State-Driven Agent Design

Artificial Intelligence for Interactive Media and Games

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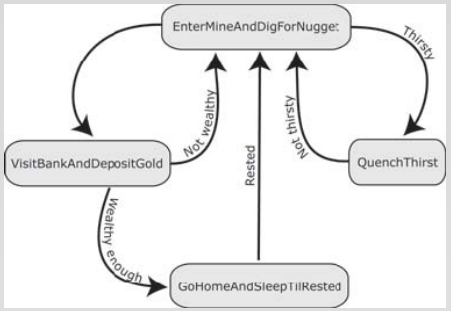
[Based on Buckland, Chapter 2 and lecture by Robin Burke]

Outline (2 days)

- State machines
  - motivation
  - West World state examples
  - implementation code
- Messages
  - motivation
  - West World message examples
  - implementation code
- Advanced concepts
  - hierarchical state machines
  - non-deterministic state machines (Markov)
- Homework #2 – Bar Fly (due Sunday midnight)
- Review Chapter 3 (steering)
- Read/prepare Chapter 4 for next week (Simple Soccer)

(Finite) State Machines (FSM's)



- Positive attributes
  - standard graphical notation
  - good for communication
  - still most commonly used AI method in games
  - easy to combine with other methods (goals, etc.)
  - fast execution
- Often very badly implemented
  - "spaghetti" code (if/then/else, switch, goto) --- a nightmare to maintain
  - we are going to study a clean, generic object-oriented implementation

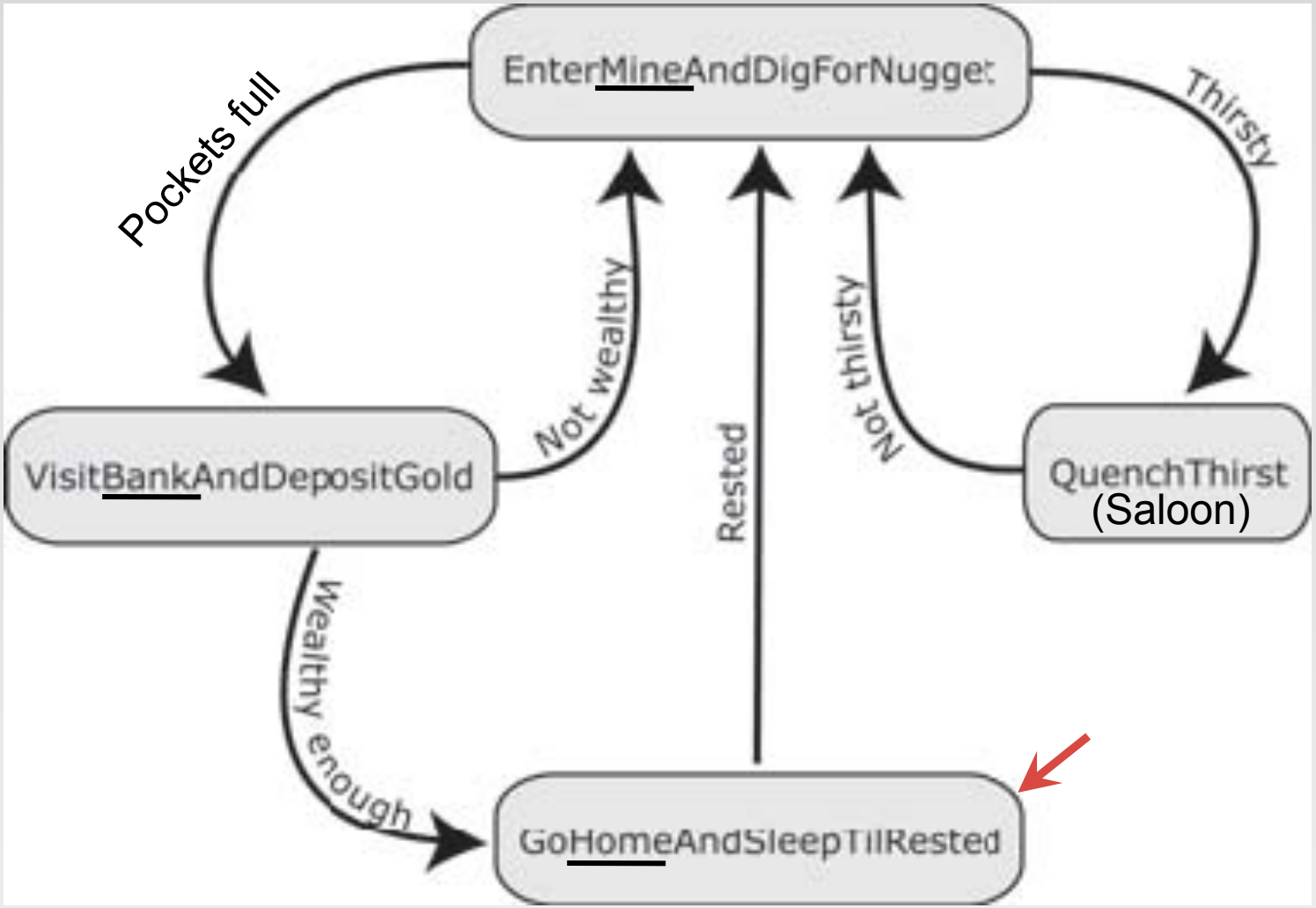
West World

- A “laboratory” for studying FSM’s
  - no graphics -- simple plain-text to console
  - allows us to study all the code in detail

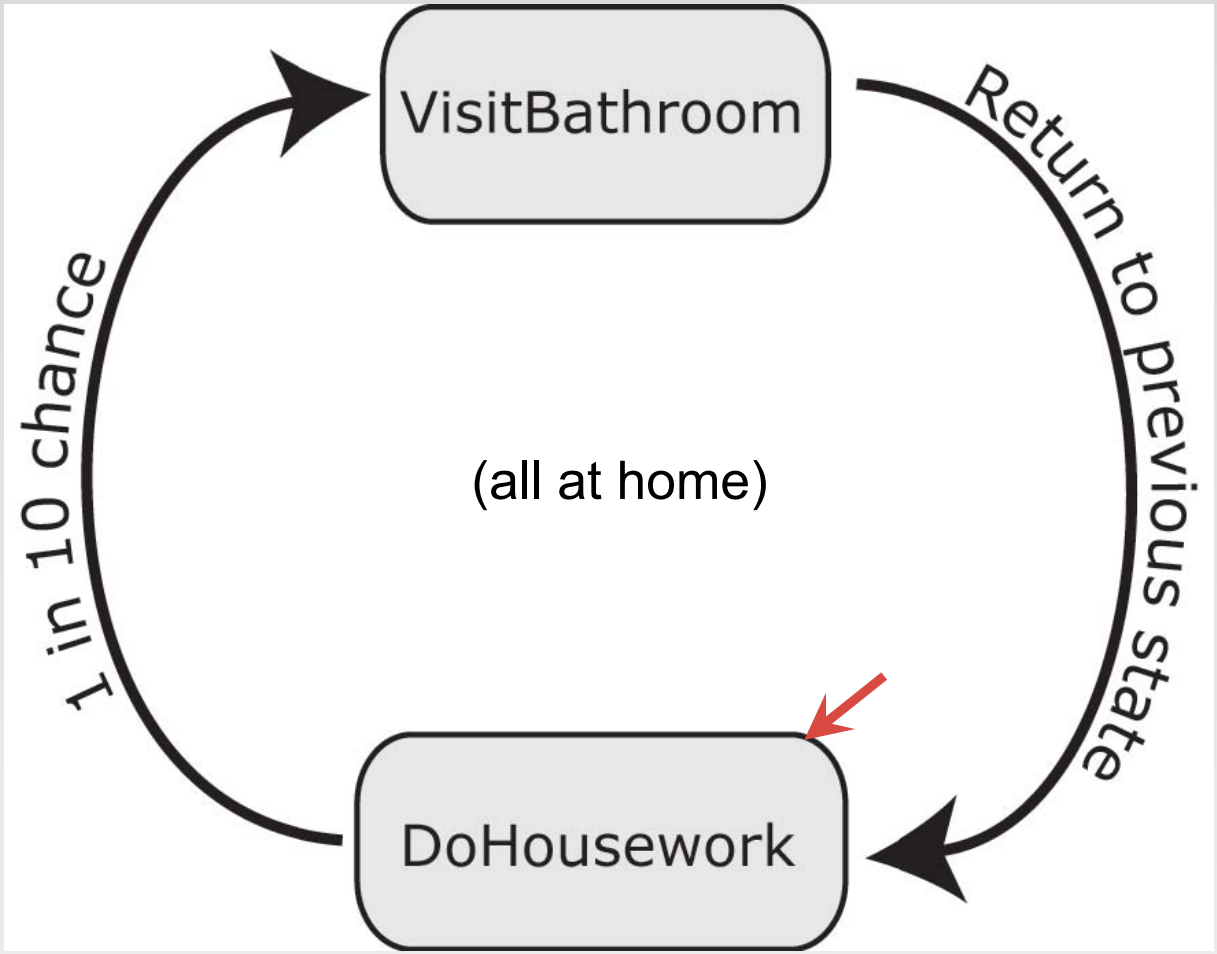
- Simulation-type game
  - two characters (agents): miner Bob and wife Elsa
  - next homework: add character Sal the bar fly
  - four locations: gold mine, bank, saloon, home
  - use FSM’s to model their activities

