CS354R

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INTRODUCTION TO GAME AI

WHAT IS AI?

- AI is the control of every non-human entity in a game
  - The other cars in a car game
  - The opponents and monsters in a shooter
  - Your units, your enemy's units and your enemy in a RTS game
- But, typically does not refer to passive things that just react to the player and never initiate action
  - That's physics or game logic
  - e.g blocks in Tetris are not AI, nor is the ball in the game you are doing, nor is a flag blowing in the wind
  - It's a somewhat arbitrary distinction…

AI IN THE GAME LOOP

- AI is updated as part of the game loop: after user input and before rendering
- There are issues here:
  - Which AI goes first?
  - Does the AI run on every frame?
  - Is the AI synchronized?

AI IN THE GAME LOOP

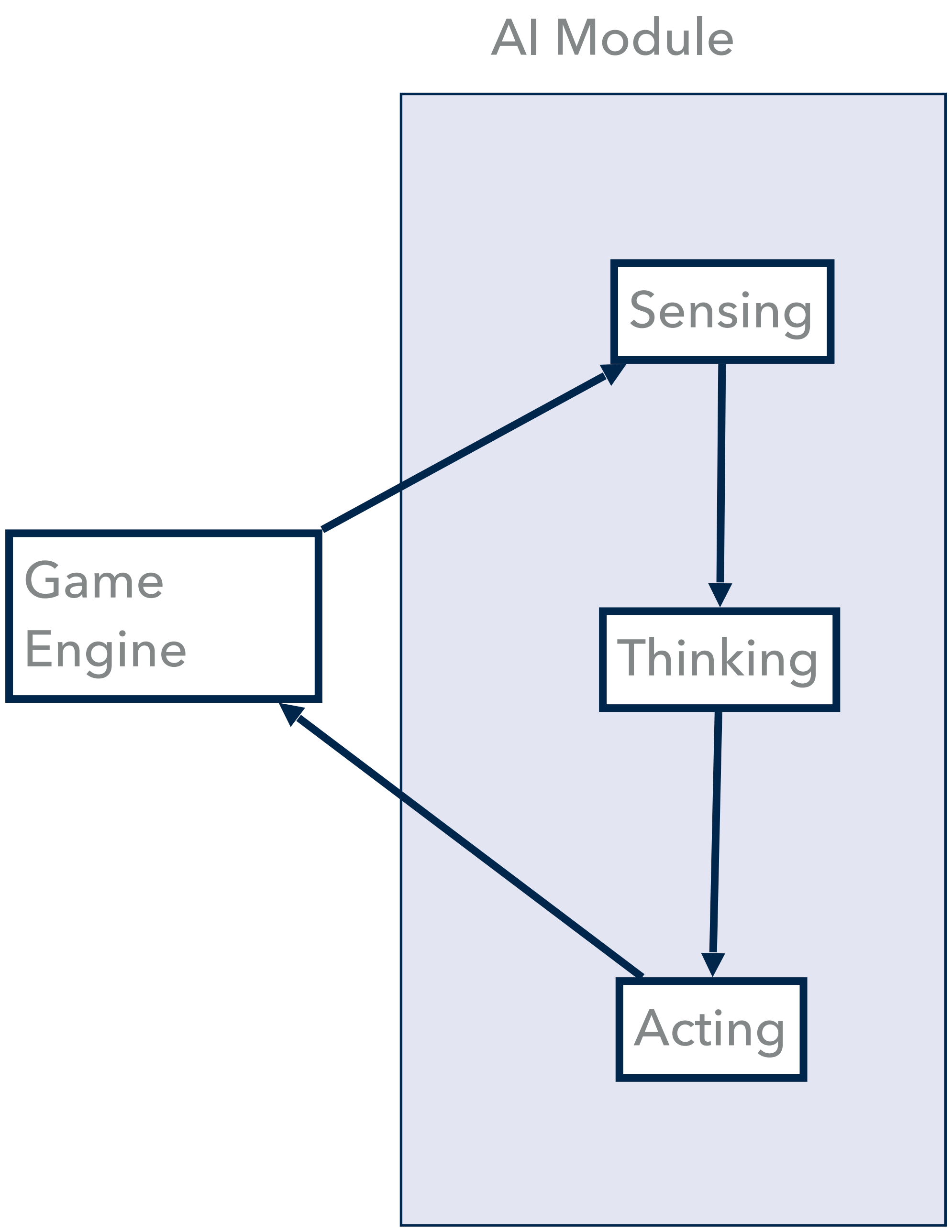
- Consider how an AI system might need to interact with other game systems
  - https://www.youtube.com/watch?v=7ESipcQunHc
  - https://www.youtube.com/watch?v=8x9xoxB1DfI
  - https://youtu.be/6402TvQMPkU?t=8348

AI AND ANIMATION

- How should AI and animation relate?
- Scenario 1: The AI issues an order (move from A to B), and the animation system controls character accordingly
- Scenario 2: The AI controls everything including which animation clip to play
- Controls depend on the AI and animation systems
  - Is the animation system based on move trees (motion capture), physics, or something else?
  - Does the AI handle collision avoidance? Does it do detailed planning?

