the gamedesigninitiative at cornell university

Lecture 11

Architecture Design

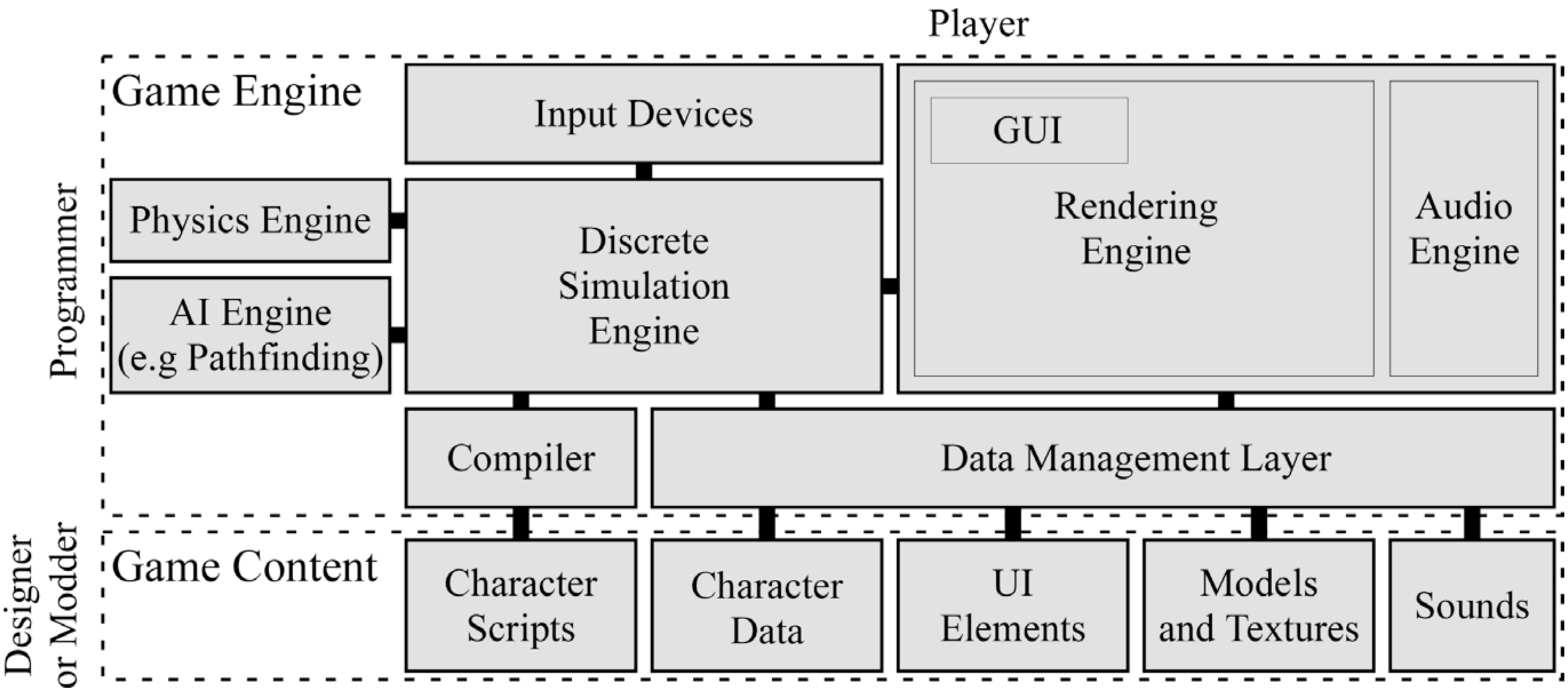
Take Away for Today

- What should the lead programmer do?
- How do CRC cards aid software design?
  - What goes on each card?
  - How do you lay them out?
  - What properties should they have?
- How do activity diagrams aid design?
  - How do they relate to CRC cards?
- Difference between design & documentation

Role of Lead Programmer

- Make high-level **architecture decisions**
  - How are you splitting up the classes?
  - What is your computation model?
  - What is stored in the data files?
  - What third party libraries are you using?
- **Divide** the work among the **programmers**
  - Who works on what parts of the game?
  - What do they need to coordinate?

Architecture: The Big Picture



Identify Modules (Subsystems)

- **Modules**: logical unit of functionality
  - Often reusable over multiple games
  - Implementation details are hidden
  - API describes interaction with rest of system
- Natural way to break down work
  - Each programmer decides implementation
  - But entire team must agree on the API
  - **Specification first, then programming**

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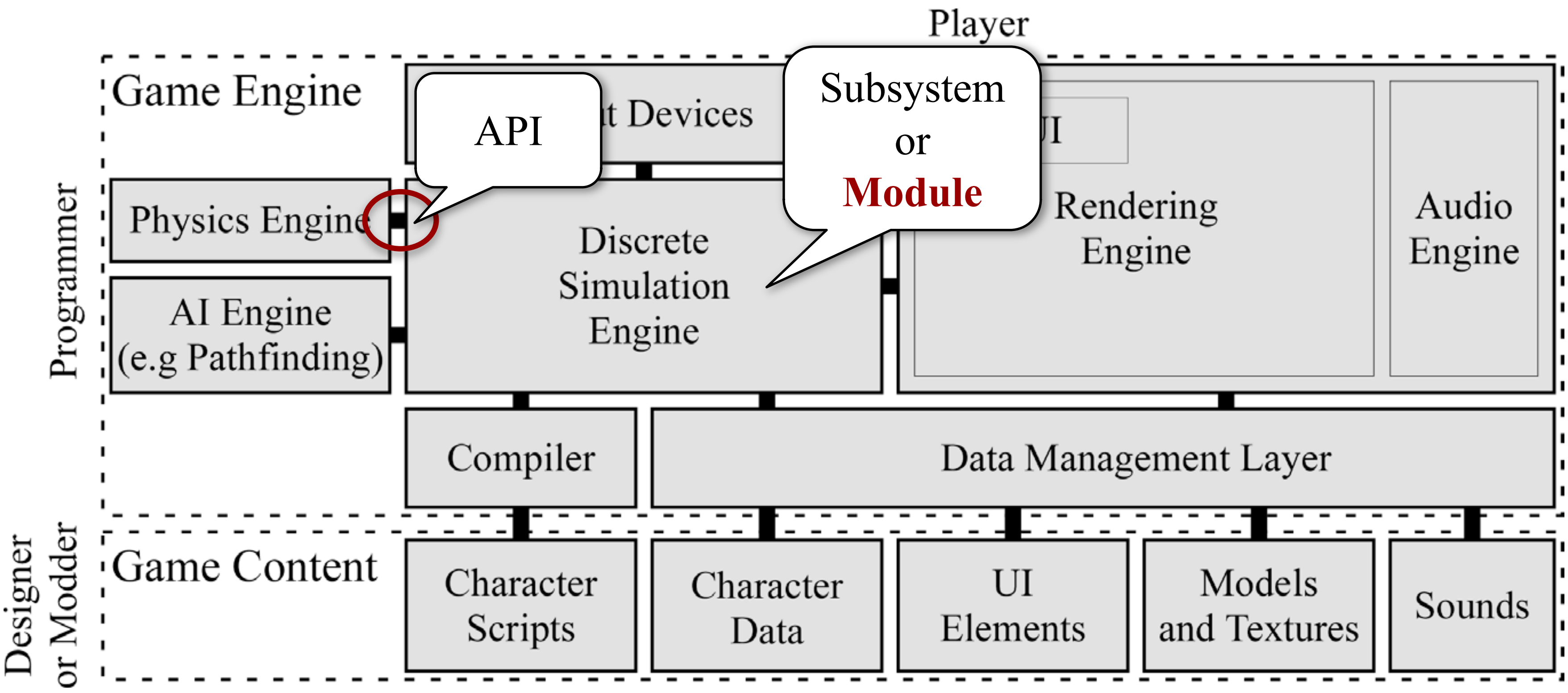
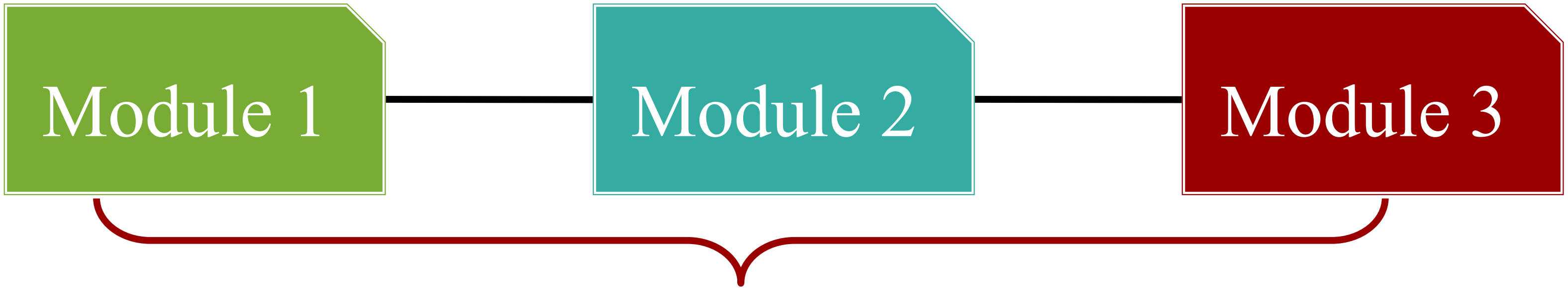