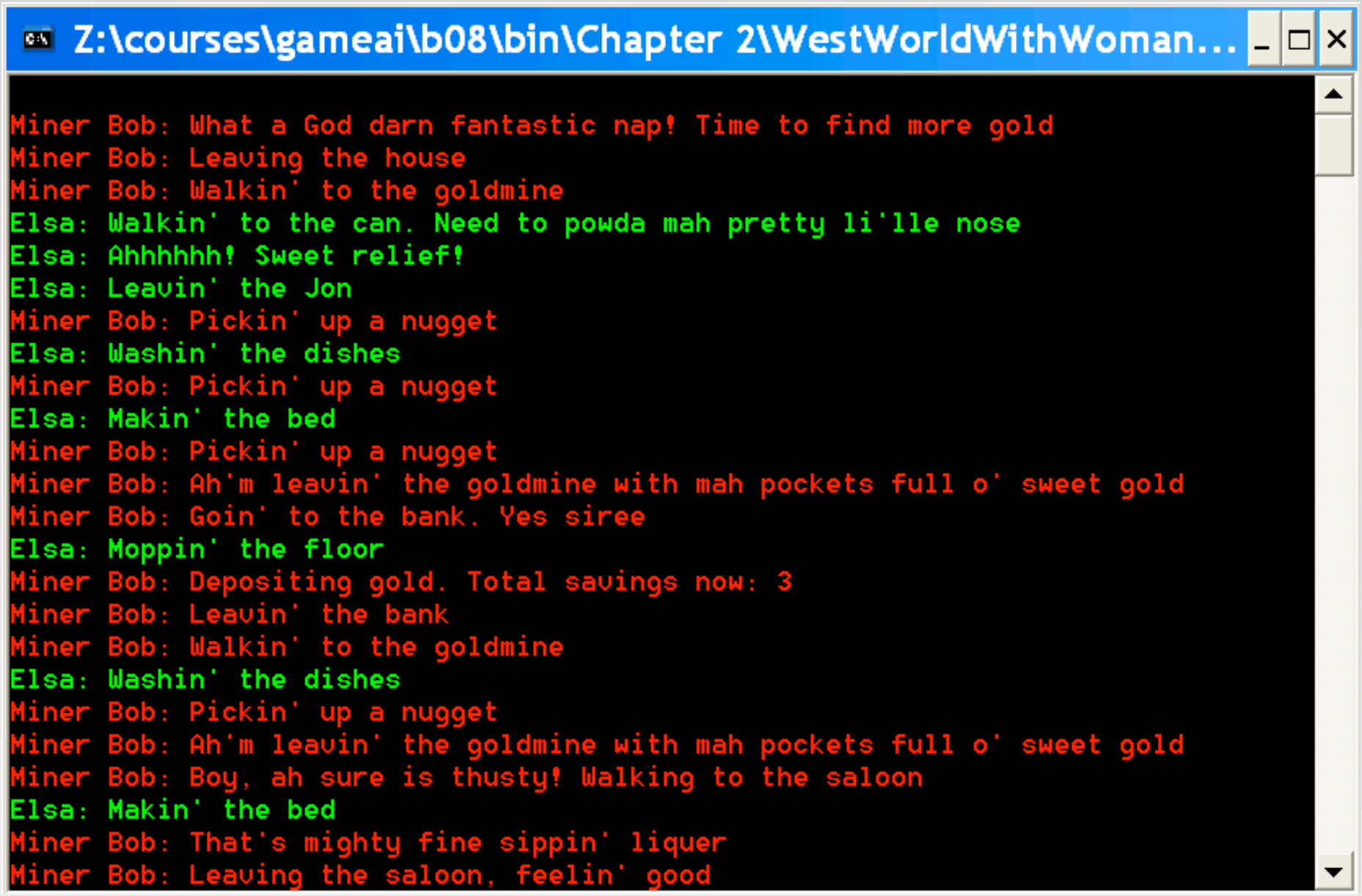
[get to do your own modeling in Homework #3]

Miner State Machine



Miner's Wife State Machine




Z:\courses\gameai\b08\bin\Chapter 2\WestWorldWithWoman...
Miner Bob: What a God darn fantastic nap! Time to find more gold
Miner Bob: Leaving the house
Miner Bob: Walkin' to the goldmine
Elsa: Walkin' to the can. Need to powda mah pretty li'lle nose
Elsa: Ahhhhhh! Sweet relief!
Elsa: Leavin' the Jon
Miner Bob: Pickin' up a nugget
Elsa: Washin' the dishes
Miner Bob: Pickin' up a nugget
Elsa: Makin' the bed
Miner Bob: Pickin' up a nugget
Miner Bob: Ah'm leavin' the goldmine with mah pockets full o' sweet gold
Miner Bob: Goin' to the bank. Yes siree
Elsa: Moppin' the floor
Miner Bob: Depositing gold. Total savings now: 3
Miner Bob: Leavin' the bank
Miner Bob: Walkin' to the goldmine
Elsa: Washin' the dishes
Miner Bob: Pickin' up a nugget
Miner Bob: Ah'm leavin' the goldmine with mah pockets full o' sweet gold
Miner Bob: Boy, ah sure is thusty! Walking to the saloon
Elsa: Makin' the bed
Miner Bob: That's mighty fine sippin' liquer
Miner Bob: Leaving the saloon, feelin' good

OO State Machine Implementation

- Each state is an object
  - encapsulates all information about the state
  - including how it decides which state (if any) to transition to next
  - generic template class, specific classes for game
  - *design issue:* states as singletons?
- Each agent has its own state machine
  - generic template class
    - current state
    - previous state (for “blips”)
    - global state (factor out shared code)

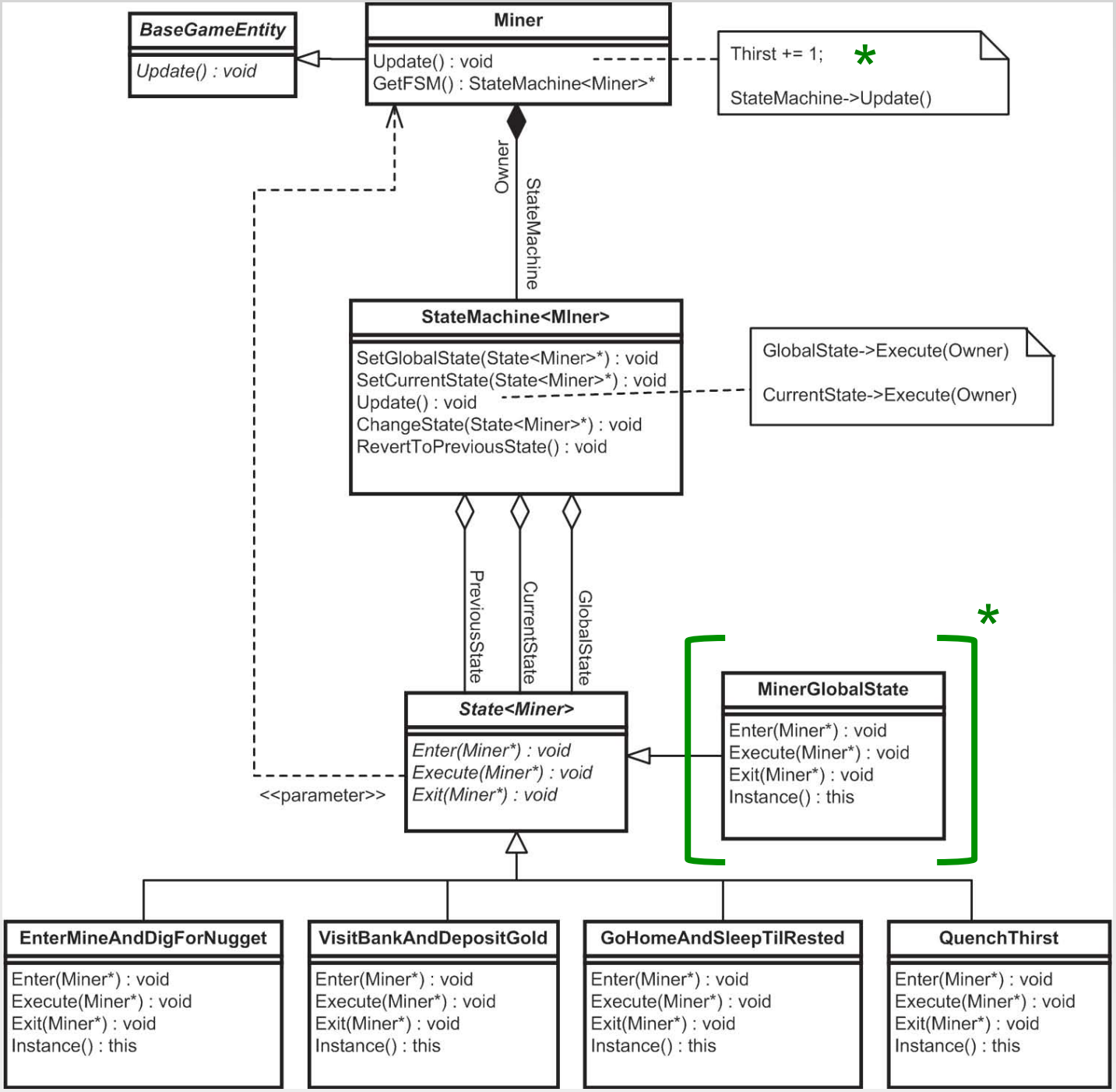
OO State Machine Implementation

- Calling sequence
  - game ➔ agent: *"update yourself"*
  - agent ➔ state machine: *"update yourself"*
  - state machine ➔ current state:

