Putting It All Together

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Lecture Goals

- Introduce two new UML diagrams
- Review material from Chapter 10 of the OO A&D textbook
  - The OO A&D project life cycle
    - Compare to other OO A&D life cycles
  - The Objectville Subway Map Example (in python)
  - Dijkstra’s Algorithm
- Discuss the example application of Chapter 10
- Emphasize the OO concepts and techniques encountered in Chapter 10

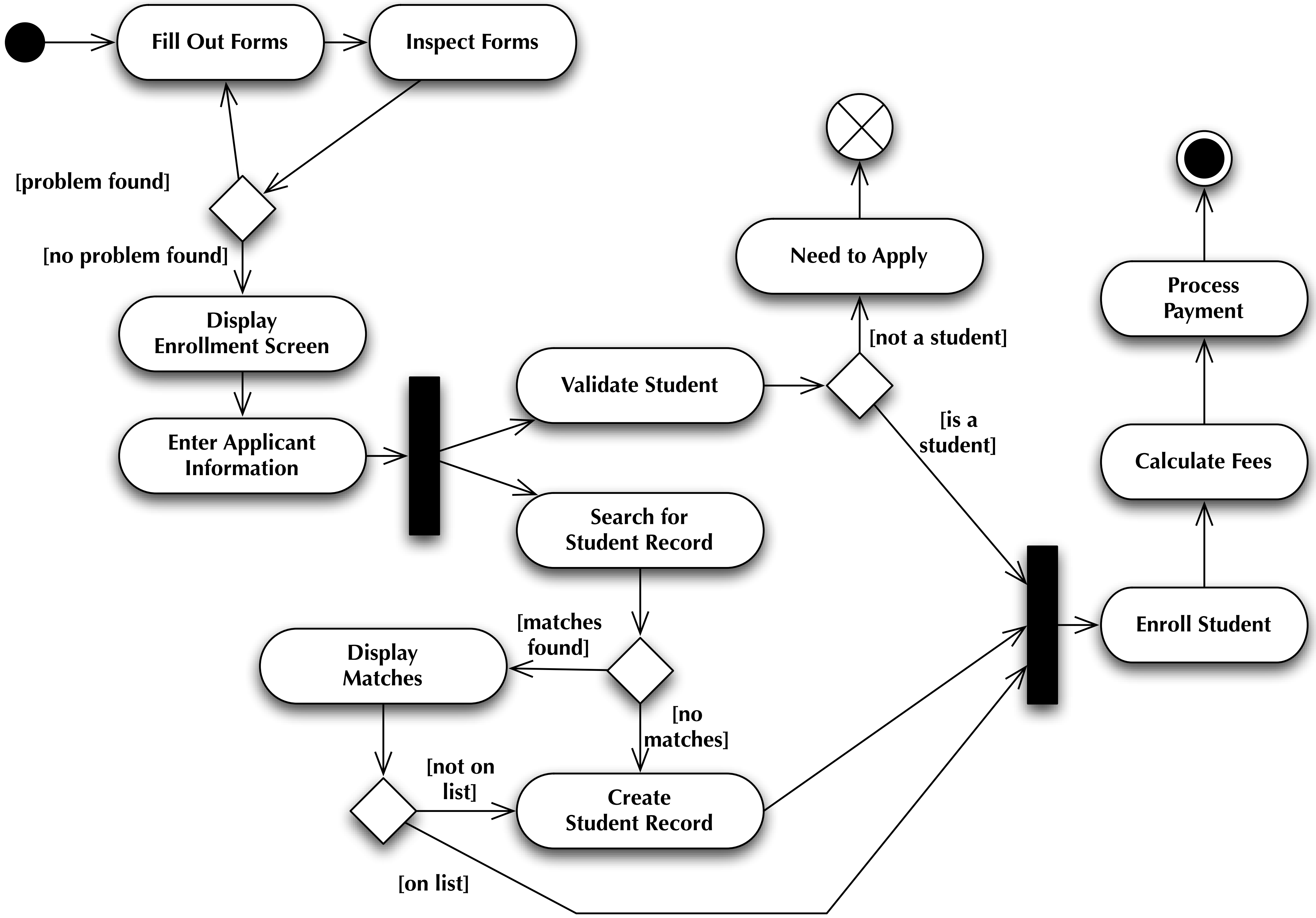
Two New UML Diagrams

- Activity Diagrams and State Diagrams
- Relationship to life cycles
    - They represent alternate ways to record/capture design information about your system. They can help you identify new classes and methods that
    - They are typically used in the following places in analysis and design
        - After use case creation: create an activity diagram for the use case
        - For each activity in the diagram: draw a sequence diagram
            - Add a class for each object in the sequence diagrams to your class diagram, add methods in sequence diagrams to relevant classes
        - Based on this information, see if you can partition an object's behavior into various categories (initializing, acquiring info, performing calcs, …)
        - Create a state diagram for the object that documents these states and the transitions between them (transitions typically map to method calls)

Activity Diagrams

- Think “Flow Chart on Steroids”
  - Able to model complex, parallel processes with multiple ending conditions
- Constructs
  - Initial Node (circle)/Final Node (circle in circle)/Early Termination Node (circle with x through it)
  - Activity: Rounded Rectangle indication an action of some sort either by a system or by a user
  - Flow: directed lines between activities and/or other constructs. Flows can be annotated with guards “[student on list]” that restrict its use
  - Fork/Join: Black bars that indicate activities that happen in parallel
  - Decision/Merge: Diamonds used to indicate conditional logic.
  - Swim Lanes: A way to layout the diagram to associate roles with activities

