

Lecture 11

Architecture Design

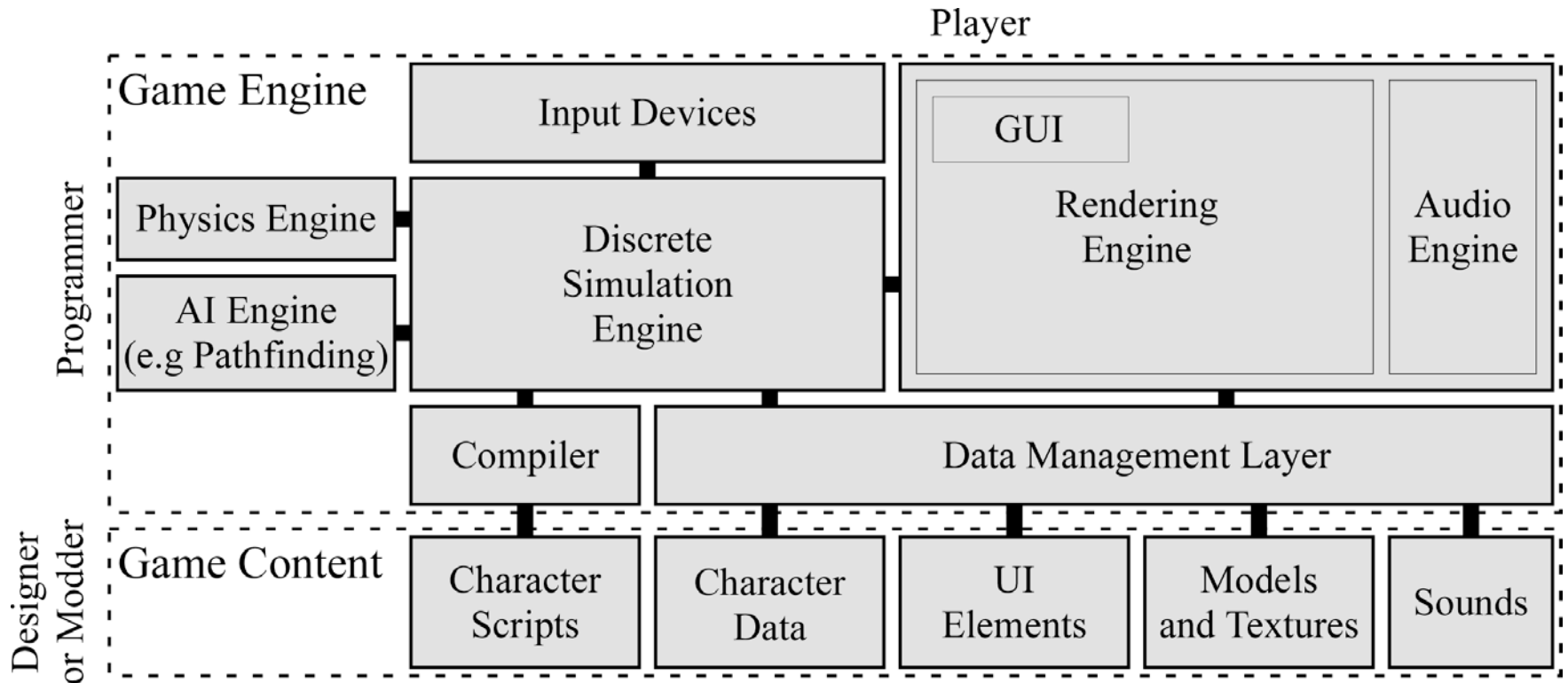
Take Away for Today

- 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?

