Principles of Computer Game Design and Implementation

Lecture 23

We already learned

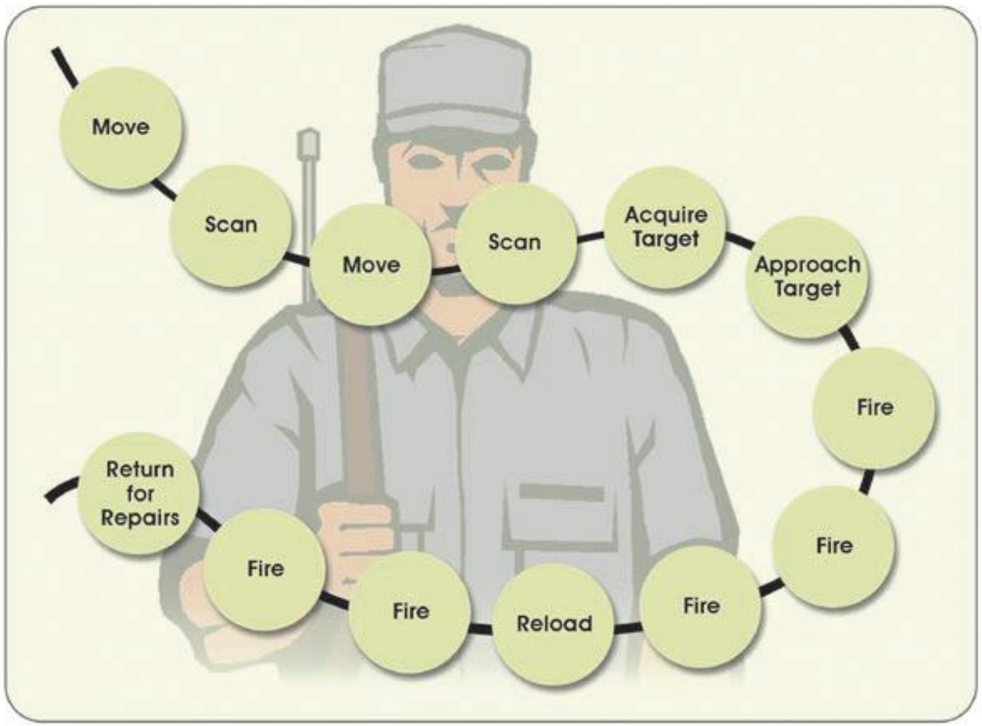
- Decision Tree

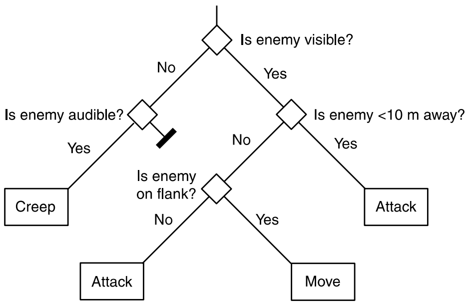
Outline for today

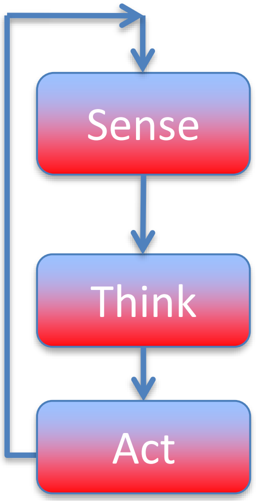
- Finite state machine

Creating & Controlling AI Behaviors

Behavior: A Sequence of Actions

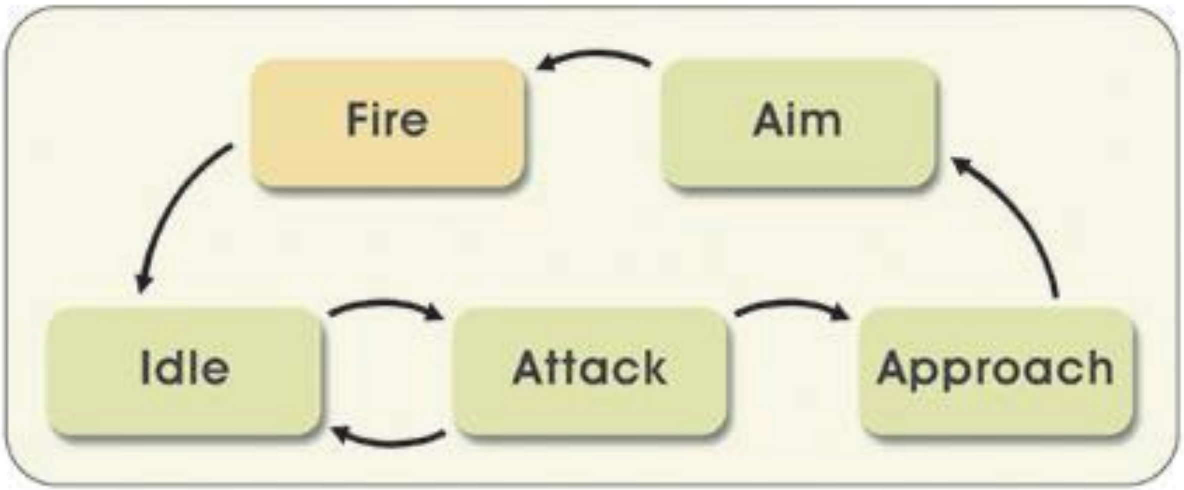






The patrol and guard behavior is defined as a sequence of actions

So, Basically…



- An agent goes through a sequence of *states*
- Arrows indicate *transitions*

Finite-State Machine (FSMs)

- Abstract model of computation
  - Formally:
    - Set of states
    - A starting state
    - An input vocabulary
    - A transition function that maps inputs and the current state to a next state

