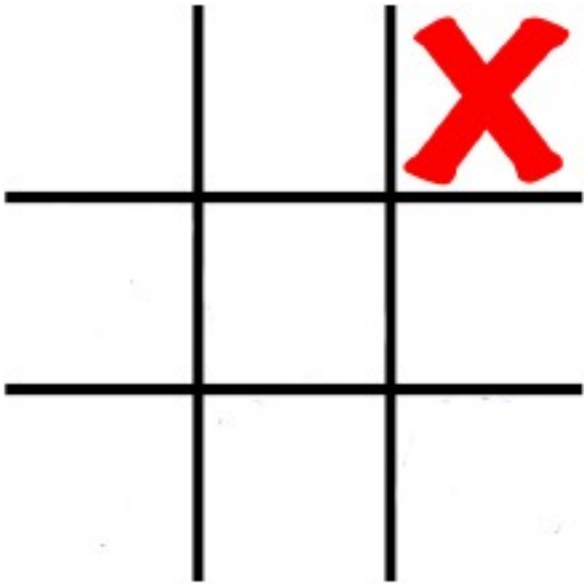


Three-Step Process

- **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



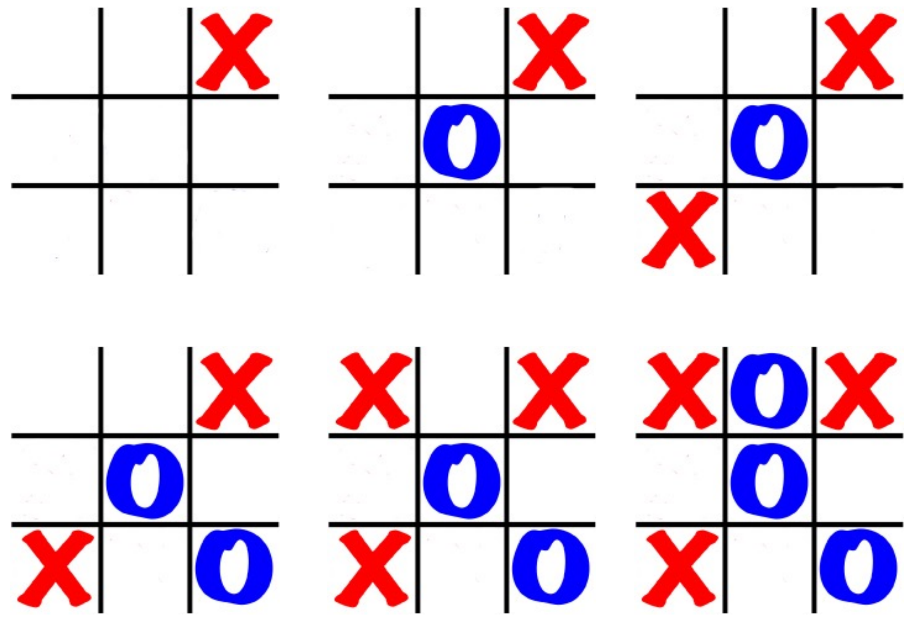
Example: Microsoft's *Age of Kings*

```
; 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)
)
```

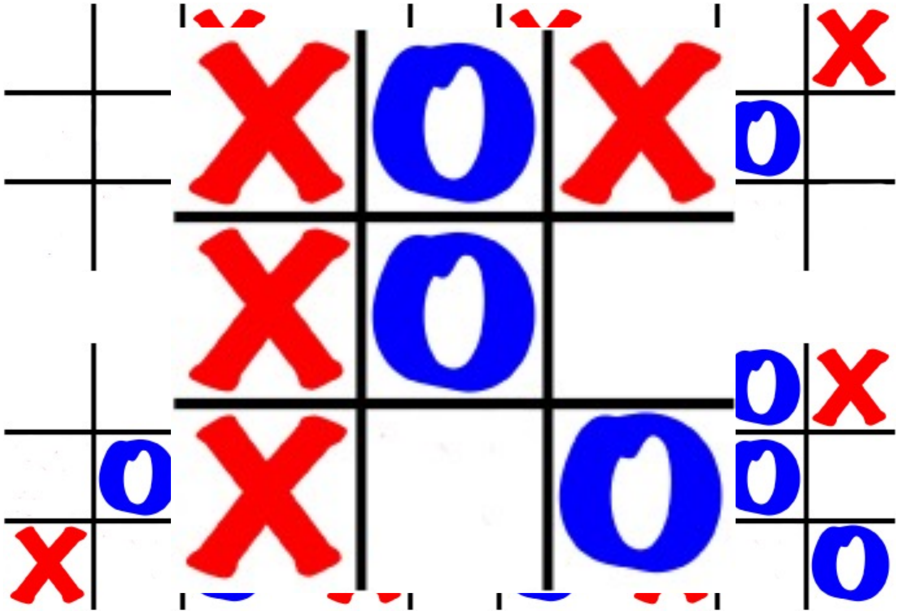
The Problems with Rules

- 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
  - 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**