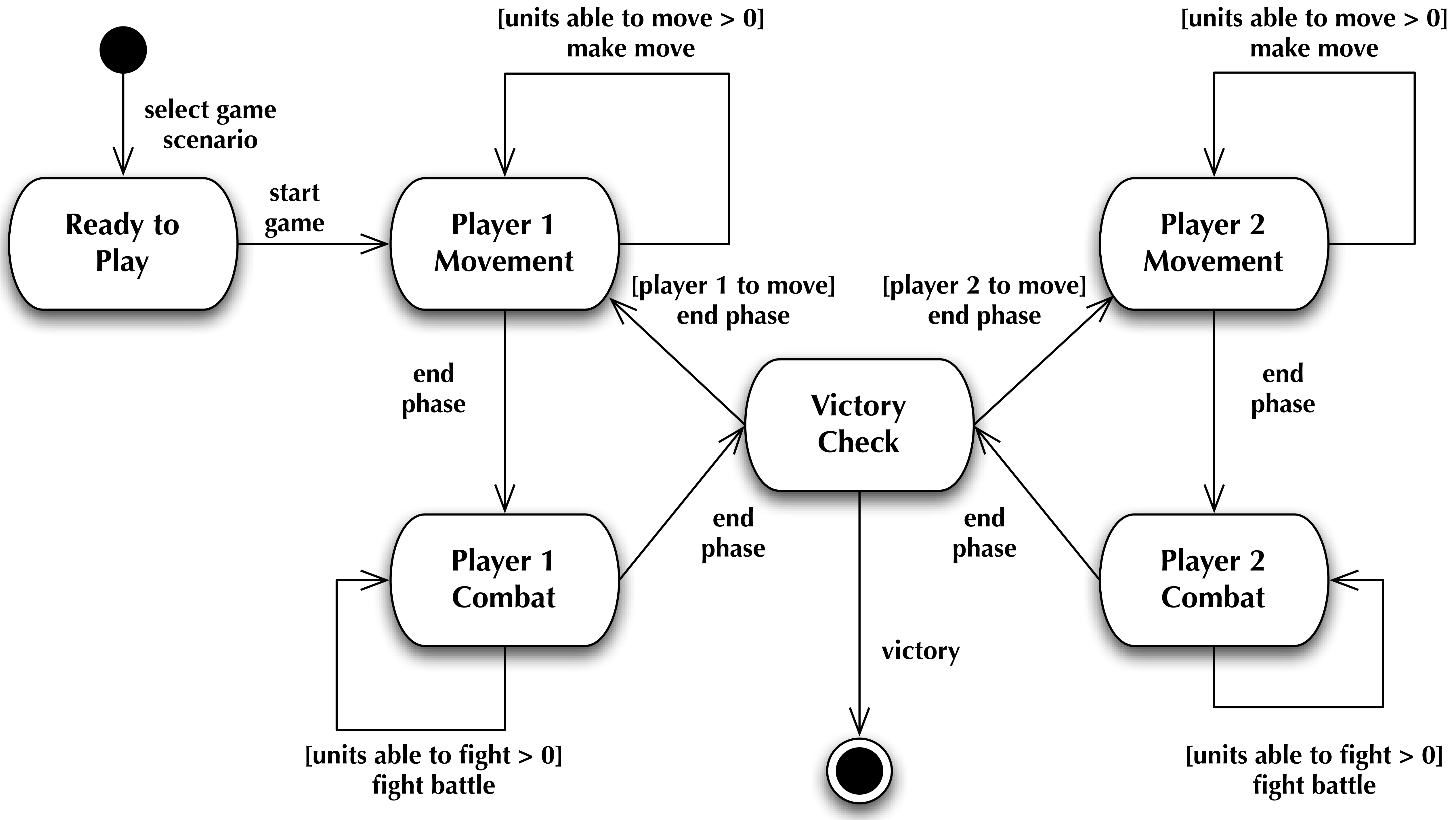
Example Activity Diagram



State Diagrams

- Shows the major states of an object or system
    - Each state appears as a rounded rectangle
    - Arrows indicate state transitions
        - Each transition has a name that indicates what triggers the transition (often times, this name corresponds to a method name)
        - Each transition may optionally have a guard that indicates a condition that must be true before the transition can be followed
    - A state diagram also has a start state and an end state
- State diagrams are useful if you have a class that has “partitions” in its behavior: it acts one way when it starts, another way when condition A occurs, another way when condition B occurs, and another way before it terminates

Example State Diagram


select game scenario
Ready to Play
start game
Player 1 Movement
[units able to move > 0] make move
end phase
Player 1 Combat
[units able to fight > 0] fight battle
end phase
Victory Check
[player 1 to move] end phase
[player 2 to move] end phase
victory
end phase
Player 2 Movement
[units able to move > 0] make move
end phase
Player 2 Combat
[units able to fight > 0] fight battle

Relationships between OO A&D Software Artifacts

$$\begin{tikzcd}
\text{Features} \arrow[r, leftrightarrow] \arrow[d, leftrightarrow] & \text{Use Case Diagram} \arrow[d, leftrightarrow] \\
\text{Requirements} \arrow[r, leftrightarrow] \arrow[d, leftrightarrow] & \text{Use Cases} \arrow[d, leftrightarrow] \\
\text{Class Diagram} \arrow[d, leftrightarrow] \arrow[dr, leftrightarrow] & \text{Activity Diagrams} \arrow[d, leftrightarrow] \\
\text{State Diagrams} & \text{Sequence Diagrams}
\end{tikzcd}$$

The OO A&D Project Life Cycle

- All software development projects require a software development life cycle to organize the work performed by their developers
  - Even when there is only one developer and the life cycle being used is “code and fix”
- After nine chapters and eight lectures, we have established a fairly complete look at the various stages of an OO A&D project life cycle
  - The overall life cycle consists of three stages
    - Make sure your software does what the customer wants it to do
    - Apply basic OO principles to add flexibility
    - Strive for a maintainable, reusable design
  - But there are many activities associated with these stages
    - plus iteration and testing!

The Activities

1. Feature List (1)	High-level view of app’s functions
2. Use Case Diagrams (1)	Types of Users and Tasks
3. Break Up the Problem (1)	Divide and Conquer
4. Requirements (1)	Gather requirements for module
5. Domain Analysis (1)	Fill in use-case details
6. Preliminary Design (2)	Class diagram, apply OO principles
7. Implementation (2/3) Repeat steps 4-7 until done	Write code, test it
8. Delivery	You’re Done

How does this compare to other life cycles?

- Background
  - In Software Engineering:
    - “Process is King”
    - We want our activities to be coordinated and planned, i.e. “engineered”
  - Life cycles make software development
    - predictable, repeatable, measurable & efficient
  - High-quality processes should lead to high-quality products
    - at least it improves the odds of producing great software

Survey of OOA&D Methods

- Generalization
    - Taken from “SE: A Practitioner’s approach, 4th ed.” by Roger S. Pressman, McGraw-Hill, 1997
- Specific Methods
    - The Booch Method
    - The Jacobson Method
    - The Rambaugh Method
    - The Unified Software Process
        - These four descriptions come from “Graham, I. Object-Oriented Methods, Addison-Wesley, Third Edition, 2001”

OO Methods in General...

- Obtain customer requirements for the OO System
    - Identify scenarios or use cases
    - Build a requirements model
- Select classes and objects using basic requirements
- Identify attributes and operations for each object
- Define structures and hierarchies that organize classes
- Build an object-relationship model
- Build an object-behavior model
- Review the OO analysis model against use cases
    - Once complete, move to design and implementation: These phases simply elaborate the previously created models with more and more detail, until it is possible to write code straight from the models

Background on OO Methods

- An OO Method should cover and include
  - requirements and business process modeling
  - a lightweight, customizable process framework
  - project management
  - component architecture
  - system specification
    - use cases, UML, architecture, etc.
  - component design and decomposition
  - testing throughout the life cycle
  - Software quality assurance
  - Configuration management

The Booch Method

- **Identify classes and objects**
    - Propose candidate objects
    - Conduct behavior analysis
    - Identify relevant scenarios
    - Define attributes and operations for each class
- **Identify the semantics of classes and objects**
    - Select scenarios and analyze
    - Assign responsibility to achieve desired behavior
    - Partition responsibilities to balance behavior
    - Select an object and enumerate its roles and responsibilities
    - Define operations to satisfy the responsibilities

Booch, continued

- **Identify relationships among classes and objects**
  - Define dependencies that exist between objects
  - Describe the role of each participating object
  - Validate by walking through scenarios
- **Conduct a series of refinements**
  - Produce appropriate diagrams for the work conducted above
  - Define class hierarchies as appropriate
  - Perform clustering based on class commonality
- **Implement classes and objects**
  - In analysis and design, this means specify everything!