AI UPDATE STEP

- Sensing
  - Determine state of the world
  - May be very simple - state changes all come by message
  - Or complex - figure out what is visible, where your team is, etc
- Thinking
  - Decide what to do
- Acting
  - Execute on decision
  - Notify animation and world state



AI BY POLLING

- The AI gets called at a fixed rate
- Sensing: agent looks to see what has changed in the world
  - Queries what it can see
  - Checks if its current animation has completed
- Thinking: agent decides on an action
- Acting: agent acts
- Why is this generally inefficient?

EVENT DRIVEN AI

- Event-driven AI responds to changes in the world
  - Events sent by message just like the user interface
- Example messages:
  - A certain amount of time has passed, so update yourself
  - You hear a sound
  - Someone has entered your field of view
- May want hybrid of polling and events depending on situation

AI TECHNIQUES

- Basic problem: Given the state of the world, what should I do?
- A wide range of techniques used in games:
  - Finite state machines, decision trees, rule-based systems, neural networks, fuzzy logic, behavior trees
- A wider range of solutions in the academic world:
  - Complex planning systems, logic programming, genetic algorithms, Bayes-nets
  - Typically, too slow for games but becoming more common

GOALS OF GAME AI

- Desirable Characteristics:
  - Goal driven - the AI decides what it should do, and figures out how to do it
  - Reactive - the AI responds to changes in the world
  - Knowledge intensive - the AI knows a lot about the world, and embodies knowledge in its own behavior
  - Characteristic - Embodies a believable, consistent character
  - Fast and easy development (designer-controlled)
  - Low CPU and memory usage
- Of course, these conflict in almost every way…

TWO MEASURES OF COMPLEXITY

- Complexity of Execution
  - How fast does it run when knowledge is added?
  - How much memory is used when knowledge is added?
  - Determines the run-time cost of the AI
- Complexity of Specification
  - How hard is it to write the code?
  - As knowledge is added, how much more code is written?
  - Determines the development cost, and risk

EXPRESSIVENESS

- What behaviors can be easily defined, or defined at all?
- Propositional logic:
  - Statements about specific objects in the world (no variables)
  - Jim is in room7, Jim has the rocket launcher, the rocket launcher does splash damage
  - Go to room8 if you are in room7 through door14
- Predicate Logic:
  - Allows general statements (using variables)
  - All rooms have doors
  - All splash damage weapons can be used around corners
  - All rocket launchers do splash damage
  - Go to a room connected to the current room

FINITE STATE MACHINES (FSMS)

- A set of the agent’s states
- Transitions between states triggered by a change in the world
- Represented as a directed graph (edges labeled with the transition events)
- Ubiquitous in computer game AI
- You might have seen them in formal language theory or compilers

CONSIDER…

- Consider the bot AI of an arena shooter (e.g. Quake). What do we need in our FSM to capture some of its desired base behaviors?