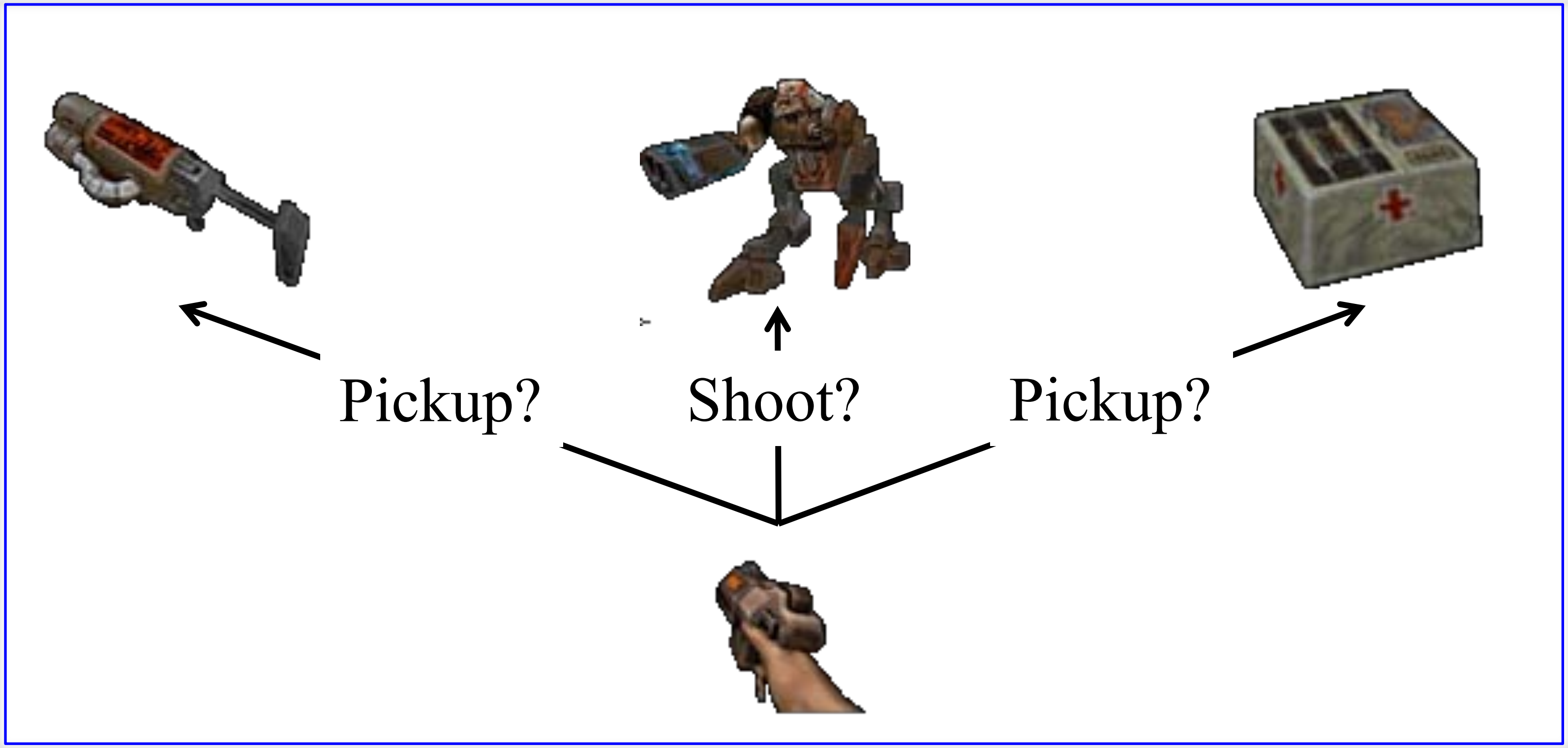


Multiple Steps: Planning

- **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

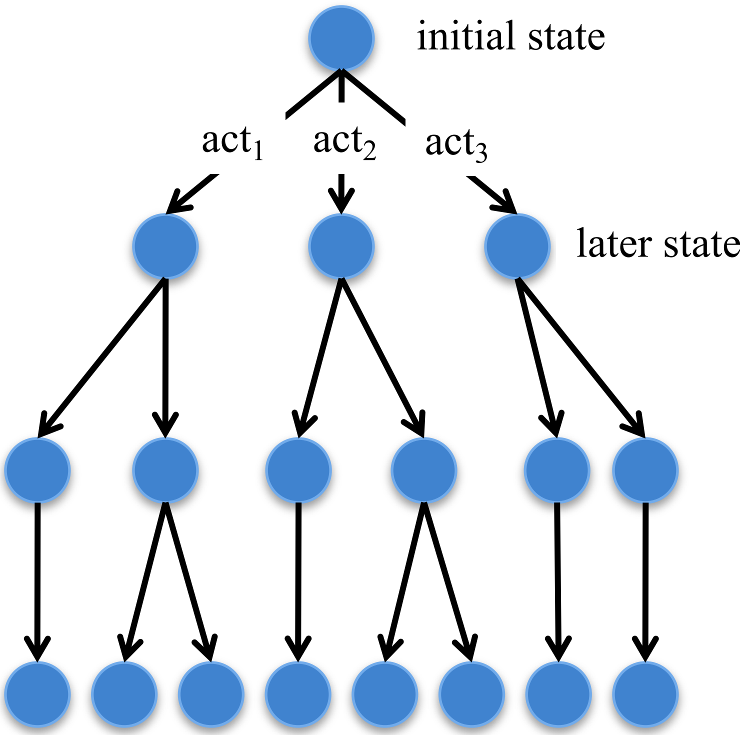
What Should We Do?

Slide courtesy of John Laird



Simplification: No Opponent

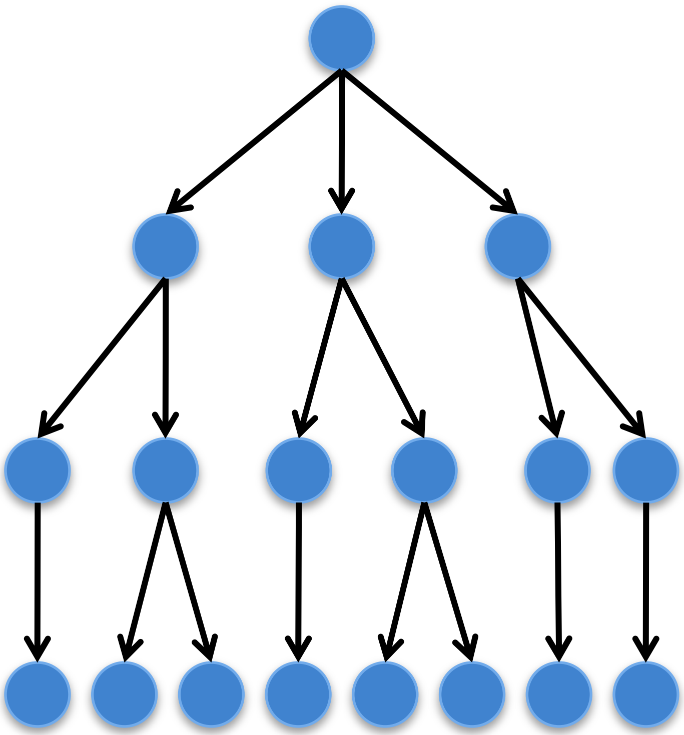
- Identify desired goal
  - **Ex**: Kill enemy, get gold
  - Design appropriate test
- List all relevant actions
  - **Ex**: Build, send troops
- **Look-ahead Search**
  - Start with initial state
  - Try all actions (look-ahead)
  - Stop if reached goal
  - Continue if not at goal



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

- Includes primary resources
  - **Example**: ammo, health
- Rough notion of position
  - **Exampl**
  - Both
- Game me... details
  - **Example**: respawn rate
  - Allows tactical decisions

Uses of Internal State

- Notice changes
  - Health is dropping
  - E... ...rby
  - ...ents
  - ...y has left the room
  - Chase after fleeing enemy
- Remember older events
  - Picked up health 30 sec ago