Example: Physics Engines

- API to manipulate objects
  - Put physics objects in “container”
  - Specify their connections (e.g. joints)
  - Specify forces, velocity
- Everything else hidden from user
  - Collisions detected by module
  - Movement corrected by module

Relationship Graph

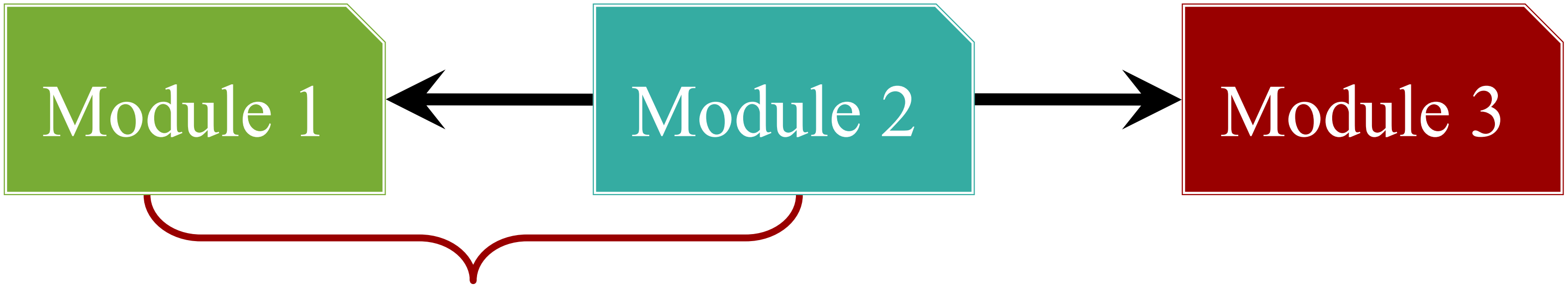
- Shows when one module "depends" on another
  - Module A calls a method/function of Module B
  - Module A creates/loads instance of Module B
- **General Rule**: Does *A* need the API of *B*?
  - How would we know this?



Module 1 does not "need" to know about Module 3

Relationship Graph

- Edges in relationship graph are often **directed**
  - If *A* calls a method of *B*, is *B* aware of it?
- But often undirected in architecture diagrams
  - Direction clear from other clues (e.g. layering)
  - Developers of both modules should still agree on API

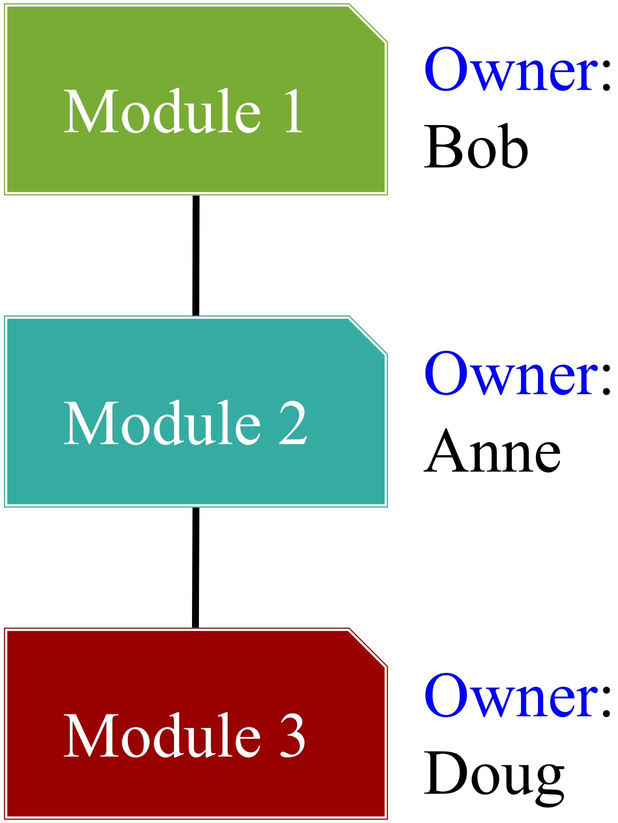


Does Module 1 need to know about Module 2?

Dividing up Responsibilities

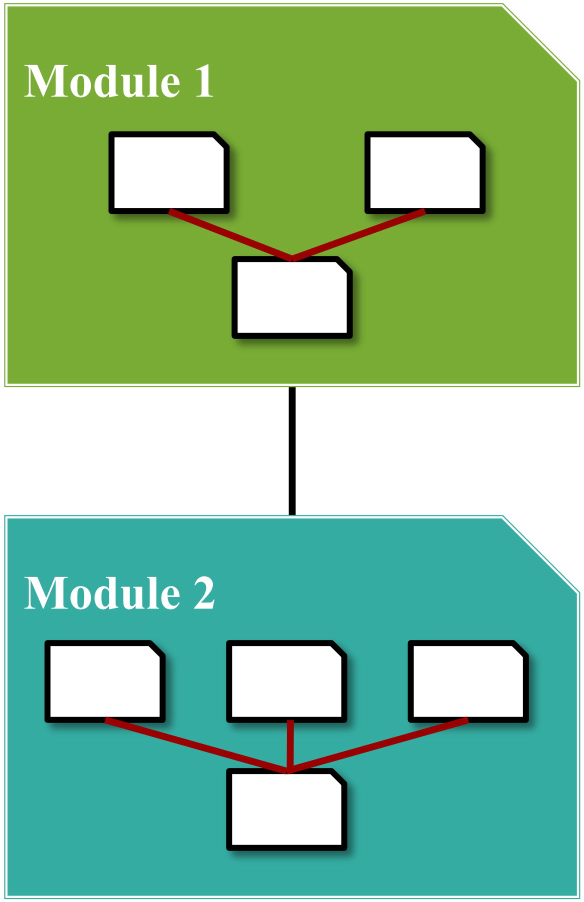
- Each programmer has a module
  - Programmer **owns** the module
  - Final word on implementation
- Owners collaborate w/ **neighbors**
  - Agree on API at graph edges
  - Call meetings “Interface Parties”
- Works, but…

  must agree on modules and responsibilities ahead of time



Nested (Sub)modules

- Can do this **recursively**
  - Module is a piece of software
  - Can break into more modules
- Nested APIs are **internal**
  - Only needed by module owner
  - Parent APIs may be different!
- Critical for very **large groups**
  - Each small team gets a modules
  - Inside the team, break up further
  - Even deeper hierarchies possible



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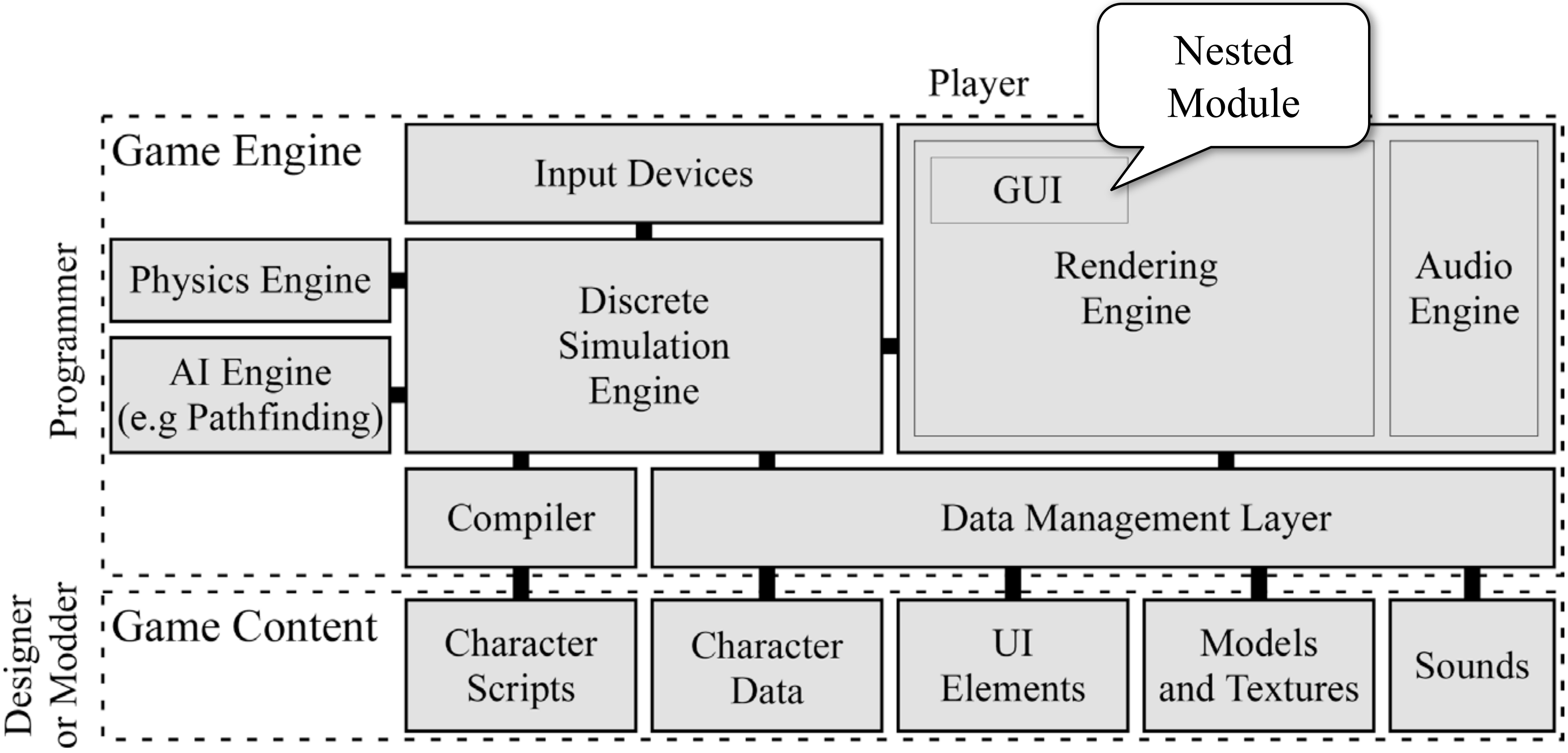

