Detailed Design

COMP6226: Software Modelling Tools and Techniques for Critical Systems

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Overview

- Design Principles
- Design Principles – SOLID
- Software Modelling
- Types of System Models
- What is detailed design?
- Main tasks in detailed design
- Object-Oriented Design
- UML diagram types

Design Principles

- What are Software Design Principles?
  - Software Design Principles are a set of guidelines that helps developers to make a good system design.
- Why are Software Design Principles important?
  - You can write code without Software Design Principles. That's the truth. But if you **want to become a Senior level** you should **understand and apply Software Design Principles** in your work.
  - We have **many recommended set of principles to apply** Software Design Principles to your project.

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Design Principles

- KISS: is an acronym for Keep It Simple, Stupid.
  - The acronym reminds us to avoid unnecessary complexity in our designs.
  - Our design need contain only enough complexity to achieve our requirements, and no more.
- DRY (Do Not Repeat Yourself)
  - We try to avoid repetition in software development.
  - Repetition means multiple- source code fragments performing a similar task.
  - This becomes a challenge when maintenance is needed, since changes must be made in more than one place.
  - The DRY principle applies to all aspects of our development work and includes scripts, tests, databases as well as source code.

Design Principles – Cont.

- YAGNI (You Aren't Gonna Need It)
  - Some software engineers have the habit of predicting future needs of clients and implementing software features in anticipation of those future requirements.
  - This is not a good practice because sometimes we invest effort in preparing for future features that never come.
  - This results in bloated software source code.
  - Instead, only functionality needed now must be implemented to boost your productivity.

Design Principles – Cont.

- GRASP
  - The General Responsibility Assignment Software Patterns (GRASP) principles, proposed by Craig Larman, provide a mental model to help object-oriented design [*].

    [*] Larman, C.: Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and Iterative Development, 3rd ed. Prentice Hall PTR, Upper Saddle River, NJ (2004)

- The GRASP pattern comprises:
  - Controller – Creator – Indirection – Information expert
  - Low coupling – High cohesion – Polymorphism – Protected variations
  - Pure fabrication

Design Principles – SOLID

- The SOLID acronym was introduced around 2004 by Michael Feathers, to help you remember good principles of object-oriented design [*].

  [*] *Martin, R.: Clean Code: A Handbook of Agile Software Craftsmanship, 1st ed. Prentice Hall, Upper Saddle River, NJ (Aug 2008)*

- The SOLID principles have some overlap with Larman's GRASP patterns.
- The SOLID acronym is derived from:
  - Single responsibility
  - Open-closed
  - Liskov substitution
  - Interface segregation
  - Dependency inversion

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SOLID Design Principles – Cont.

- Single responsibility: every class should have only one responsibility
  - Consequently, it should only have one reason to change.
  - Less functionality in a single class will have fewer dependencies and this means lower coupling.
- Open-closed: Objects or entities should be open for extension but closed for modification.
  - In doing so, we stop ourselves from modifying existing code and causing potential new bugs in an otherwise happy application.

SOLID Design Principles – Cont.

- Liskov substitution: Let q(x) be a property provable about objects of x of type T. Then q(y) should be provable for objects y of type S where S is a subtype of T.
  - If class A is a subtype of class B, we should be able to replace B with A without disrupting the behaviour of our program.
- Interface segregation: A client should never be forced to implement an interface that it doesn't use, or clients shouldn't be forced to depend on methods they do not use.
  - Larger interfaces should be split into smaller ones.
  - By doing so, we can ensure that implementing classes only need to be concerned about the methods that are of interest to them.

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SOLID Design Principles – Cont.

- Dependency inversion: Entities must depend on abstractions, not on concretions. It states that the high-level module must not depend on the low-level module, but they should depend on abstractions.
  - The principle of dependency inversion refers to the decoupling of software modules.
  - This way, instead of high-level modules depending on low-level modules, both will depend on abstractions.