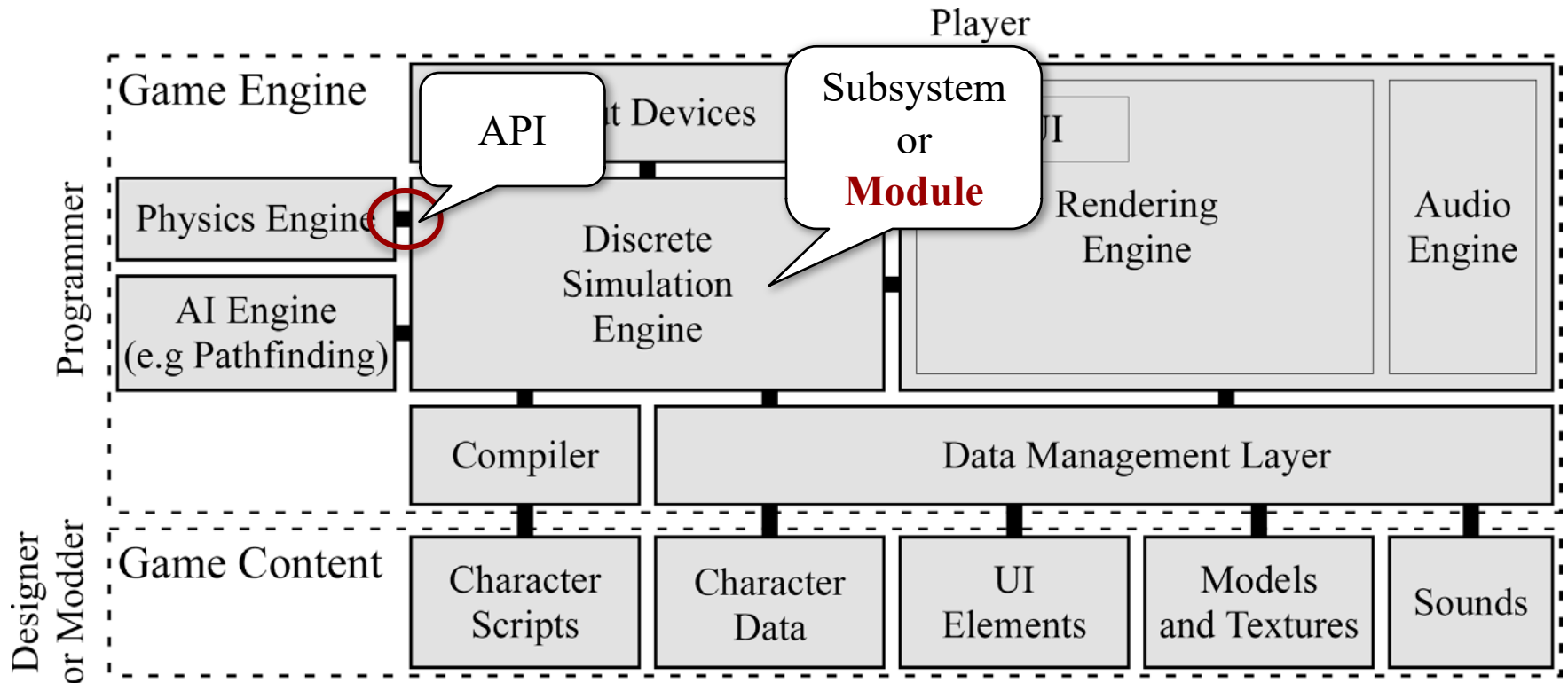
Architecture: The Big Picture



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**

Architecture: The Big Picture



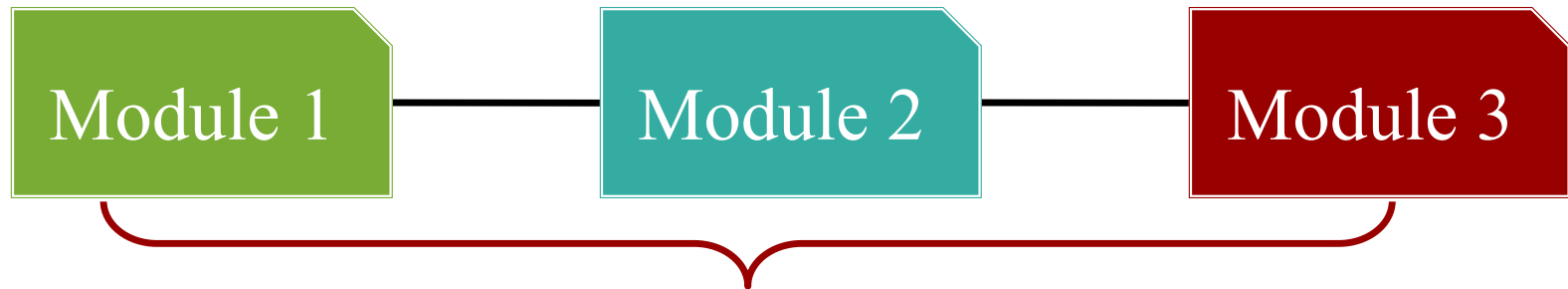
Example: Physics Engines

- 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

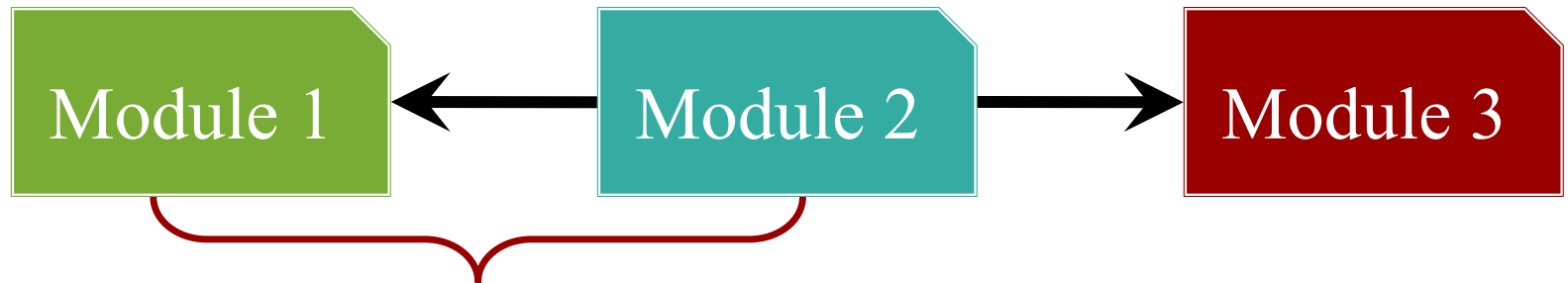
- Shows when one module “depends” on another
 - Module A calls a method/function of Module B
 - Module A creates/loads instance of Module B
- **General Rule:** Does *A* need the API of *B*?
 - How would we know this?



Module 1 does not “need” to know about Module 3

Relationship Graph

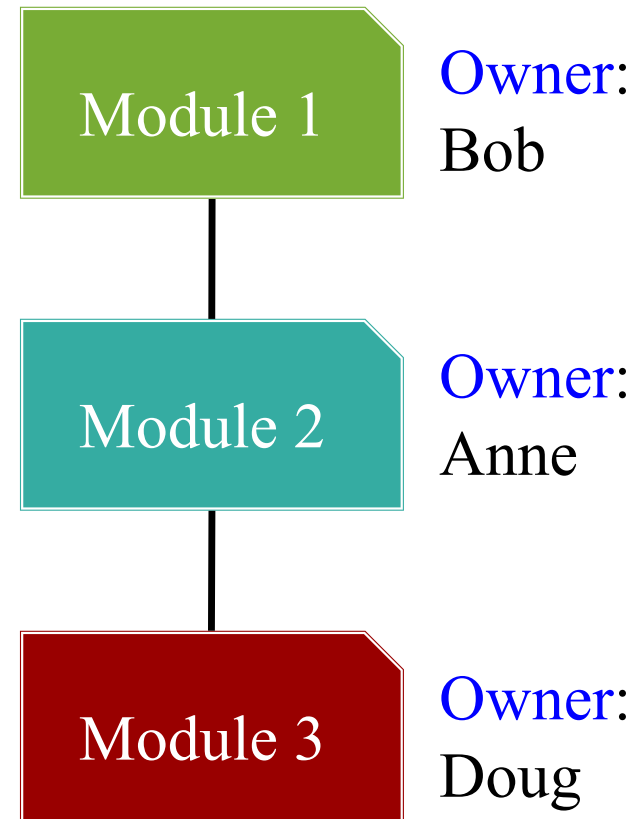
- Edges in relationship graph are often **directed**
 - If A calls a method of B , is B aware of it?
- But often undirected in architecture diagrams
 - Direction clear from other clues (e.g. layering)
 - Developers of both modules should still agree on API



Does Module 1 need to know about Module 2?