The Jacobson Method

- Object-Oriented Software Engineering
    - Primarily distinguished by the use-case
    - Simplified model of Objectory
        - Objectory evolved into the Rational Unified Software Development Process
    - For more information on this Objectory precursor, see
        - Jacobson, I., Object-Oriented Software Engineering, Addison-Wesley, 1992.

Jacobson, continued

- **Identify the users of the system and their overall responsibilities**
- **Build a requirements model**
  - Define the actors and their responsibilities
  - Identify use cases for each actor
  - Prepare initial view of system objects and relationships
  - Review model using use cases as scenarios to determine validity
- Continued on next slide

Jacobson, continued

- **Build analysis model**
    - Identify interface objects using actor-interaction information
    - Create structural views of interface objects
    - Represent object behavior
    - Isolate subsystems and models for each
    - Review the model using use cases as scenarios to determine validity

The Rumbaugh Method

- Object Modeling Technique (OMT)
  - Rumbaugh, J. et al., Object-Oriented Modeling and Design, Prentice-Hall, 1991
- Analysis activity creates three models
  - Object model
    - Objects, classes, hierarchies, and relationships
  - Dynamic model
    - object and system behavior
  - Functional model
    - High-level Data-Flow Diagram

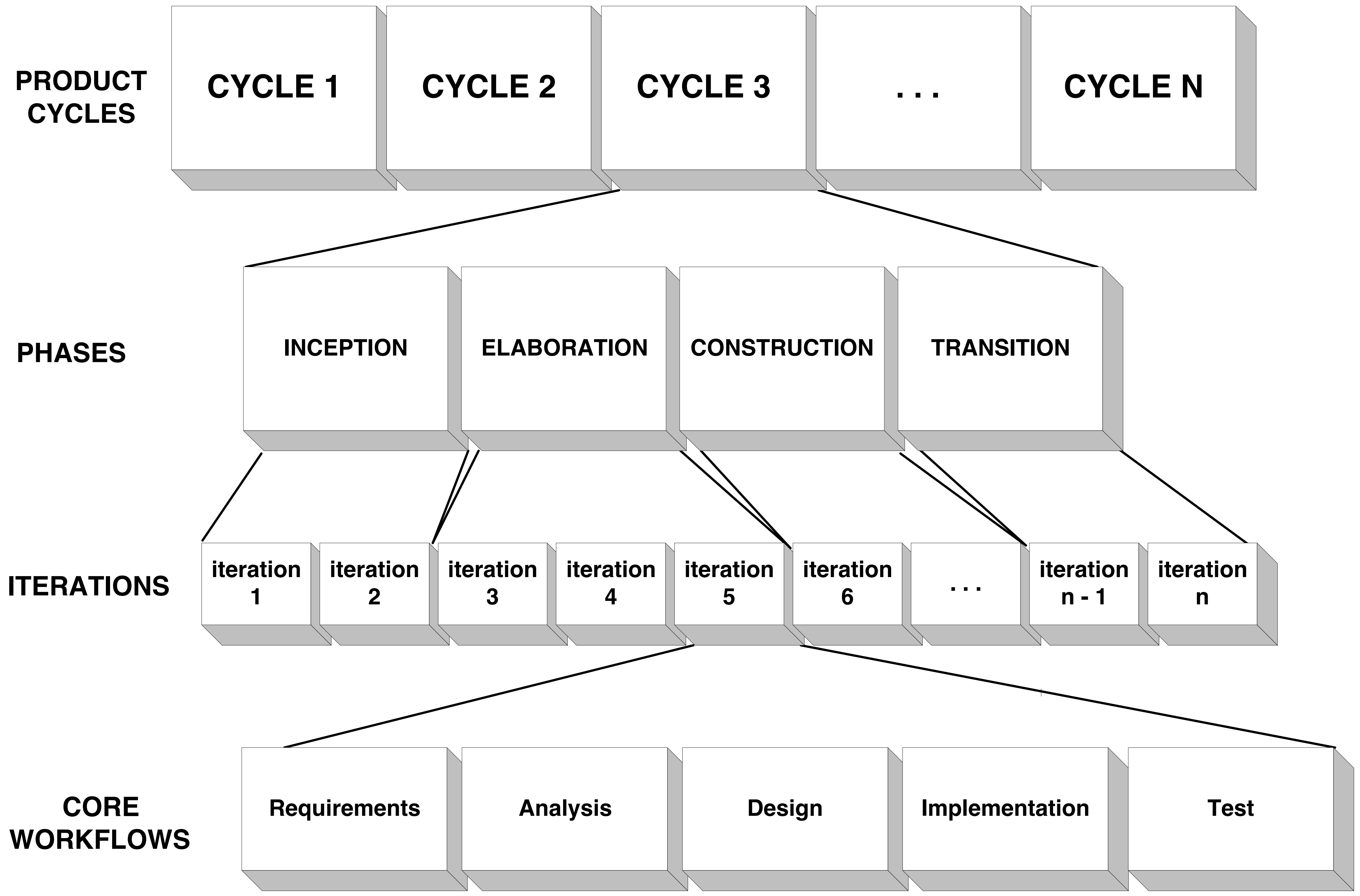
Rumbaugh, continued

- **Develop a statement of scope for the problem**
- **Build an object model**
  - Identify classes that are relevant for the problem
  - Define attributes and associations
  - Define object links
  - Organize object classes using inheritance
- **Develop a dynamic model**
  - Prepare scenarios
  - Define events and develop an event trace for each scenario
  - Construct an event flow diagram and a state diagram
  - Review behavior for consistency and completeness

Rumbaugh, continued

- **Construct a functional model for the system**
  - Identify inputs and outputs
  - Use data flow diagrams to represent flow transformations
  - Develop a processing specification for each process in the DFD
  - Specify constraints and optimization criteria
- Iterate

Rational Unified Process: Overview



Inception

- High-level planning for the project
- Determine the project’s scope
- If necessary
    - Determine business case for the project
        - Estimate cost and projected revenue

Elaboration

- Develop requirements and initial design
- Develop Plan for Construction phase
- Risk-driven approach
  - Requirements Risks
  - Technological Risks
  - Skills Risks
  - Political Risks

Requirements Risks

- Is the project technically feasible?
- Is the budget sufficient?
- Is the timeline sufficient?
- Has the user really specified the desired system?
- Do the developers understand the domain well enough?