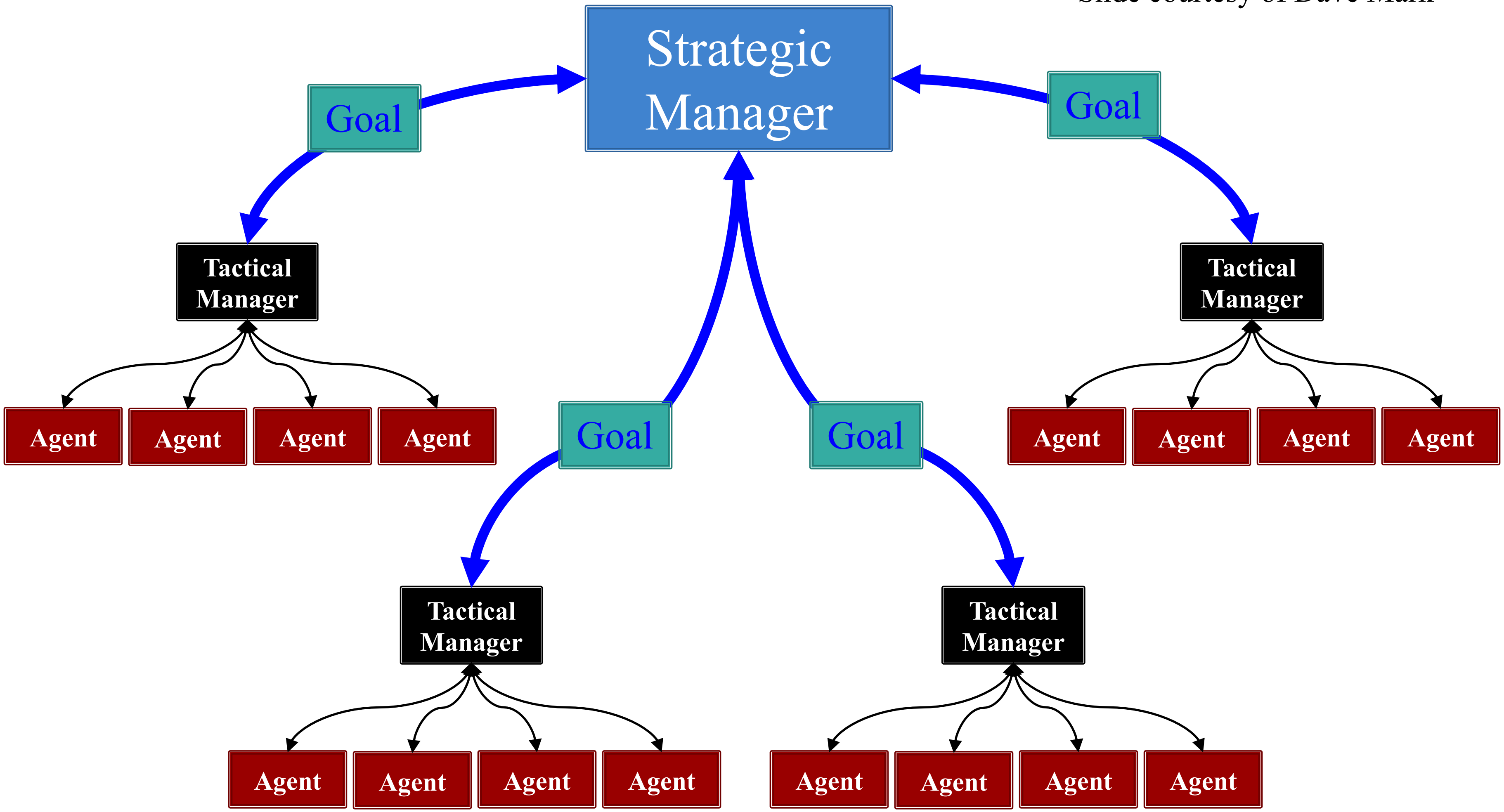
Similar to Non-Digital Prototype

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

Internal Action Representation

Simplified Action Model

- Internal Actions = *operators*
  - Just mathematical functions
  - Operators alter internal state
- **Pre-condit**
  - What
  - Often
- **Effects**
  - How action changes state
  - Both global and for NPC

Designing Actions

- Extrapolate from gameplay
  - Start with an internal state
  - Pick "canonical" game state
  - o state
  - te
- Remove any uncertainty
  - Deterministic NPC behavior
  - "Average" random results
  - Or pick worse case scenario

Like Gameplay Specification,
but actions, interactions combined

Example: Pick-Up Health Op

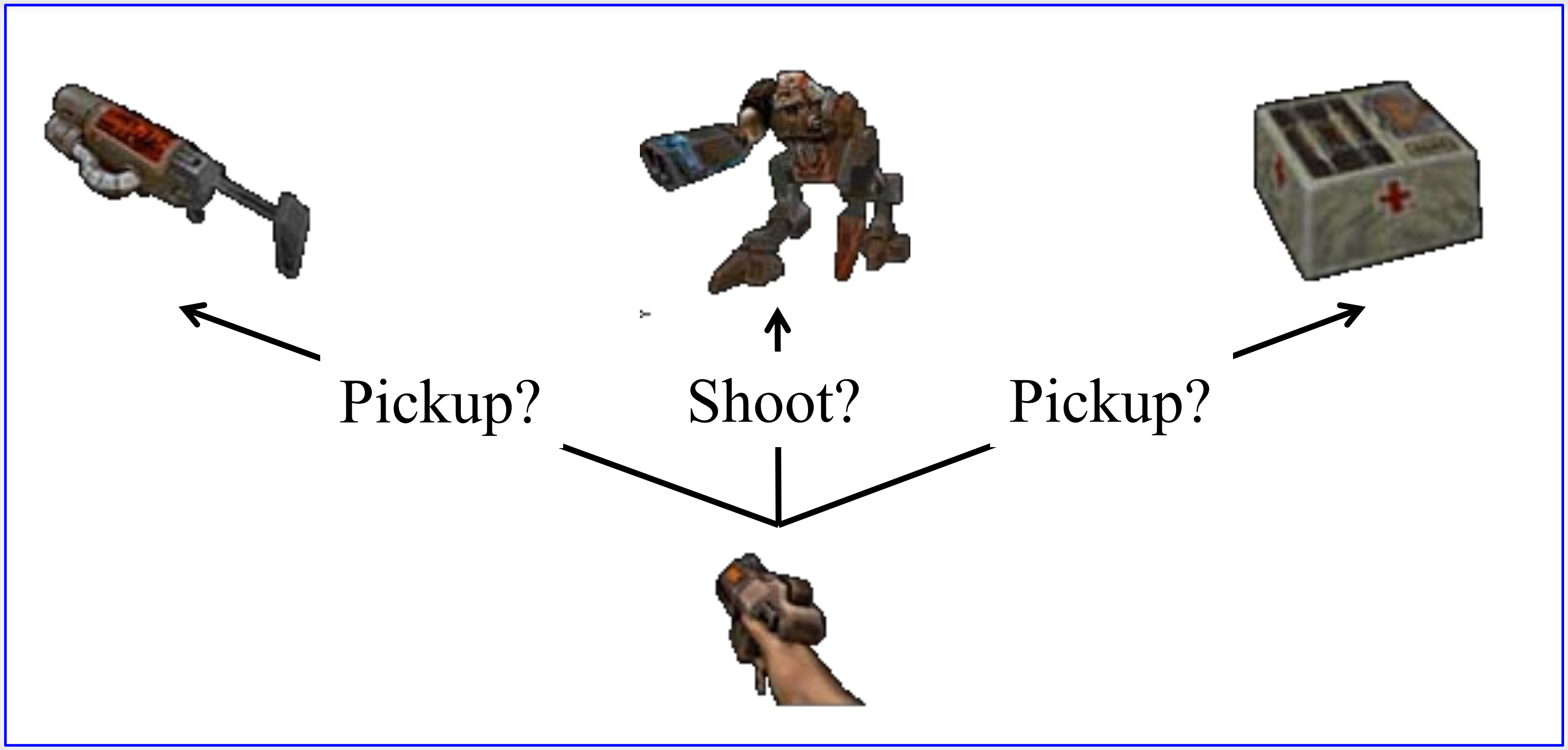
- **Preconditions**:
  - Self.current-room = Powerup.current-room
  - Self.current-health < full-health
  - Powerup.type = health
  - Powerup.available = yes
- **Effects**:
  - Self.last-health = self.current-health
  - Self.current-health = current-health + health-powerup-amount
  - Powerup.available = no
  - Powerup.estimated-spawn-time = current-time + respawn-rate

Building Internal Models

- Planning is only as accurate as model
  - Bad models → bad plans
  - But complex models → 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