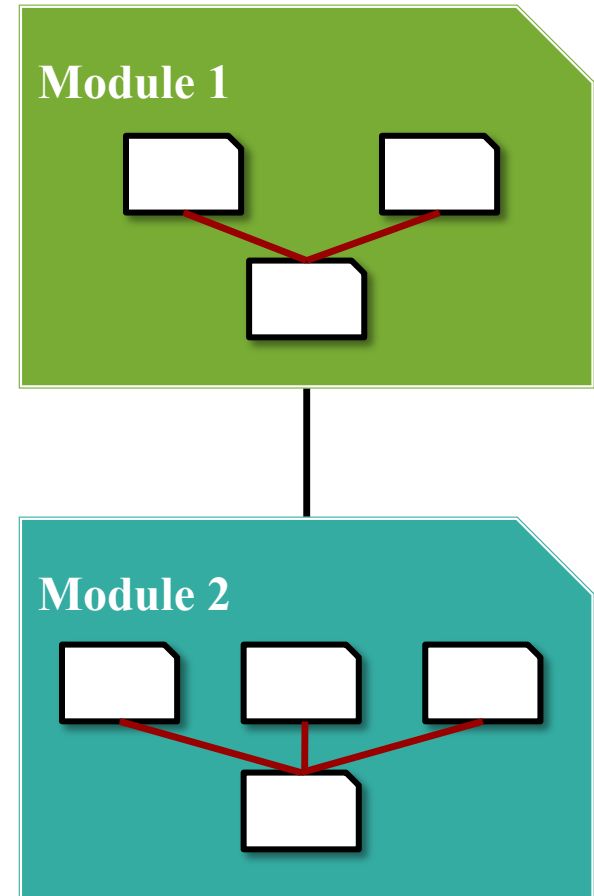
Dividing up Responsibilities

- 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

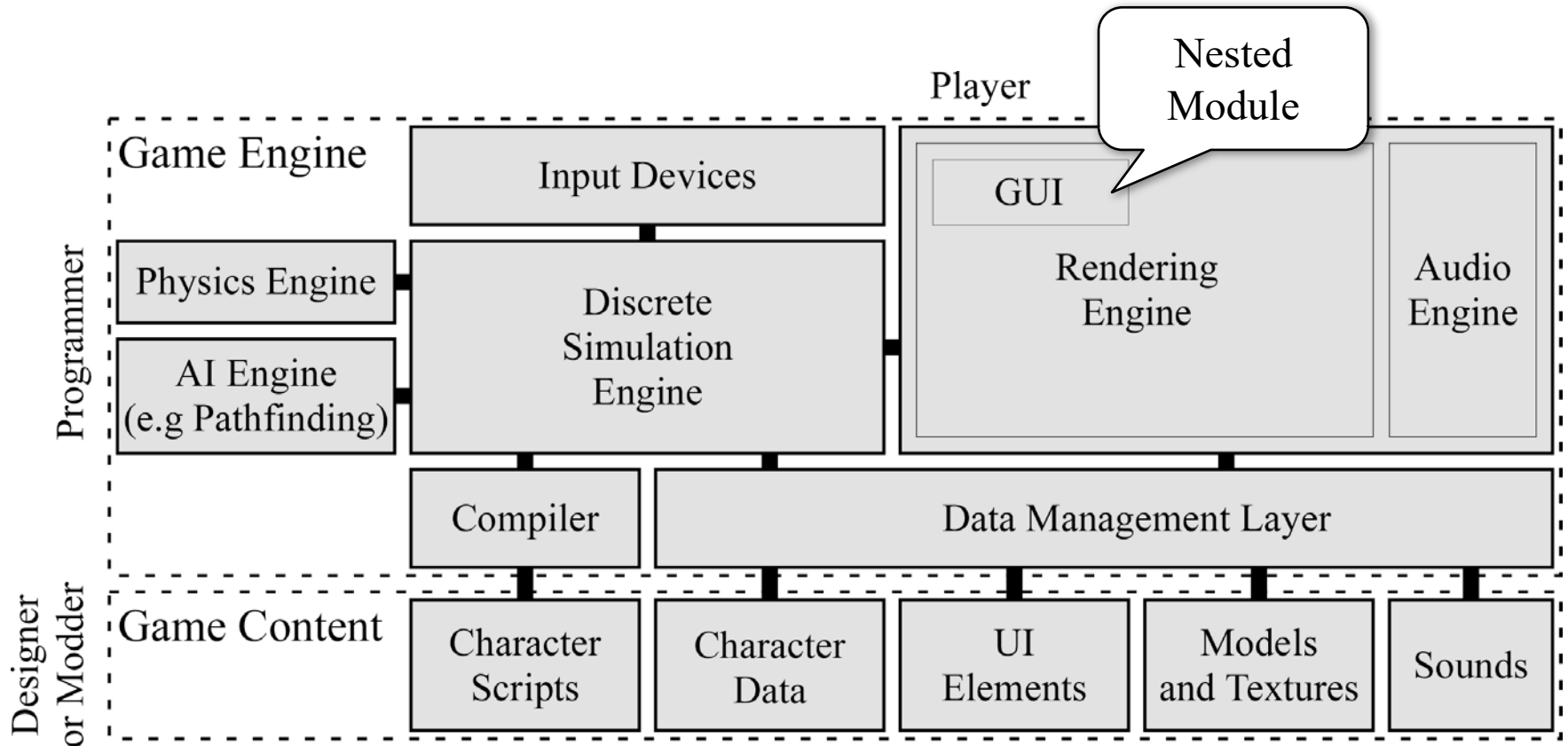


Nested (Sub)modules

- 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



Architecture: The Big Picture



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

Controller	
AI Controller	
Class Name	