    "you are being entered for first time"

    "execute yourself"

    "you are being exited"


BaseGameEntity
Update() : void
Miner
Update() : void
GetFSM() : StateMachine<Miner>*
Thirst += 1;
StateMachine->Update()
*
Owner
StateMachine
StateMachine<MIner>
SetGlobalState(State<Miner>*) : void
SetCurrentState(State<Miner>*) : void
Update() : void
ChangeState(State<Miner>*) : void
RevertToPreviousState() : void
GlobalState->Execute(Owner)
CurrentState->Execute(Owner)
PreviousState
CurrentState
GlobalState
State<Miner>
Enter(Miner*) : void
Execute(Miner*) : void
Exit(Miner*) : void
<<parameter>>
MinerGlobalState
Enter(Miner*) : void
Execute(Miner*) : void
Exit(Miner*) : void
Instance() : this
*
EnterMineAndDigForNugget
Enter(Miner*) : void
Execute(Miner*) : void
Exit(Miner*) : void
Instance() : this
VisitBankAndDepositGold
Enter(Miner*) : void
Execute(Miner*) : void
Exit(Miner*) : void
Instance() : this
GoHomeAndSleepTilRested
Enter(Miner*) : void
Execute(Miner*) : void
Exit(Miner*) : void
Instance() : this
QuenchThirst
Enter(Miner*) : void
Execute(Miner*) : void
Exit(Miner*) : void
Instance() : this

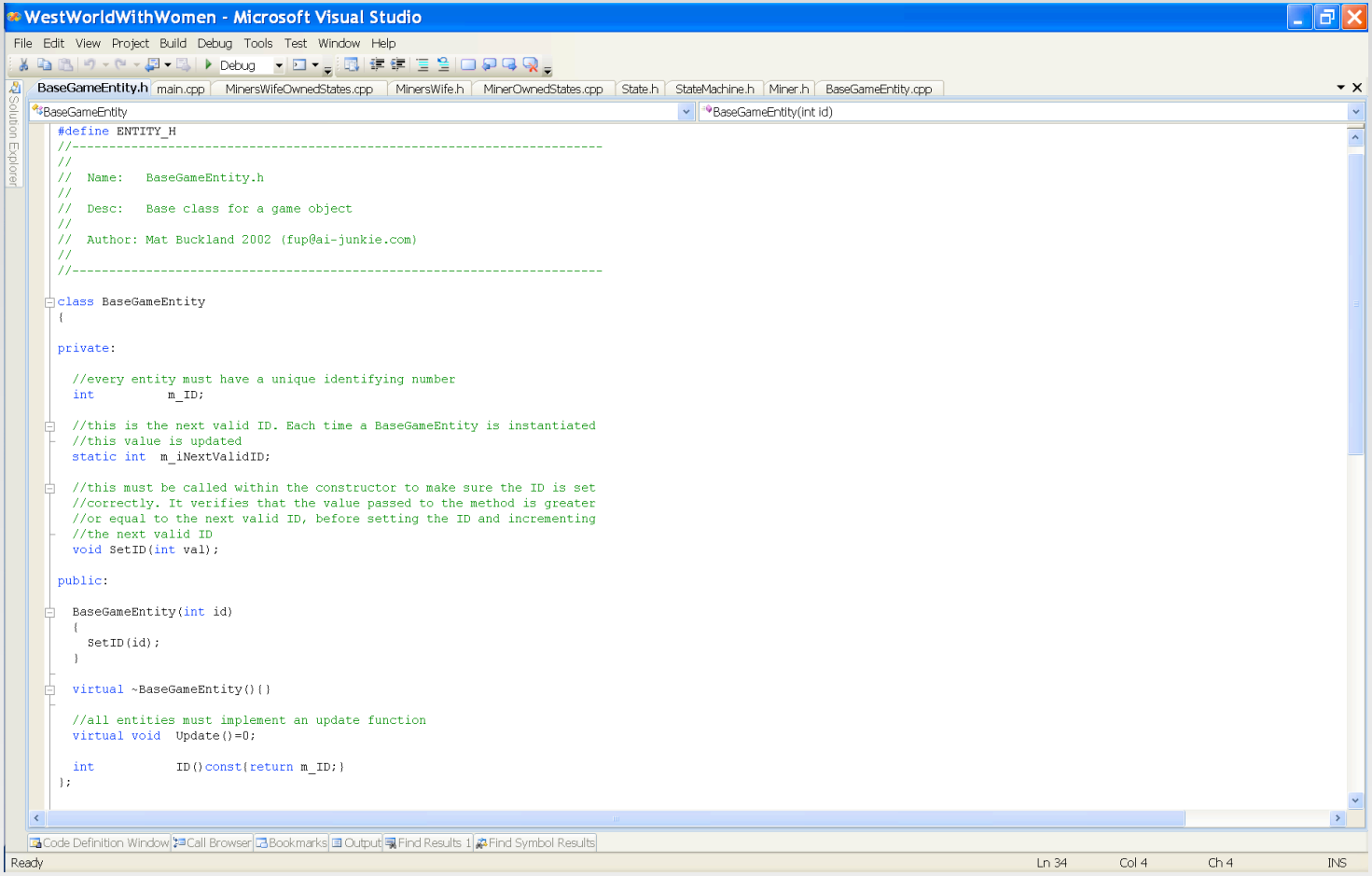
States as Singletons

- Each state class, e.g., QuenchThirst, has only a single instance
  - *Benefit:* don't need to manage allocation and destruction of state objects
  - *Drawback:* since all agents share same state objects, agent-specific information must be stored in agent (even if logically associated with state, e.g., thirst)
    - not a problem in West World, since only one miner, wife with distinct states
    - adding a new state with agent-specific information requires editing both state *and* agent files

Singleton Design Pattern

```
// ------------- MyClass.h -------------------
class MyClass
{
private:
   MyClass(){}
   ~MyClass(){}
   MyClass(const MyClass&);
   MyClass& operator= (const MyClass&);

   int m_iNum; // member data

public:
   static MyClass* Instance();
   int GetVal() const { return m_iNum; } // access data
}

// ------------- MyClass.cpp -------------------
MyClass* MyClass::Instance()
{
   static MyClass instance;
   return &instance;
}

MyClass::Instance()->GetVal();
```

Code Walk


WestWorldWithWomen - Microsoft Visual Studio
File Edit View Project Build Debug Tools Test Window Help
Debug
BaseGameEntity.h main.cpp MinersWifeOwnedStates.cpp MinersWife.h MinerOwnedStates.cpp State.h StateMachine.h Miner.h BaseGameEntity.cpp
BaseGameEntity
BaseGameEntity(int id)
#define ENTITY_H
//--
//
// Name: BaseGameEntity.h
//
// Desc: Base class for a game object
//
// Author: Mat Buckland 2002 (fup@ai-junkie.com)
//
//--
class BaseGameEntity
{
private:
  //every entity must have a unique identifying number
  int   m_ID;
  //this is the next valid ID. Each time a BaseGameEntity is instantiated
  //this value is updated
  static int m_iNextValidID;
  //this must be called within the constructor to make sure the ID is set
  //correctly. It verifies that the value passed to the method is greater
  //or equal to the next valid ID, before setting the ID and incrementing
  //the next valid ID
  void SetID(int val);
public:
  BaseGameEntity(int id)
  {
    SetID(id);
  }
  virtual ~BaseGameEntity(){}
  //all entities must implement an update function
  virtual void Update()=0;
  int   ID()const{return m_ID;}
};
Code Definition Window Call Browser Bookmarks Output Find Results 1 Find Symbol Results
Ready
Ln 34 Col 4 Ch 4 INS