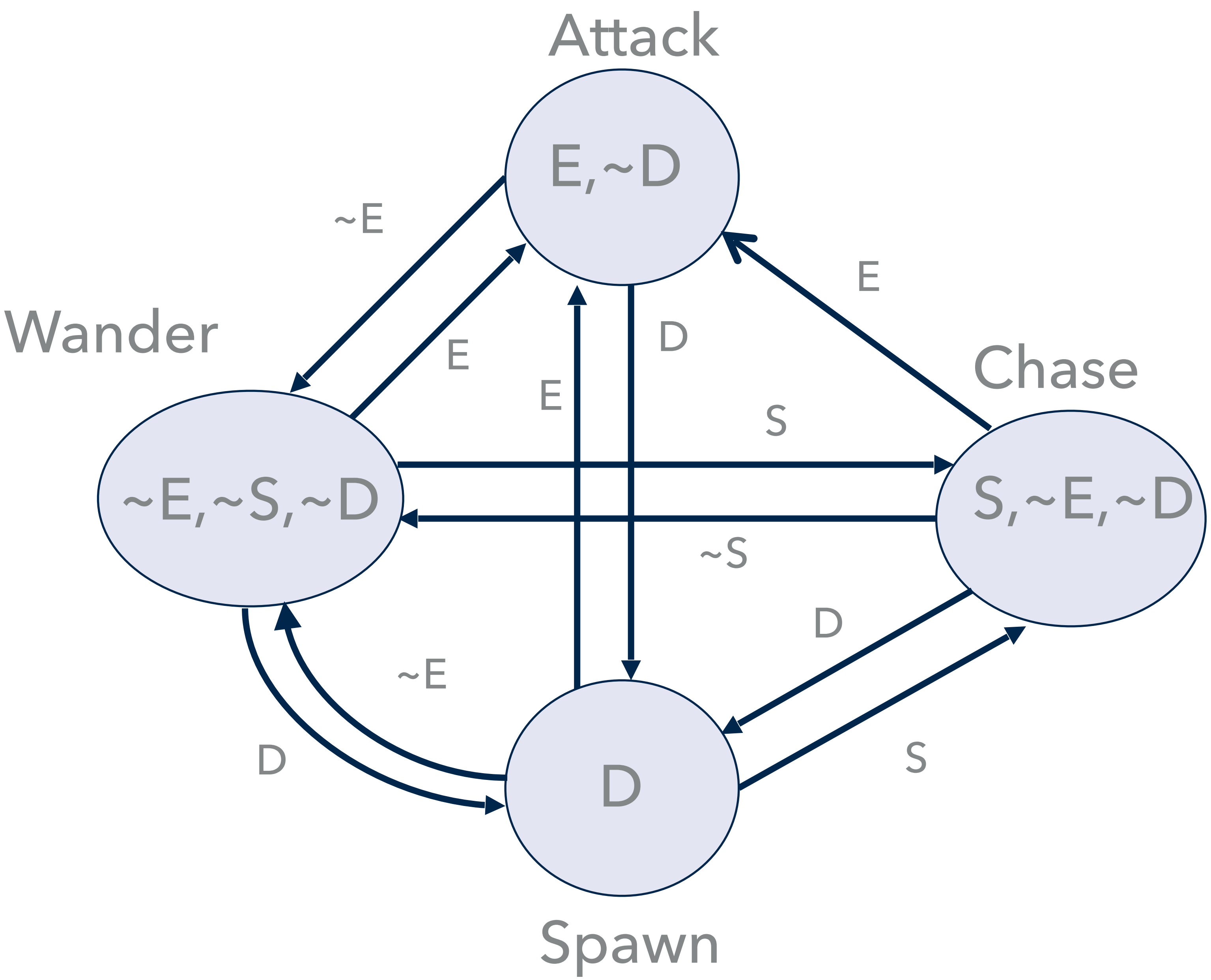
QUAKE BOT EXAMPLE

- Types of behavior to capture:
  - Wander randomly if no sight or sound of an enemy
  - When enemy is seen, attack
  - When enemy is heard, chase
  - When dead, respawn
  - When health is low and enemy is seen, retreat
- Extensions:
  - When power-ups are seen, collect

(from John Laird and Mike van Lent's GDC tutorial)