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	
Class Name	
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
...	...
...	...
...	...
...	...
...	...
...	...
...	...
...	...
...	...

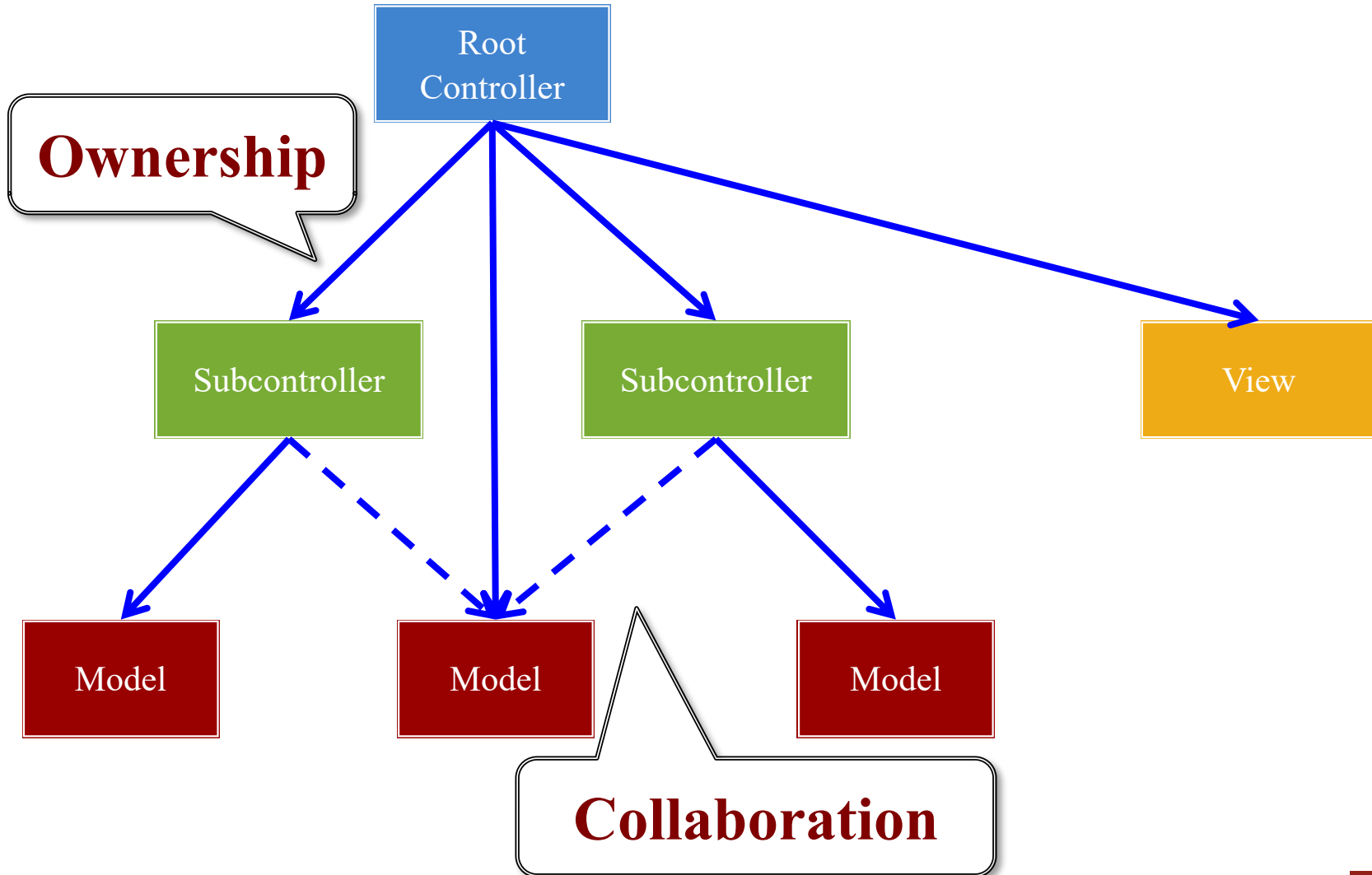
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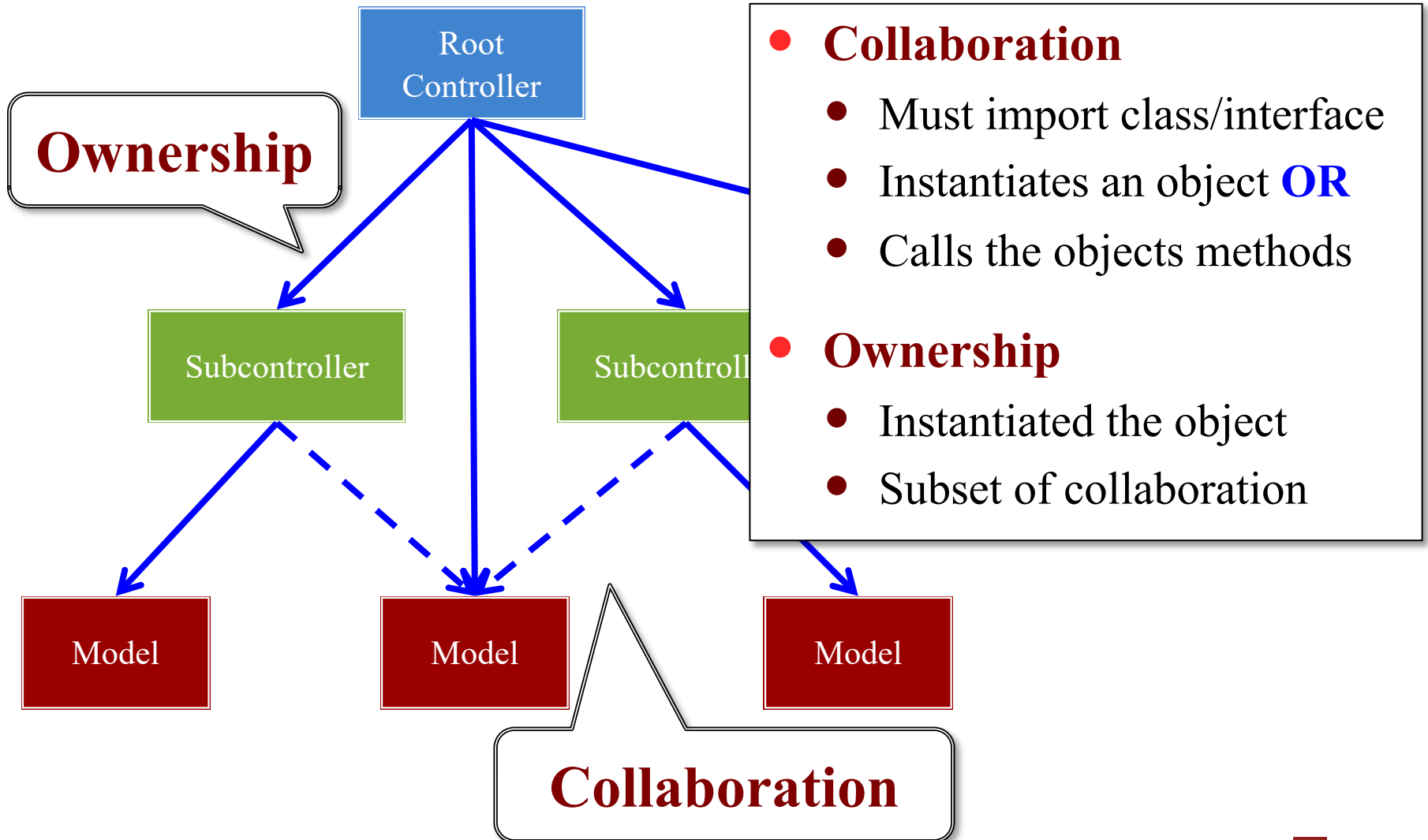
Module 1	
Responsibility	Collaboration
...	...
...	...
...	...