Event-Based Architecture

Adding Messaging to the FSM's

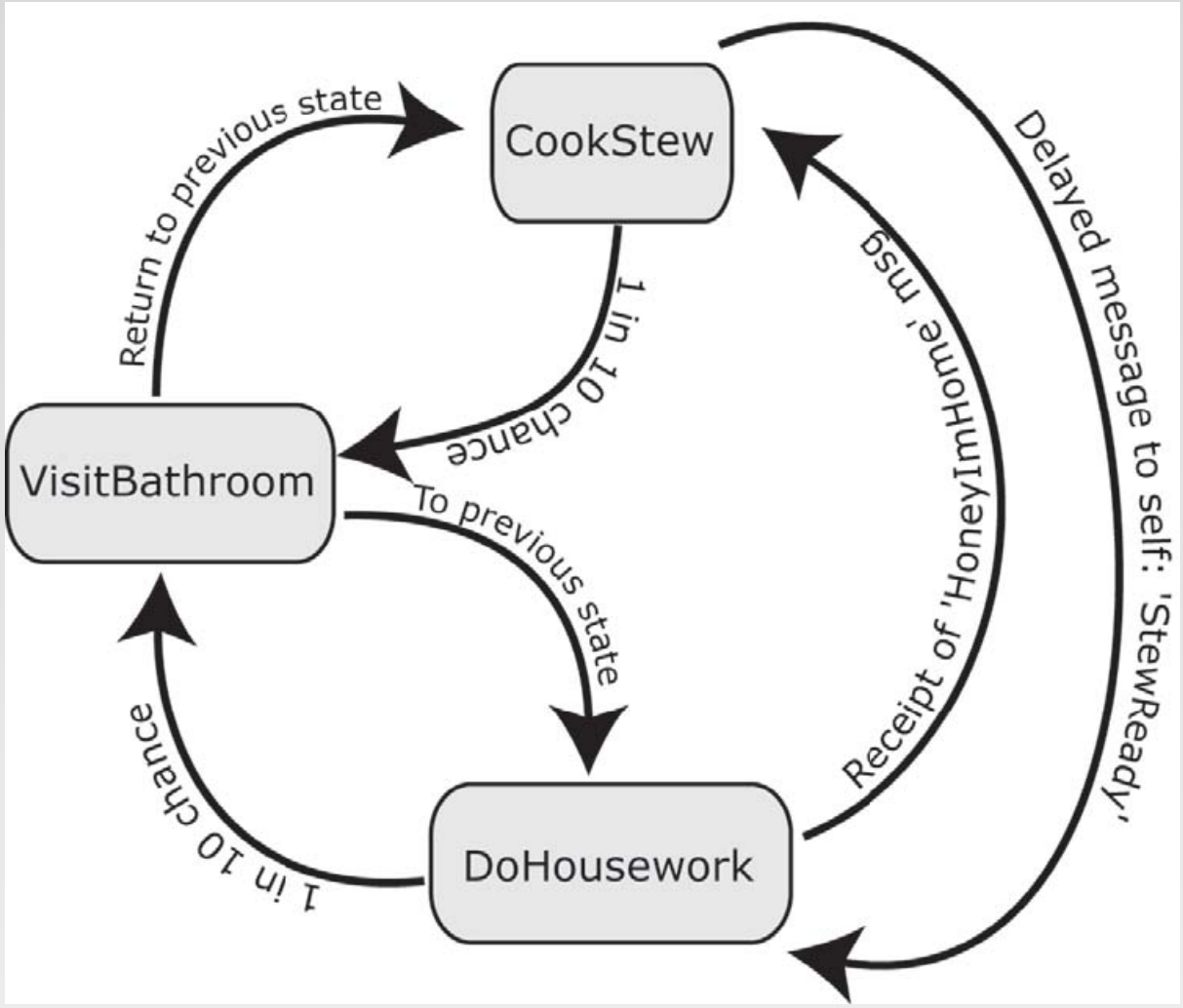
Messaging – Why?

- Miner and wife in WWwW don't really interact
  - separate state machines running independently
  - states could "communicate" by shared variables
    - poor modularity
    - hard to add new agents which interact with existing
- A solution to the "perception" problem
  - avoids expensive polling algorithms (busy-wait)
    - e.g., if guard does nothing until player enters room, it should not be constantly be checking "did player enter" on every update cycle
    - instead, have player *send a message* to every entity in the room when she enters the room
- Modern games use messaging extensively

Messaging - Implementation Issues

- Requires unique id registry for every participating entity
  - see BaseGameEntity and EntityRegistry
- Different delivery variations
  - *point-to-point* (messages addressed to specific recipients) -- as in Buckland code
  - *delayed delivery* – as in Buckland code
  - *broadcast* (all messages broadcast to all entities --- expensive)
  - *subscription based on*
    - location (e.g., room)
    - message type

Miner's Wife State Machine (extended)



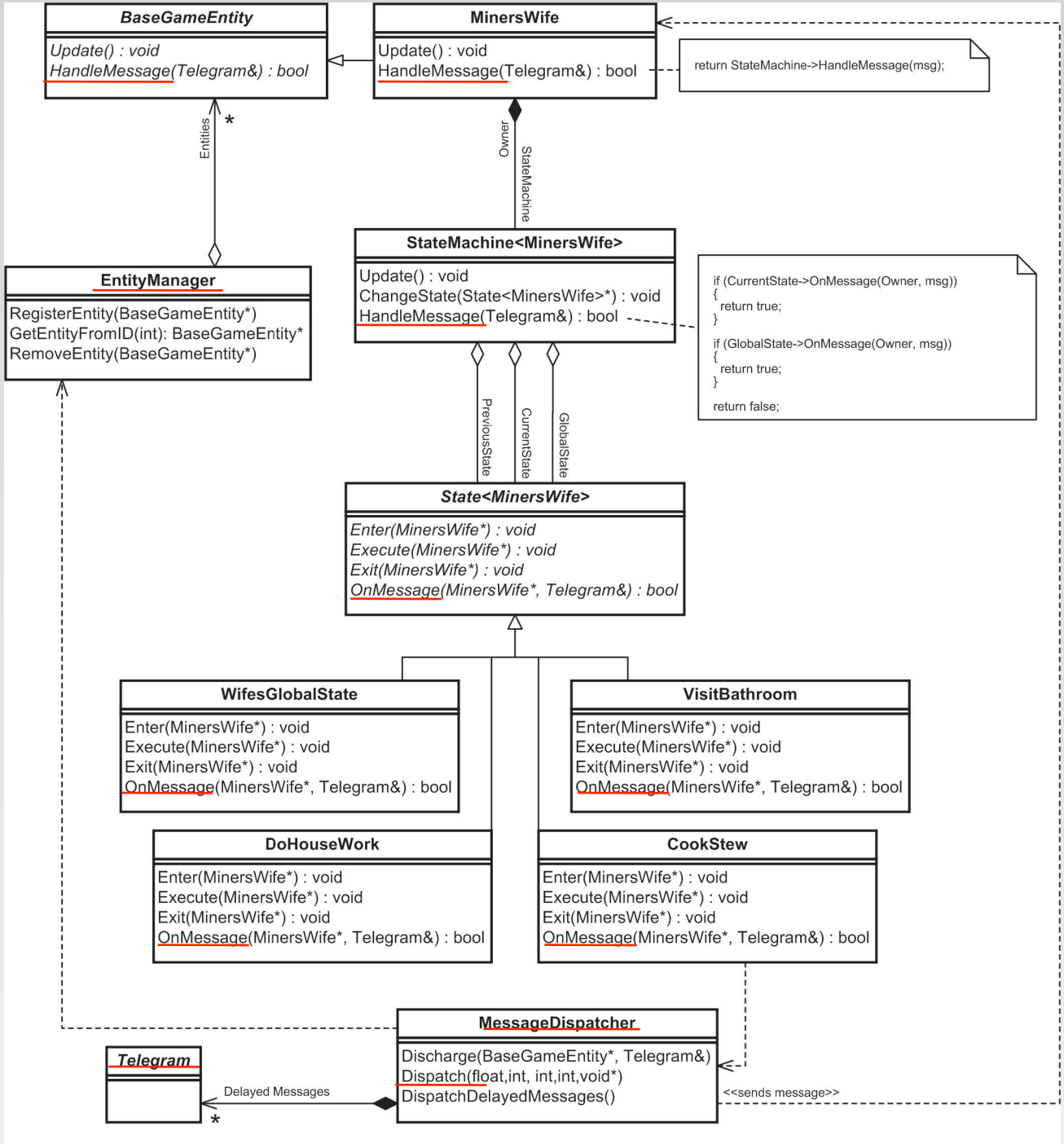
West World Message Types

- ***HiHoneyImHome***
  - sent by Bob to Elsa when entering GoHomeAndSleepTilRested state
  - Elsa responds in WifesGlobalState by changing state to CookStew

- ***StewReady***
  - sent by Elsa to self (with delay) when entering CookStew state
  - Elsa responds in CookStew state by sending StewReady message (note reuse) to Bob
  - Bob responds in GoHomeAndSleepTilRested state by changing state to EatStew (blip)