Dealing with Requirements Risks

- Construct models to record Domain and/or Design knowledge
  - Domain model (vocabulary)
  - Use Cases
  - Design model
    - Class diagrams
    - Activity diagrams
- Prototype construction

Dealing with Requirements Risks

- Begin by learning about the domain
    - Record and define jargon
    - Talk with domain experts and end-users
- Next construct use cases
    - What are the required external functions of the system?
    - Iterative process; Use Cases can be added as they are discovered

Dealing with Requirements Risks

- Finally, construct design model
  - Class diagrams identify key domain concepts and their high-level relationships
  - Activity diagrams highlight the domain’s work practices
    - A major task here is identifying parallelism that can be exploited later
- Be sure to consolidate iterations into a final consistent model

Dealing with Requirements Risks

- Build prototypes
    - Used only to help understand requirements
    - Throw them all out!
        - Do not be tied to an implementation too early
        - Make use of rapid prototyping tools
            - 4th Generation Programming Languages
            - Scripting and/or Interpreted environments
            - UI Builders
- Be prepared to educate the client as to the purpose of the prototype

Technology Risks

- Are you tied to a particular technology?
- Do you “own” that technology?
- Do you understand how different technologies interact?
- Techniques
    - Prototypes
    - Class diagrams, package diagrams
    - “Scouting” — evaluate technology early

Skill Risks

- Do the members of the project team have the necessary skills and background to tackle the project?
- If not your options are
    - Training
    - Consulting
    - Mentoring
    - Hiring new people

Political Risks

- How well does the proposed project mesh with corporate culture?
    - Consider the attempt to use Lotus Notes at Arthur Anderson
        - Lotus Notes attempts to promote collaboration
        - Arthur Anderson consultants compete with each other!
        - Orlikowski, W. J. (1992). "Learning from Notes: Organizational Issues in Groupware Implementation". Proceedings of ACM CSCW'92 Conference on Computer-Supported Cooperative Work: 362-369.
- Consider e-mail: any employee can ignore the org chart and mail the CEO!
- Will the project directly compete with another business unit?
- Will it be at odds with some higher level manager's business plan?

- Any of these can kill a project…

Ending Elaboration

- Baseline architecture constructed
    - List of Use Cases (with estimates)
    - Domain Model
    - Technology Platform
- AND
    - Risks identified
    - Plan constructed
        - Use cases assigned to iterations

Construction

- Each iteration produces a software product that implements the assigned Use cases
    - Additional analysis and design may be necessary as the implementation details get addressed for the first time
- Extensive testing should be performed and the product should be released to (some subset of) the client for early feedback

Transition

- Final phase before release 1.0
- Optimizations can now be performed
  - Optimizing too early may result in the wrong part of the system being optimized
  - Largest boosts in performance come from replacing non-scalable algorithms or mitigating bottlenecks

Summary

- All OO Design Methods share a similar structure
    - The design method described in our textbook
        - is compatible with the methods discussed in this lecture
        - is lighter weight, allowing you to get to code more quickly
- The important point is to use a process that has you switching between A&D activities and coding in a fairly regular fashion
    - This helps you shift your perspective from “internal” to “external” and allows you to keep in mind your ultimate goal:
        - delivering a system that meets your customer’s needs

Back to the book’s life cycle...

1. Feature List (1)	High-level view of app’s functions
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Example: Objectville Subway

- To emphasize how much we have learned, the book performs this life cycle on a project that models a subway system and can find the shortest route between any two subway stops
  - We'll review portions of this process
    - And code the solution in Python for comparison
- Vision Statement from Objectville Travel
  - They need a RouteFinder for the Objectville Subway System
  - First step?
    - Feature List

Phase One: Feature List

Objectville RouteFinder Feature List

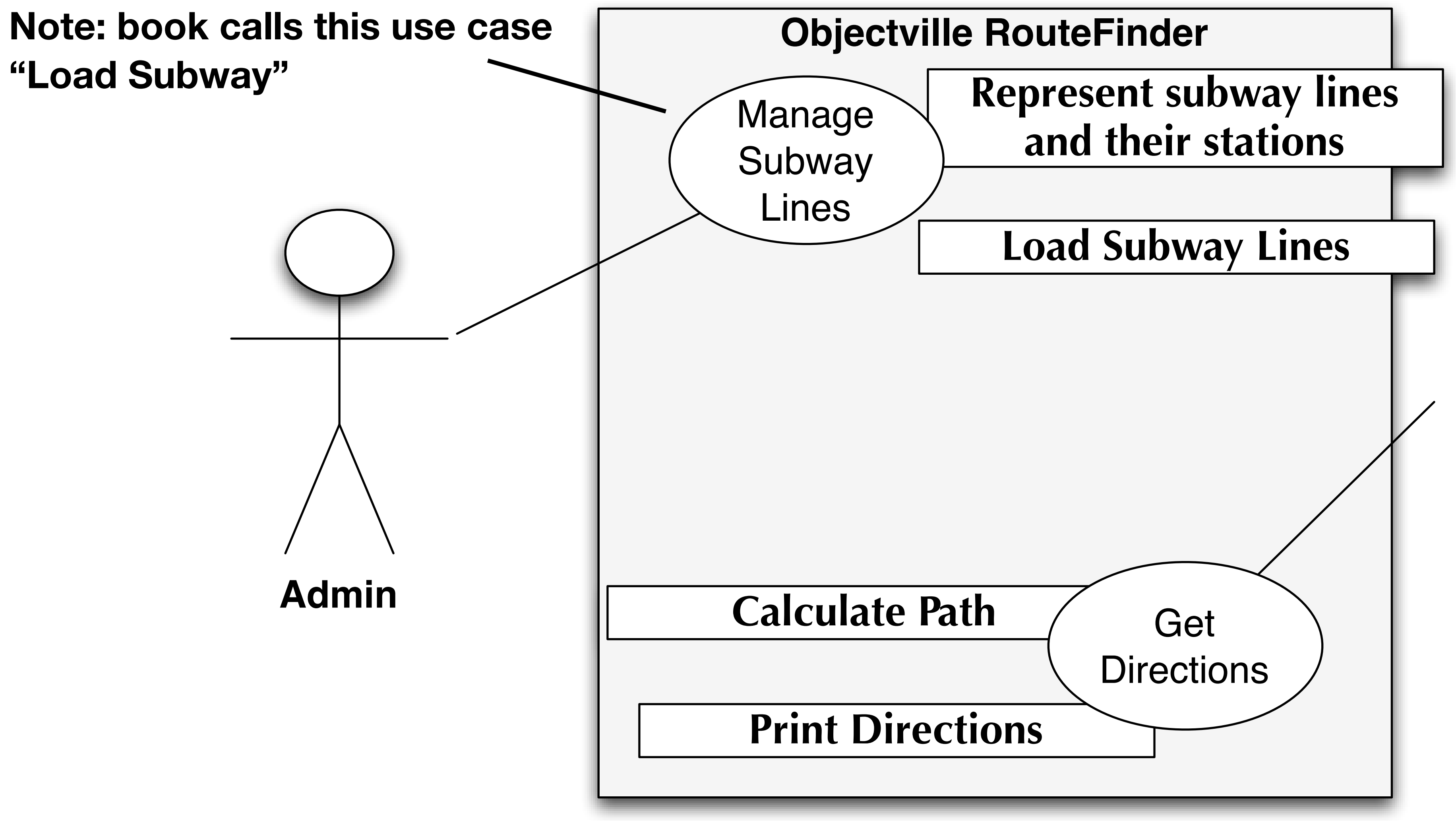
1. Represent subway line and stations along that line.
2. Load subway lines into program, including lines that intersect
3. Calculate path between any two stations in the subway system
4. Print a route between two stations as a set of directions

Feature lists are all about understanding what your software is **supposed to do…**