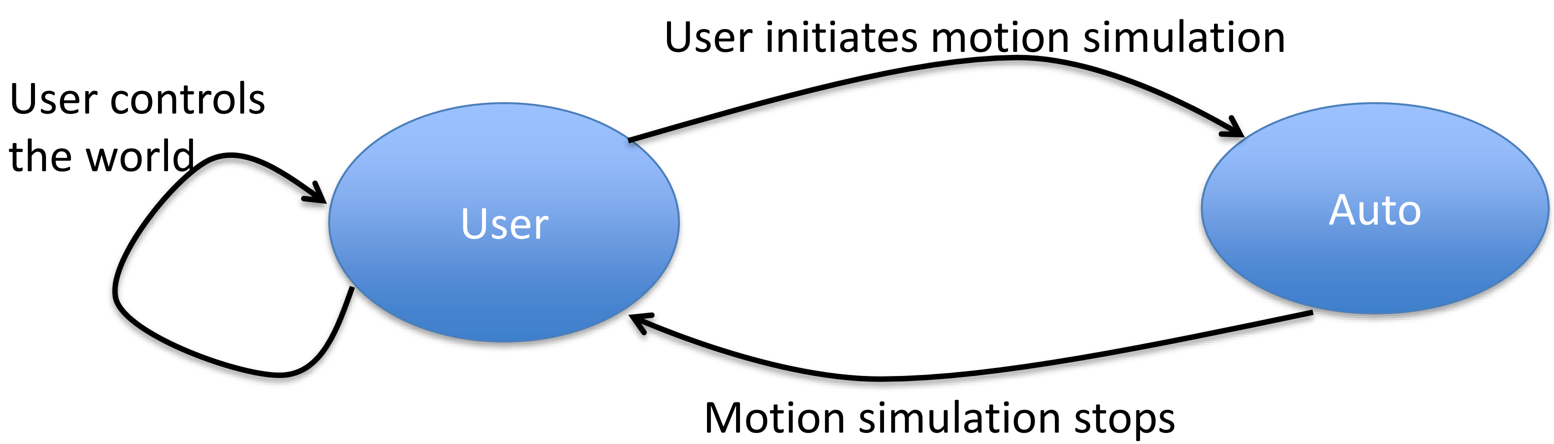
FSMs In Game Development

Deviate from formal definition

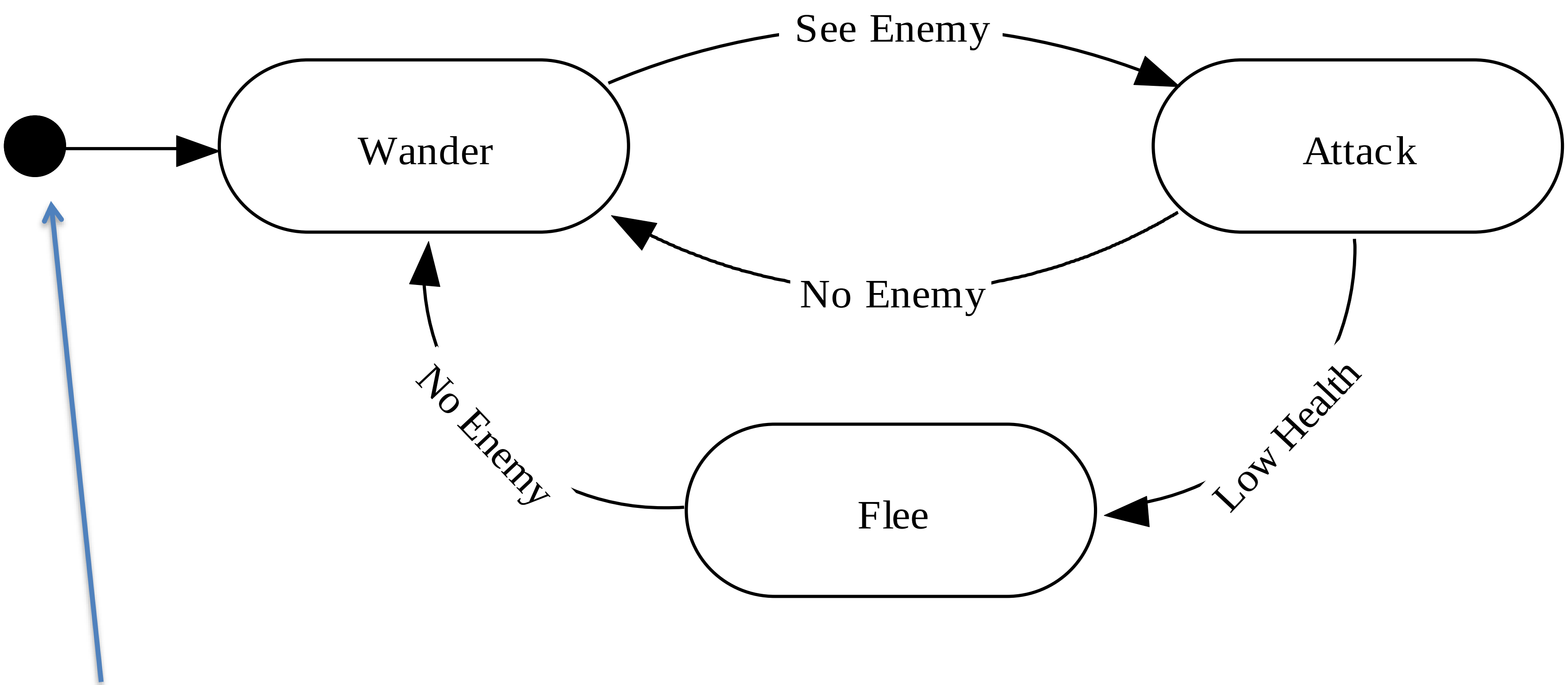
1. States define behaviors (containing code)
    - Wander, Attack, Flee
    - As longer as an agent stays in a state, it carries on the same action
2. Transition function divided among states
    - Keeps relation clear
3. Extra state information
    - For example, health