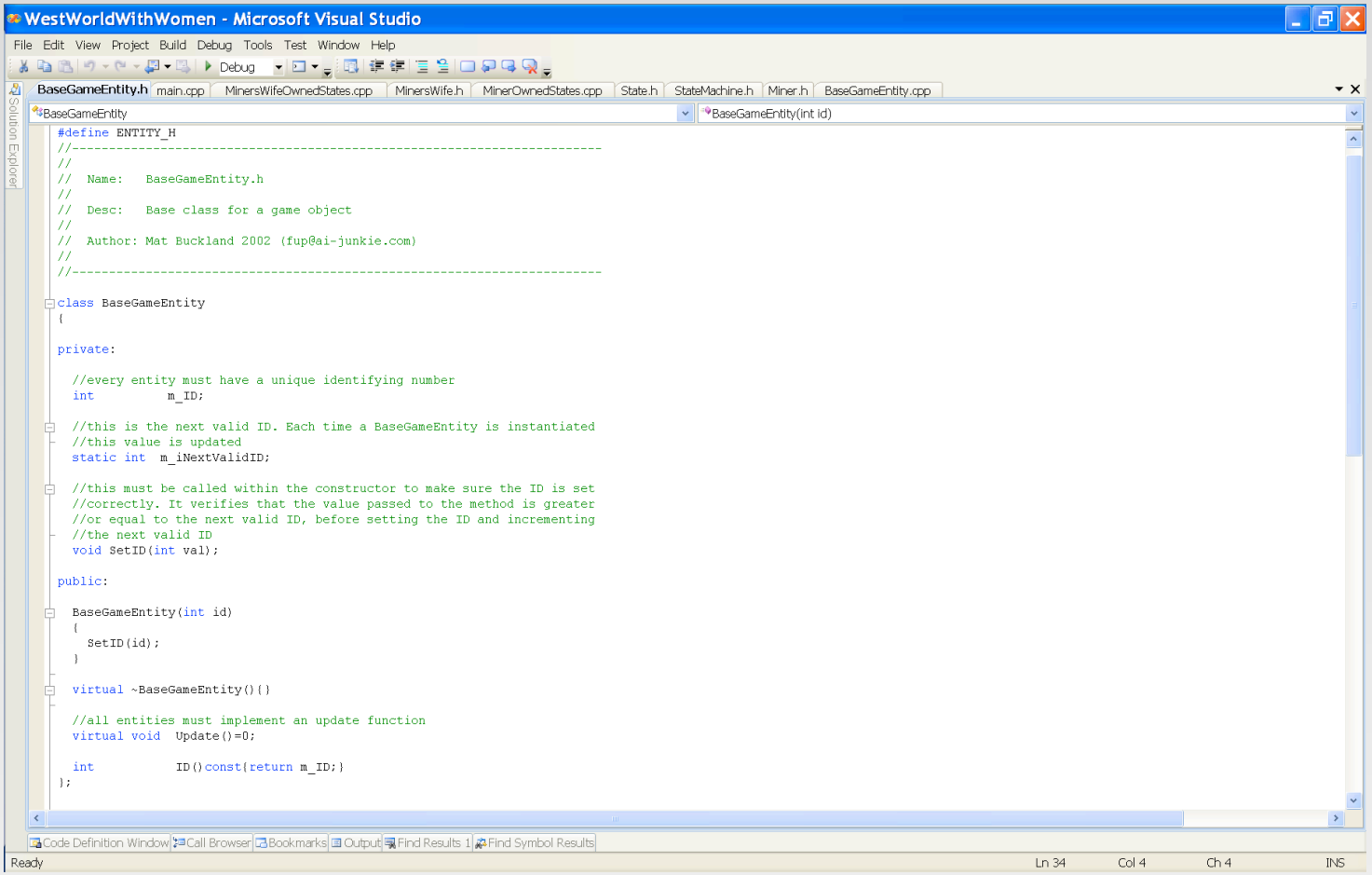
WestWorldWithMessaging Demo

- Various text strings printed to console by Elsa and Bob at various points, e.g.
  - “putting the stew in the oven”
  - “smells Reaaal goood Elsa!”
  - don’t confuse these “messages” with MessageType’s
- This is *programming*!
  - with all the bugs and debugging
  - if a message not handled properly or ignored, whole simulation can stall


BaseGameEntity
Update() : void
HandleMessage(Telegram&) : bool
MinersWife
Update() : void
HandleMessage(Telegram&) : bool
return StateMachine->HandleMessage(msg);
Entities
*
Owner
StateMachine
EntityManager
RegisterEntity(BaseGameEntity*)
GetEntityFromID(int): BaseGameEntity*
RemoveEntity(BaseGameEntity*)
StateMachine<MinersWife>
Update() : void
ChangeState(State<MinersWife>*) : void
HandleMessage(Telegram&) : bool
if (CurrentState->OnMessage(Owner, msg))
{
return true;
}
if (GlobalState->OnMessage(Owner, msg))
{
return true;
}
return false;
PreviousState
CurrentState
GlobalState
State<MinersWife>
Enter(MinersWife*) : void
Execute(MinersWife*) : void
Exit(MinersWife*) : void
OnMessage(MinersWife*, Telegram&) : bool
WifesGlobalState
Enter(MinersWife*) : void
Execute(MinersWife*) : void
Exit(MinersWife*) : void
OnMessage(MinersWife*, Telegram&) : bool
VisitBathroom
Enter(MinersWife*) : void
Execute(MinersWife*) : void
Exit(MinersWife*) : void
OnMessage(MinersWife*, Telegram&) : bool
DoHouseWork
Enter(MinersWife*) : void
Execute(MinersWife*) : void
Exit(MinersWife*) : void
OnMessage(MinersWife*, Telegram&) : bool
CookStew
Enter(MinersWife*) : void
Execute(MinersWife*) : void
Exit(MinersWife*) : void
OnMessage(MinersWife*, Telegram&) : bool
MessageDispatcher
Discharge(BaseGameEntity*, Telegram&)
Dispatch(float,int, int,int,void*)
DispatchDelayedMessages()
Telegram
Delayed Messages
*
<<sends message>>

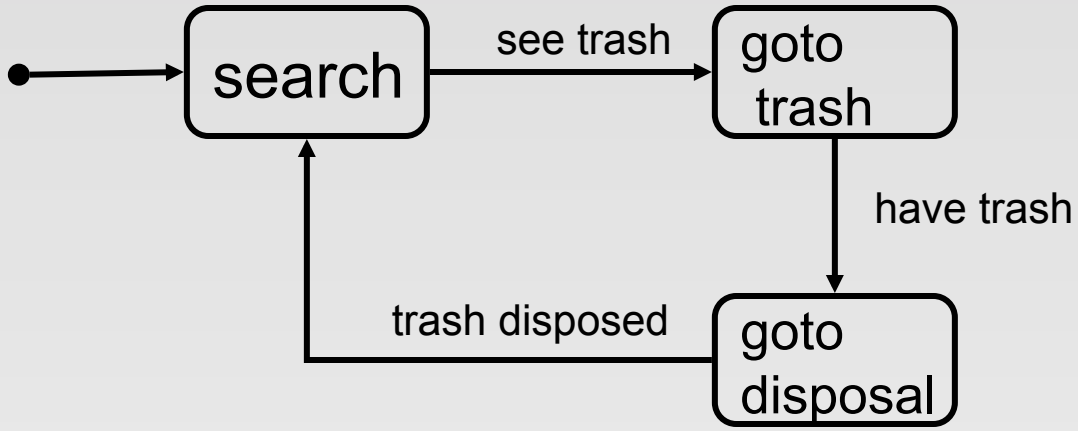
Code Walk

Focus on new code added for messaging....

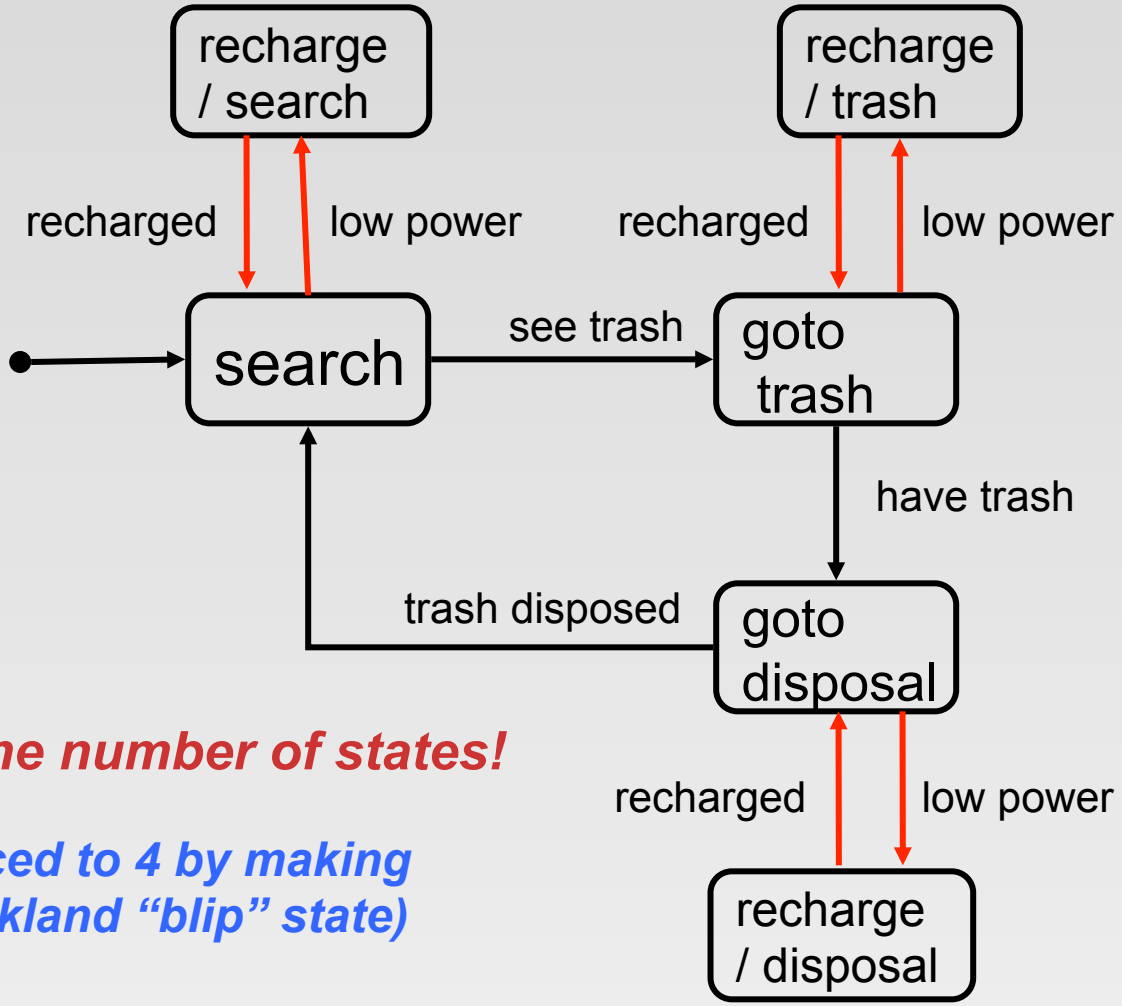


Hierarchical State Machines

- Why?