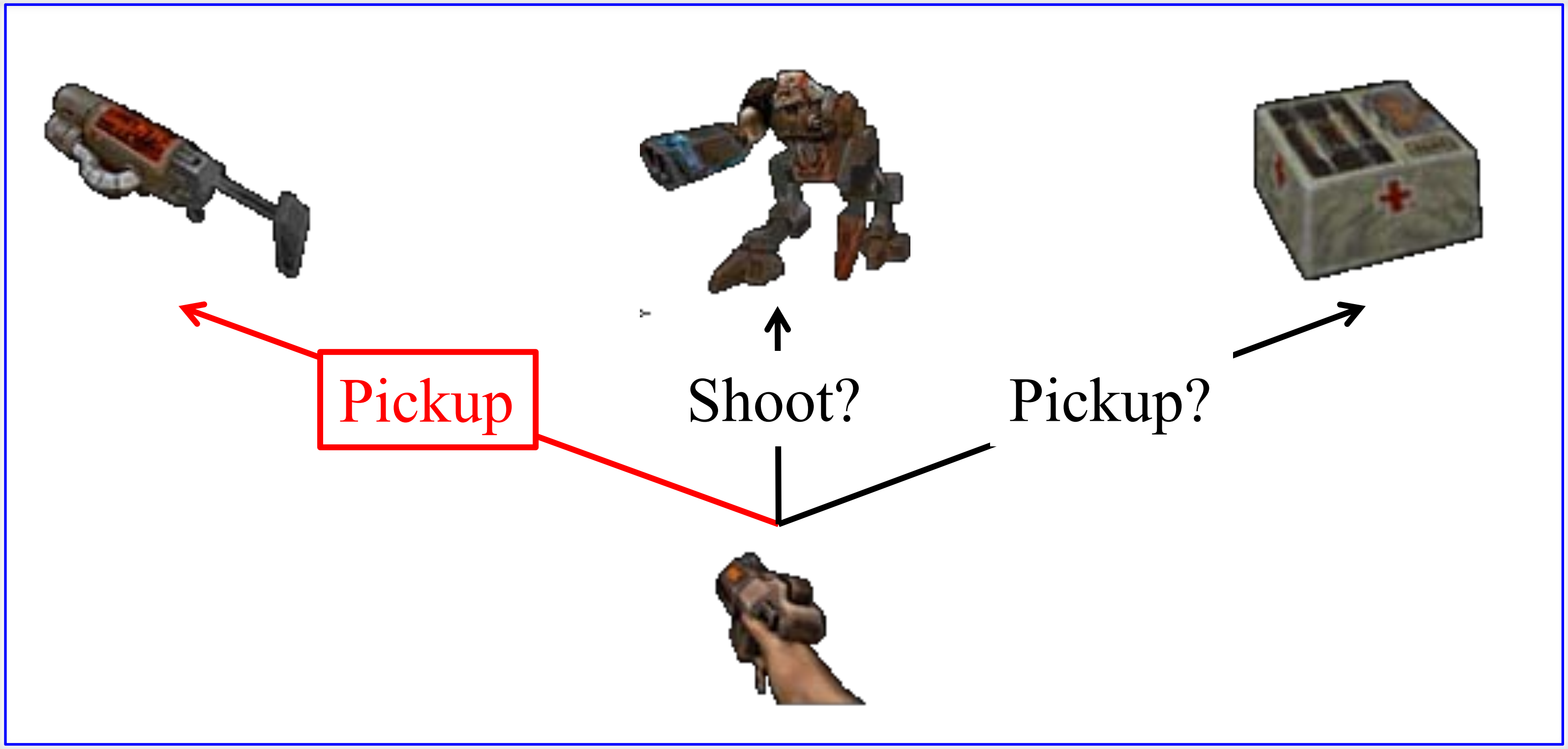
Self.current-health = 20
Self.current-weapon = blaster

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



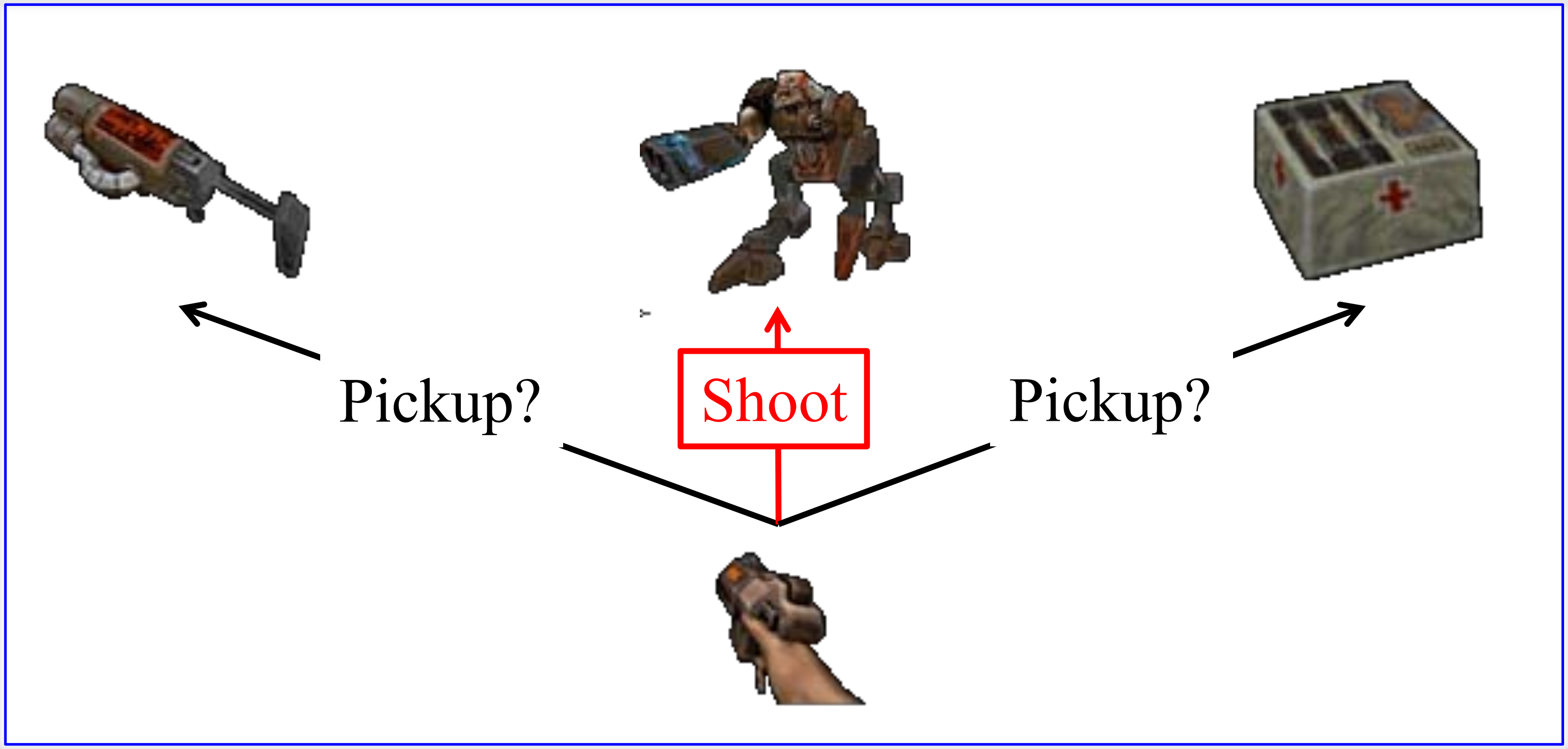
Self.current-health = 10
Self.current-weapon = railgun