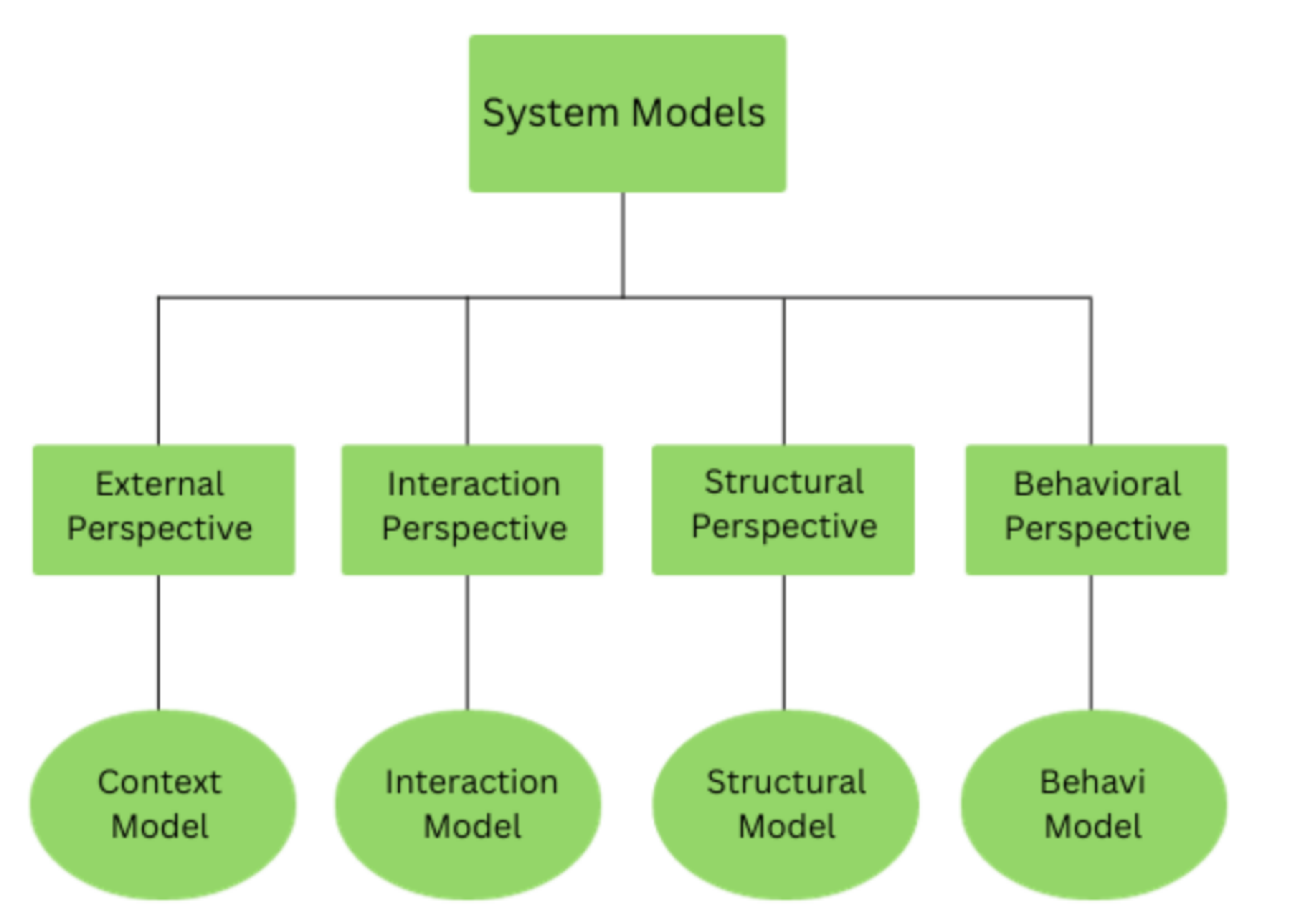
Reference:

A Solid Guide to SOLID Principles

Software Modelling

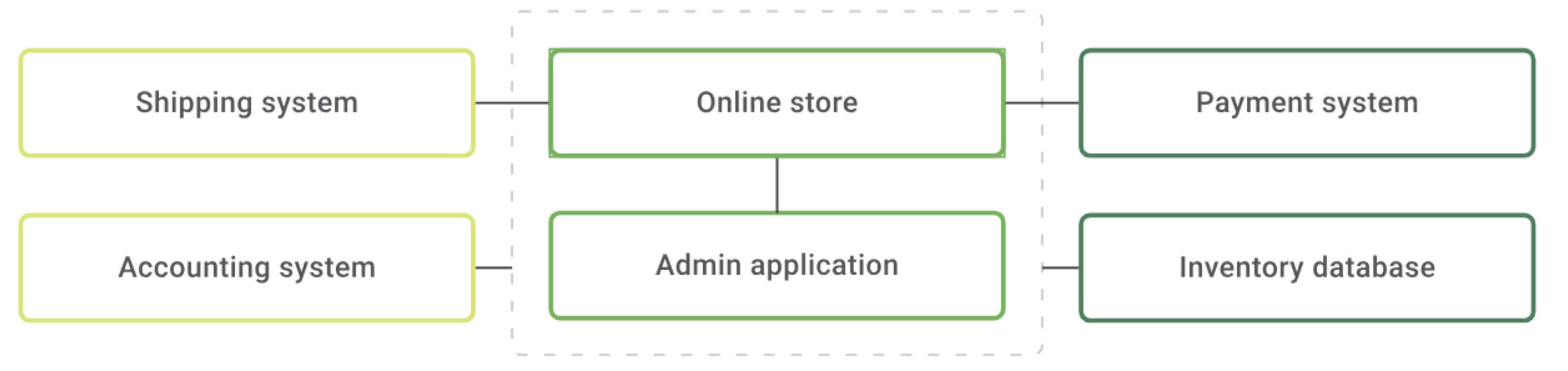
- For software modelling, we use models that are based on some kind of *graphical* or *textual* notation.
- The *Unified Modelling Language* (*UML*) is a commonly used graphical representation.
- The *two main types* of model: *structural* and *Behavioural*.
  - *Structural modelling* is used to illustrate a software application's physical or logical model from the perspective of its composition, architecture, componentization, and/or organization.
  - *Behavioural modelling* is a model type that focuses on identifying and defining the dynamic behavioural aspects of software components.
  - The goal is to represent how software functions, features, and system elements behave when in operation.

Types of System Models



Four views of the system

- External perspective
  - An external perspective, where you model environment or the context of the system.



- Interaction perspective
  - An interaction perspective, where you model the interactions between a system and its environment, or between the components of a system.