…even (relatively) simple programs like this

Next Up? Use Case Diagram

Phase Two: Use Case Diagram

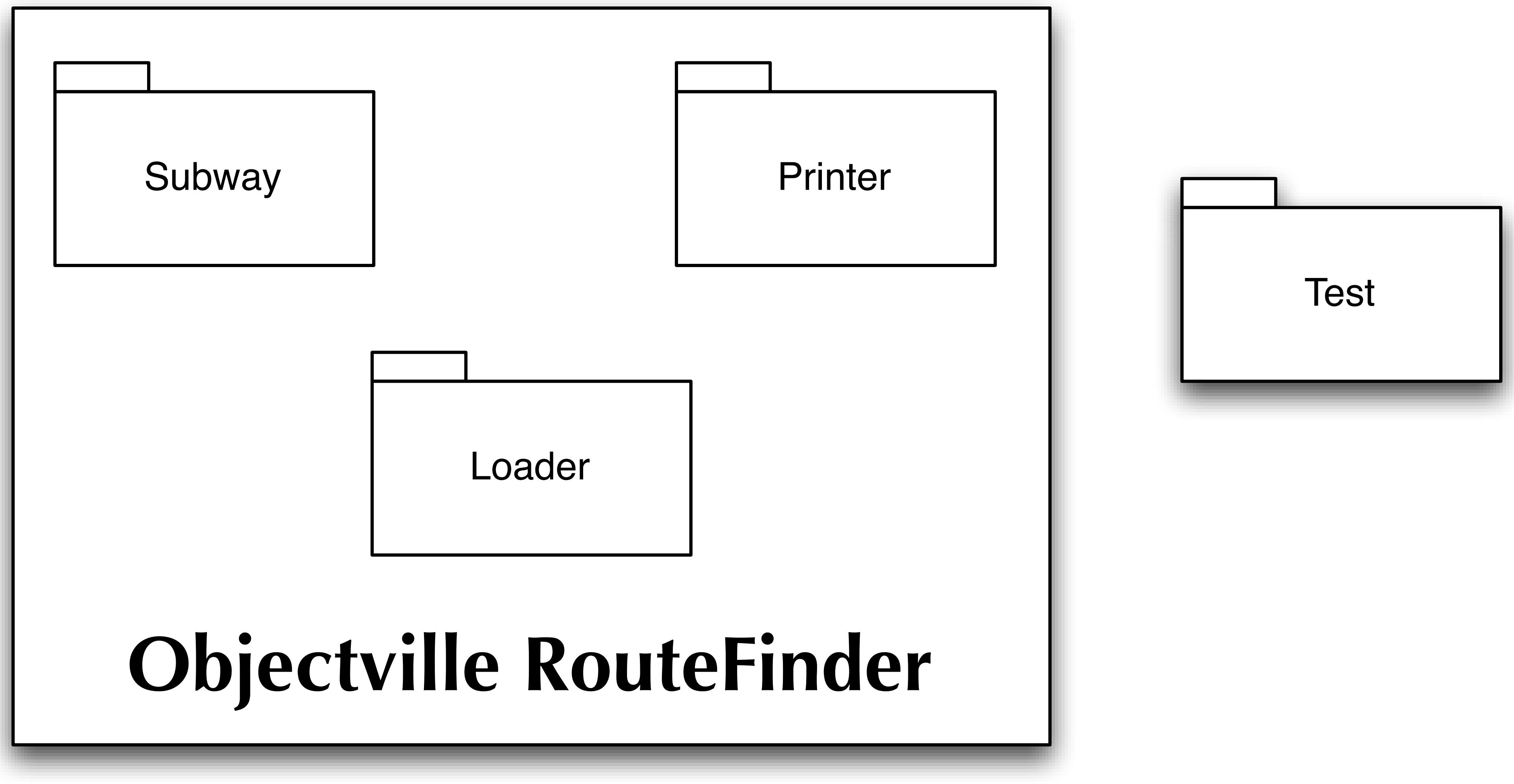


Your use case diagram lets you think about how your software will be **used**, without requiring a lot of detail; features can be assigned to use cases

Features vs. Use Cases

- Use cases reflect usage; Features reflect functionality
    - When we match features to use cases we are indicating that a particular use case depends on a particular feature having been implemented
    - Features and use cases work together, but they are **not** the same thing
- Not all features will match to use cases directly
    - instead indirect relationships may exist
        - The book uses the example of not being able to load subway lines until you have a representation (data structure) for subway lines
        - The use case for loading subway lines will only use the “representation feature” indirectly