How Do We Get Started?

- Remember the design caveat:
  - Must agree on module responsibilities first
  - Otherwise, code is **duplicated** or even **missing**
- Requires a **high-level architecture** plan
  - Enumeration of all the modules
  - What their responsibilities are
  - Their relationships with each other
- Responsibility of the lead architect

Design: CRC Cards

- Class-Responsibility-Collaboration
  - **Class**: Important class in subsystem
  - **Responsibility**: What that class does
  - **Collaboration**: Other classes required
    - May be part of another subsystem
- English description of your API
  - Responsibilities become methods
  - Collaboration identifies dependencies

CRC Card Examples

AI Controller

Responsibility	Collaboration
Pathfinding: Avoiding obstacles	Game Object, Scene Model
Strategic AI: Planning future moves	Player Model, Action Model
Character AI: NPC personality	Game Object, Level Editor Script

Scene Model

Responsibility	Collaboration
Enumerates game objects in scene	Game Object
Adds/removes game objects to scene	Game Object
Selects object at mouse location	Mouse Event, Game Object

CRC Card Examples

Class Name

Controller	**AI Controller**
Responsibility	**Collaboration**
Pathfinding: Avoiding obstacles	Game Object, Scene Model
Strategic AI: Planning future moves	Player Model, Action Model
Character AI: NPC personality	Game Object, Level Editor Script

Model	**Scene Model**
Responsibility	**Collaboration**
Enumerates game objects in scene	Game Object
Adds/removes game objects to scene	Game Object
Selects object at mouse location	Mouse Event, Game Object

Creating Your Cards

- Start with MVC Pattern
  - Gives 3 basic subsystems
  - List responsibilities of each
  - May be all that you need (TemperatureConverter)
- Split up a module if
  - Too much for one person
  - API for module too long
- Don’t need to nest (**yet**)
  - Perils of **ravioli code**

Module	
Responsibility	**Collaboration**
…	…
…	…
…	…
…	…
…	…
…	…
…	…
…	…

Creating Your Cards

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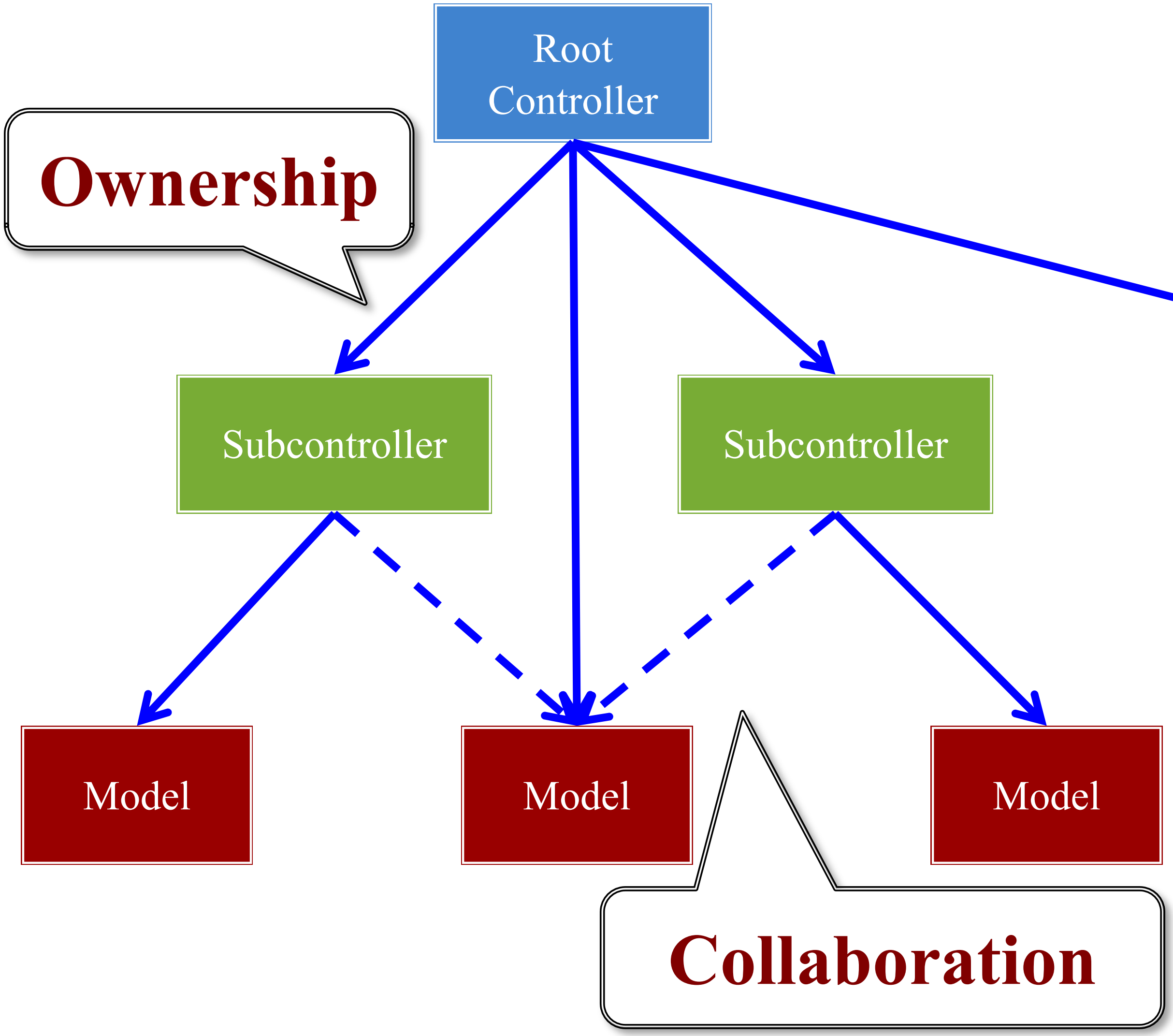
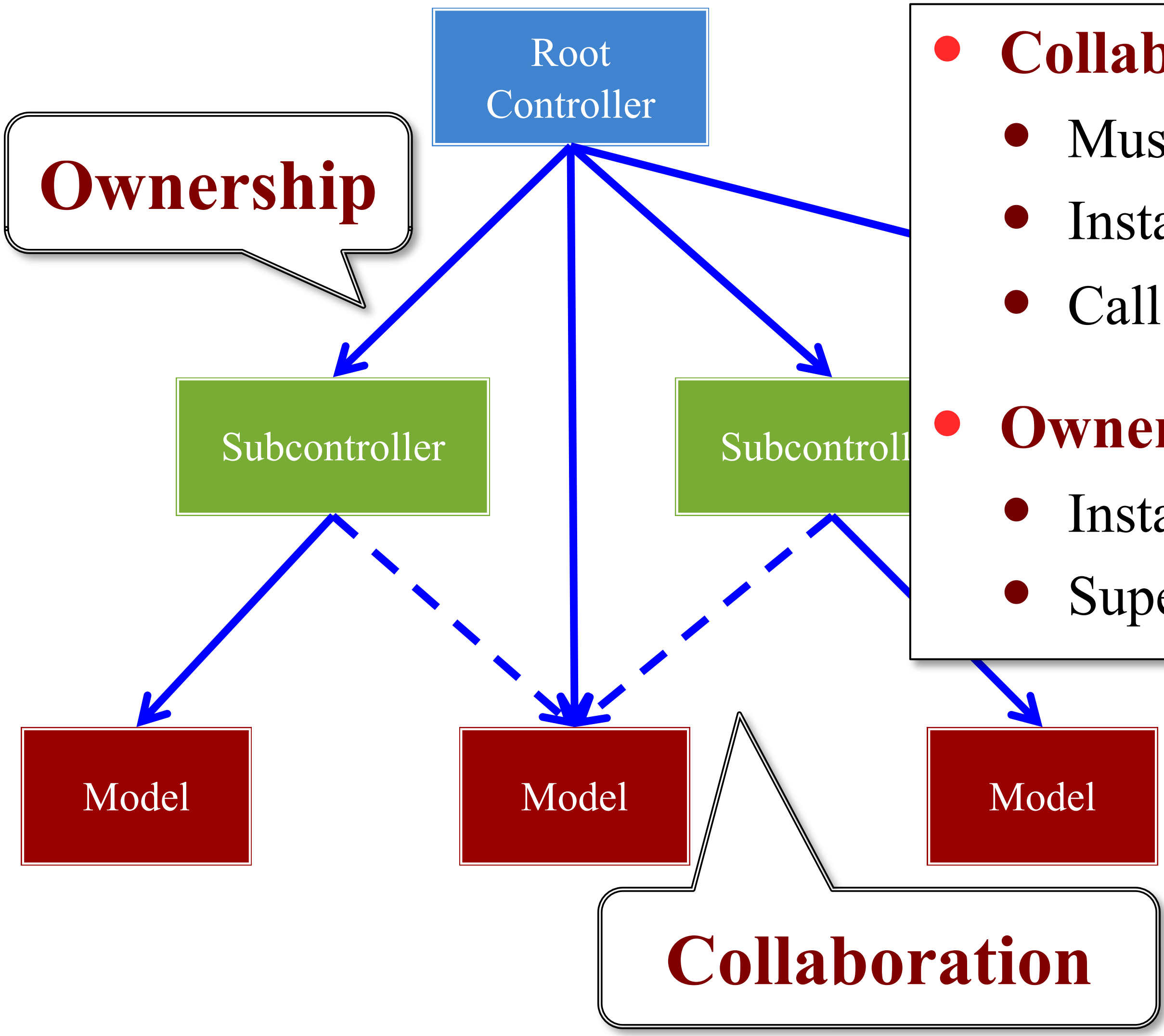
Module 1	
Responsibility	**Collaboration**
…	…
…	…
…	…