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



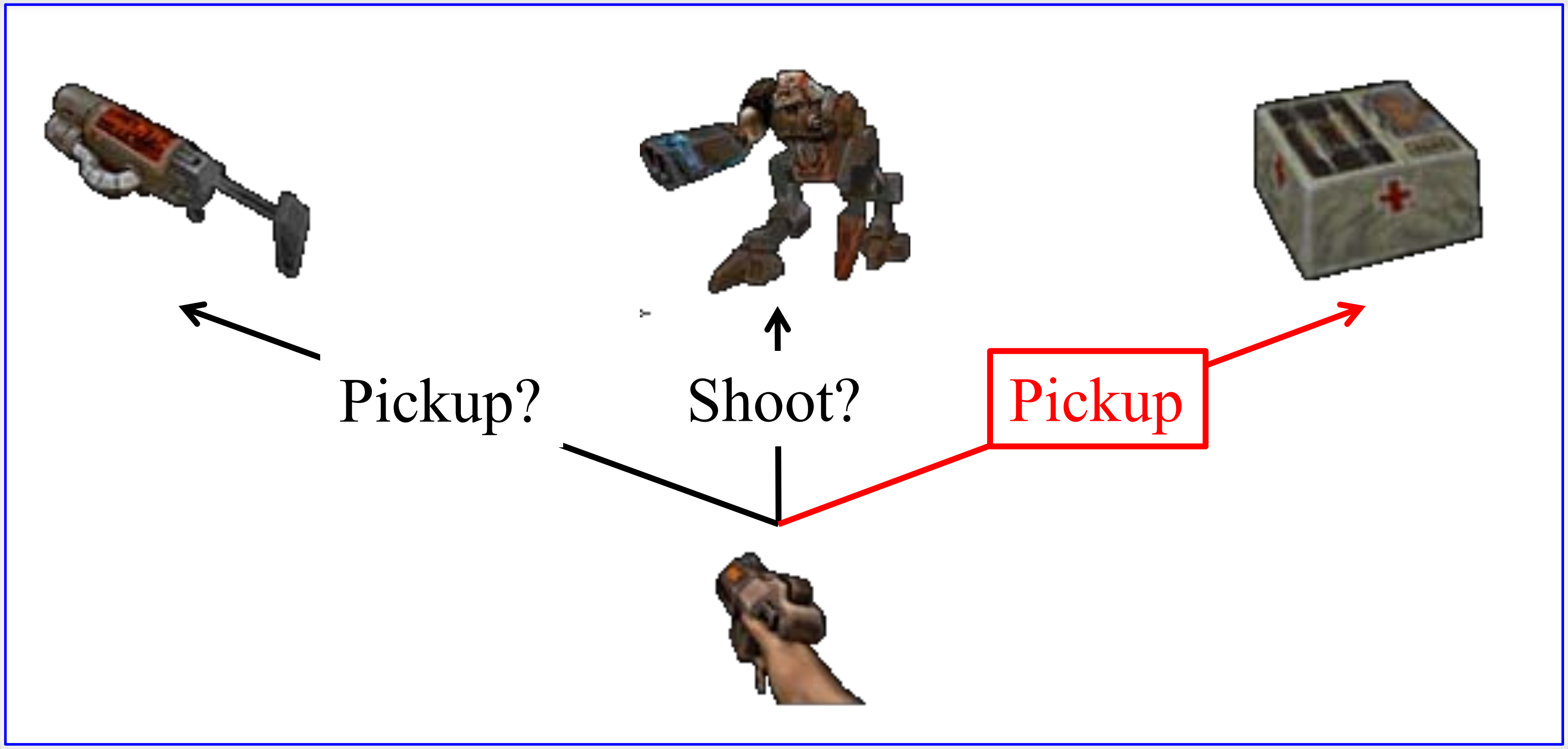
Self.current-health = 10
Self.current-weapon = blaster

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



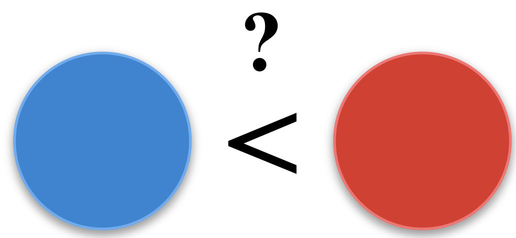
Self.current-health = 90
Self.current-weapon = blaster

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

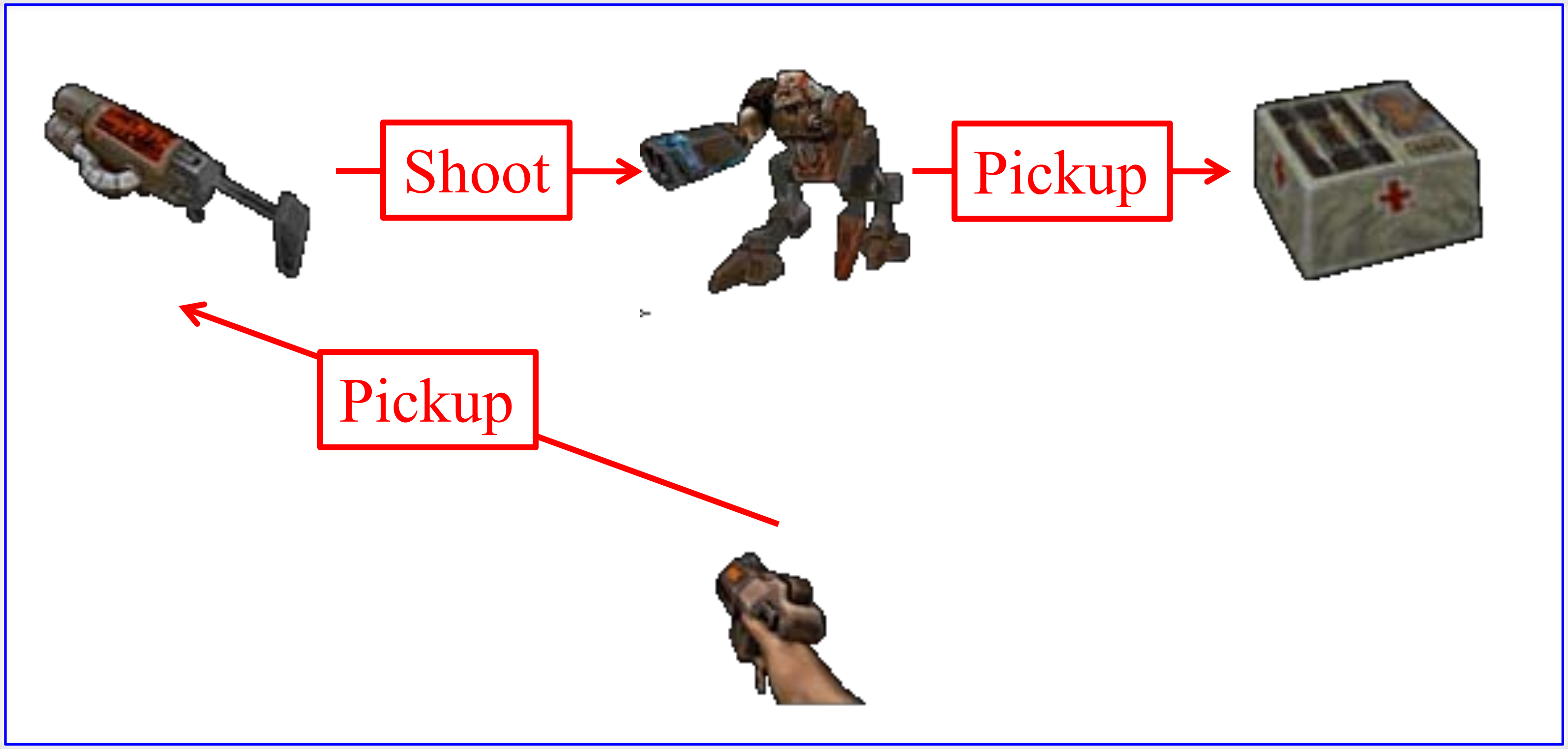
Self.current-health = 80
Self.current-weapon = blaster