Recall: User Control V Modelling

- In these examples, user controlled completely the state of the world or there was no user input.
  - How to mix user control and physical modelling?
    - Game states



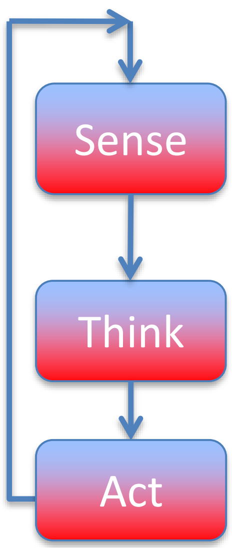
Finite-State Machine: UML Diagram



Initial state

State Actions

- Actions is what player sees
  - Movement
  - Animation
- Instead of one action can consider
  - onEntry
    - Executed when FSM enters the state
  - onExit
  - onUpdate
    - Runs *every tick* while FSM is in the state



Finite-State Machine: Approaches

- Three approaches
  - Hardcoded (switch statement)
  - Scripted
  - Hybrid Approach

Hard-Coded FSM

```
enum State {wander, attack, flee};
State state;
…
switch (state )
    {
        case wander:
            Wander();
            if( SeeEnemy() )     { state = State.attack; }
            break;

        case attack:
            Attack();
            if( LowOnHealth() ) { state = State.flee; }
            if( NoEnemy() )      { state = State.wander; }
            break;

        case flee:
            Flee();
            if( NoEnemy() )      { state = State.wander; }
            break;
    }
```

Hard-Coded FSM: Weaknesses

- Maintainability
  - Language doesn't enforce structure
  - Can't determine 1st time state is entered
- FSM change -> recompilation
  - Critical for large projects
  - Cannot be changed by game designers / players
- Harder to extend
  - Hierarchical FSMs
  - Probabilistic / fuzzy FSMs

Finite-State Machine:
Scripted with alternative language

```
BeginFSM
    State( STATE_Wander )
      OnEnter
         Java code
      OnUpdate
         Java code

         if(seeEnemy()) ChangeState(STATE_Attack);

      OnExit
         Java code
State( STATE_Attack )
    OnEnter
               Java code
      OnUpdate
                  Java code to execute every tick
      OnExit
EndFSM
```

Finite-State Machine: Scripting Advantages

1. Structure enforced
2. Events can be handed as well as polling
3. OnEnter and OnExit concept exists
4. Can be authored by game designers
   – Easier learning curve than straight C/C++

Finite-State Machine: Scripting Disadvantages

- Not trivial to implement
- Several months of development
  - Custom compiler
    - With good compile-time error feedback
  - Bytecode interpreter
    - With good debugging hooks and support
- Scripting languages often disliked by users
  - Can never approach polish and robustness of commercial compilers/debuggers

Finite-State Machine: Hybrid Approach

- Use a class and C-style macros to approximate a scripting language
- Allows FSM to be written completely in C++ leveraging existing compiler/debugger
- Capture important features/extensions
  - OnEnter, OnExit
  - Timers
  - Handle events
  - Consistent regulated structure
  - Ability to log history
  - Modular, flexible, stack-based
  - Multiple FSMs, Concurrent FSMs
- Can't be edited by designers or players