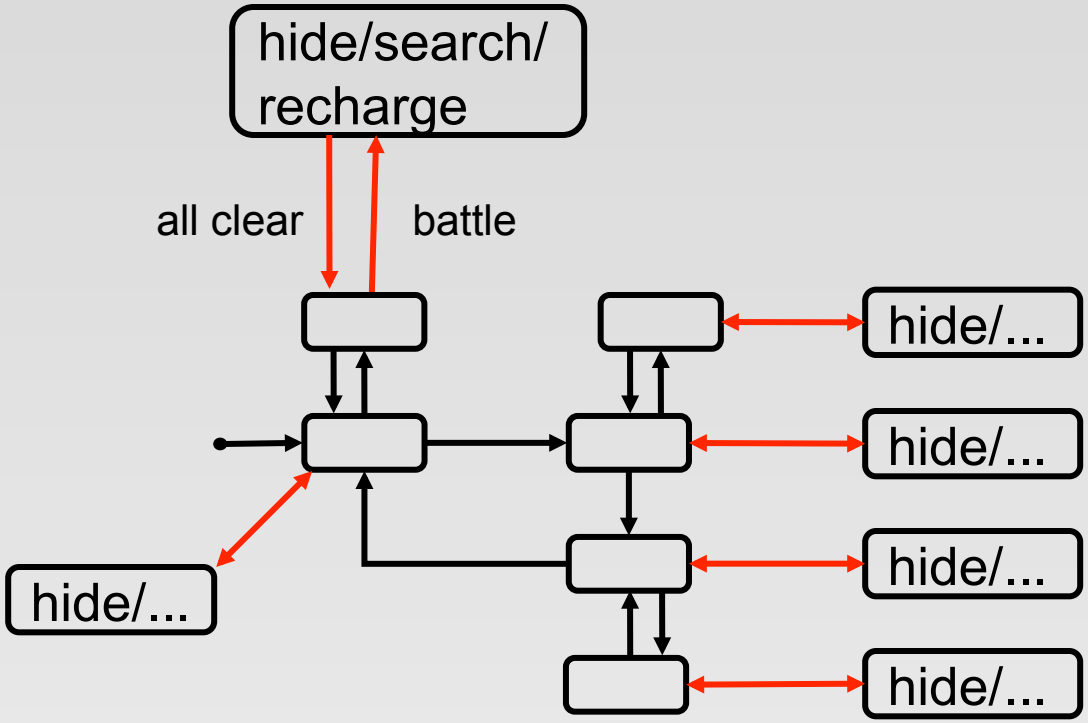
Interruptions (e.g., Alarms)



6 - doubled the number of states!

(could be reduced to 4 by making recharge a Buckland "blip" state)

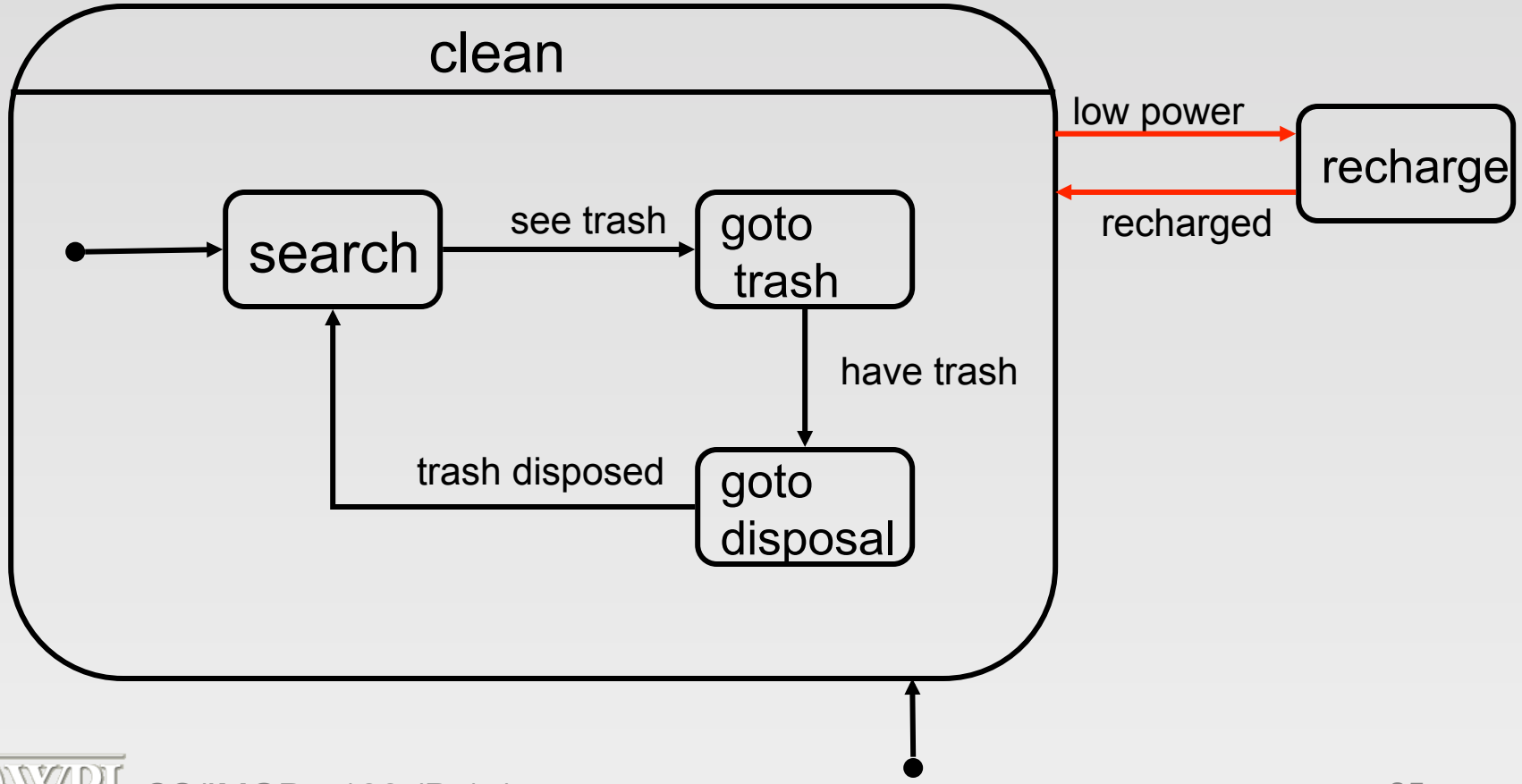
Add Another Interruption Type



12 - doubled the number of states again!