Enemy.estimated-health = 40

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

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

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

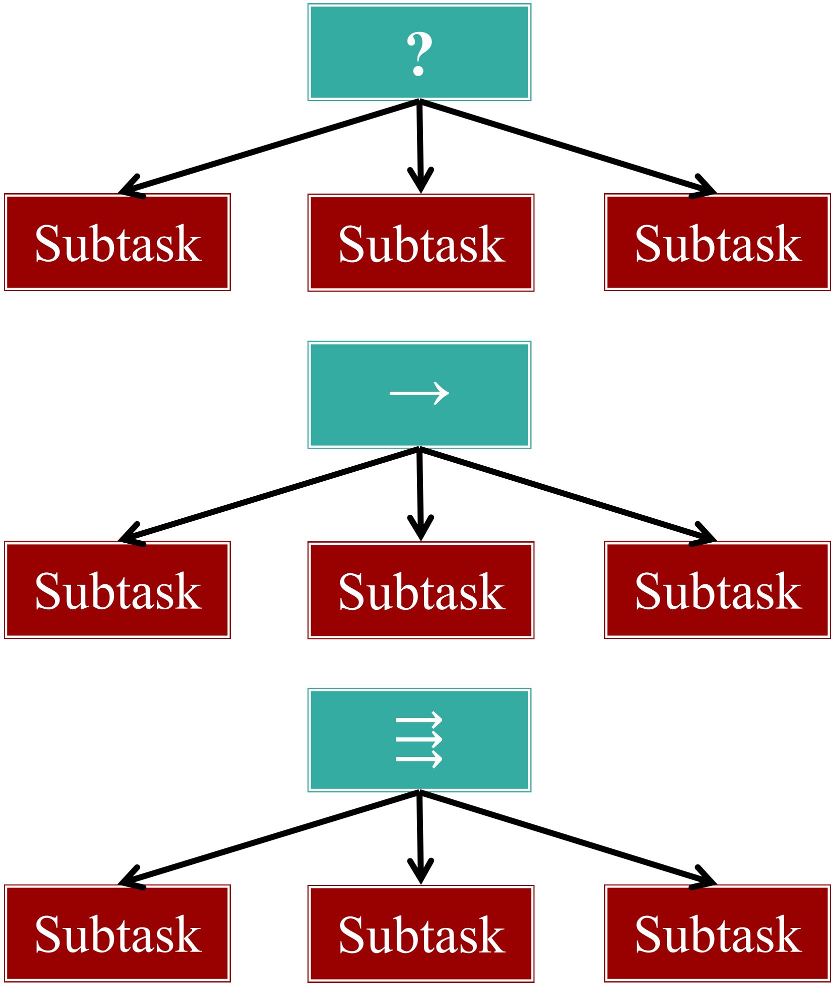
Multistep Tree Search

```
[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

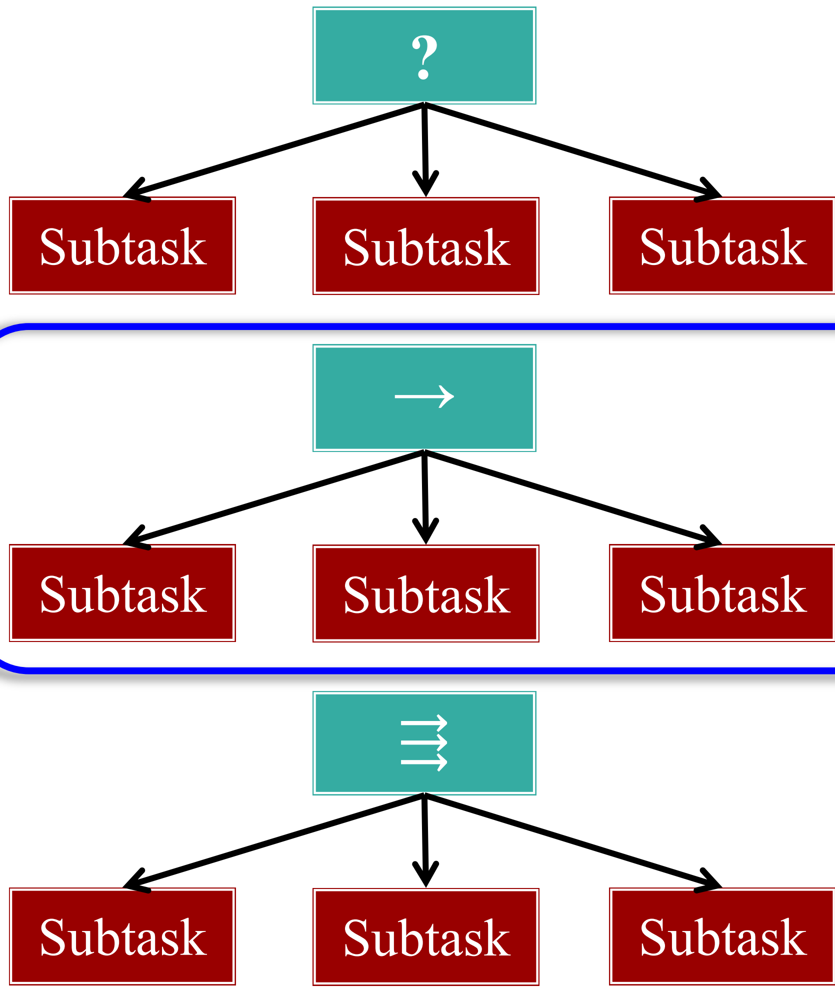
- Are more steps better?
  - Longer, more elaborate plans
  - More time & space consuming
  - Opponent or environment can mess up plan
  - Simplicity of internal model causes problems
- In this class, limit three or four steps