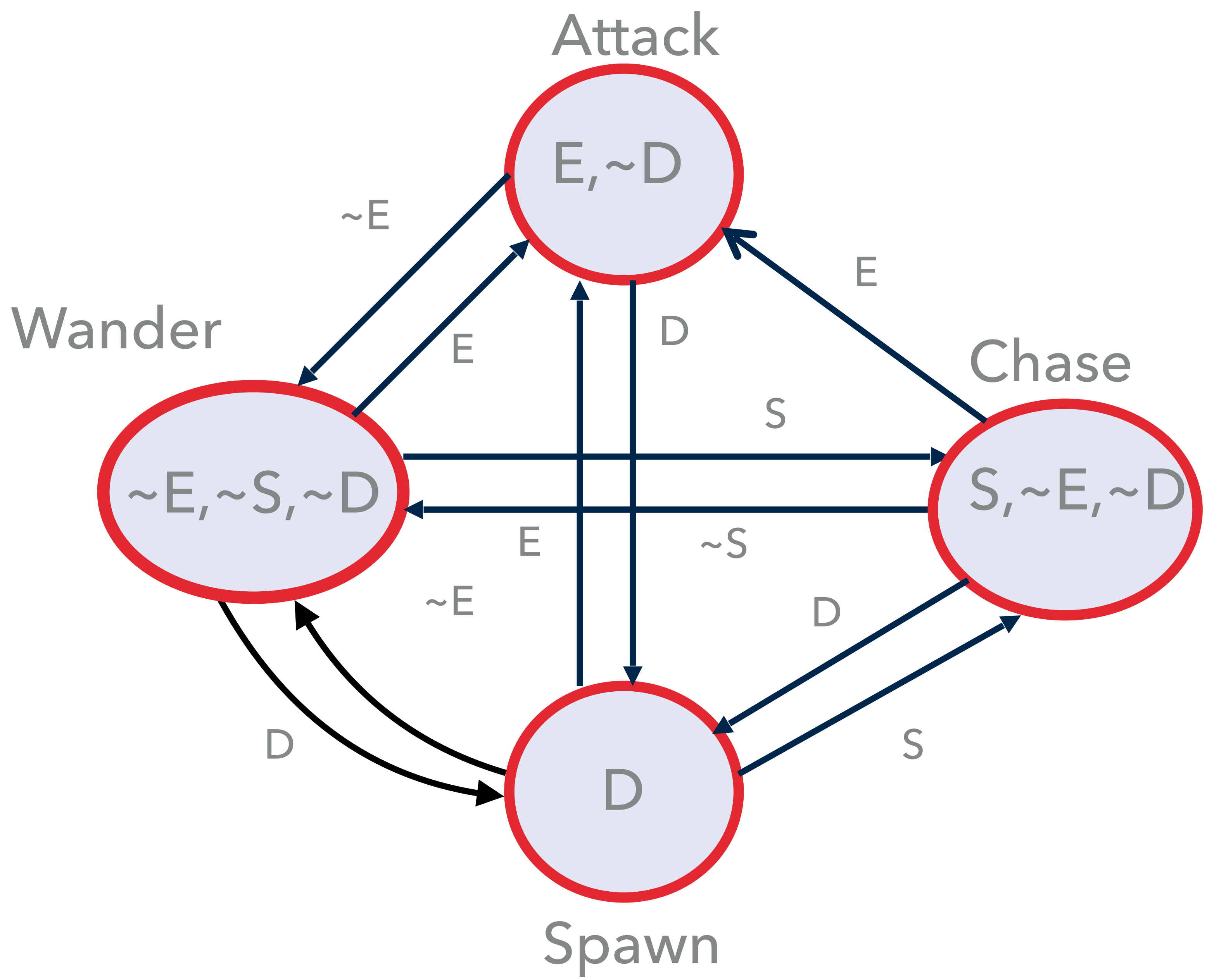
EXAMPLE FSM

- States:
  - E: enemy in sight
  - S: sound audible
  - D: dead
- Events:
  - E: see an enemy
  - S: hear a sound
  - D: die
- Action performed:
  - On each transition
  - On each state updated



EXAMPLE FSM PROBLEM

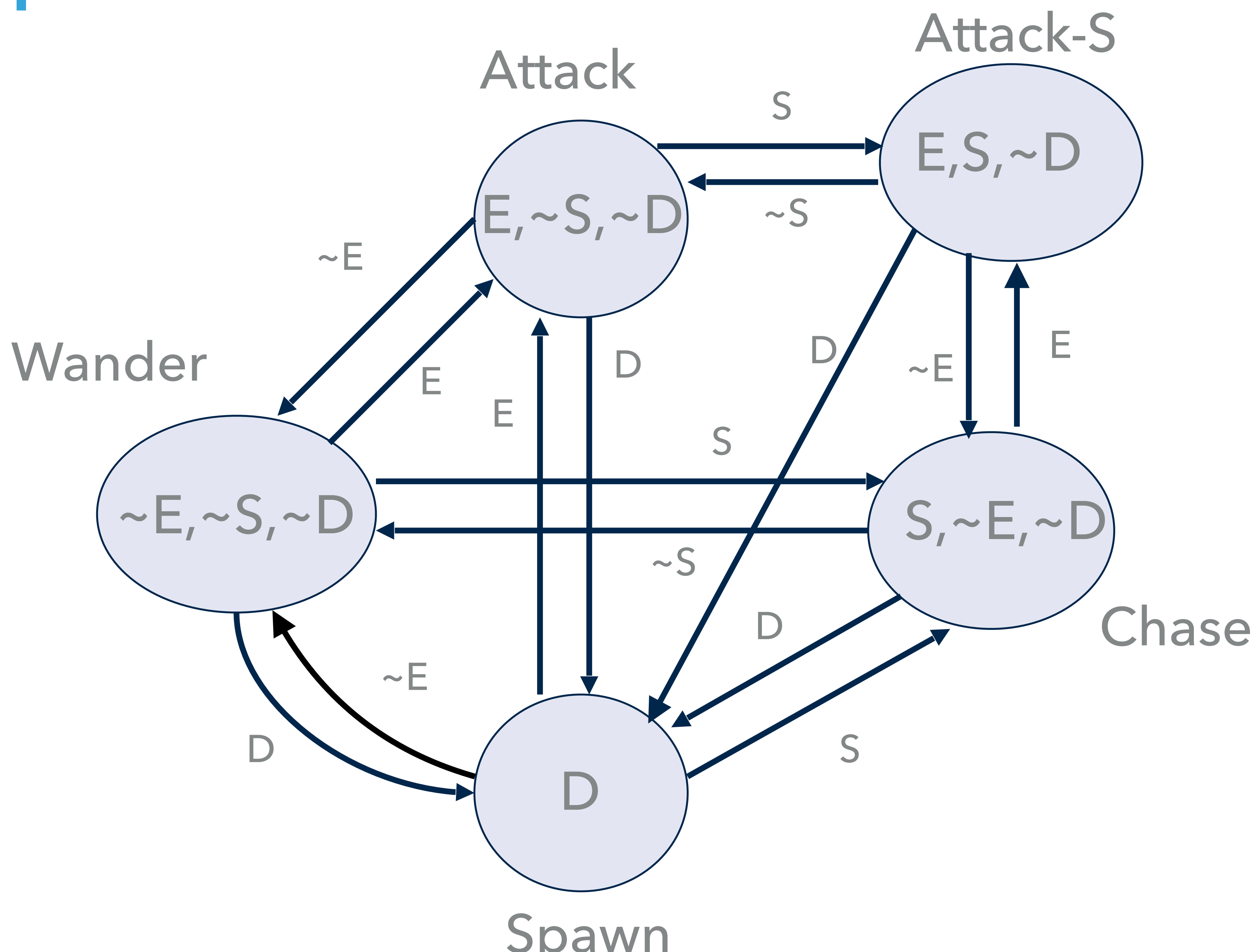
- States:
  - E: enemy in sight
  - S: sound audible
  - D: dead
- Events:
  - E: see an enemy
  - S: hear a sound
  - D: die