Module 2	
Responsibility	**Collaboration**
…	…
…	…
…	…

Application Structure

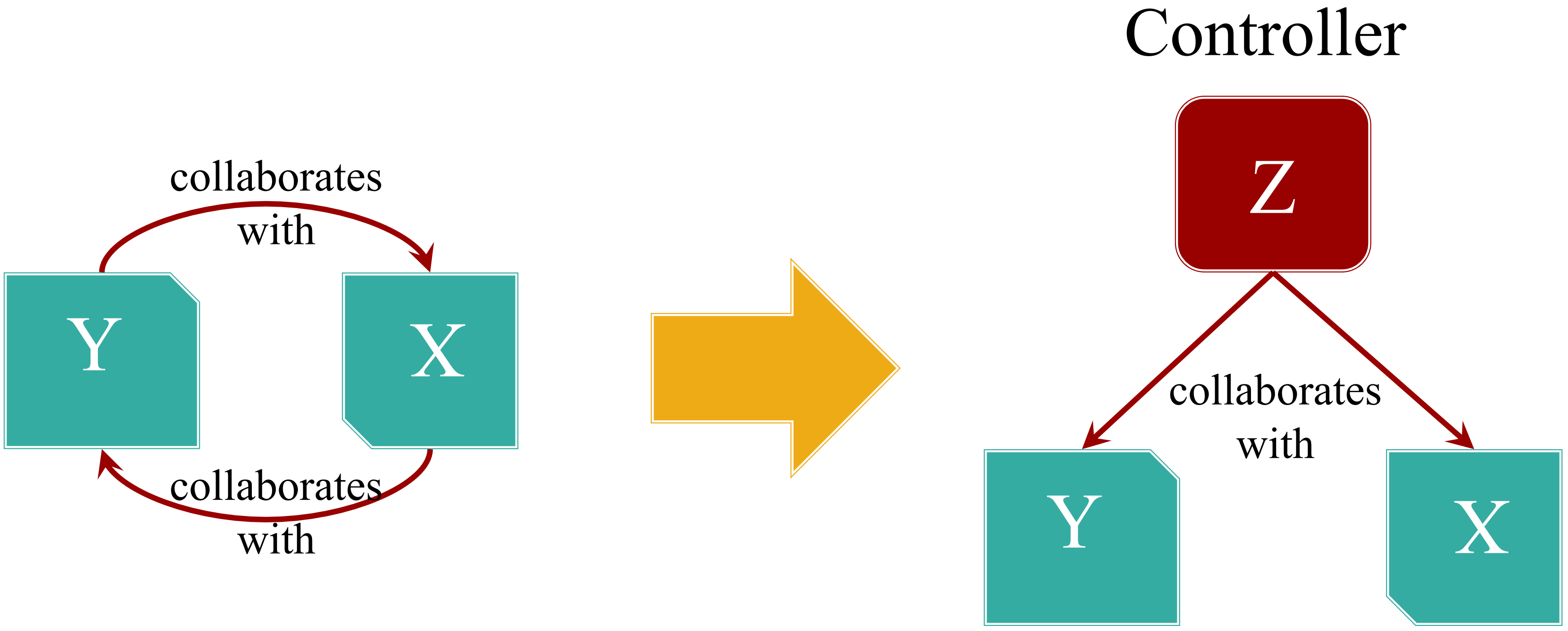


Application Structure



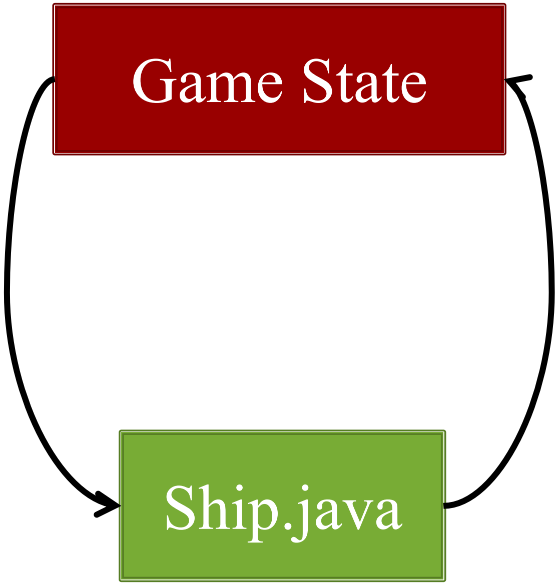
- **Collaboration**
  - Must import class/interface
  - Instantiates an object **OR**
  - Calls the objects methods
- **Ownership**
  - Instantiated the object
  - Superset of collaboration

Avoid Cyclic Collaboration



Avoid Cyclic Collaboration

- **Example**: Lab 3
  - Ship fires projectiles
  - Must add to game state
- Originally all in model
  - Ship referenced game state
  - And game state stored ship
  - **Cyclic Reference**
- We added a new controller
  - It references game state
  - Only it adds to game state
  - **Cycle broken**