  - Anything more, and AI is too complicated
  - **Purpose is to be challenging, 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 succees; else none
- **Parallel** rules
  - Tests each subtask for success
  - Tasks are tried simultaneously
  - Does all if succees; else none

Recall: LibGDX Behavior Trees

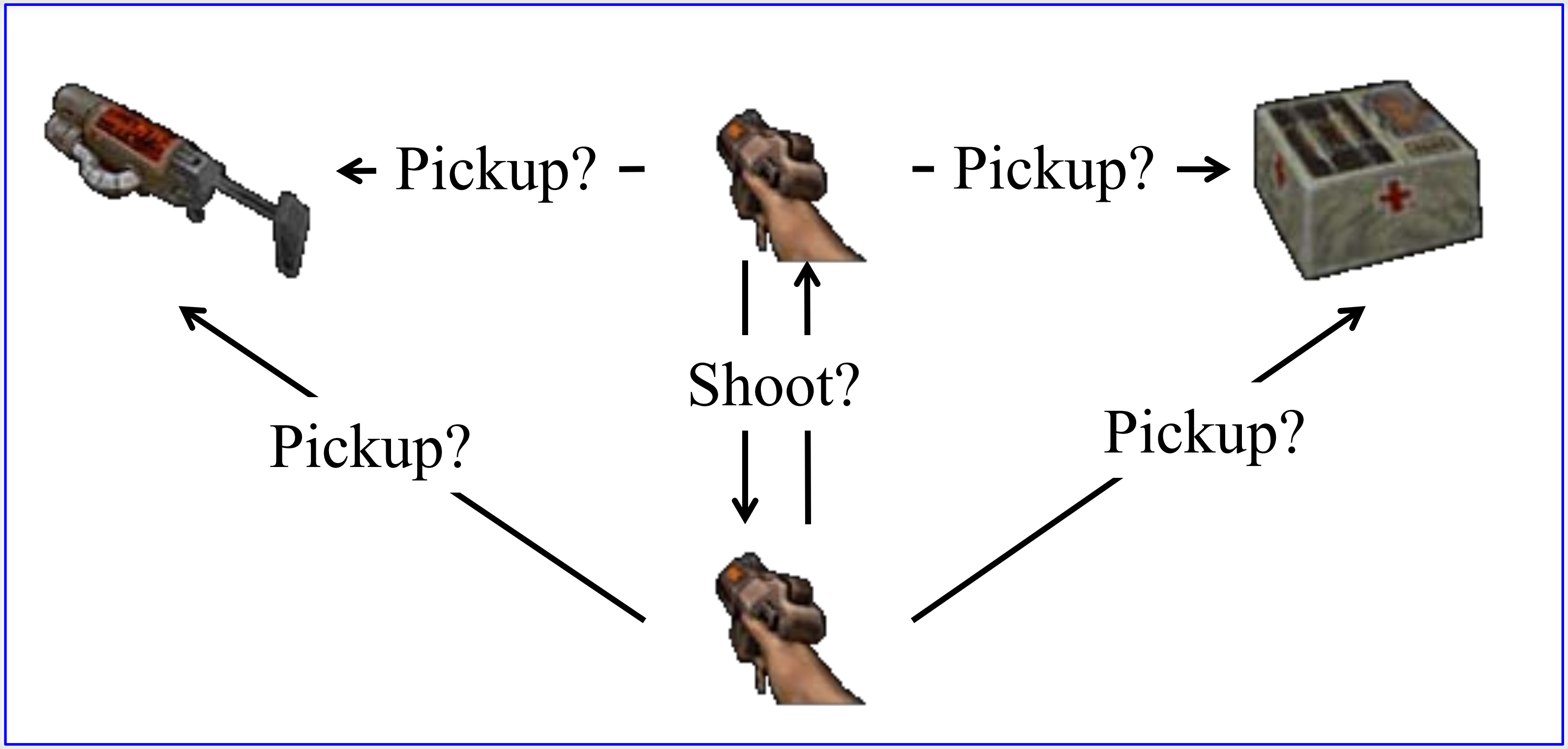


Lookahead search, but only checks if plan is *acceptable*

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

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

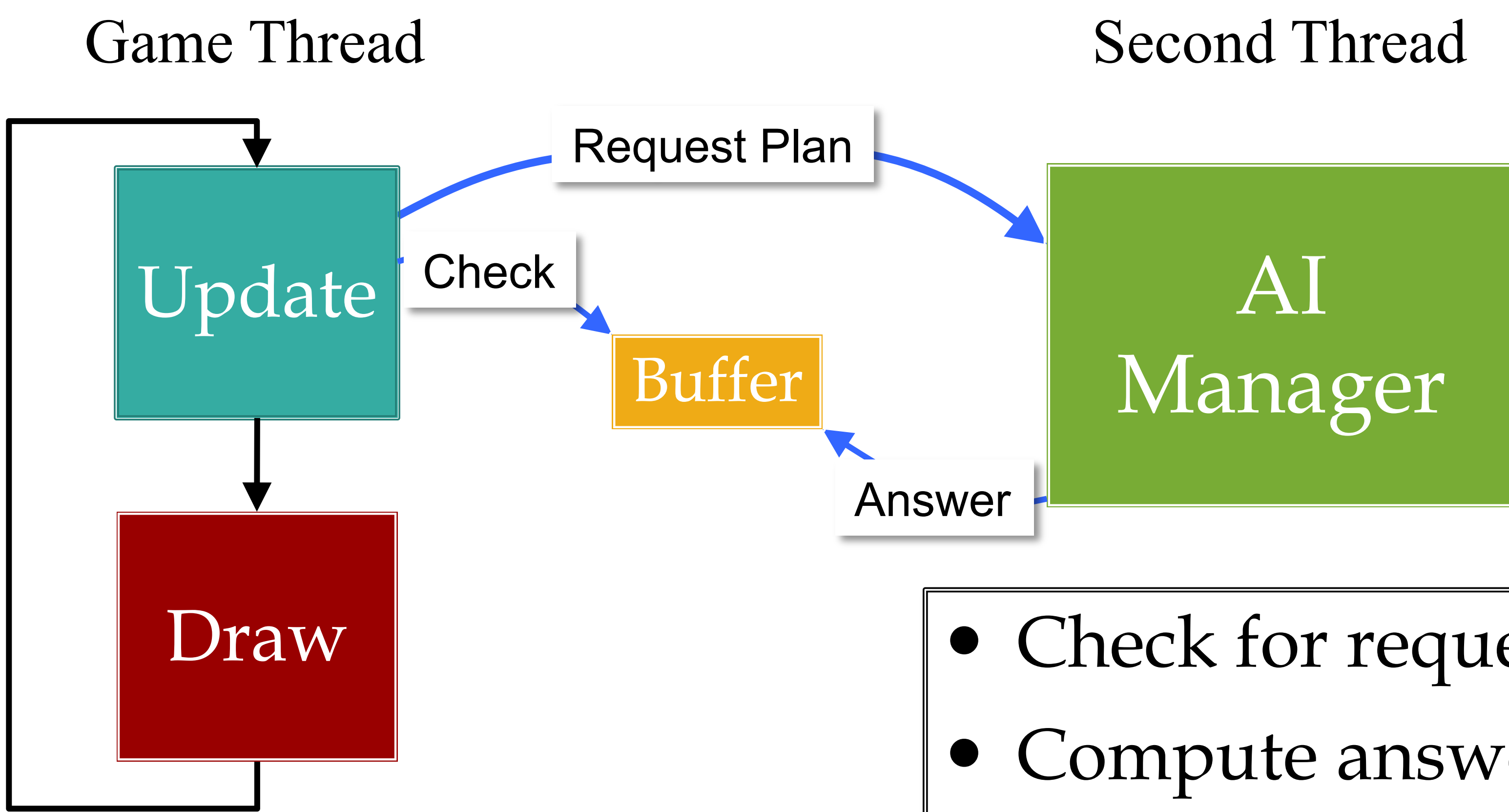
Opponent Model

- **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