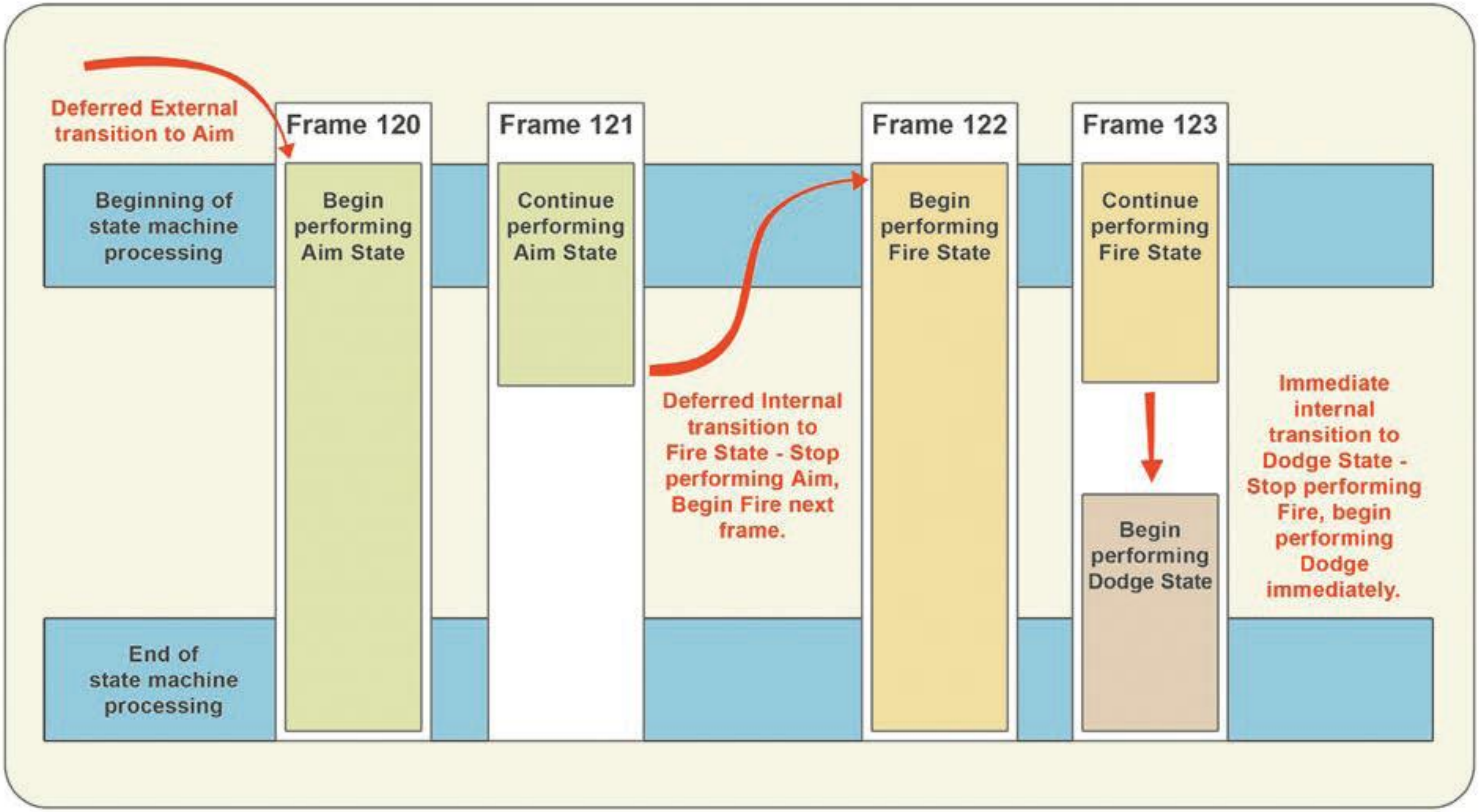
Transitions

- Internal
  - Independent of environment
  - E.g. out of ammo
- External
  - Event-driven
- Immediate
- Deferred
  - E.g. to wait till animation sequence stops

Transitions

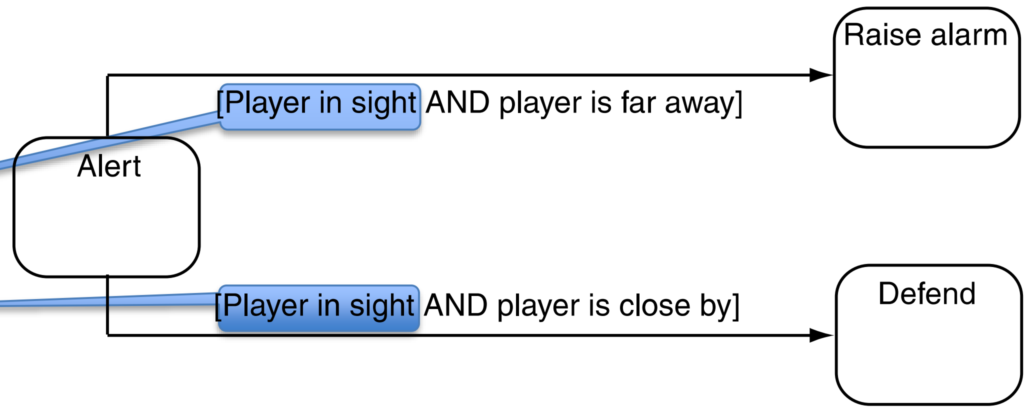
	Immediate	Deferred
Internal	Immediate transitions are used internally to eliminate delays in time critical operations.	Deferred transitions are used internally for most operations.
External	External transitions are not normally immediate.	External transitions are best performed using a deferred transition.