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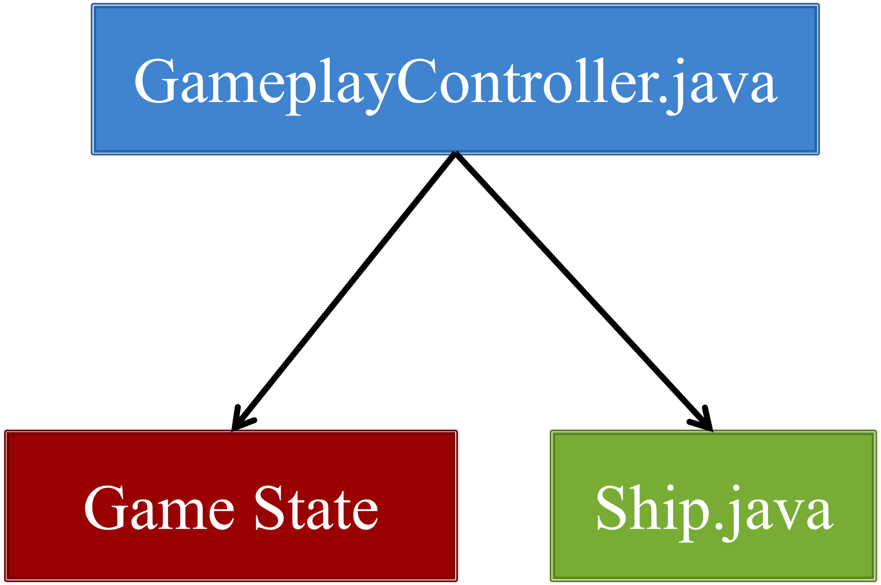
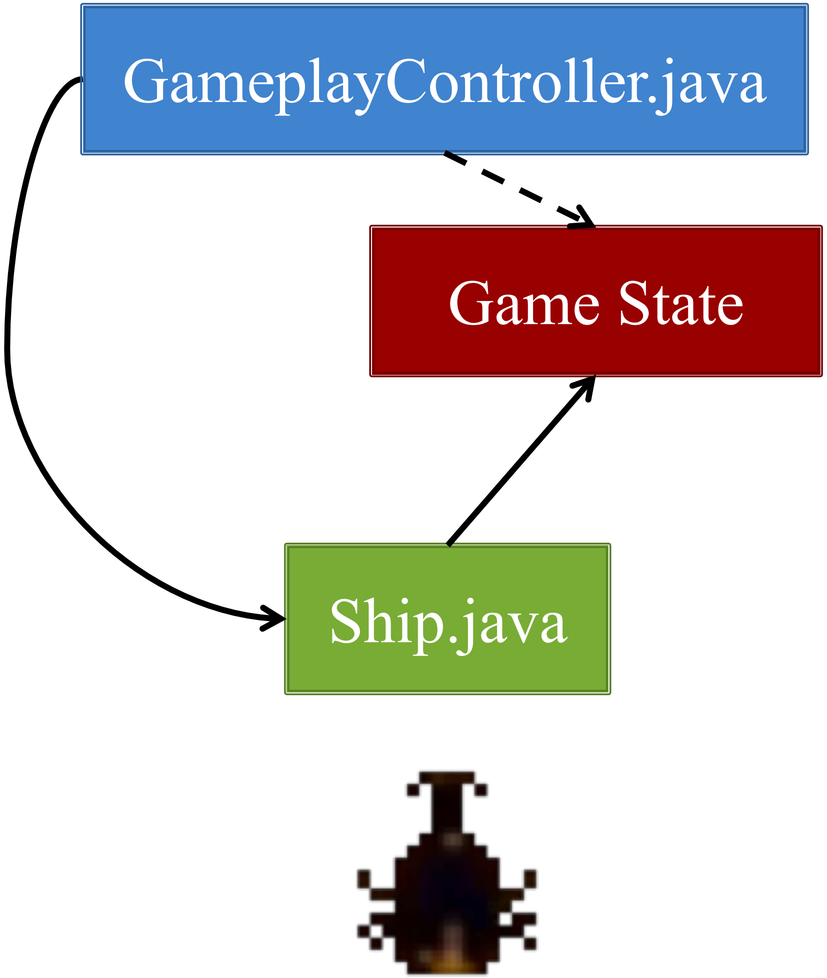
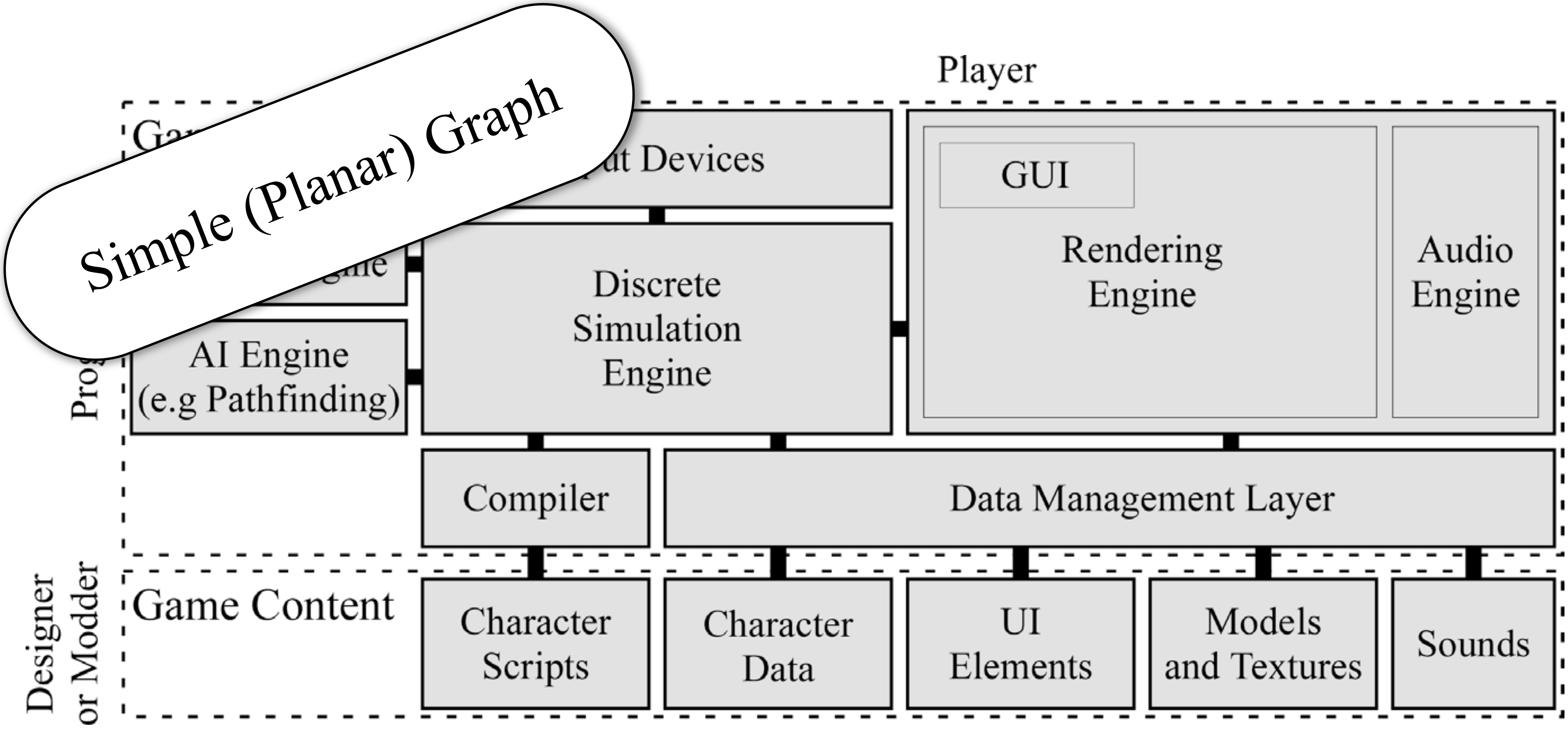


Alternative: Interfaces

- Relationships are for APIs
  - Implementation not relevant
  - Can be class or interface
- Interfaces can break cycles
  - Start with single class
  - Break into many interfaces
  - Refer to interface, not class
- Needed if actions in model
  - Abstracts game state
  - Hides all but relevant data



Architecture: The Big Picture



CRC Index Card Exercise

Try to make collaborators adjacent

Class 1	
Responsibility	**Collaboration**
…	Class 2
…	Class 3
…	Class 4

If cannot do this, time to think about nesting!

Class 2	
Responsibility	**Collaboration**
…	…
…	…
…	…

Class 3	
Responsibility	**Collaboration**
…	…
…	…
…	…

Class 4	
Responsibility	**Collaboration**
…	…
…	…
…	…

Designing Class APIs

- Make classes formal
- Turn responsibilities into methods
- Turn collaboration into parameters

Scene Model	
Responsibility	**Method**
Enumerates game objects	`Iterator<GameObject> enumObjects()`
Adds game objects to scene	`void addObject(gameObject)`
Removes objects from scene	`void removeObject(gameObject)`
Selects object at mouse	`GameObject getObject(mouseEvent)`

Documenting APIs

- Use a formal **documentation style**
  - What parameters the method takes
  - What values the method returns
  - What the method does (side effects)
  - How method responds to errors (exceptions)
- Make use of **documentation comments**
  - **Example**: JavaDoc in Java
  - Has become defacto-standard (even used in C++)

Documenting API

```
/**
 * Returns an Image object that can then be painted on the screen.
 * <p>
 * The url argument must specify an absolute {@link URL}. The name argument is a specifier that
 * is relative to the url argument.
 * <p>
 * This method always returns immediately, whether or not the image exists. When this applet
 * attempts to draw the image on the screen, the data will be loaded. The graphics primitives that
 * draw the image will incrementally paint on the screen.
 *
 * @param url an absolute URL giving the base location of the image
 * @param name the location of image, relative to the url argument
 * @return the image at the specified URL
 * @see Image
 */
public Image getImage(URL url, String name) {
  try {
     return getImage(new URL(url, name));
  } catch (MalformedURLException e) { return null; } }
```