Four views of the system

- Structural perspective
  - A structural perspective, where you model organisation of a system, or the structure of the data is processed by the system.
- Behavioural perspective
  - A behavioural perspective, where you model the dynamic behaviour of the system and how it responds to events.

What constitutes a good model?

- A model should
  - use a standard notation
  - be understandable by clients and users
  - Help software engineers to gain insights about the system
  - provide abstraction, modularisation, ..
- Models are used:
  - to help communicate with stakeholders.
  - to permit analysis and review of those designs.
  - as the core documentation describing the system.
  - to generate code

What is detailed design?

- The process of *refining* and *expanding* the *software architecture* of a system or a component to the extent that the design is *sufficiently complete* to be implemented.
- During *Detailed Design* designers go deep into each component to define its internal *structure* and *behavioral* capabilities.
  - the resulting design should lead to efficient construction of software.
- *Architecture is design, but not all design is architecture.*
  - Detailed design is *closely related* to *architecture*;
  - Therefore, designers are required to have or acquire a full understanding of the *system's requirements* and *architecture*.

Main tasks in detailed design

- The major tasks identified for carrying out the detailed design activity include:
  - Understanding the architecture and requirements
  - Creating detailed designs
  - Evaluating detailed designs
  - Documenting software design
  - Monitoring and controlling implementation
- This process can be especially tough for large-scale systems, built from scratch without experience with the development of similar systems.

Object-Oriented Design

A discipline that utilises the object-oriented paradigm to achieve the aims of software engineering

A discipline its aims are:

- To provide an effective approach to cope with ever-increasing *complexity* of systems
- The production of a relatively fault-free software,
- Delivered on time and within budget,
- That satisfies the client's needs
- Furthermore, the software must be easy to modify when it needs to change

Object-Oriented Design – Various approaches

- In heavyweight software development processes, the entire Design is completed before coding/implementation begins.

- In lightweight software development processes, an outline design is made before coding, but the details are completed as part of the coding process.

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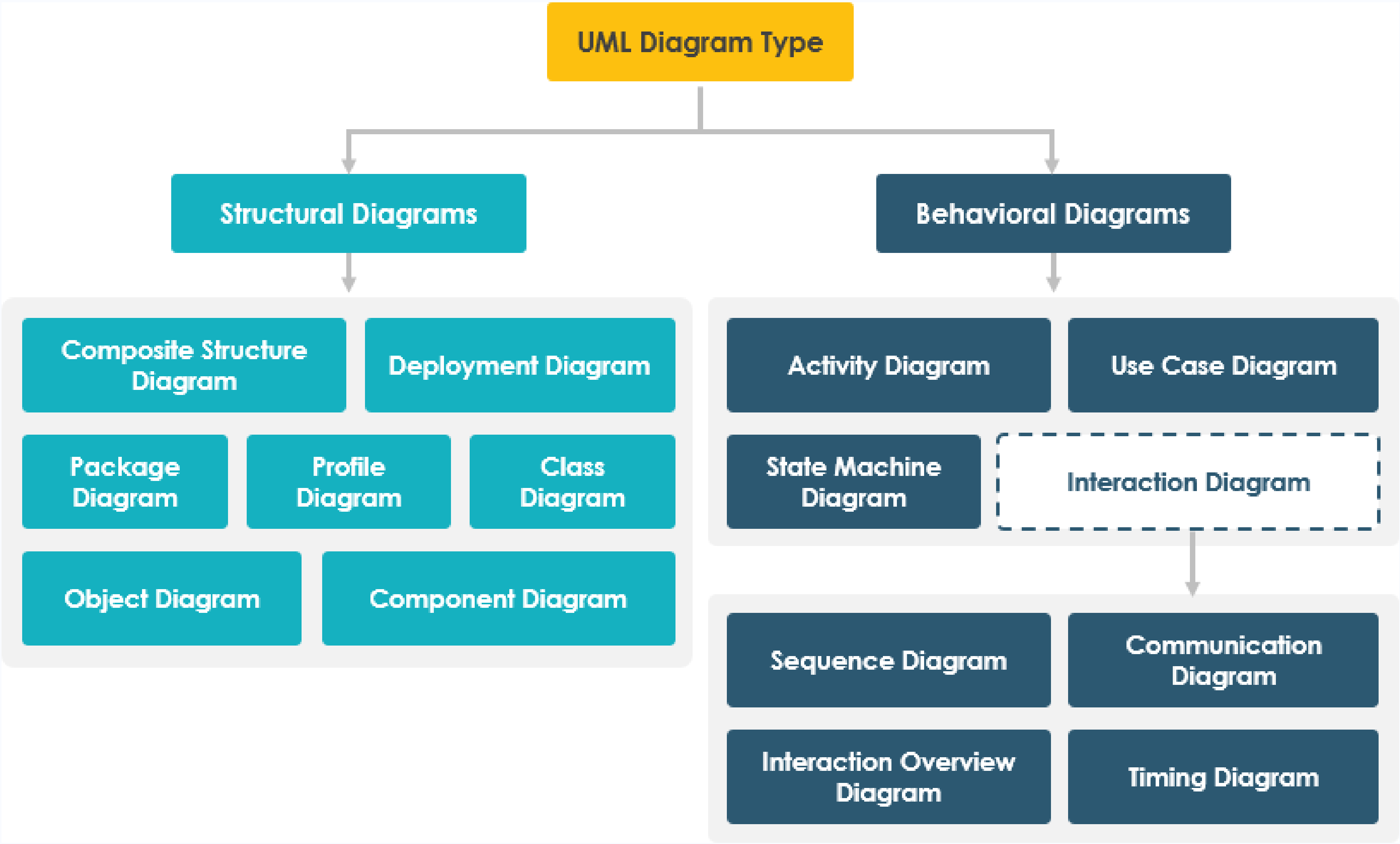
UML diagram types



UML diagrams – Cont.