Transitions



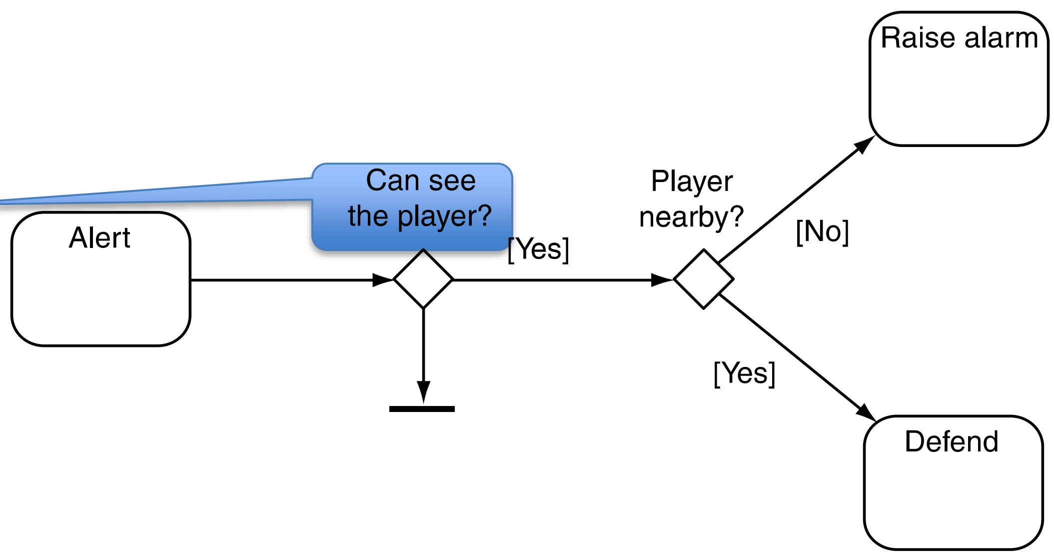
Decision Trees in Transitions

- Compare



Computationally-expensive test performed **twice**

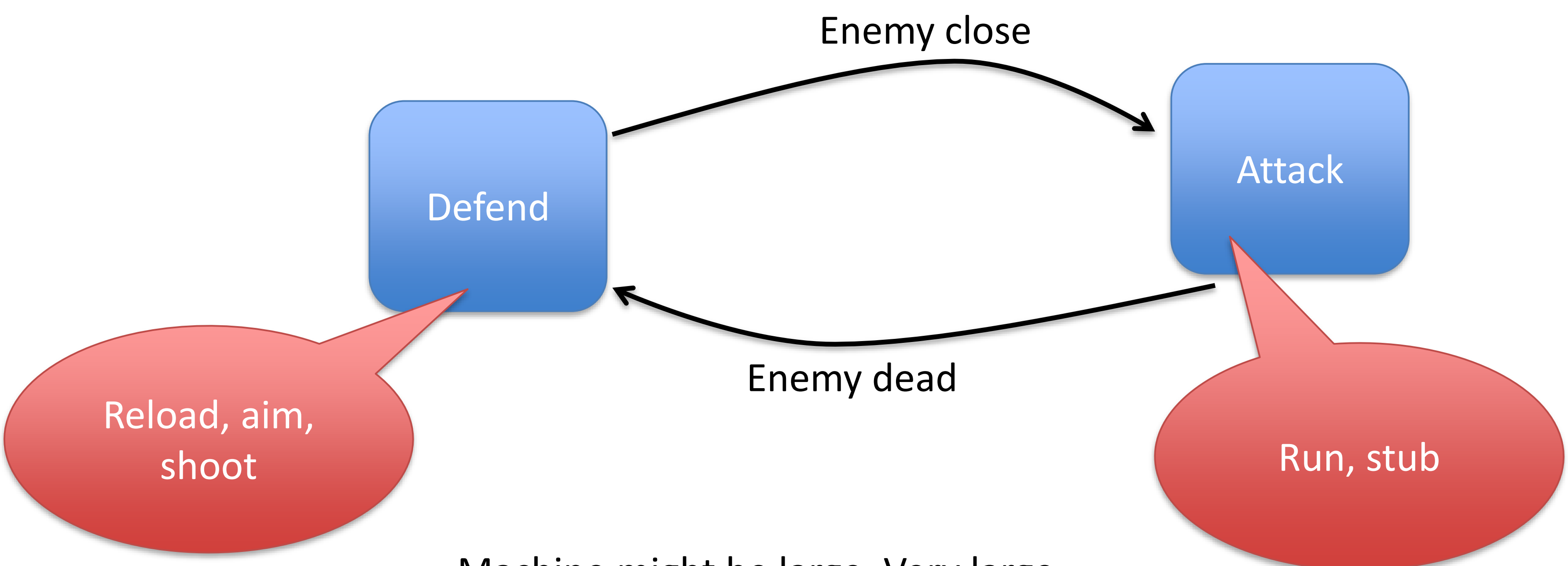
- With



Computationally-expensive test performed **once**

Generalisation: Hierarchical FSM

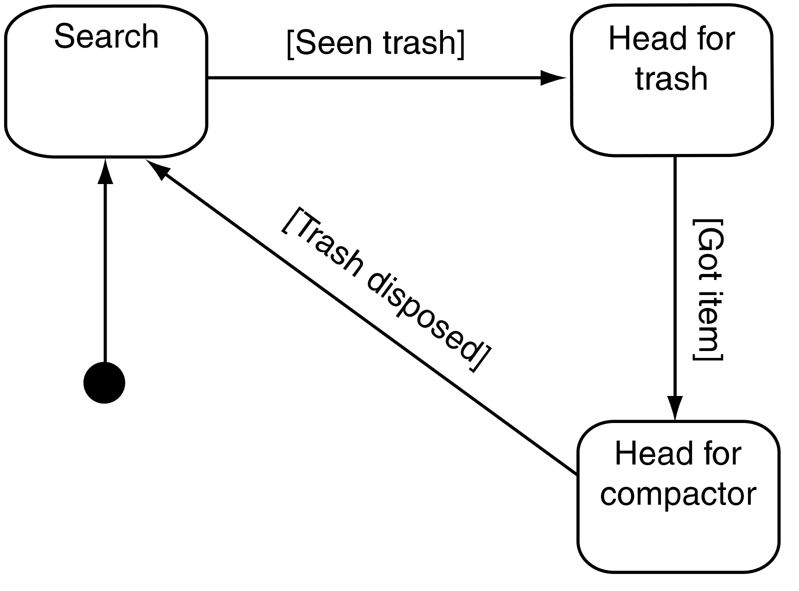
- Often, there are several "levels" of behaviour
  - Complications from "insignificant details"



Machine might be large. Very large.