Module 2	
Responsibility	Collaboration
...	...
...	...
...	...

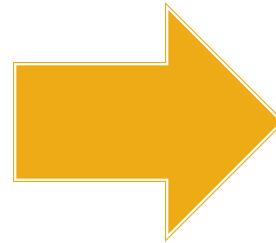
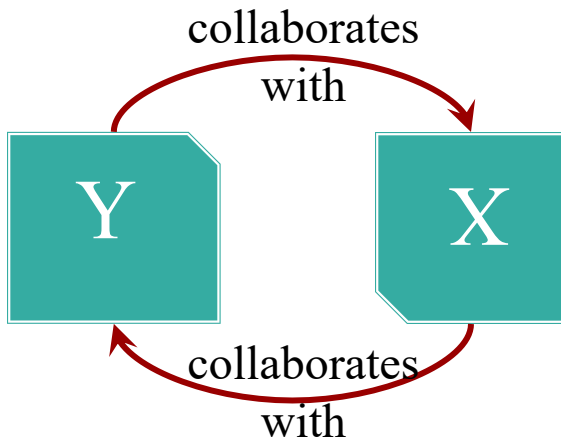
Application Structure



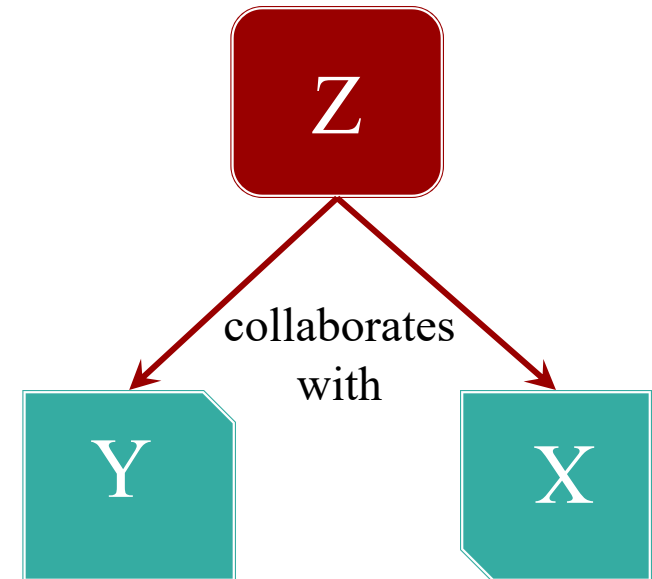
Application Structure



Avoid Cyclic Collaboration

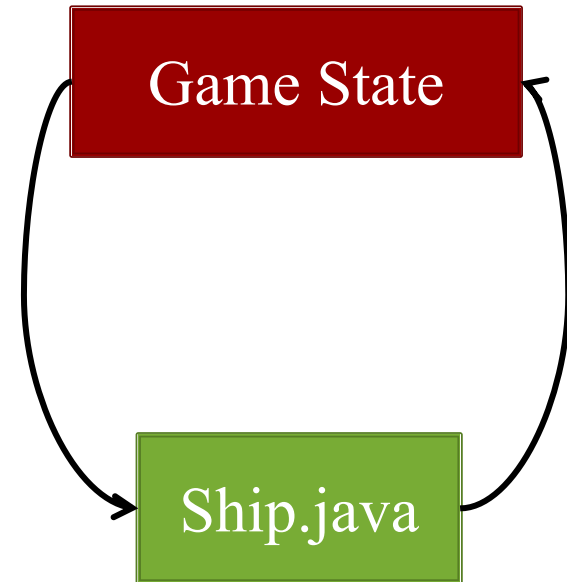


Controller



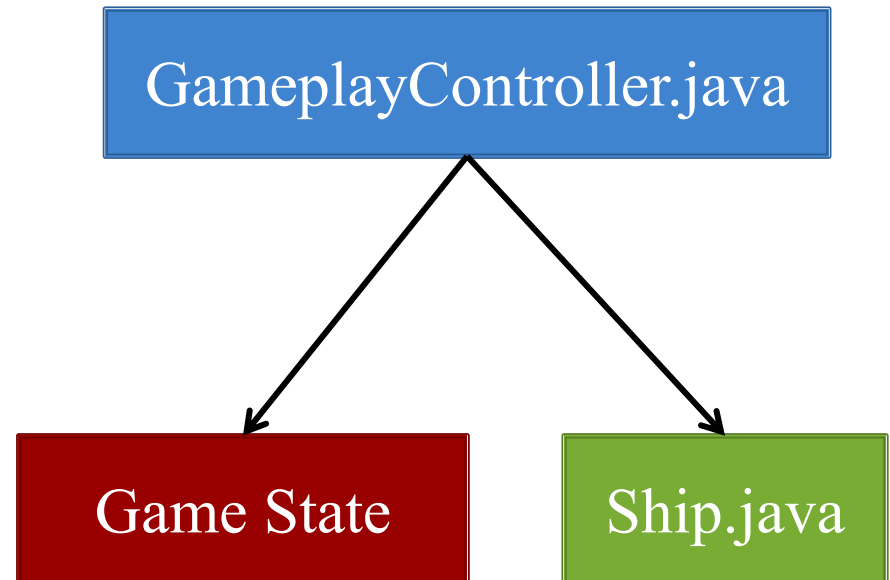
Avoid Cyclic Collaboration

- **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**



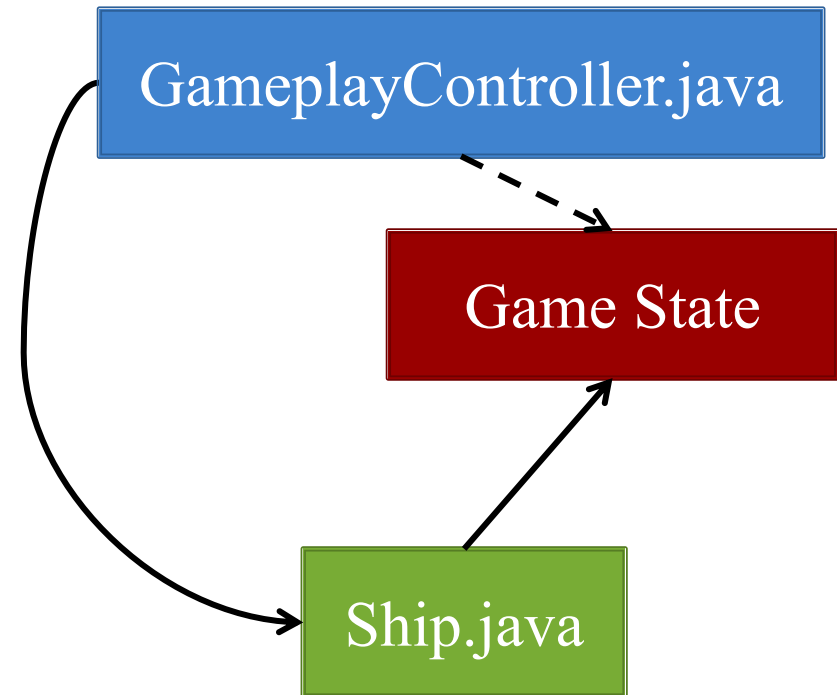
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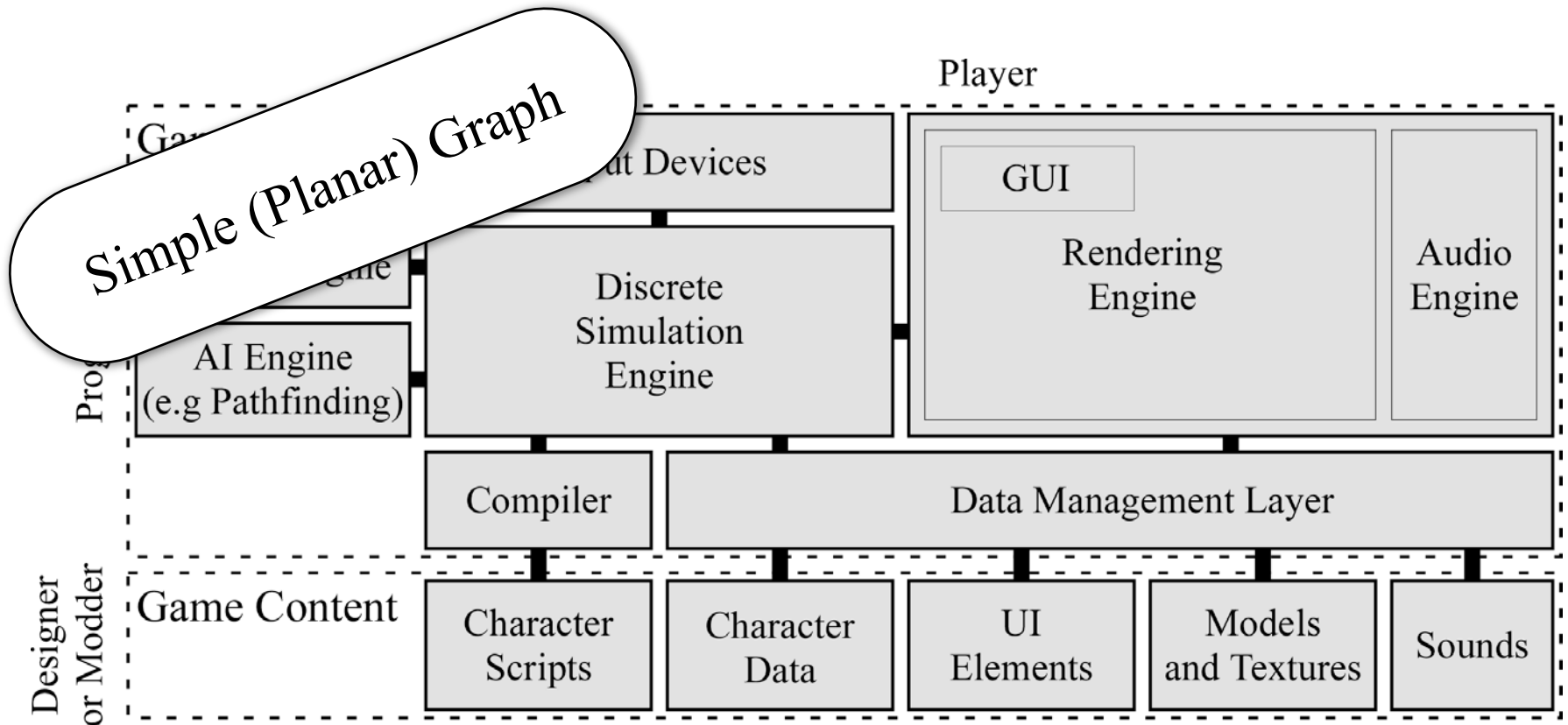


Alternative: Interfaces

- 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

Class 2	
Responsibility	Collaboration
...	...
...	...
...	...

Class 3	
Responsibility	Collaboration
...	...
...	...
...	...

Class 4	
Responsibility	Collaboration
...	...
...	...
...	...

If cannot do this, time to think about nesting!

Designing Class APIs

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

Scene Model	
Responsibility	Method
Enumerates game objects	<code>Iterator<GameObject> enumObjects()</code>
Adds game objects to scene	<code>void addObject(GameObject)</code>
Removes objects from scene	<code>void removeObject(GameObject)</code>
Selects object at mouse	<code>GameObject getObject(MouseEvent)</code>