Models used mainly for requirements

- Use case diagram shows a set of use cases and actors and their relationships.
- Activity diagram (flowchart) shows the flow from one activity to another activity within a system.

Models used mainly for systems architecture

- Component diagram shows the organisation and dependencies among a set of components.
- Deployment diagram shows the configuration of processing nodes and the components that live on them.

UML diagrams – Cont.

Models used mainly for detailed design

- Class diagram: shows a set of classes, interfaces, and collaborations with their relationships.
- Sequence diagrams: time ordering of messages
- State diagrams and activity diagrams also are widely used.

UML Models - Interactive Aspects of Systems

- These models can be used for requirements analysis or detailed design.
  - Sequence diagrams: time ordering of messages
  - activity diagrams shows the flow from one activity to another activity within a system.

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Different Approaches to Modelling

You can create UML models at different stages and with different purposes and levels of details

- System Analysis Model (Conceptual Models):
  - Developed during analysis phase to learn about the domain (modelling problem)
- System Architecture Model (Specification Models):
  - High level abstract classes representing system architecture and the interfaces
- Detailed Design Model (design Models):
  - Refine the high-level models until the material is in a form that can be implemented by the programmers (modelling solution)

OO Design - Basic steps

It is essential that pay attention that UML does not provide a methodology, however you may devise one like:

Step 1: Analyse use cases

Step 2: Create activity diagrams for each use case

Step 3: Create class diagram based on 1 and 2

Step 4: possibly create sequence/state diagrams for activities contained in diagrams created in step 2

Step 5: Iterate; each step above will reveal information about the other models that will need to be updated

- For instance, services specified on objects in a sequence diagram, must be added to those objects' classes in the class diagram.
- Activity diagrams can reveal control/boundary objects

The Importance of Class Diagram in OO Design

- Class diagrams are used to create structural models that visualise the organisation of a system or the current environment. You start by:
  - Identify a first set of candidate classes
  - Add associations and attributes and Find generalisations
  - List the main responsibilities of each class
  - Decide on specific operations
  - Iterate over the entire process until the model is satisfactory
    - Add or delete classes, associations, attributes, generalisations, responsibilities or operations
    - Identify interfaces
    - Apply design patterns

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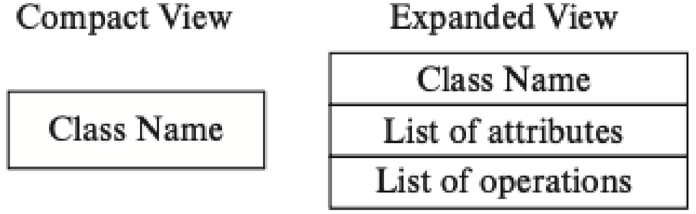
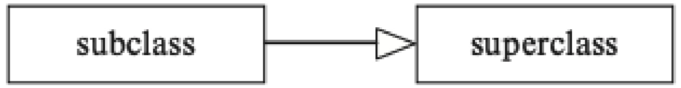
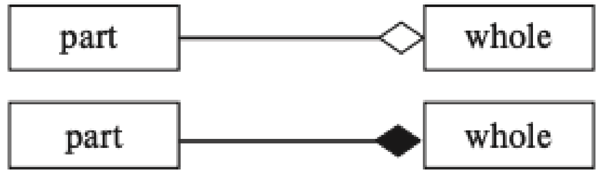
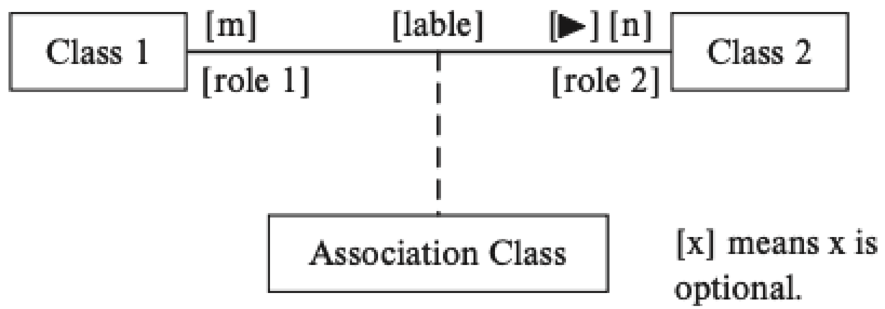
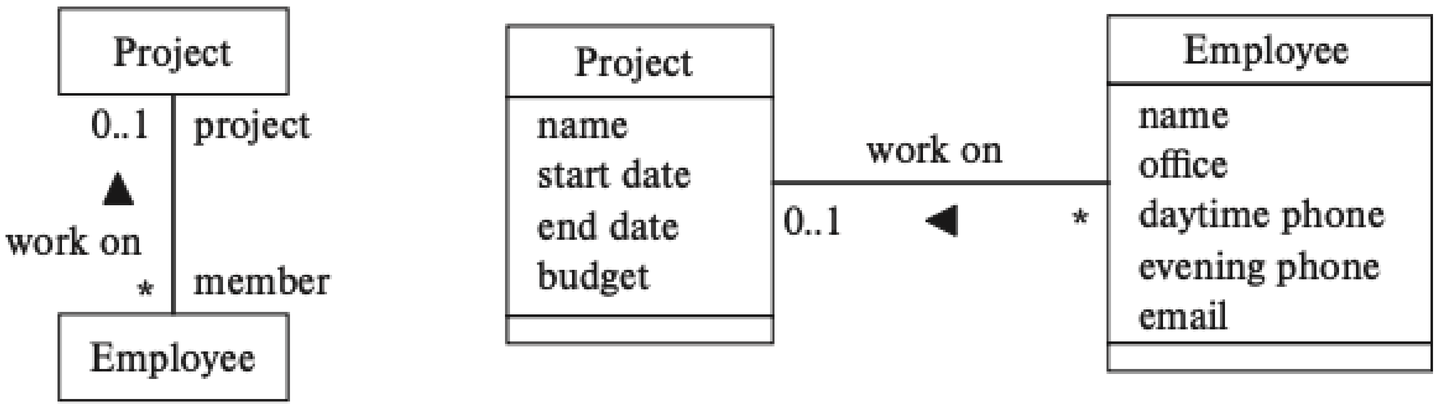
Commonly used class diagram notions and notations