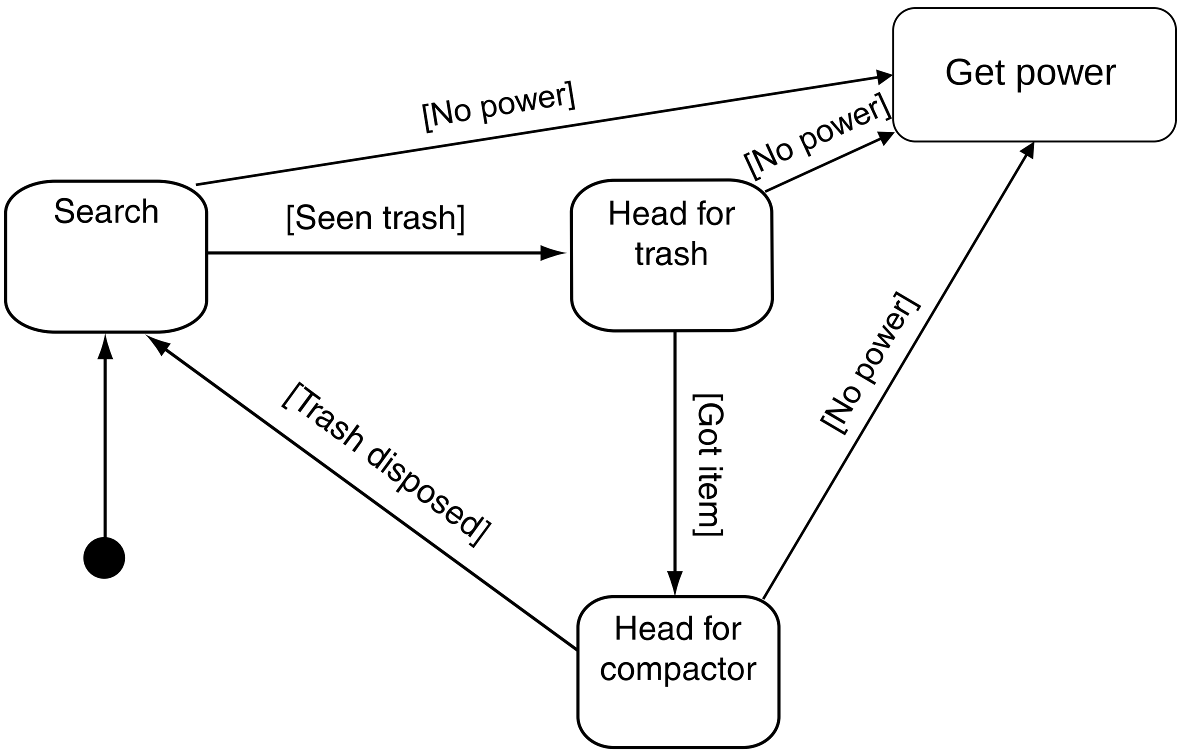
Clean Up FSM Example

- A robot cleans a floor space



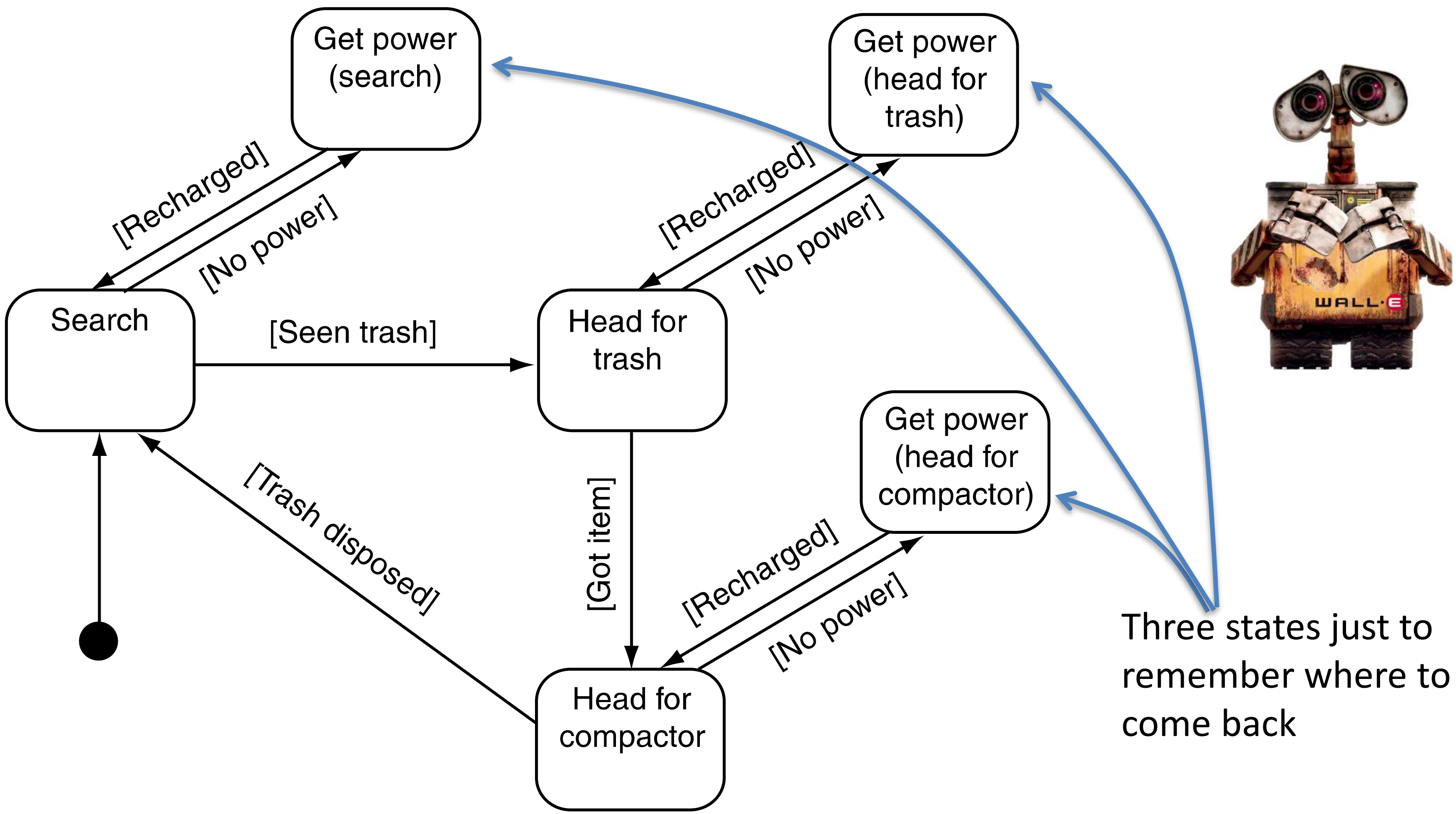