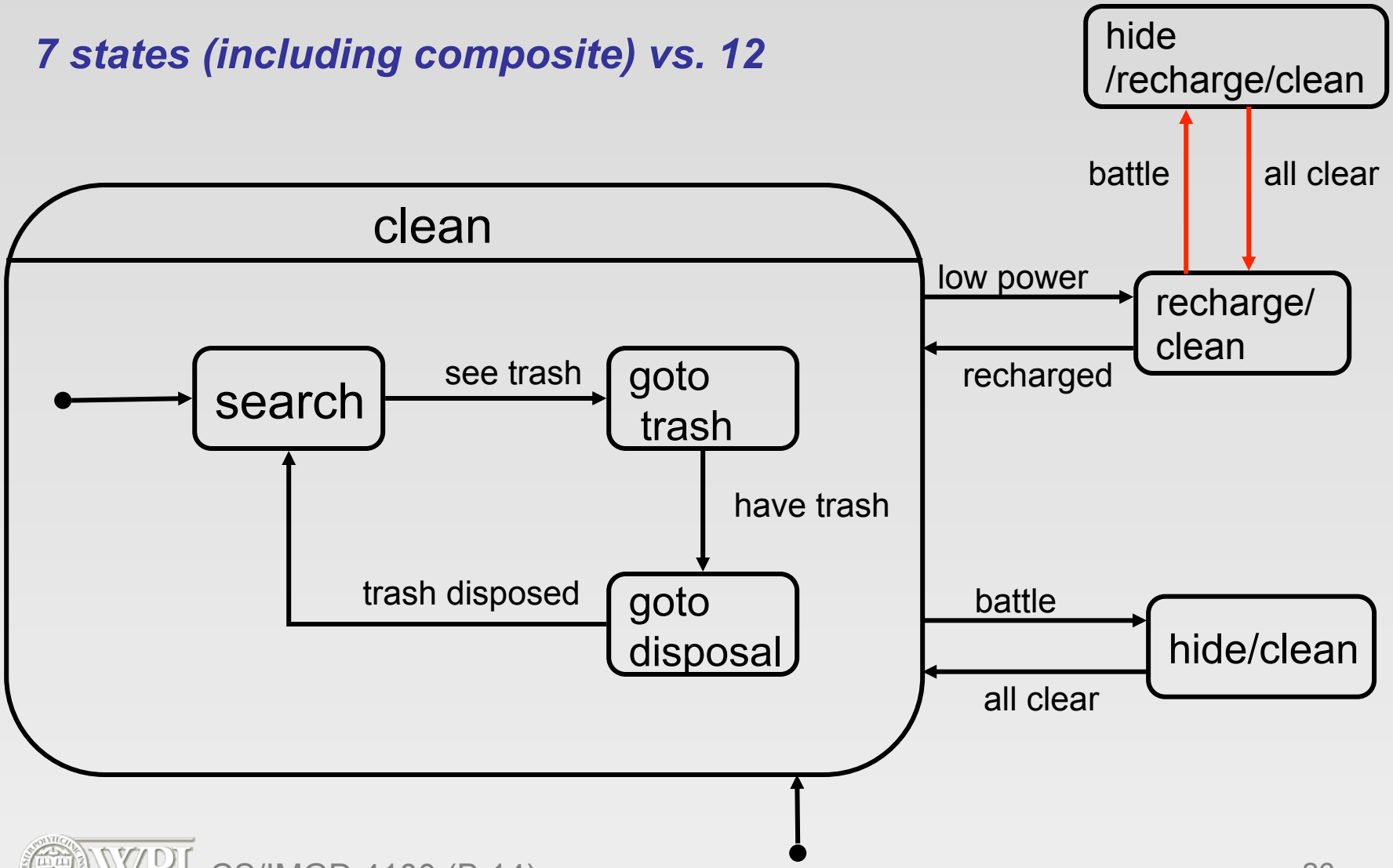
Hierarchical State Machines

- *leave any state in (composite) 'clean' state when 'low power'*
- *'clean' remembers internal state and continues when returned to via 'recharged"*



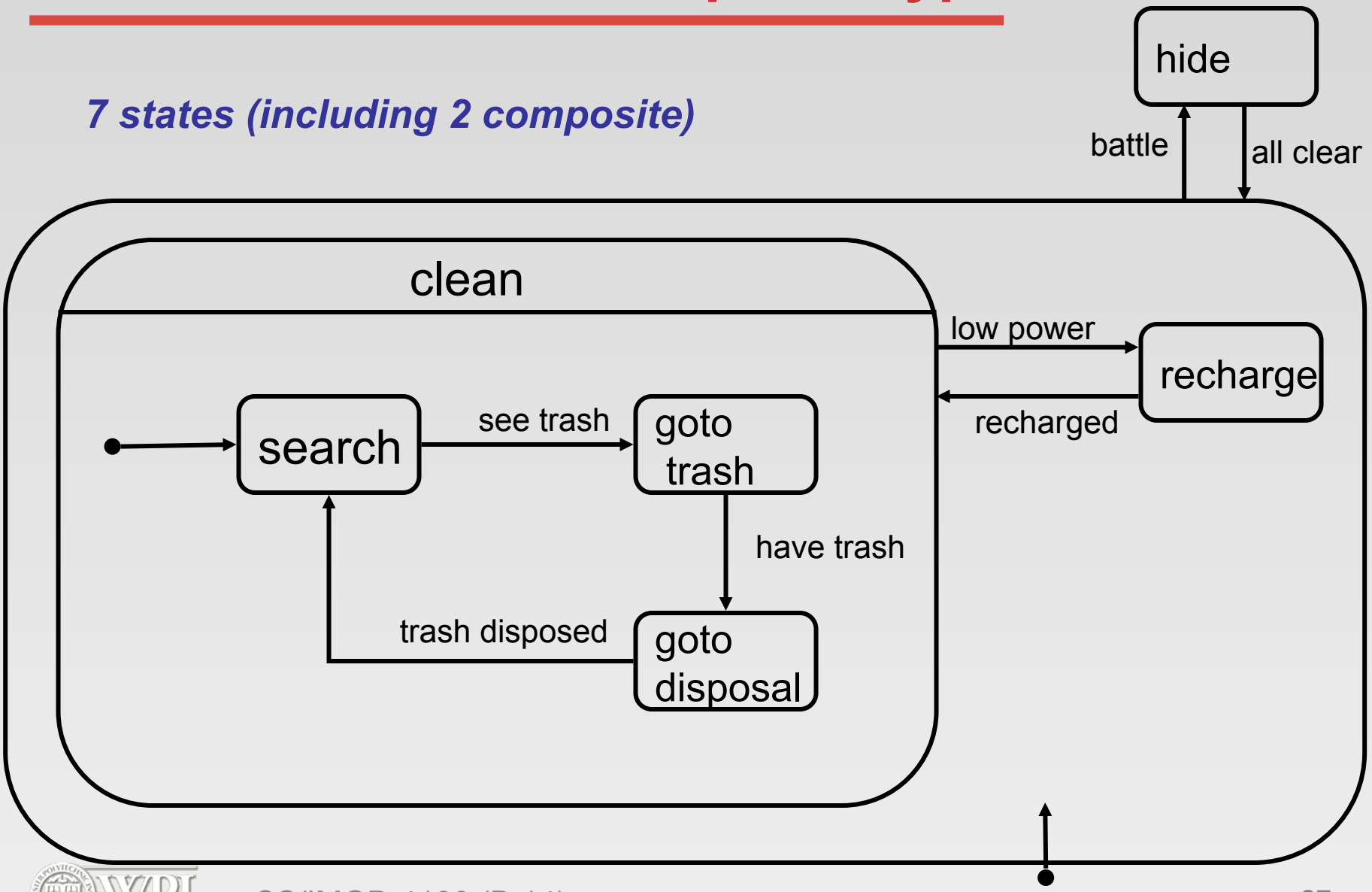
Add Another Interruption Type

7 states (including composite) vs. 12



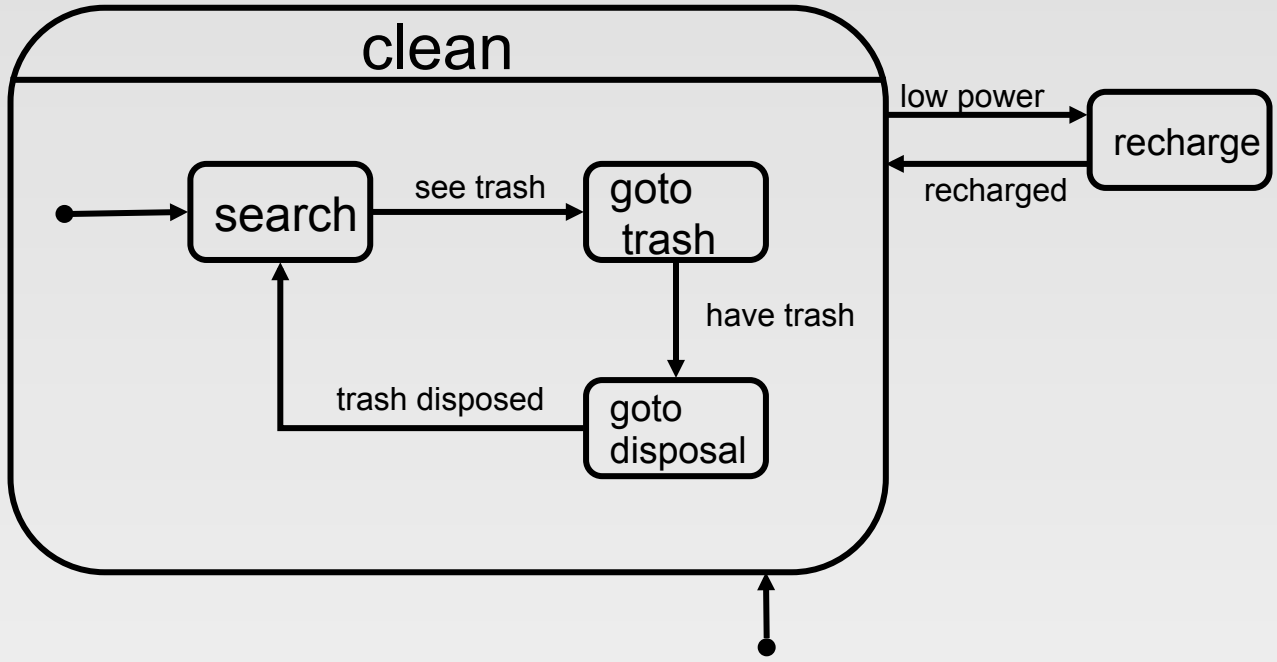
Add Another Interruption Type

7 states (including 2 composite)