Notion	Semantics	Notation
Class attribute operation	A class is a type; its attributes and operations characterize the objects of the class.	
Inheritance	A generalization/ specialization relationship between two classes.	
Aggregation	A part-of relation between two classes. Part-of exclusively.	
Association, direction, multiplicity, role Association class	A binary relation between two classes. A class that describes an association.	

A UML class diagram is a structural diagram that depicts the classes, their attributes and operations, and relationships between the classes.

Representing classes in compact and expanded views



(a) Compact view (b) Expanded view

0..1	zero or one	m..n	m to n
0..m	zero to m	m..*	m or more
,0..	zero or more	m	exactly m
1	exactly one (default)	1..*	one or more
i,j,k	explicitly enumerated		

Symbols for expressing various multiplicity assertions

Own

Customer	Account
c1	a1
c1	a2
c2	a2
c2	a3
c3	a4

(a) Instances of a binary association

Work-Supervised-by

Student	Project	Professor
Chen	OOM	Baker
Chen	SOA	Liu
Gupta	SOA	Liu
Rosa	Security	Brown
Smith	Security	Shah

(b) Instances of a ternary association

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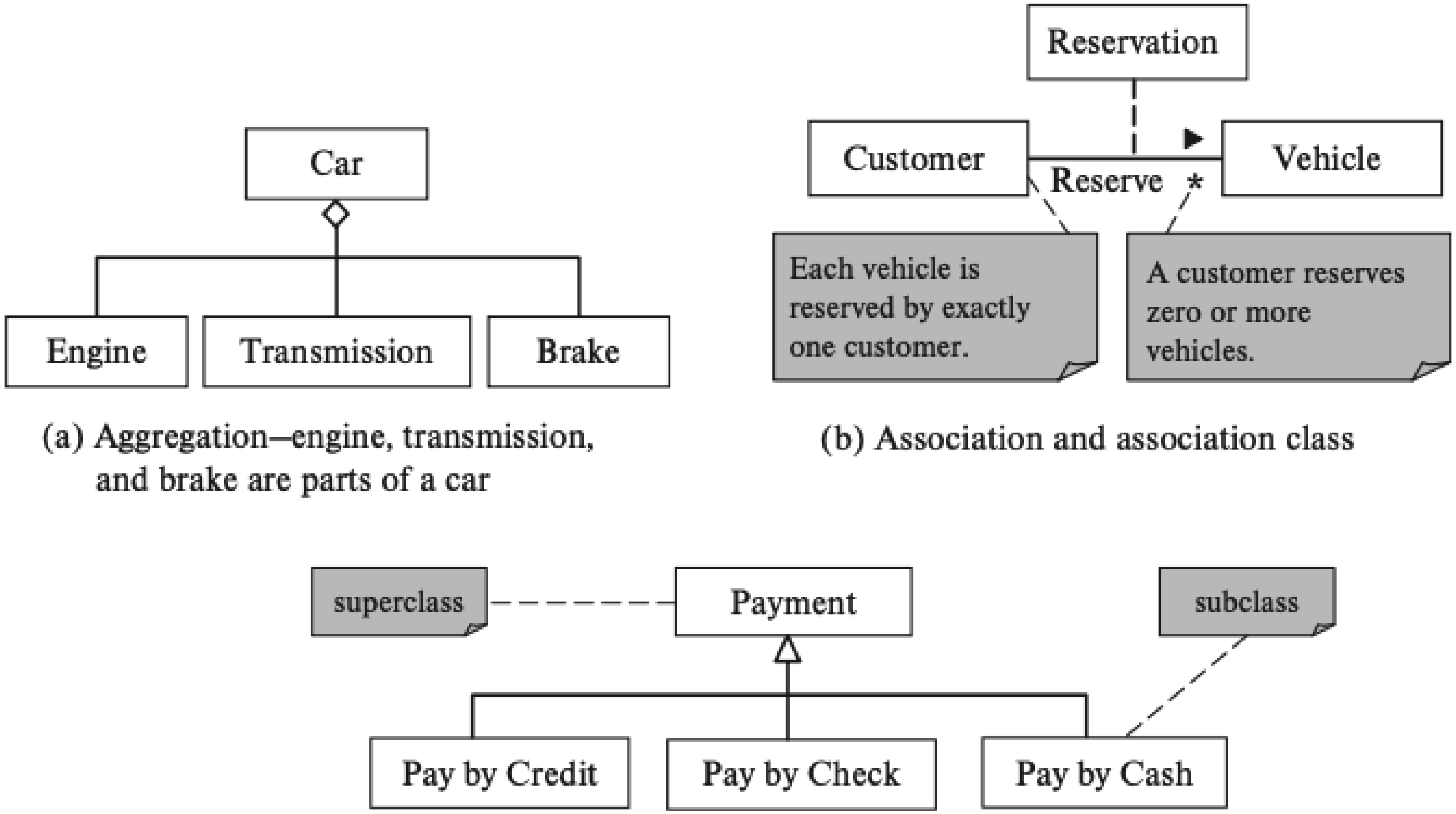
Aggregation, Association and Inheritance