Problem: Can't go directly from attack to chase. Why not?

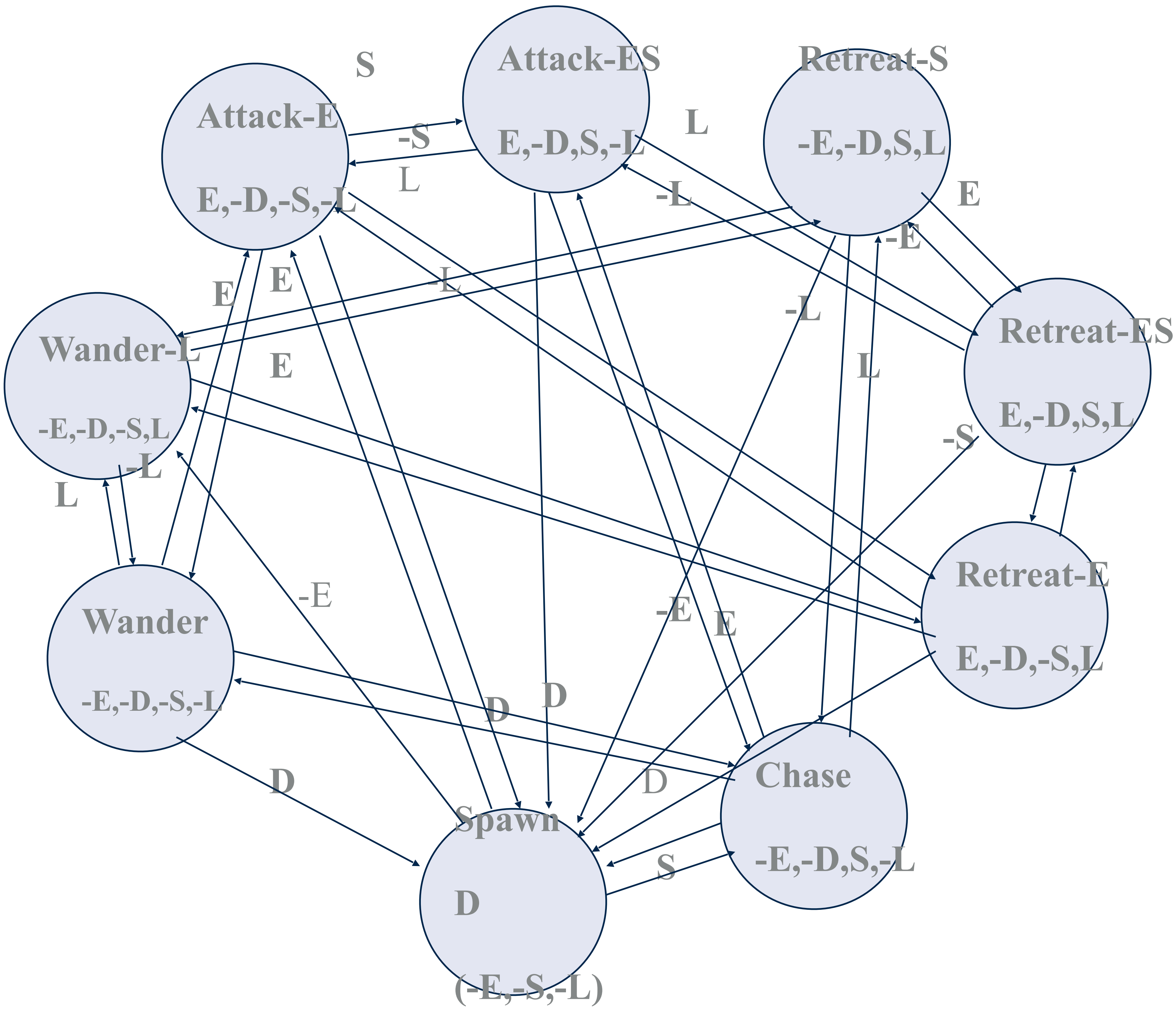
BETTER EXAMPLE FSM

- States:
  - E: enemy in sight
  - S: sound audible
  - D: dead
- Events:
  - E: see an enemy
  - S: hear a sound
  - D: die



- Extra state to recall whether or not heard a sound while attacking

EXAMPLE FSM WITH RETREAT



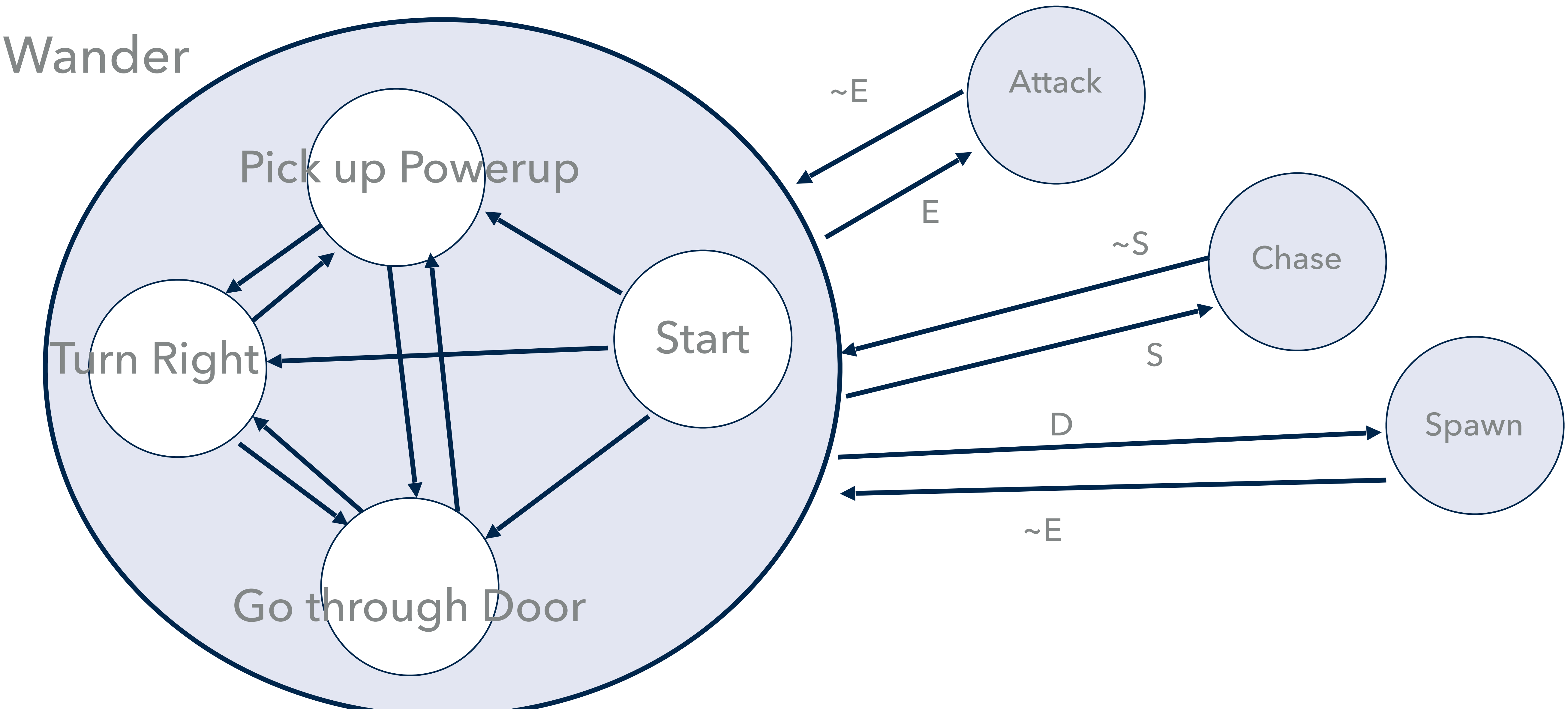
- States:
  - E: enemy in sight
  - S: sound audible
  - D: dead
  - L: Low health
- Worst case: Each extra state variable can add *2n* extra states
  - *n* = number of existing states

HIERARCHICAL FSMS

- What if there is no simple action for a state?
- Expand a state into its own FSM, explaining what to do
- Some events move you along the same level in the hierarchy, some move you up a level
- When entering a state, choose a state for its child in the hierarchy
  - Set a default, and always go to that
  - Or, random choice
  - Depends on the nature of the behavior!