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

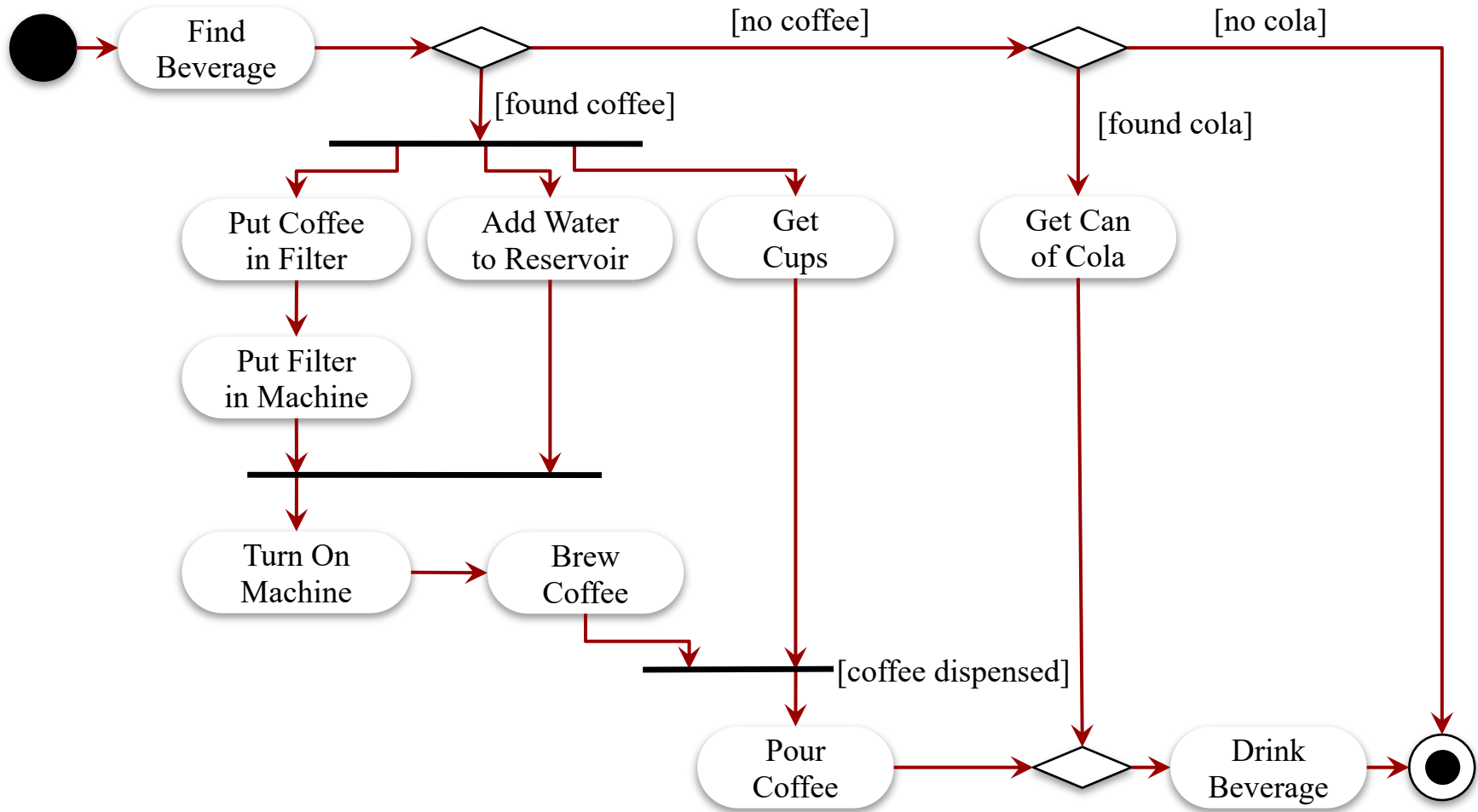


Activity Diagrams

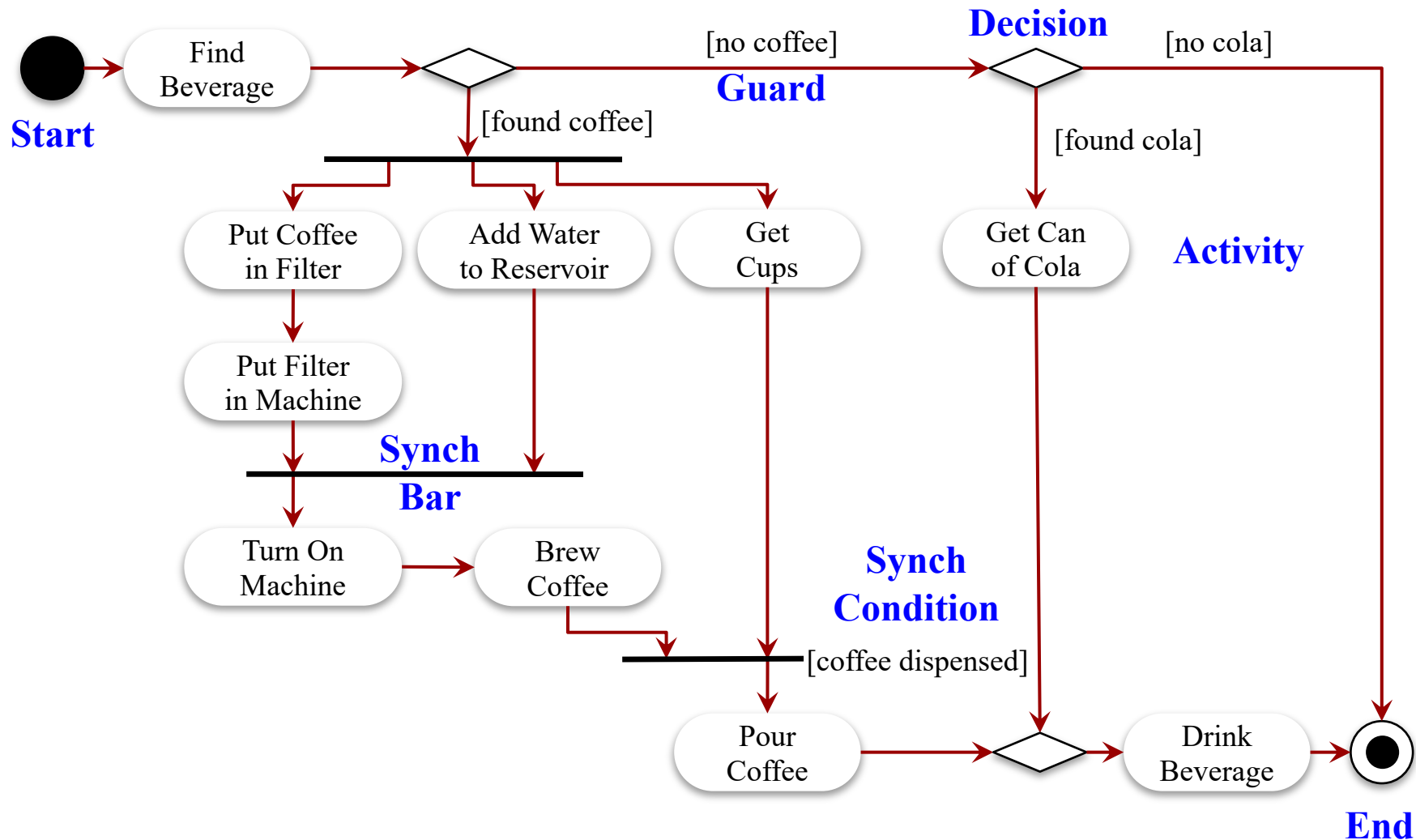
- Define the **workflow** of your program
 - Very similar to a standard flowchart
 - Can follow simultaneous paths (threads)
- Are an *component* of **UML**
 - But did not originate with UML
 - Mostly derived from **Petri Nets**
 - One of most useful UML *design* tools
- Activity diagrams are only UML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



Activity Diagram Example



Activity Diagram Example



Activity Diagram Components

- **Synchronization Bars**

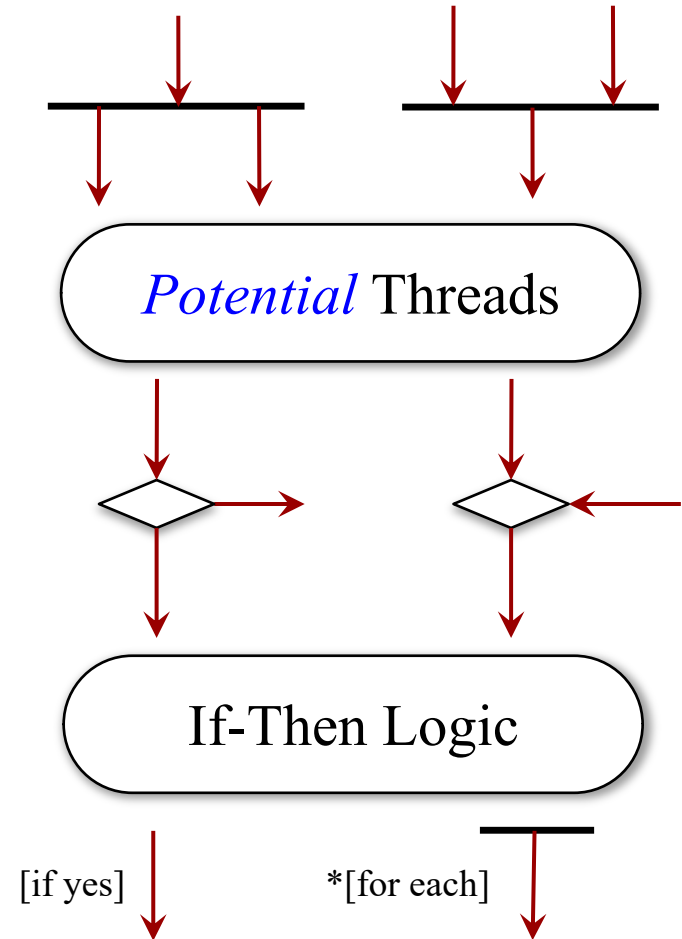
- **In:** Wait until have happened
- **Out:** Actions “simultaneous”
- ... or order does not matter