(a) Aggregation—engine, transmission, and brake are parts of a car

(b) Association and association class

(c) Inheritance—pay by credit, pay by check, and pay by cash are payment

Deriving Class Diagrams

- Where do the class diagrams come from?
  - Well, from requirements (use cases or user stories)
- But how?
  - You need to look for nouns and verbs.
- *Nouns* are words that describe a *person*, *place*, *thing*, *quality* or *idea*.
  - In software design, when we see *nouns* in our requirements, we are thinking of things that *might appear* in the system we are *developing* or in its *application domain*.
  - For example, if we think about *banking*, the noun account might be implemented as a *bank account* in our software.

Deriving Class Diagrams – Cont.

- Verb and Verb Phrases
  - In contrast to nouns, verbs describe actions.
  - In software engineering, verbs that appear in our requirements might end up being implemented as methods or operations.
  - For example, if we think about banking, the verbs *open* or *close* might be implemented as *operations* on a *bank account* in our software.

动词和名次

Class Identification: A Library Example

- The library contains books and journals. It may have several copies of a given book.
- Some of the books are reserved for short-term loans only.
- All others may be borrowed by any library member for three weeks.
- Members of the library can normally borrow up to six items at a time, but members of staff may borrow up to 12 items at one time.
- Only members of staff may borrow journals.
- The system must keep track of when books and journals are borrowed and returned and enforce the rules.

The Importance of Class Diagram in OO Design

- Class diagrams are used to create structural models that visualise the organisation of a system or the current environment. You start by:
  - Step 1: Identify a first set of candidate classes
  - Step 2: Add associations and attributes and Find generalisations
  - Step 3: List the main responsibilities of each class
  - Step 4: Decide on specific operations
  - Step 5: Iterate over the entire process until the model is satisfactory
    - Add or delete classes, associations, attributes, generalisations, responsibilities or operations
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- Only members of staff may borrow journals.
- The system must keep track of when books and journals are borrowed and returned and enforce the rules.

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Step 1: Identifying Candidate Classes

Noun	Comments
Library	*the name of the system*
Book	
Journal	
Copy	
ShortTermLoan	*event*
LibraryMember	
Week	*measure*
MemberOfLibrary	*repeat of LibraryMember*
Item	*book or journal*
Time	*abstract term*
MemberOfStaff	
System	*general term*
Rule	*general term*

Identifying Relations Between Classes

Book	is an	Item
Journal	is an	Item
Copy	is a copy of a	Book
LibraryMember		
Item		
MemberOfStaff	is a	LibraryMember