Taking This Idea Further

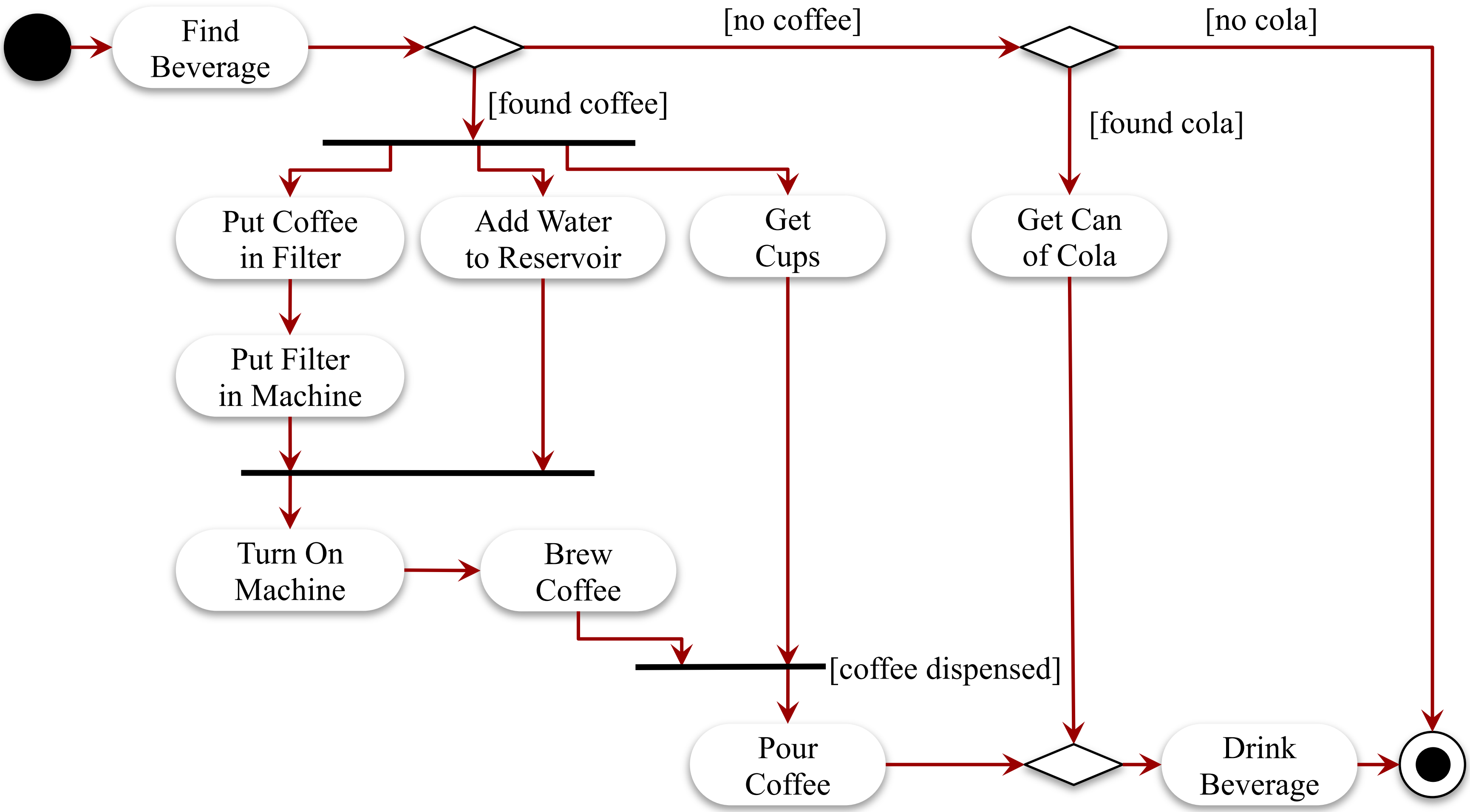
- **UML**: Unified Modeling Language
  - Often used to specify class relationships
  - But expanded to model other things
  - **Examples**: data flow, human users

- How useful is it?
  - Extremely useful for documentation
  - Less useful for design (e.g. before implementation)
  - A language to program in another language

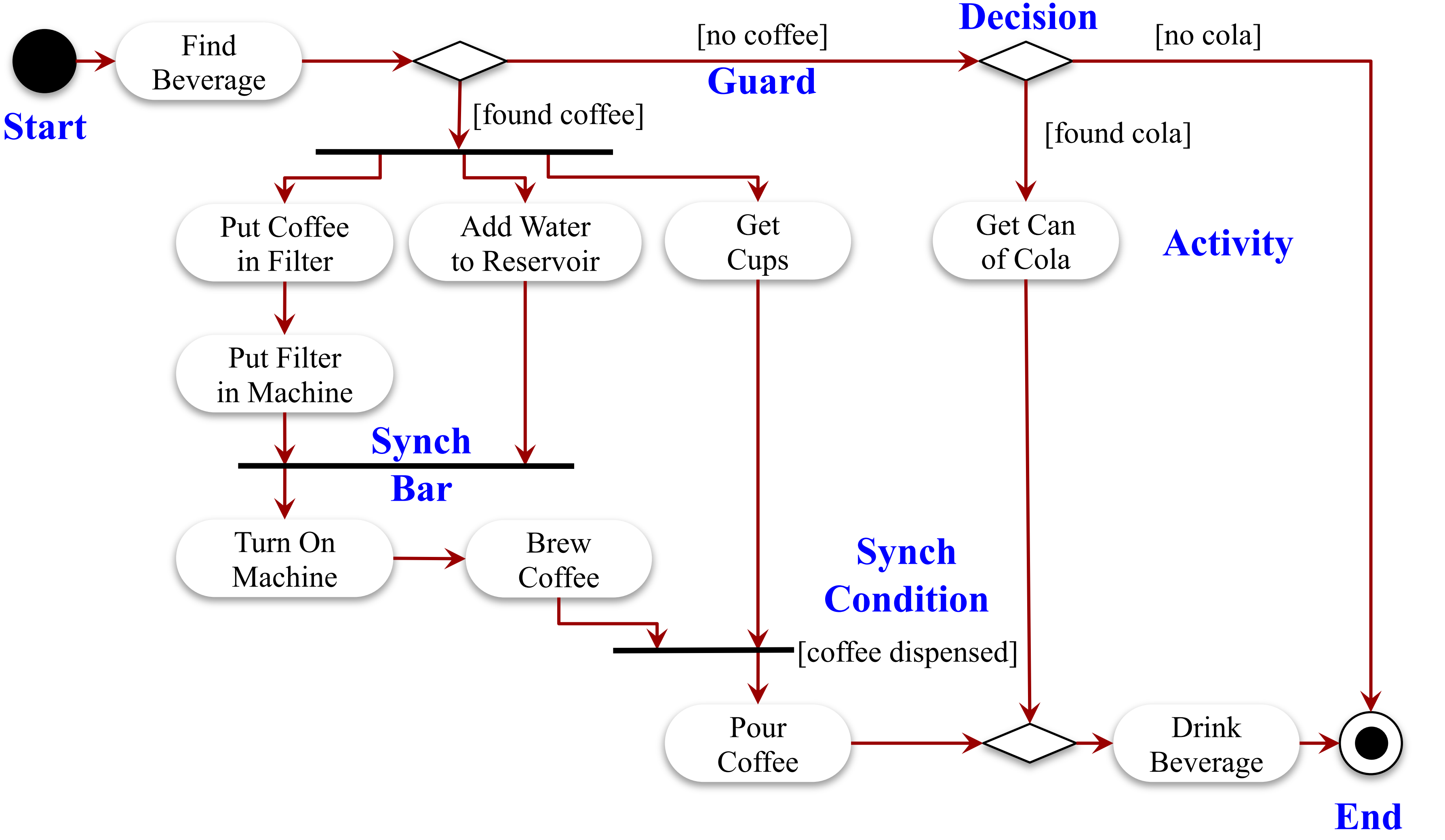
Activity Diagrams

- Define the **workflow** of your program
  - Very similar to a standard flowchart
  - Can follow simultaneous paths (threads)
- Are an *component* of **UML**
  - But did not originate with UML
  - Mostly derived from **Petri Nets**
  - One of most useful UML *design* tools
- Activity diagrams are only UML we use