Phase Three: The Big Break Up

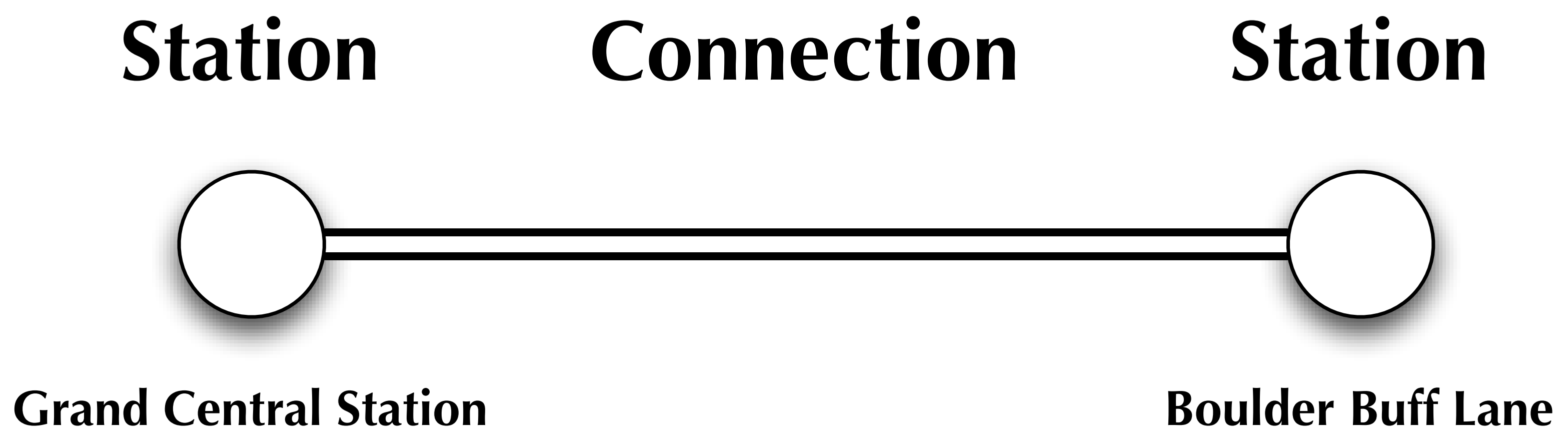


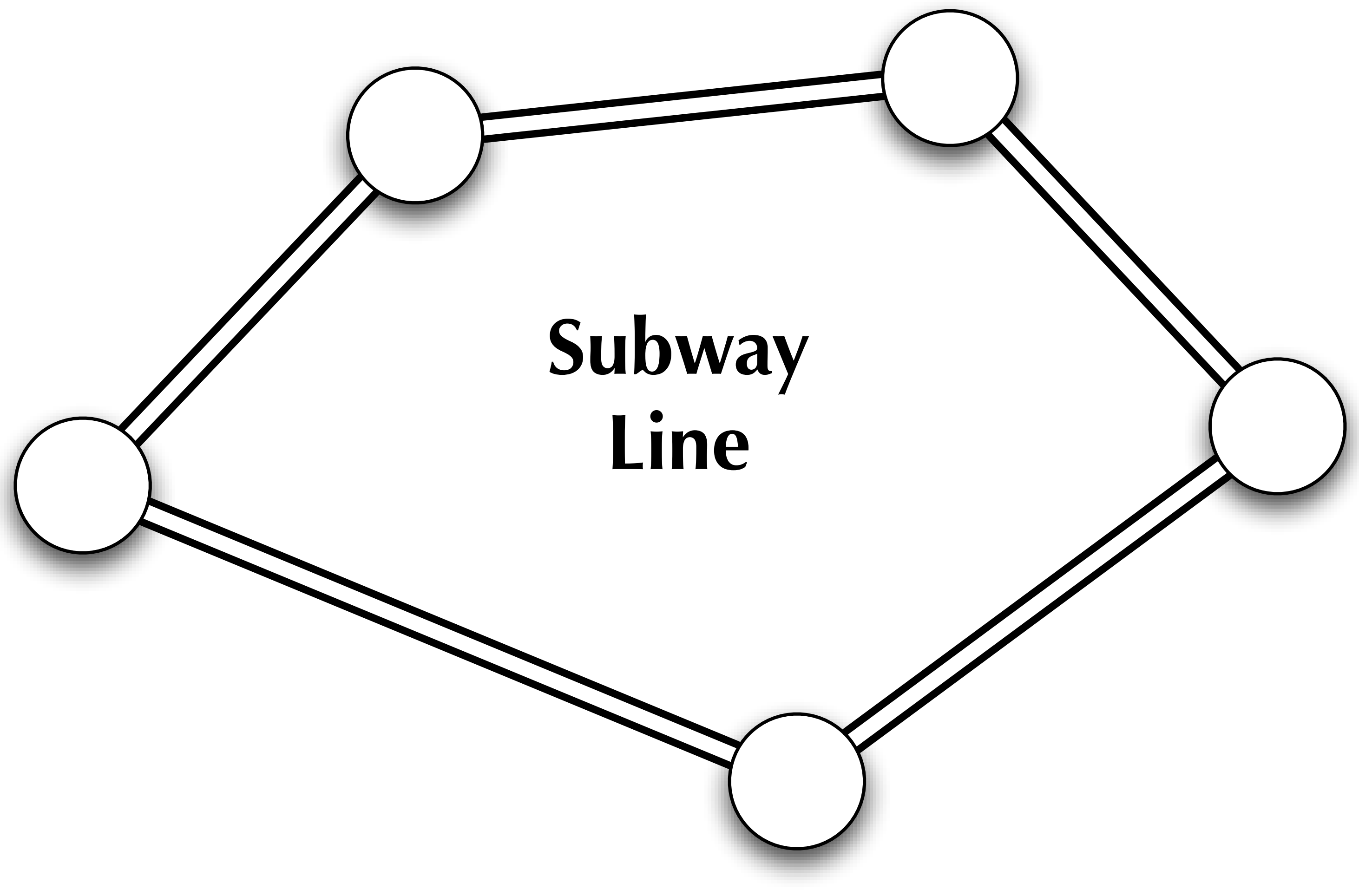
For this small problem, we could have used just a single package, but the book applied the single-responsibility principle and encapsulation to create the modules above

New Step! Understand the Problem

- The next step in the original life cycle is “Requirements”
    - We would focus on generating lists of requirements and filling out the details of our use cases
- But, if you find that you don’t understand the problem well enough to supply the details of a use case, you need to start the requirements process with activities that will help you analyze the problem and gain a deeper understanding
- In the example, we start iteration 1 by focusing on the “Load Subway Lines” use case
    - And then first do some domain analysis to understand the problem domain a bit better and get us the details we need to write the use case

Understanding Our Domain (I)





A subway line is a series of stations, each connected to each other

Understanding Our Domain (II)

```
Ajax Rapids
Algebra Avenue
Boards 'R' Us
Break Neck Pizza
Choc-O-Holic, Inc.
CSS Center
Design Patterns Plaza
DRY Drive
EJB Estates
GoF Gardens
Head First Labs
Head First Lounge
Head First Theater
HTML Heights
Infinite Circle
JavaBeans Boulevard
JavaRanch
JSP Junction
LSP Lane
Mighty Gumball, Inc.
Objectville Diner
Objectville Pizza Store
OCP Orchard
OOA&D Oval
PMP Place
Servlet Springs
SimUDuck Lake
SRP Square
The Tikibean Lounge
UML Walk
Weather-O-Rama, Inc.
Web Design Way
XHTML Expressway

Booch Line
Ajax Rapids
UML Walk
Objectville Pizza Store
Head First Labs
```

The client supplied this input file.

It starts by listing all stations

Then defines subway lines

Use Case Details

Load Subway Network

1. The admin supplies a file of stations and lines.
2. The system reads in the name of a station.
3. The system **validates that the station doesn't already exist**.
4. The system adds the new station to the subway.
5. The system repeats steps 2-4 until all stations are added.
6. The system reads in the name of a line.
7. The system reads in two stations that are connected.
8. The system **validates that the stations exist**.
9. The system creates a new connection between the two stations, **going in both directions**, on the current line.
10. The system repeats steps 7-9 until the line is complete.
11. The system repeats steps 6-10 until all lines are entered.

Use case documents the algorithm for reading input file.

This is a horrible use case because:

a. too low level

b. too brittle

c. all of the above

“Yeah, I can think of something better…” *

Load Subway Network

1. The admin requests system to load subway file.
2. The system validates that file exists.
3. The system loads data.
4. The system validates data.
5. The system displays subway.

Use case is still low level, but now less brittle. If the file format changes, we don’t have to update this use case.

Indeed, I think this functionality is better represented as a feature than a use case.

You don’t need use cases for everything.

* Reference to Steve Martin Movie: “Roxanne”