Step 2: Identifying Relations Between Classes

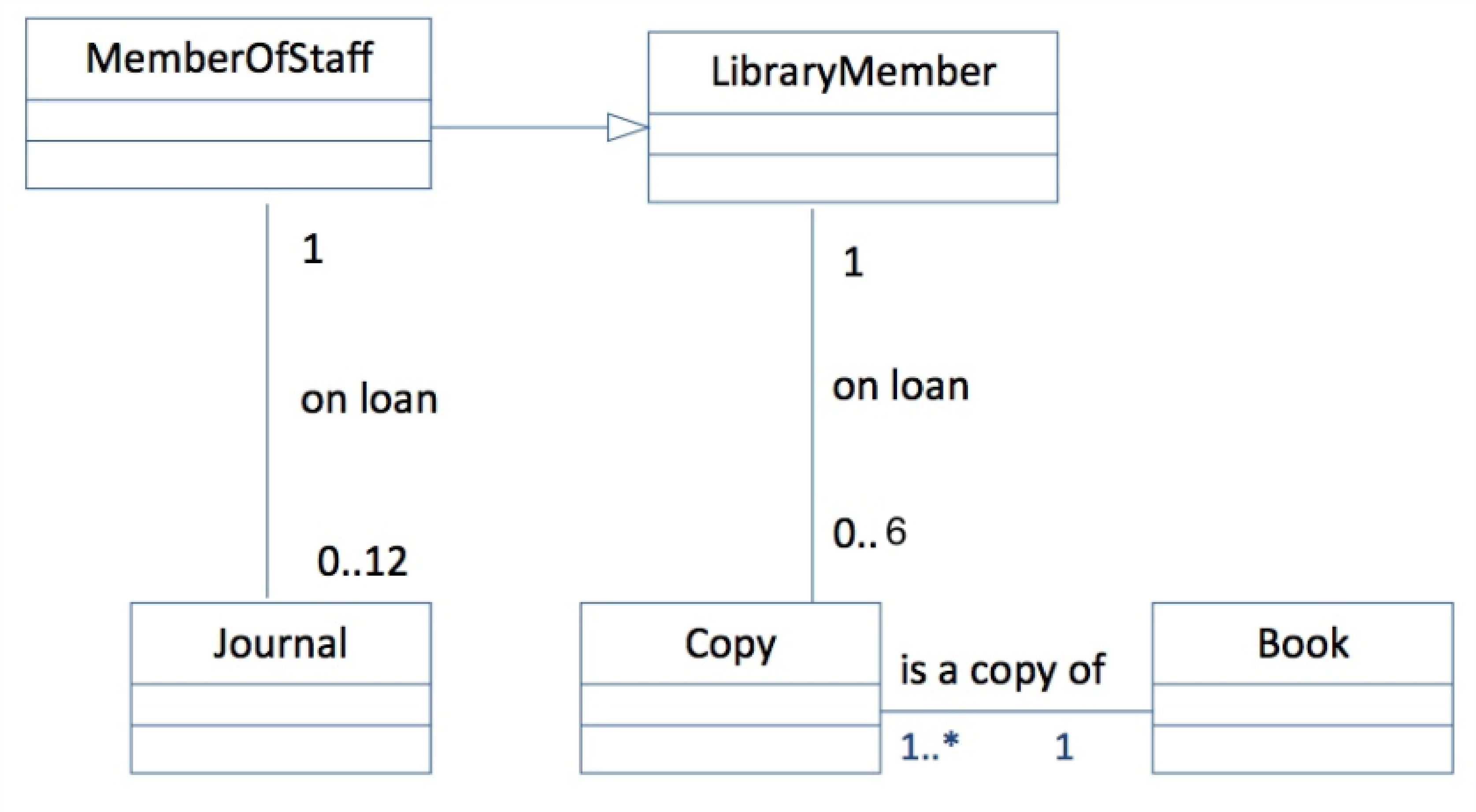
Book	is an	Item
Journal	is an	Item
Copy	is a copy of a	Book
LibraryMember		
Item		
MemberOfStaff	is a	LibraryMember

Step 3: Identifying Methods of Classes

LibraryMember	borrows	Copy
LibraryMember	returns	Copy
MemberOfStaff	borrows	Journal
MemberOfStaff	returns	Journal

Item not needed yet.

Class Diagram – First Shot



Identifying associations and attributes – Some Notes

- Start with classes you think are most **central** and important
  - Decide on the clear and obvious data it must contain and its relationships to other classes.
- Work outwards towards the classes that are less important.
- Avoid adding many associations and attributes to a class
- An association should exist if a class
  - *Possesses, controls, is connected to, is related to*
  - *is a part of, has parts, is a member of*, or *has members*
- Several nouns rejected as classes, may now become attributes

Identifying generalisations and interfaces – Recommendations

- There are two ways to identify generalisations:
  - bottom-up
    - Group together similar classes creating a new superclass
  - top-down
    - Look for more general classes first, specialise them if needed
- Create an interface, instead of a superclass if
  - The classes are very dissimilar except for having a few operations in common
  - One or more of the classes already have their own superclasses
  - Different implementations of the same class might be available