Activity Diagram Example

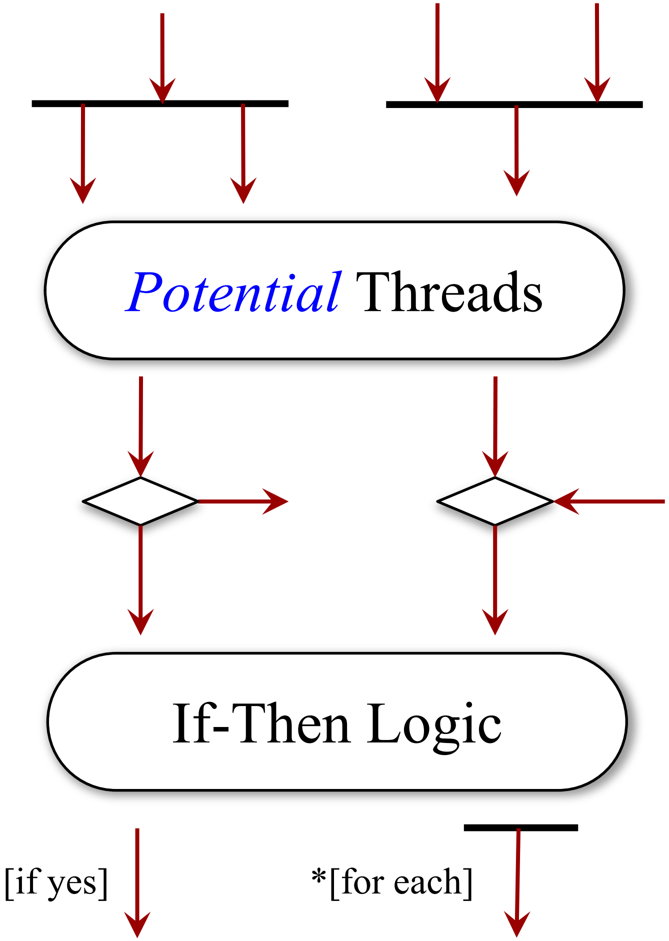


Activity Diagram Example

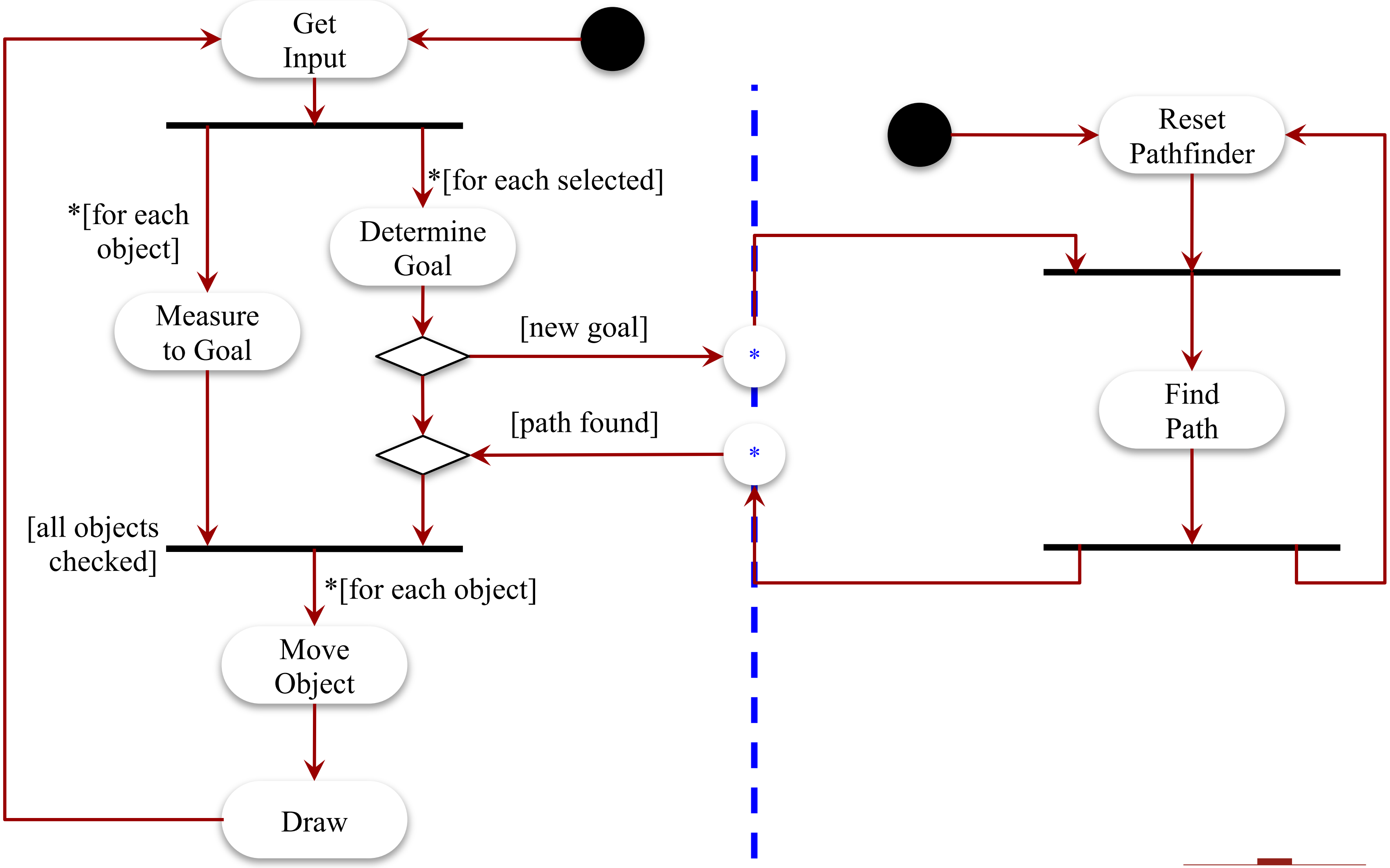


Activity Diagram Components

- **Synchronization Bars**
  - **In**: Wait until have happened
  - **Out**: Actions "simultaneous"
  - … or order does not matter
- **Decisions**
  - **In**: Only needs one input
  - **Out**: Only needs one output
- **Guards**
  - When we can follow edge
  - * is iteration over *container*



Asynchronous Pathfinding



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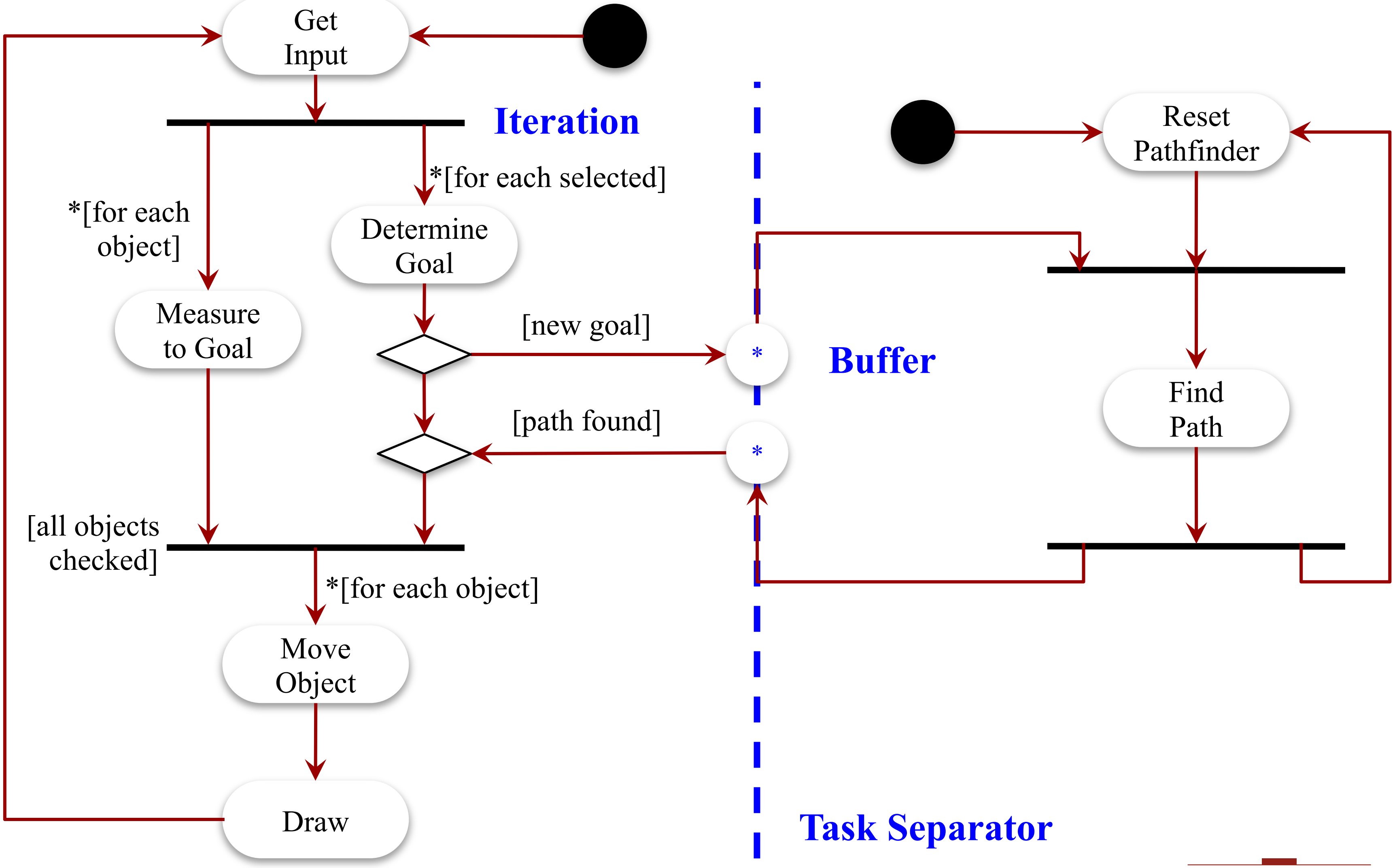
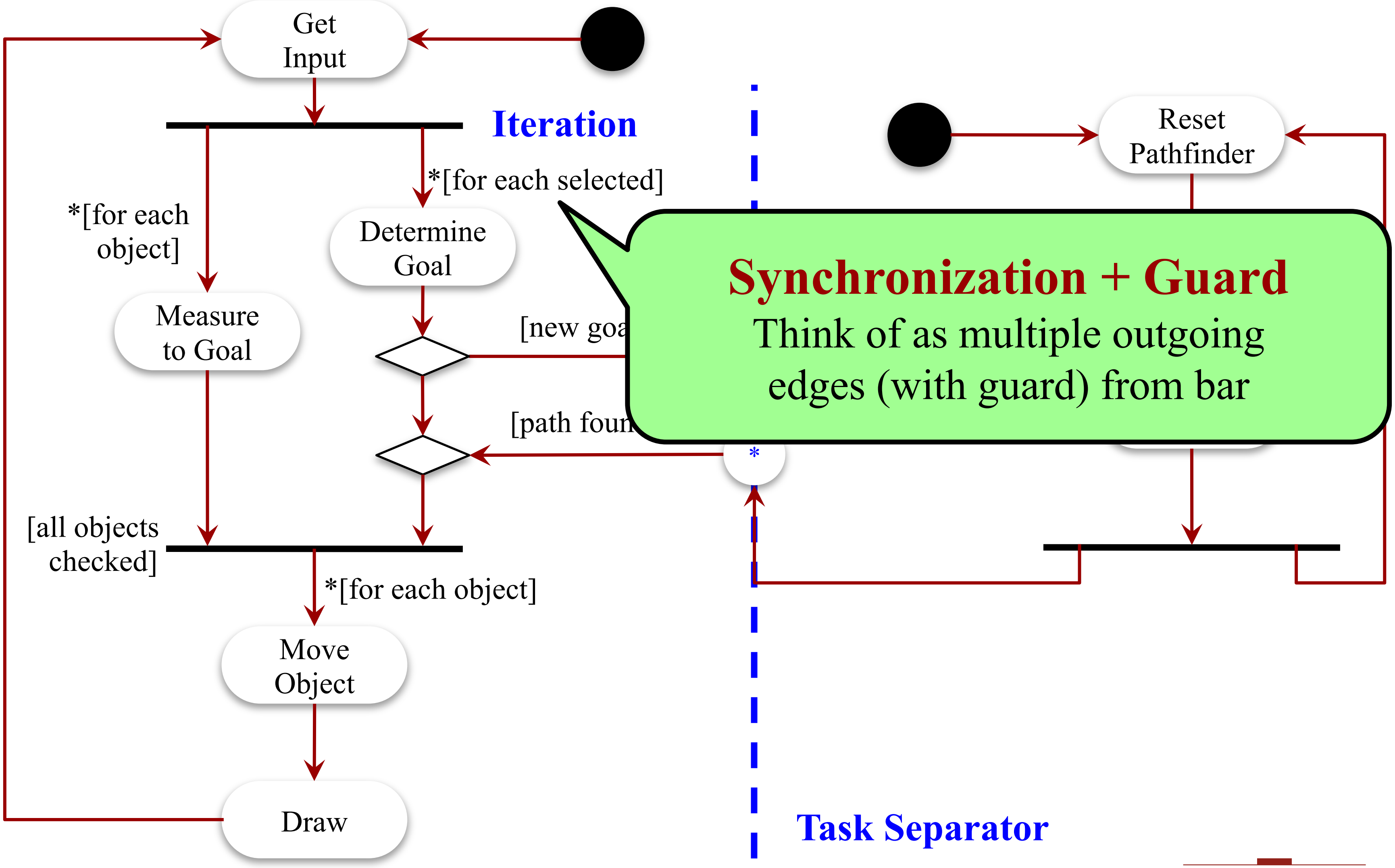