- **Decisions**

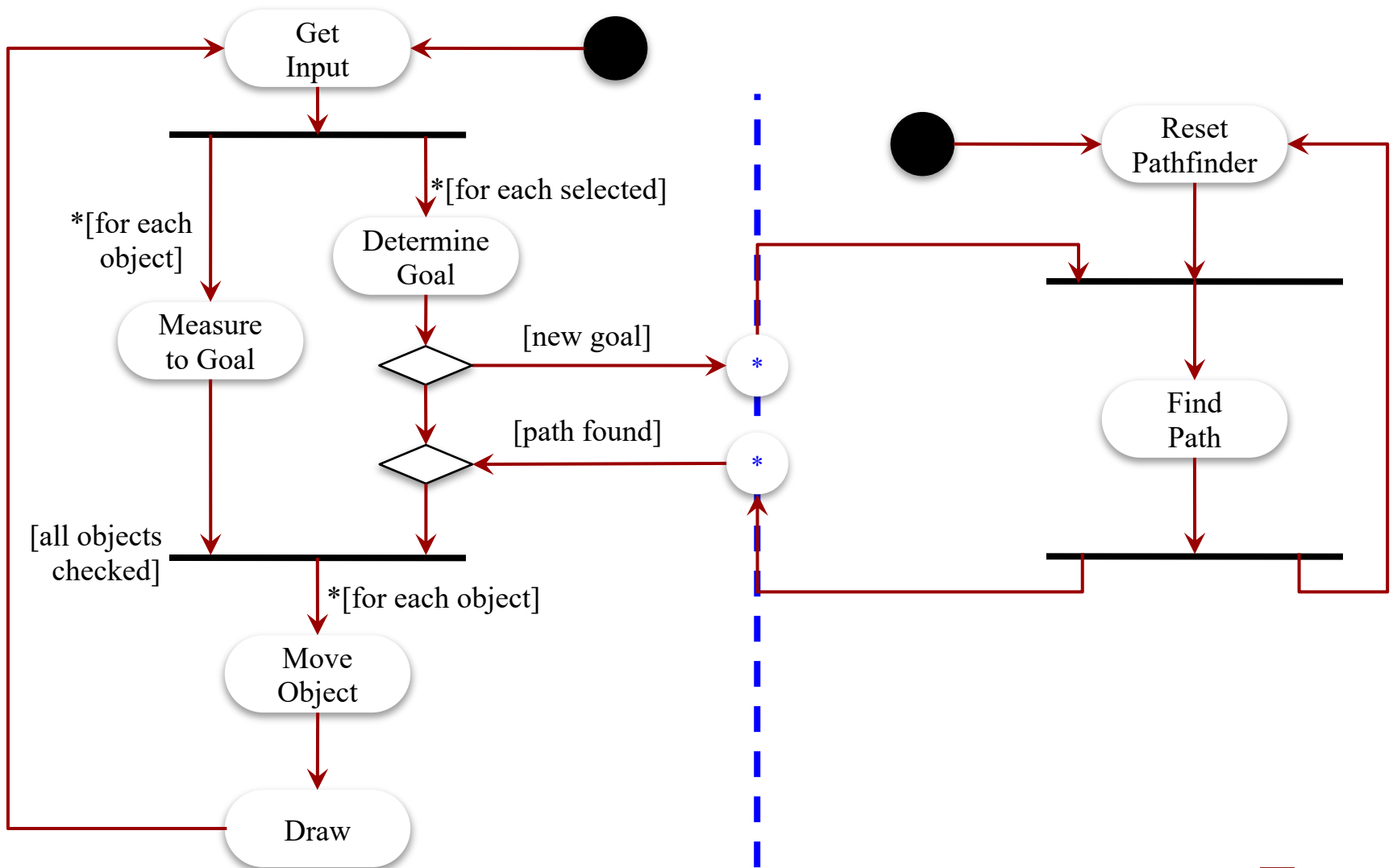
- **In:** Only needs one input
- **Out:** Only needs one output

- **Guards**

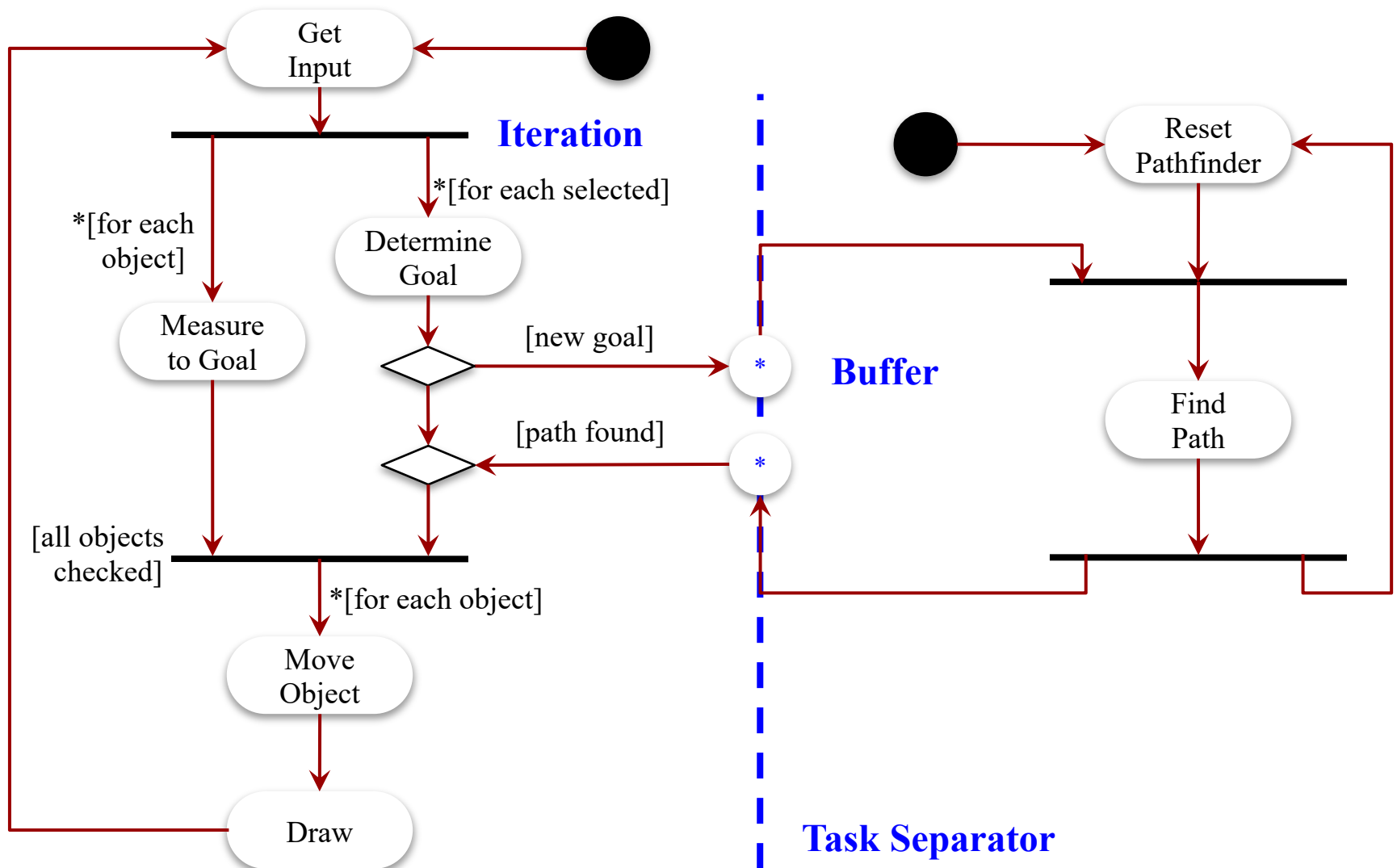
- When we can follow edge
- * is iteration over *container*