- Unless it recharges, it breaks

Recharging Clean Up FSM Example

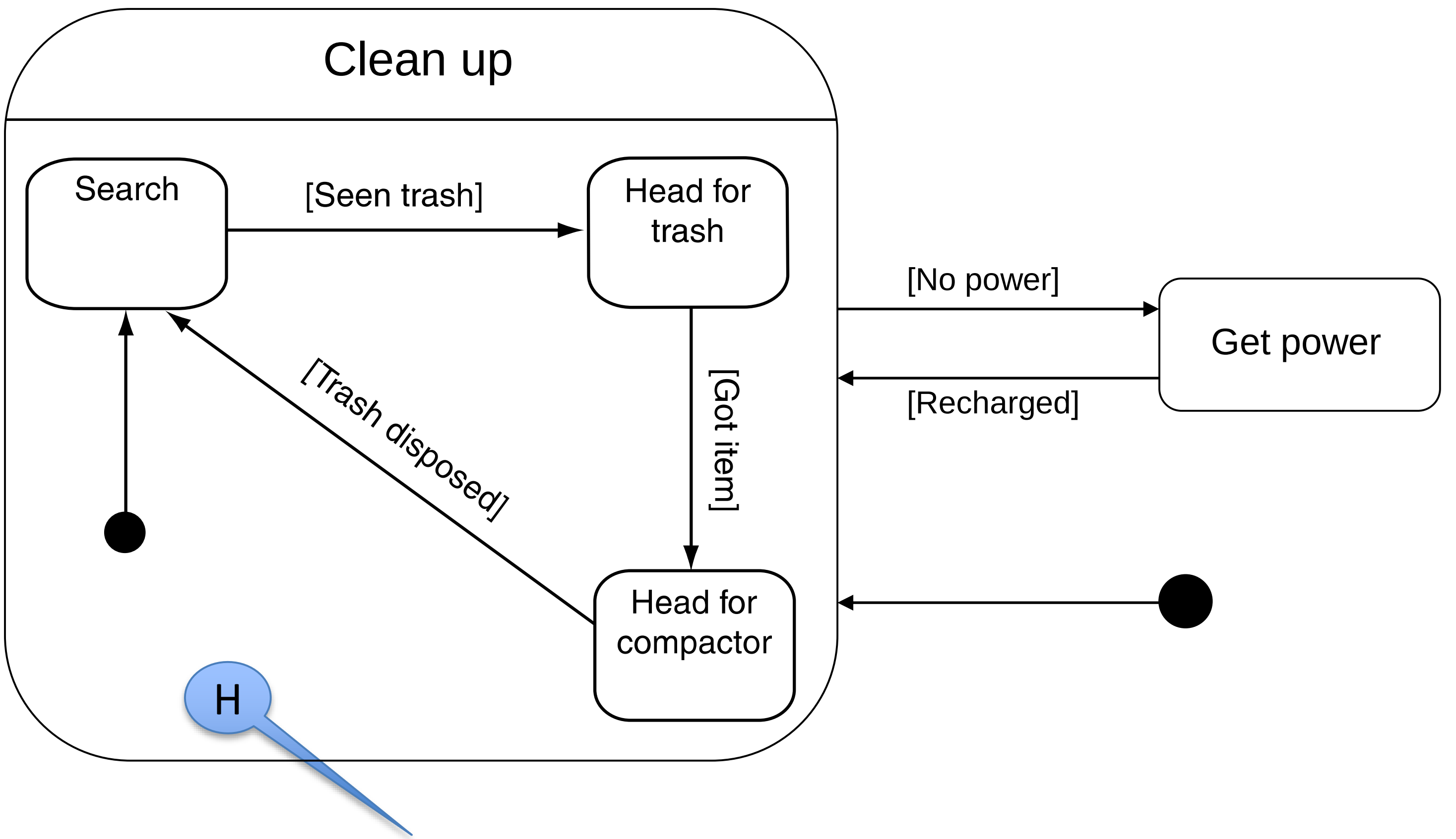


But what to do **after** charging???