But, back to the original for textual analysis

Load Subway Network

1. The admin supplies a file of stations and lines.
2. The system reads in the name of a station.
3. The system **validates that the station doesn't already exist**.
4. The system adds the new station to the subway.
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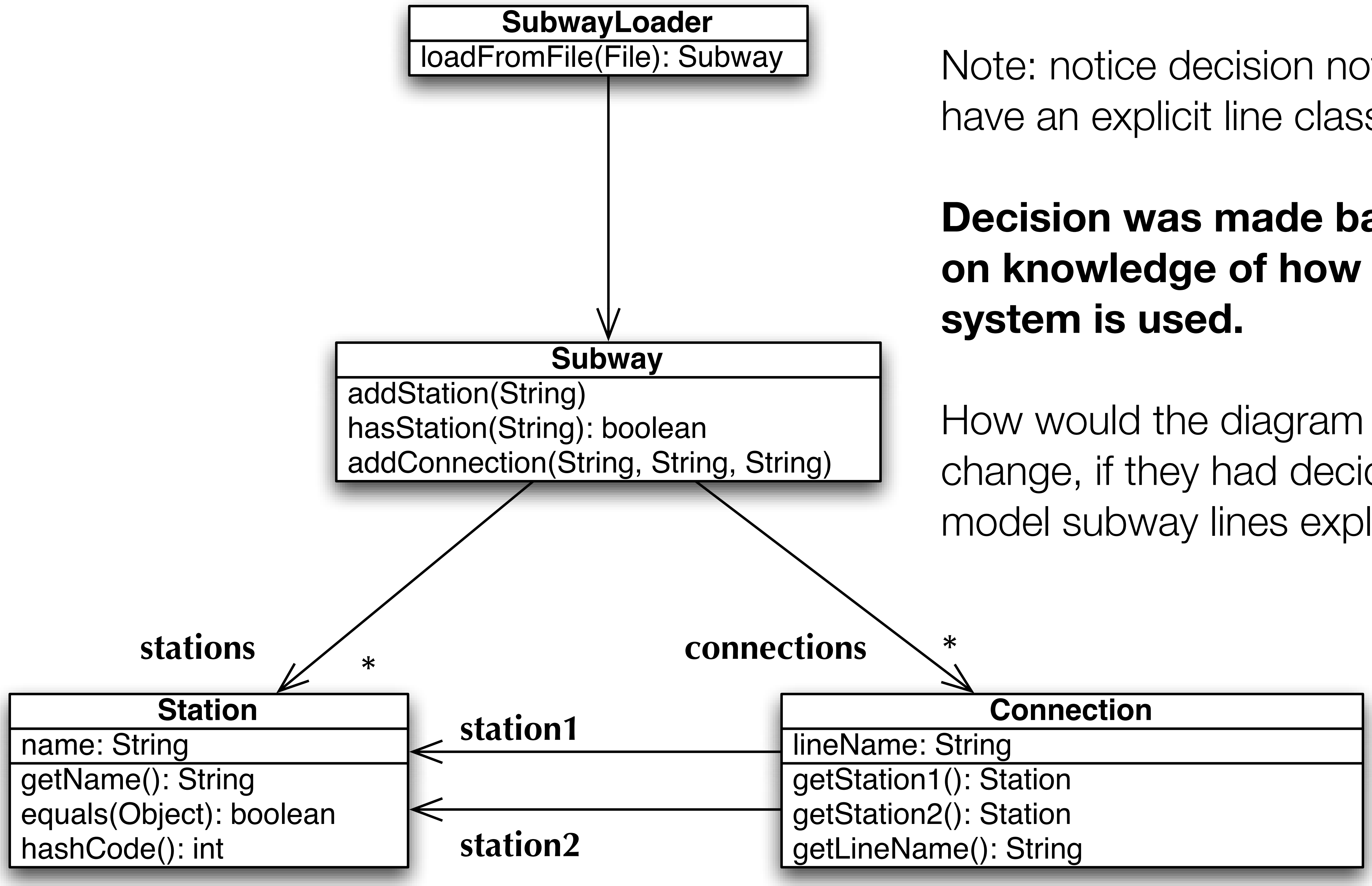
Nouns (Classes):
- ~~admin~~
- ~~system~~
- ~~file~~
- station
- subway
- connection
- line

Verbs (methods)
- supplies a file
- ~~reads in~~
- validates station
- adds a station
- ~~repeats~~
- adds a connection

Class Diagram: Domain Model



Note: notice decision not to have an explicit line class.

Decision was made based on knowledge of how this system is used.

How would the diagram change, if they had decided to model subway lines explicitly?

Have Use Case, Have Class Diagram, Will Code

```python
class Station(object):
    """The Station class represents a single named station on a subway line."""

    def __init__(self, name):
        """Every Station object has a name attribute."""
        self.name = name

    def __eq__(self, obj):
        """Equality of Station objects depends on the lowercase version of
           their names."""
        if not isinstance(obj, Station):
             return False
        return self.name.lower() == obj.get_name().lower()

    def __hash__(self):
        """A Station object's hash code depends on the hash code of
           the lowercase version of its name."""
        return self.name.lower().__hash__()

    def get_name(self):
        """Retrieves the Station object's name."""
        return self.name
```

Python equivalent of Station class shown in text book

Code for Connection

```python
from Station import Station

class Connection(object):
    """The Connection class represents a connection between two subway
       stations along a particular subway line. Note: this class
       is an information holder. It does nothing but store data."""

    def __init__(self, station1, station2, line):
        """Every Connection object has two stations and the name of its line."""
        self.station1 = station1
        self.station2 = station2
        self.line     = line

    def get_station1(self):
        """Retrieves a Connection object's first station."""
        return self.station1

    def get_station2(self):
        """Retrieves a Connection object's second station."""
        return self.station2

    def get_line(self):
        """Retrieves the name of a Connection object's subway line."""
        return self.line

```

equals() method for Connection objects

```python
    def __eq__(self, obj):
        """Equality of Connection objects depends on the equality
           of their attributes: station1, station2, line."""
        if not isinstance(obj, Connection):
            return False
        result1 = self.station1 == obj.get_station1()
        result2 = self.station2 == obj.get_station2()
        result3 = self.line == obj.get_line()
        return result1 and result2 and result3
```

Why define an equals() method for Station and Connection?

Because, we don’t want the standard equality metric (two variables pointing at the same object). We want two separate objects with the same attributes to be considered equal. Why?

It enables code like this

```python
    def add_station(self, name):
        """If we have never seen the specified station name before, then
           we add it to our collection of station objects."""
        if not self.has_station(name):
            self.stations.append(Station(name))

    def has_station(self, name):
        """Returns True if we have a station with the specified name."""
        station = Station(name)
        return station in self.stations
```

add_station and has_station both take in strings, create Station objects, and then do their jobs. In has_station(), we create a Station object and then check to see if another object that equals it exists in the self.stations collection

What are the trade-offs with this style of coding?

Ease of Expression: whenever I need a new Station object, just create one!

Loss of Efficiency: more station objects == more memory consumed

Code for Subway

```python
from Connection import Connection
from Station    import Station

class Subway(object):
    """The Subway class represents a subway line with stations and
       connections between those stations."""

    def __init__(self):
        """Every Subway object has a collection of stations and a list
           of connections."""
        self.stations = []
        self.connections = []

    def add_station(self, name):
        """If we have never seen the specified station name before, then
           we add it to our collection of station objects."""
        if not self.has_station(name):
            self.stations.append(Station(name))

    def has_station(self, name):
        """Returns True if we have a station with the specified name."""
        station = Station(name)
        return station in self.stations

    def has_connection(self, name1, name2, line):
        """Returns True if we have a connection with the specified atts."""
        connection = Connection(Station(name1), Station(name2), line)
        return connection in self.connections

    def add_connection(self, name1, name2, line):
        """Adds a connection going in both directions to the subway
           as long as specified names reference existing stations."""
        if self.has_station(name1) and self.has_station(name2):
            connection1 = Connection(Station(name1), Station(name2), line)
            connection2 = Connection(Station(name2), Station(name1), line)
            self.connections.append(connection1)
            self.connections.append(connection2)
```

Loose Coupling in RouteFinder

- The book raises an interesting issue about the interface of the Subway class
    - In particular, addStation() and addConnection() accept strings rather Station objects
- Why?
    - To promote lose coupling. If the clients of Subway only ever deal with strings, then they do not depend on classes like Station and Connection
    - Those classes are used internally but not needed externally
- You should only expose clients of your code to the classes that they NEED to interact with
- Classes that the clients don’t interact with can be changed with minimal client code being affected.