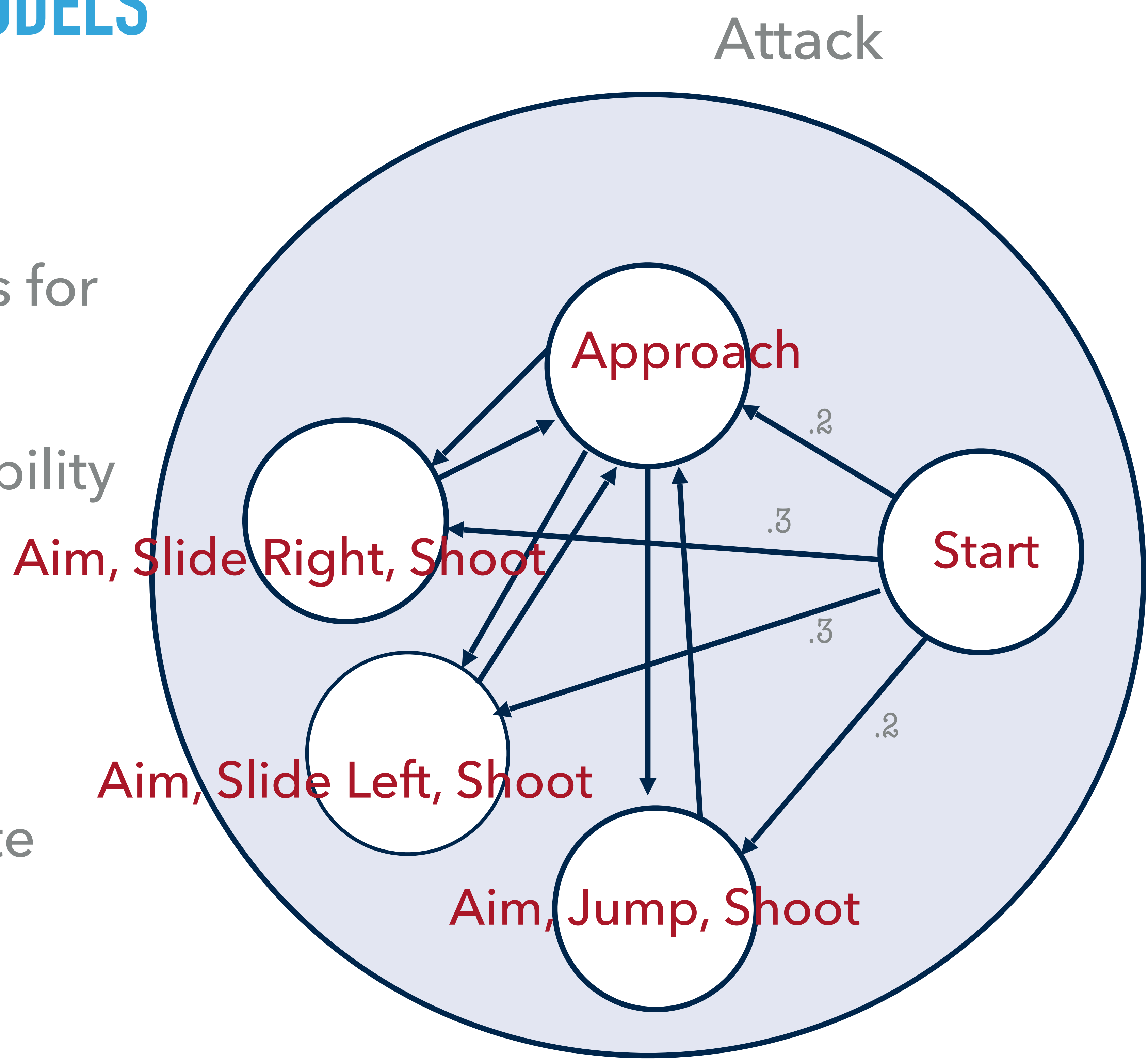
HIERARCHICAL FSM EXAMPLE

- All links between top level states still exist
- Note: This is not a complete FSM (need more states for wander)