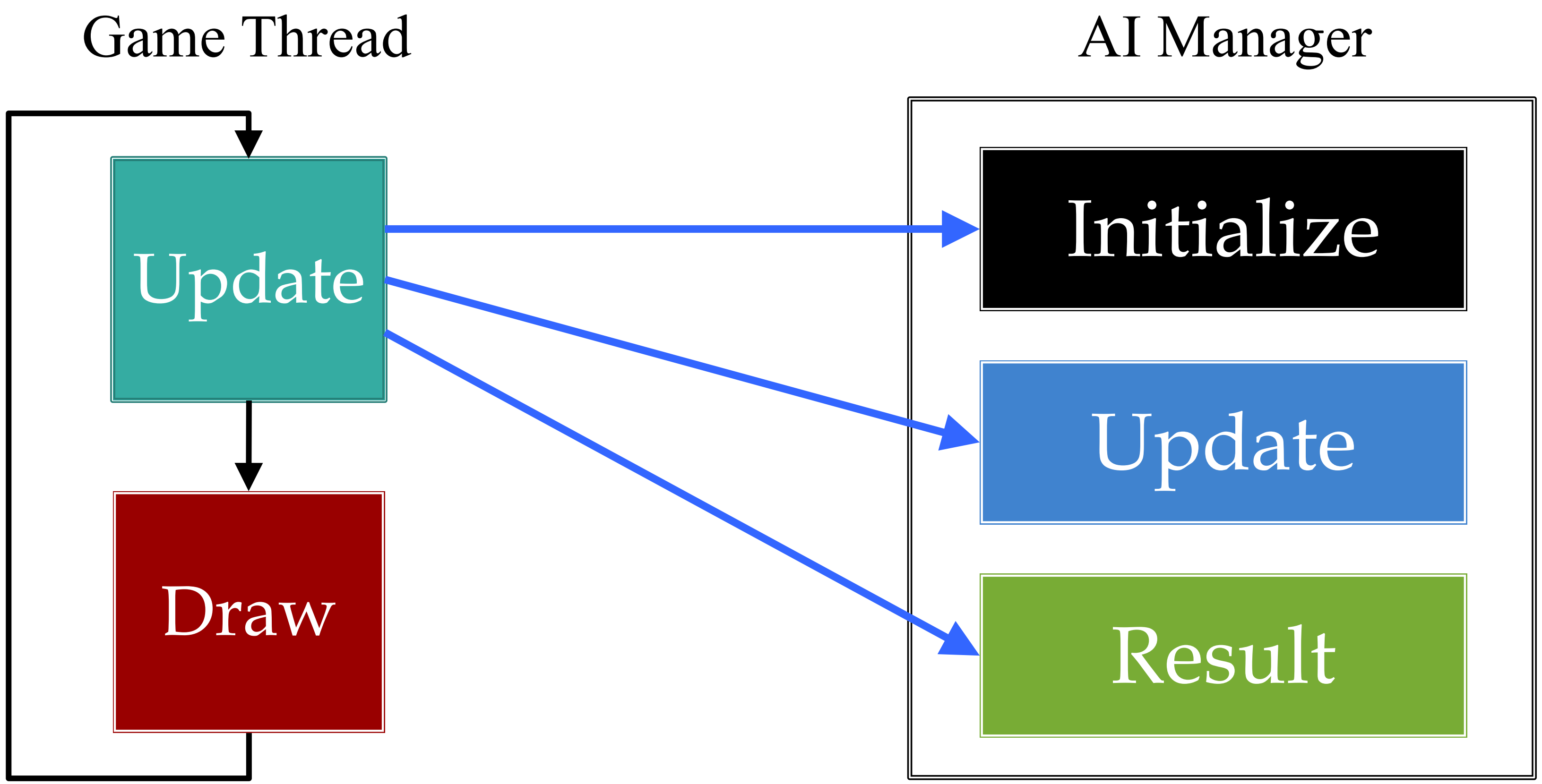
- Opponent actions may prevent yours
  - **Example**: Opponent grabs railgun first
  - Need to take into account in your plan
- **Solution**: Iteration
  - Plan once with no interference
  - Run again, assuming best plans of the opponent
  - Keep iterating until happy (or run out of time)
- Planning is very *expensive*!

Asynchronous AI

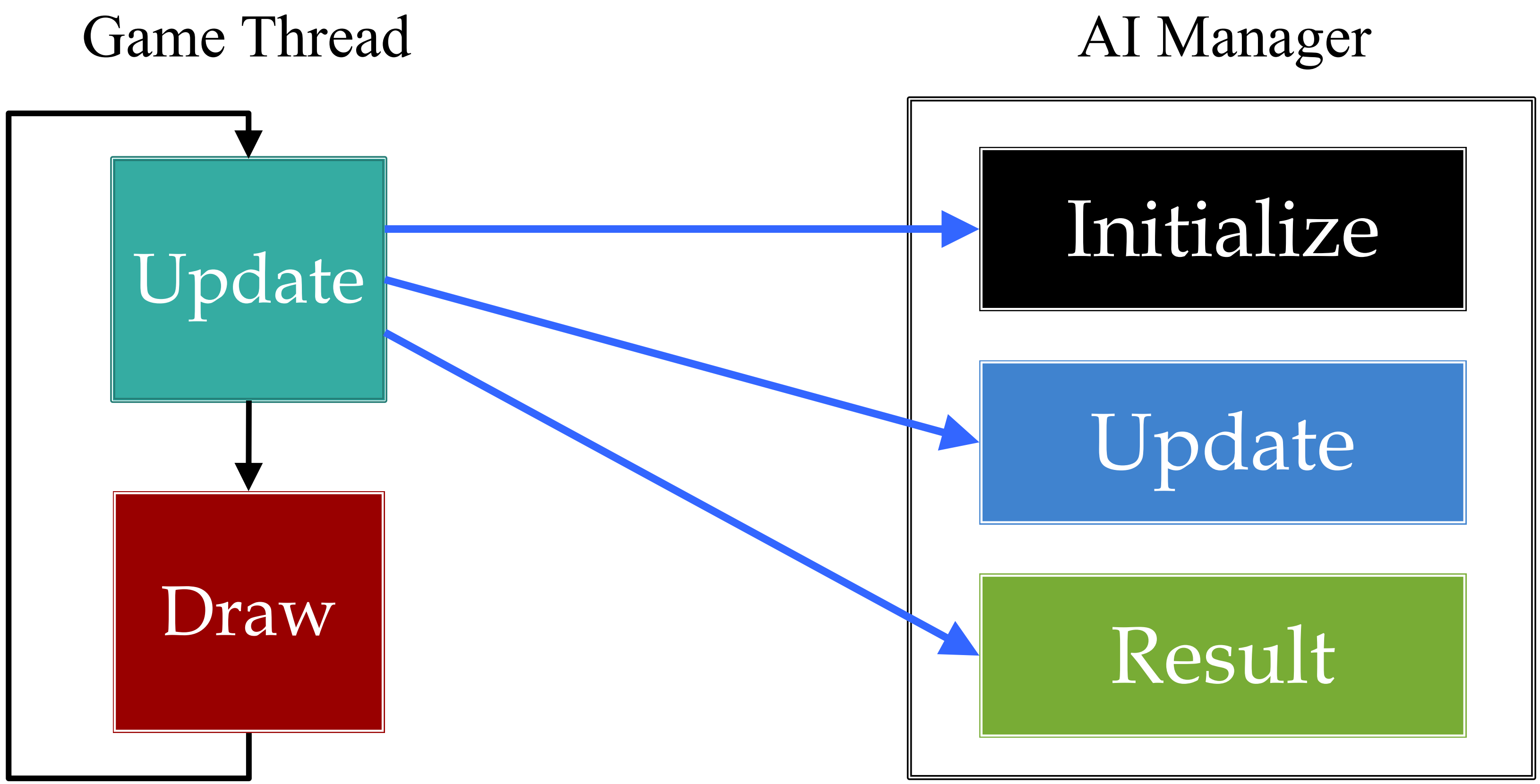


- Check for request
- Compute answer
- Store in buffer

Alternative: Iterative AI



Alternative: Iterative AI



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**