Next Steps

- Create Code for Subway Loader
- Create Test Case for Subway Loader
  - Requires adding has_connection() to Subway class
- Demonstration

- We’ve now finished the first use case “Load Subway”
  - Its time to perform a second iteration to tackle “Get Directions”
  - We loop back to the Requirements stage and try to write this use case

Get Directions Use Case

Get Directions

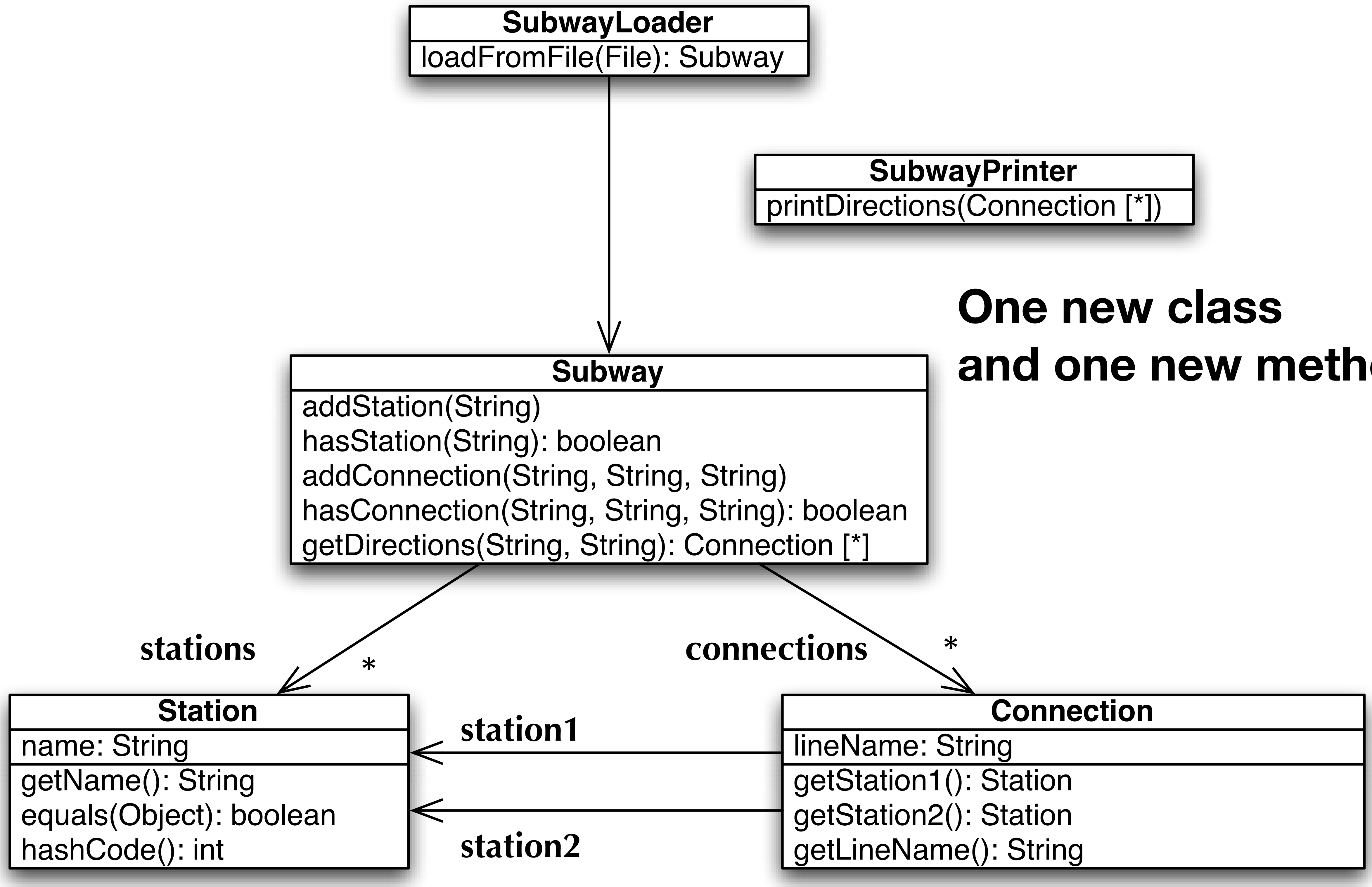
1. The travel agent supplies a starting and ending station.
2. System validates that stations exist.
3. System calculates route.
4. System prints route.

Looks simple enough!

Note: we've switched our focus from code back to customer. We'll use this switch in focus to identify new requirements, do some design, and then go back to focusing on code.

You will shift focus like this multiple times as you progress

Update Class Diagram



One new class and one new method

Changes to Subway

- We need to use Dijkstra’s algorithm to discover the shortest path between any two stations (nodes) on our subway (graph)
  - To do that, we have to update Subway such that
    - It contains a hash table called network that keeps track of what stations are directly reachable from a particular station
      - For example, starting at XHTML Expressway, there are four stations that are directly reachable: Weather-O-Rama, Inc., LSP Lane, Infinite Circle, Choc-O-Holic, Inc.
  - We then implement Dijkstra’s algorithm in the getDirections() method

Layman’s Description of Dijkstra’s Algorithm

- Adapted from Wikipedia: <http://en.wikipedia.org/wiki/Dijkstra's_algorithm>
    - Using a street map, mark streets (trace a street with a marker) in a certain order, until you have a route marked from a starting point to a destination.
    - The order is simple: from all the street intersections of the already marked routes, find the closest unmarked intersection - closest to the starting point (the "greedy" part).
    - Your new route is the entire marked route to the intersection plus the street to the new, unmarked intersection
    - Mark that street to that intersection, draw an arrow with the direction, then repeat
    - Never mark any intersection twice
    - When you get to the destination, follow the arrows backwards. There will be only one path back against the arrows, the shortest one.

Last Step: Implement SubwayPrinter

- Accept route from getDirections()
- print “Start out at <starting point> and get on <first line>”
- Loop until destination is reached
    - If next connection on same line, then print “continue past <station>”
    - Otherwise, print “when you reach <station> switch to <next line>”
- print “Get off at <destination> and enjoy yourself”

- Need to write test case and test results

Demonstration

- Review Dijkstra code in Subway.py
- Review printing code in SubwayPrinter.py
- Try out test code in SubwayLoader.py

We’re Done!

- We’ll almost
    - We could always add additional ways to print out the route
    - We could look for additional ways to clean up the current design
    - We could look for additional functionality and continue to iterate
- The important thing is that we’ve seen how to bring everything we’ve discussed this semester together to solve a software design problem from start to finish
    - Take a look at the two implementations of this system
        - Find similarities and differences
        - Be sure to understand the code

Coming Up Next

- Midterm and Midterm Discussion (Week 8)
- Intro to Design Patterns (Week 9)
  - Start of Semester Project
- Framework Project Demonstrations (Week 10)