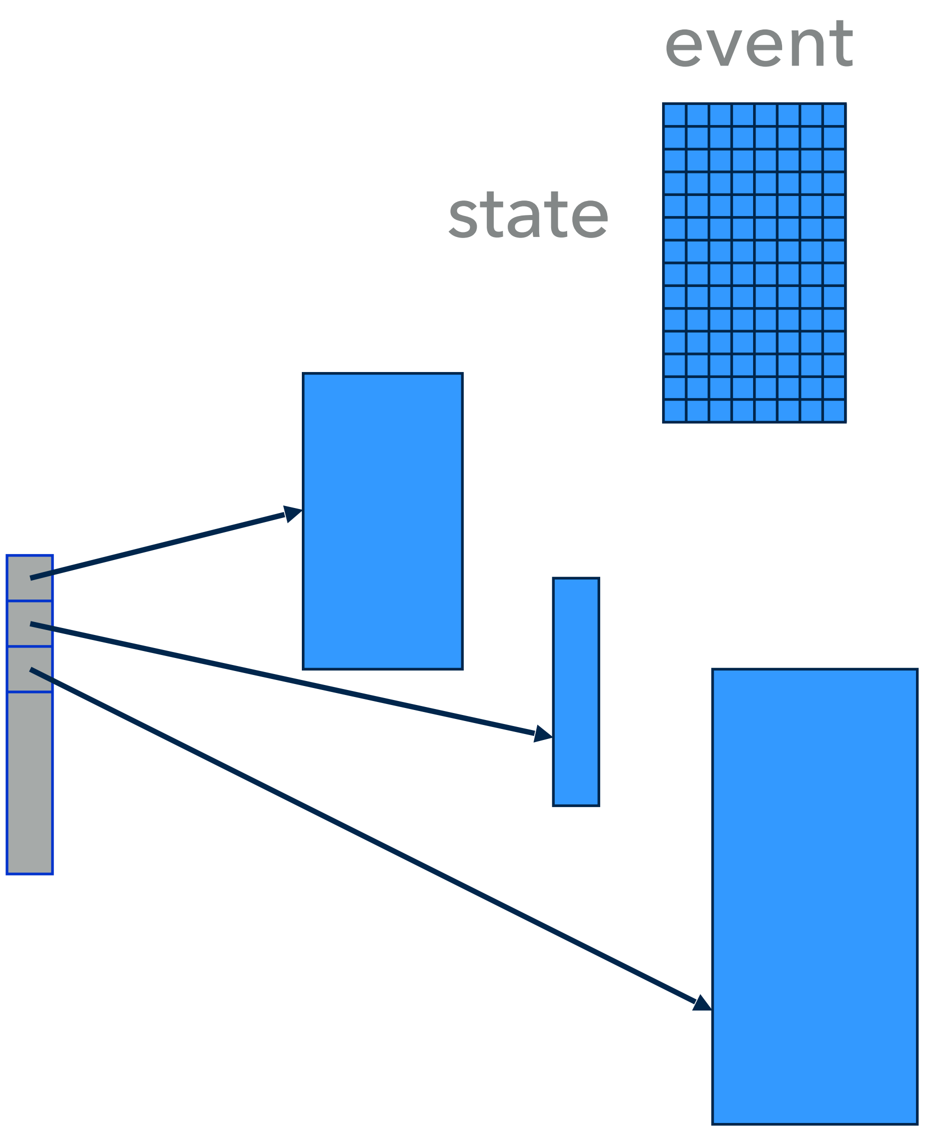
NON-DETERMINISTIC MODELS

- Adds variety to actions
- Have multiple transitions for the same event
- Label each with a probability that it will be taken
- Randomly choose a transition at run-time
- Markov Model: New state only depends on the previous state



"EFFICIENT" IMPLEMENTATION

- Compile into an array of state-name, event
- state-name$_{i+1}$:= array[state-name$_i$, event]
- Switch on state-name to call execution logic
- Hierarchical
  - Create array for every FSM
  - Have stack of states
    - Classify events according to stack
    - Update state which is sensitive to current event
- Markov: Have array of possible transitions for every (state-name,event) pair, and choose one at random



FSM ADVANTAGES

- Very fast – one array access
- Expressive enough for simple behaviors or characters that are intended to be “dumb”
- Can be compiled into compact data structure
  - Dynamic memory: current state
  - Static memory: state diagram – array implementation
- Can create tools for non-programmers to build behavior
- Non-deterministic FSM makes behavior unpredictable

FSM DISADVANTAGES

- Number of states can grow very fast
  - Exponentially with number of events: $s = 2^e$
- Number of transitions can grow even faster: $a = s^2$
- Propositional representation
  - Difficult to put in “pick up the better powerup”, “attack the closest enemy”
  - Expensive to count: Wait until the third time I see enemy, then attack
    - Need extra events: First time seen, second time seen, and extra states to take care of counting