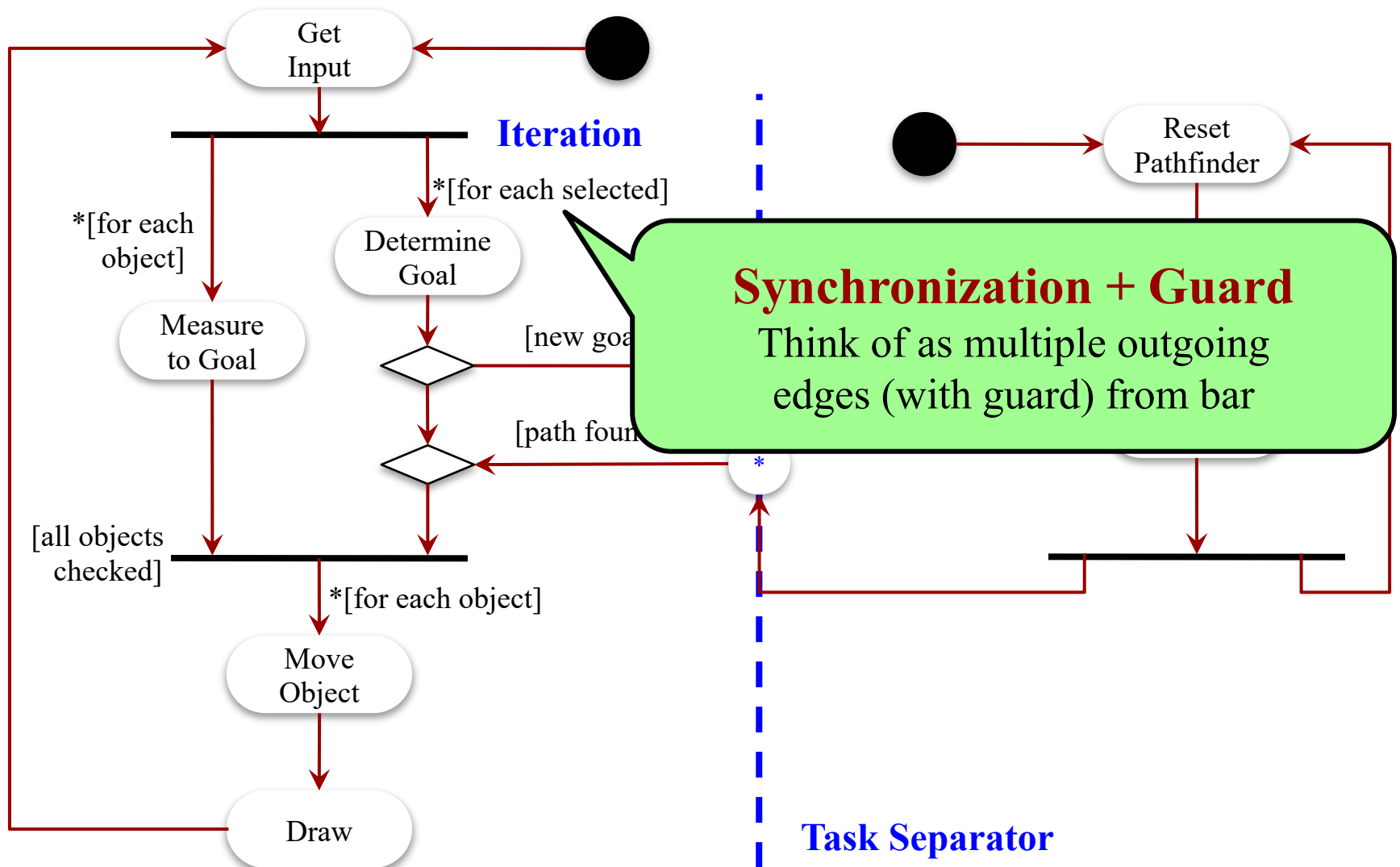
Asynchronous Pathfinding



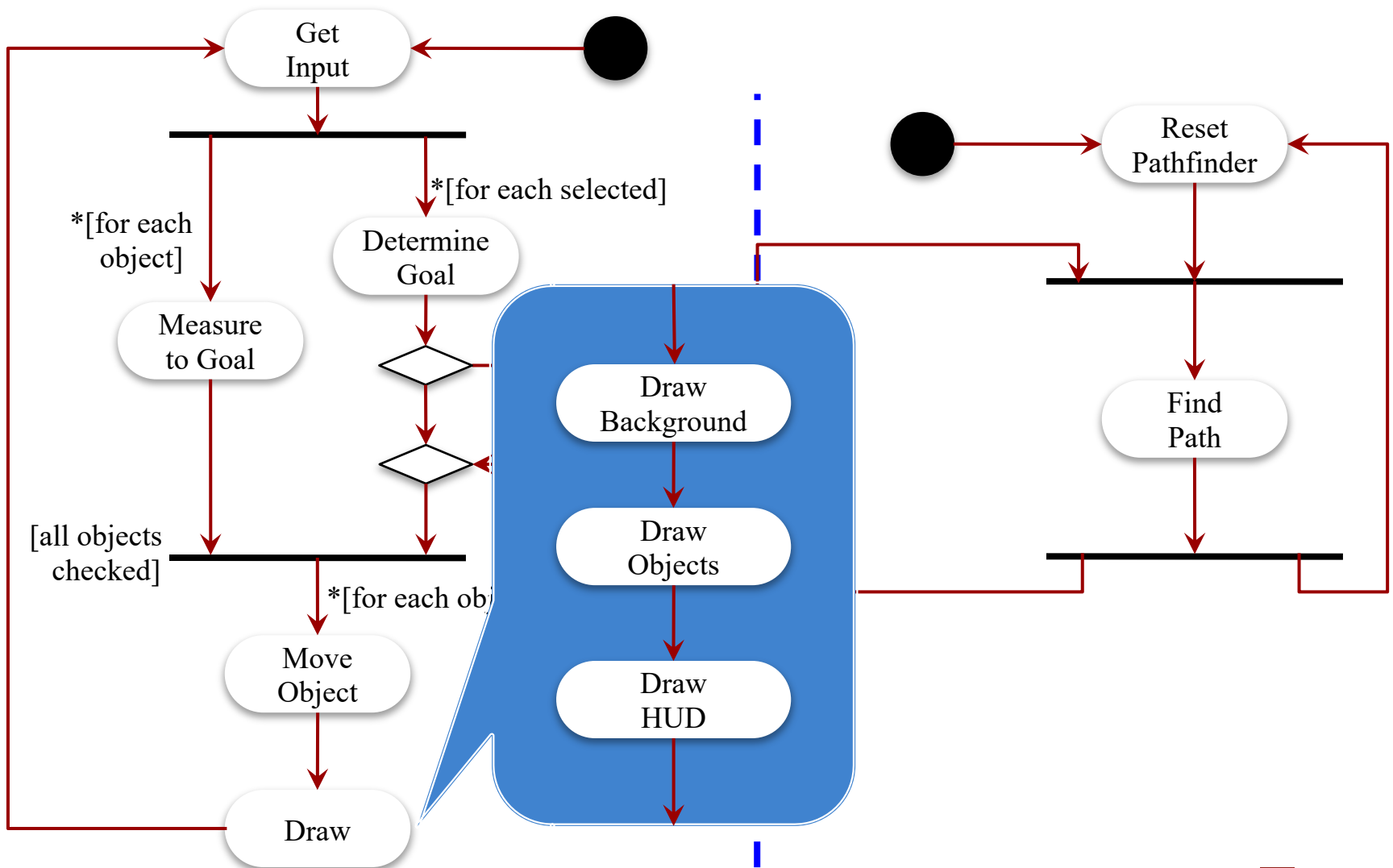
Asynchronous Pathfinding



Asynchronous Pathfinding

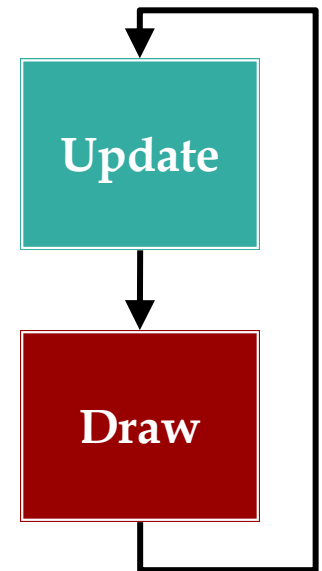


Expanding Level of Detail



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