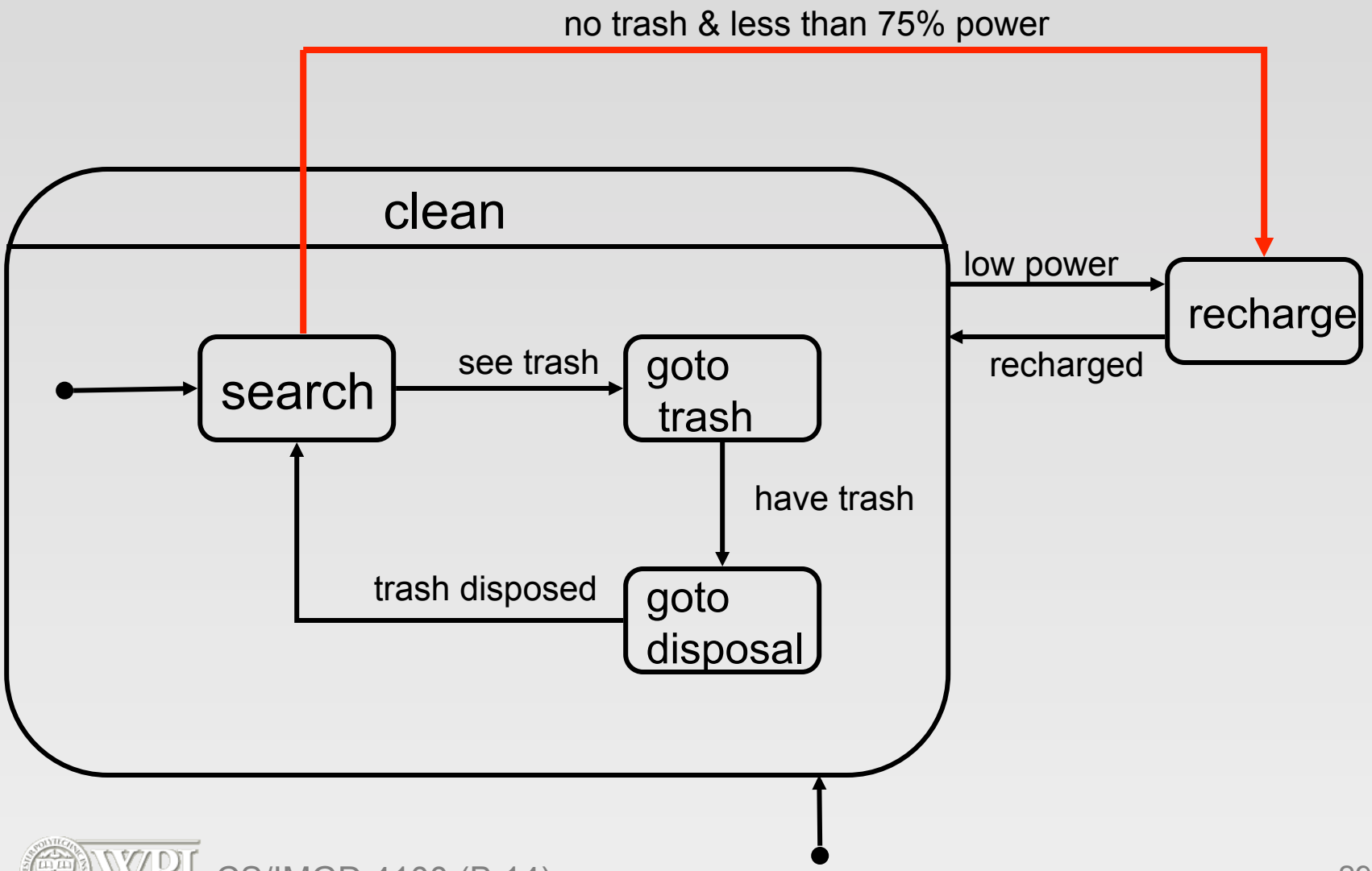


Cross-Hierarchy Transitions

- Why?
  - suppose we want robot to top-off battery if it doesn't see any trash (regardless of power level)

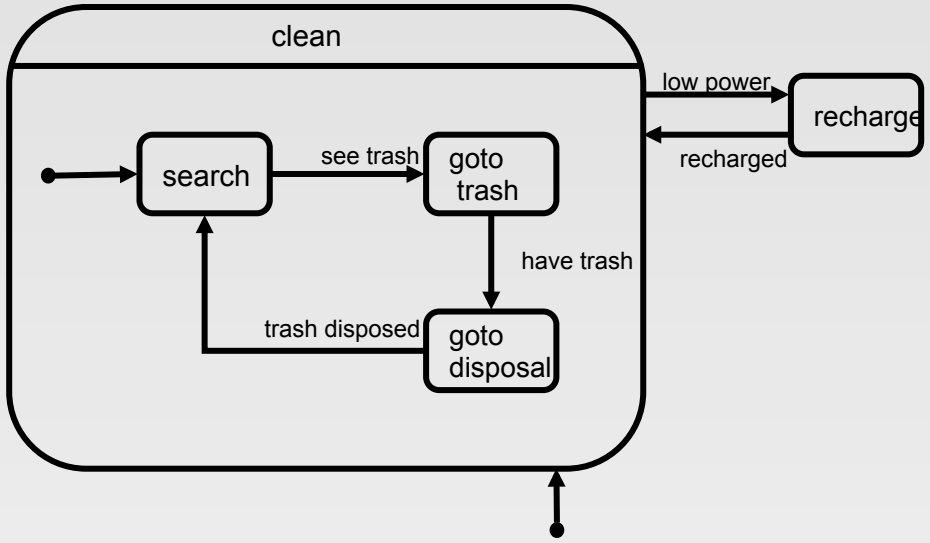


Cross-Hierarchy Transitions



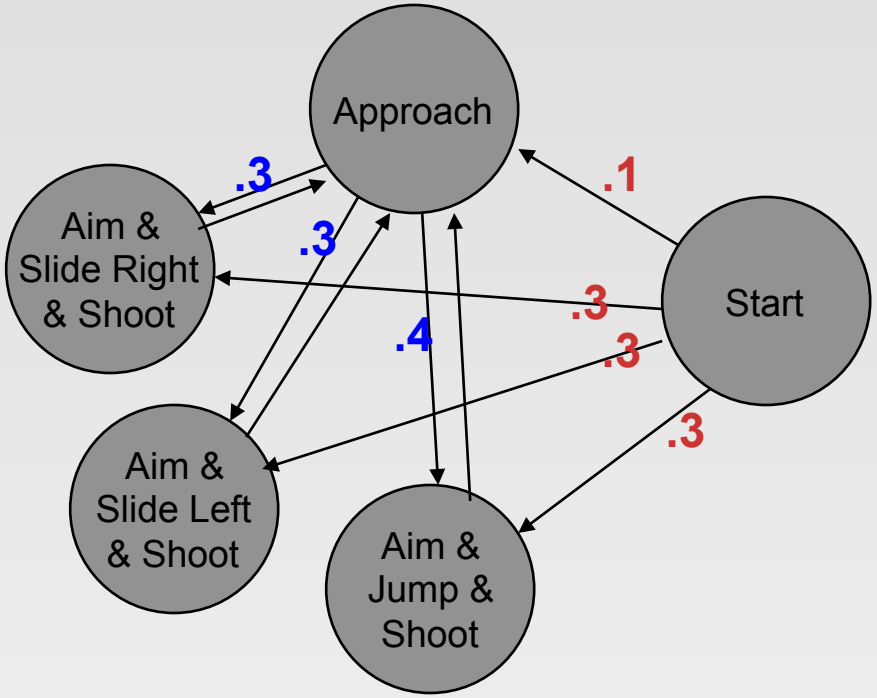
Hierarchical State Machines

- 'Blip' states in Buckland implementation are simple case (remembers single previous state)
- General case has full push-down stack
- See Millington Sec. 5.3.9 for more details



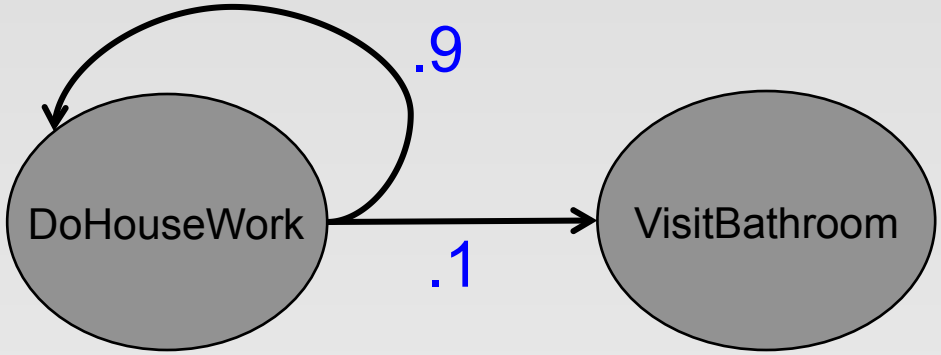
Non-deterministic State Machines

- multiple transitions for same event
- label each with probability (Σ=1)
- state machine randomly chooses at run time, based on probabilities
- adds variety to actions



Non-deterministic State Machines

- Also known as "Markov Models"
- Similar effect achieved in miner's wife states using ad hoc code rather than general machine



- See Millington, Sec. 5.5.2 for more details
- Similar variety effect can also be obtained with fuzzy logic (Chapter 10)

Coming up...

- Homework #2 – Bar Fly (due Sunday midnight)
  - adding another character/agent to West World
  - new states and messages
- Study Chapter 3 (steering) on your own
- Start reading (at least first 1/3) of Chapter 4 to prepare for next week (Simple Soccer): Mon, Tues, & Thurs