Recharging Cleaner FSM

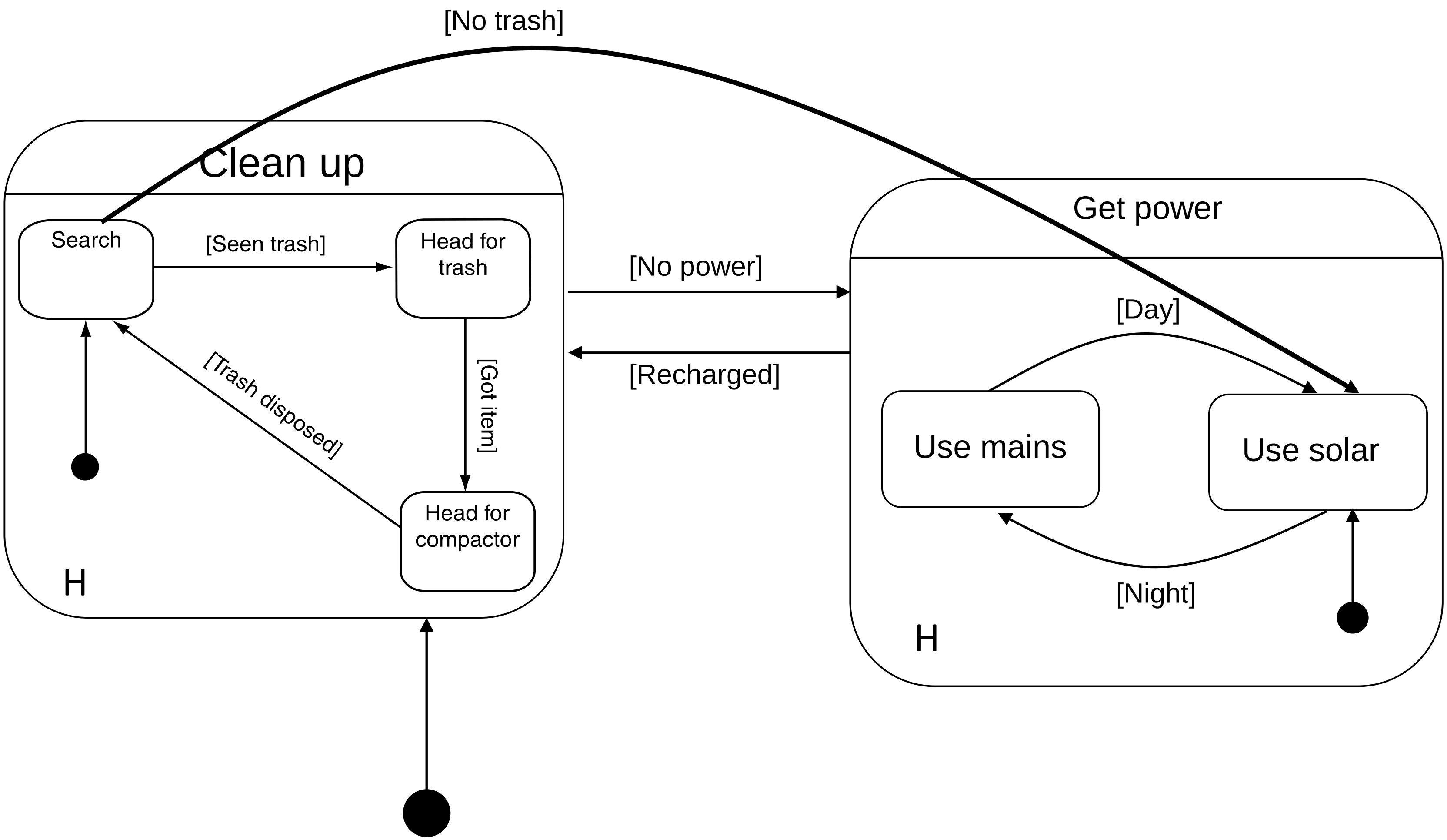


Hierarchical Approach



Hierarchical state

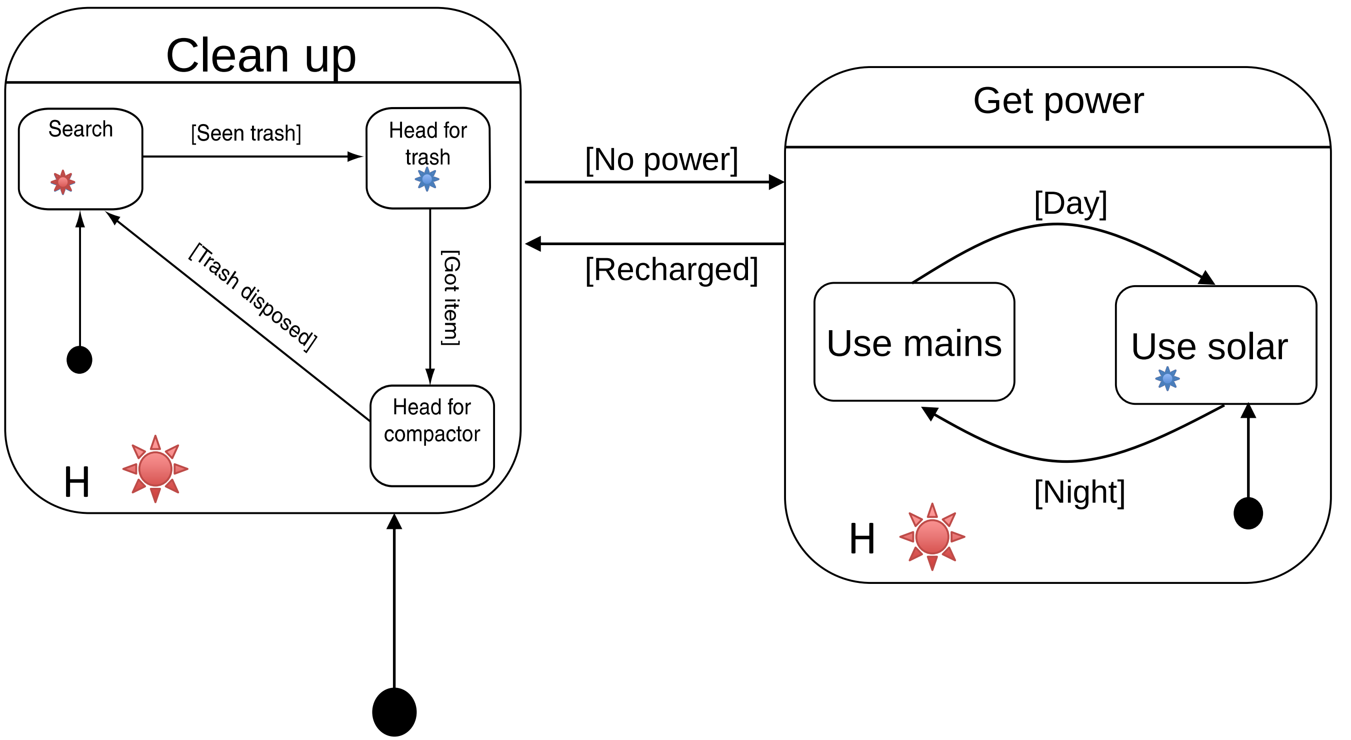
Hierarchical Recharge



Algorithm

- Based on the notion of a *current state*
  - Every state stores the current state of its sub FSM
- Hierarchical evaluation
  - If transition is applicable to higher-level current state
    - Change state
  - Else
    - Execute the OnStay method
    - Apply transition to the sub FSM

Example



Events:

- No power
- Recharged
- Seen trash
- No power
- …

Stack-Based FSMs

- This idea can be extended to allow storing past states using a stack
- Every time a machine is “suspended” the current state is pushed into the stack
- Every time it is “resumed” the state is popped from the stack
  – E.g. several machines and a switch between them

Finite-State Machine In Game Development: Summary

- Most common game AI software pattern
  - Natural correspondence between states and behaviors
  - Easy to diagram
  - Easy to program
  - *Easy to debug*
  - Completely general to any problem
- Problems
  - Explosion of states
  - Too predictable
  - Often created with ad hoc structure