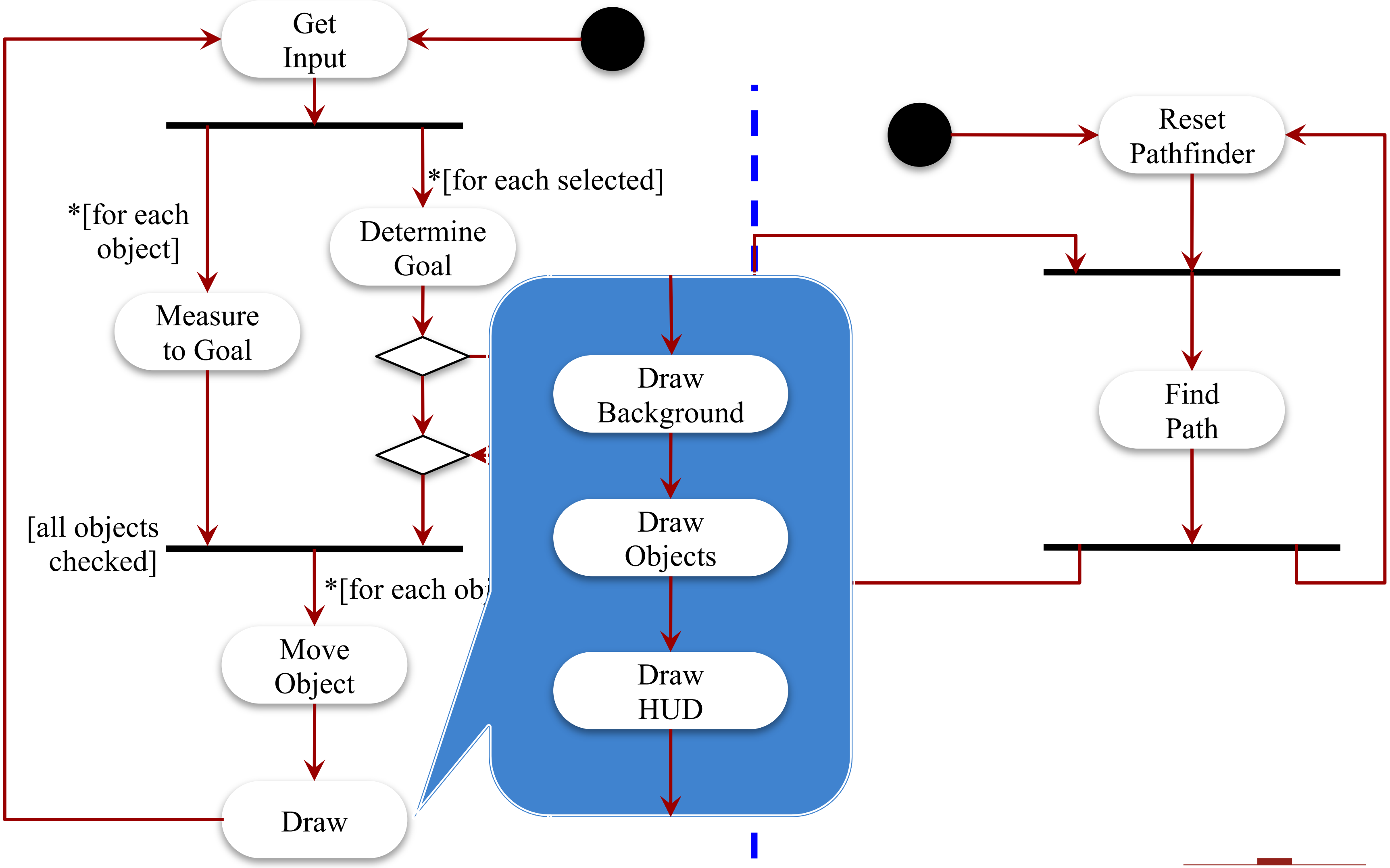
Asynchronous Pathfinding



Synchronization + Guard

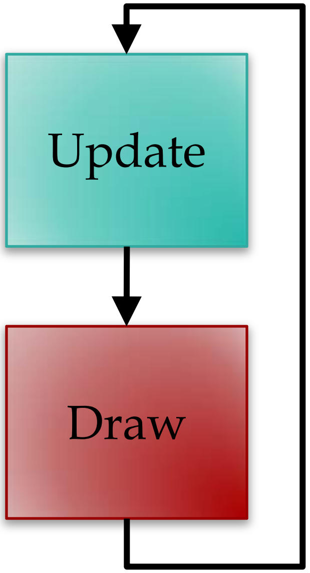
Think of as multiple outgoing edges (with guard) from bar

Expanding Level of Detail



Using Activity Diagrams

- Good way to identify major subsystems
  - Each action is a responsibility
  - Need extra responsibility; create it in CRC
  - Responsibility not there; remove from CRC
- Do activity diagram first?
  - Another iterative process
  - Keep level of detail simple
  - Want outline, not software program



Architecture Design

- Identify major subsystems in **CRC cards**
  - List responsibilities
  - List collaborating subsystems
- Draw **activity diagram**
  - Make sure agrees with CRC cards
  - Revise CRC cards if not
- Create **class API** from CRC cards
  - Recall intro CS courses: *specifications first*!
  - But **not** actually part of specification document

Programming Contract

- Once create API, it is a **contract**
  - Promise to team that "works this way"
  - Can change implementation, but not interface
- If change the interface, must **refactor**
  - Restructure architecture to support interface
  - May change the CRCs and activity diagram
  - Need to change any written code

Summary

- Architecture design starts at a high level
  - **Class-responsibilities-collaboration**
  - Layout as cards to visualize dependencies
- **Activity diagrams** useful for update loop
  - Outline general flow of activity
  - Identifies *dependencies* in the process
- Must formalize **class APIs**
  - No different from standard Java documentation
  - Creates a contract for team members

Where to From Here?

- Later lectures fill in architecture details
  - Data-Driven Design: Data Management
  - 2D Graphics: Drawing
  - Physics Engines: Collisions, Forces
  - Character AI: Sense-Think-Act cycle
  - Strategic AI: Asynchronous AI
  - Networking (at end of course)
- But there is more design coming too