implementation usually easy than extend

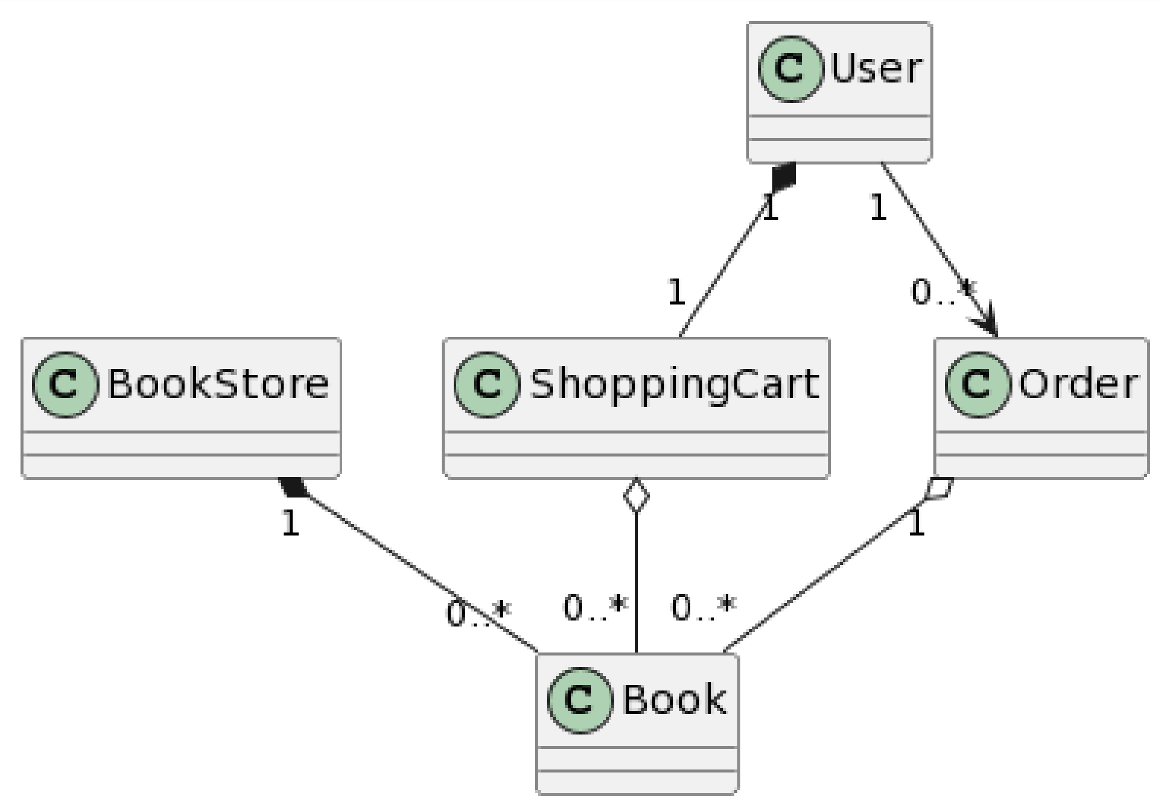
Walkthroughs & Refining the design

- Walkthroughs in this sense enable you:
  - To test scenarios and Use Cases (flow of events)
  - To discover missing responsibilities
- It's ok to identify classes
  - But it quickly becomes apparent we need more notation to describe the system (refining your design)
- You need many forms of system visualisation – Different modelling notations
  - Class diagrams as well as Dynamic aspects such as:
  - Collaboration diagrams, Sequence diagrams, State Diagrams

An Online Bookstore – Partial Specification

- Develop an online book ordering system for a **bookstore** that allows **users** to browse, search, and purchase **books**.
- The system should enable users add/remove books to/from their **shopping carts and** pay for their **orders** through an external API.

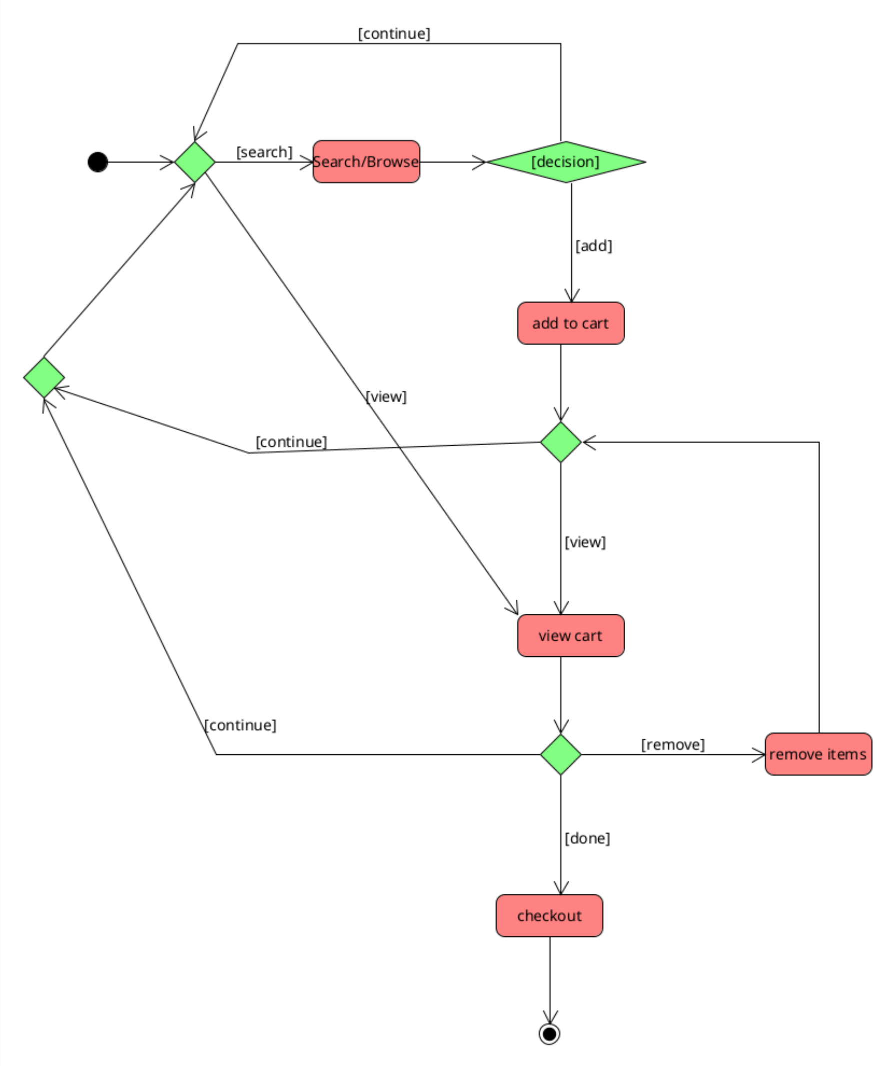
An Online Bookstore – Candidate classes



domain modelling

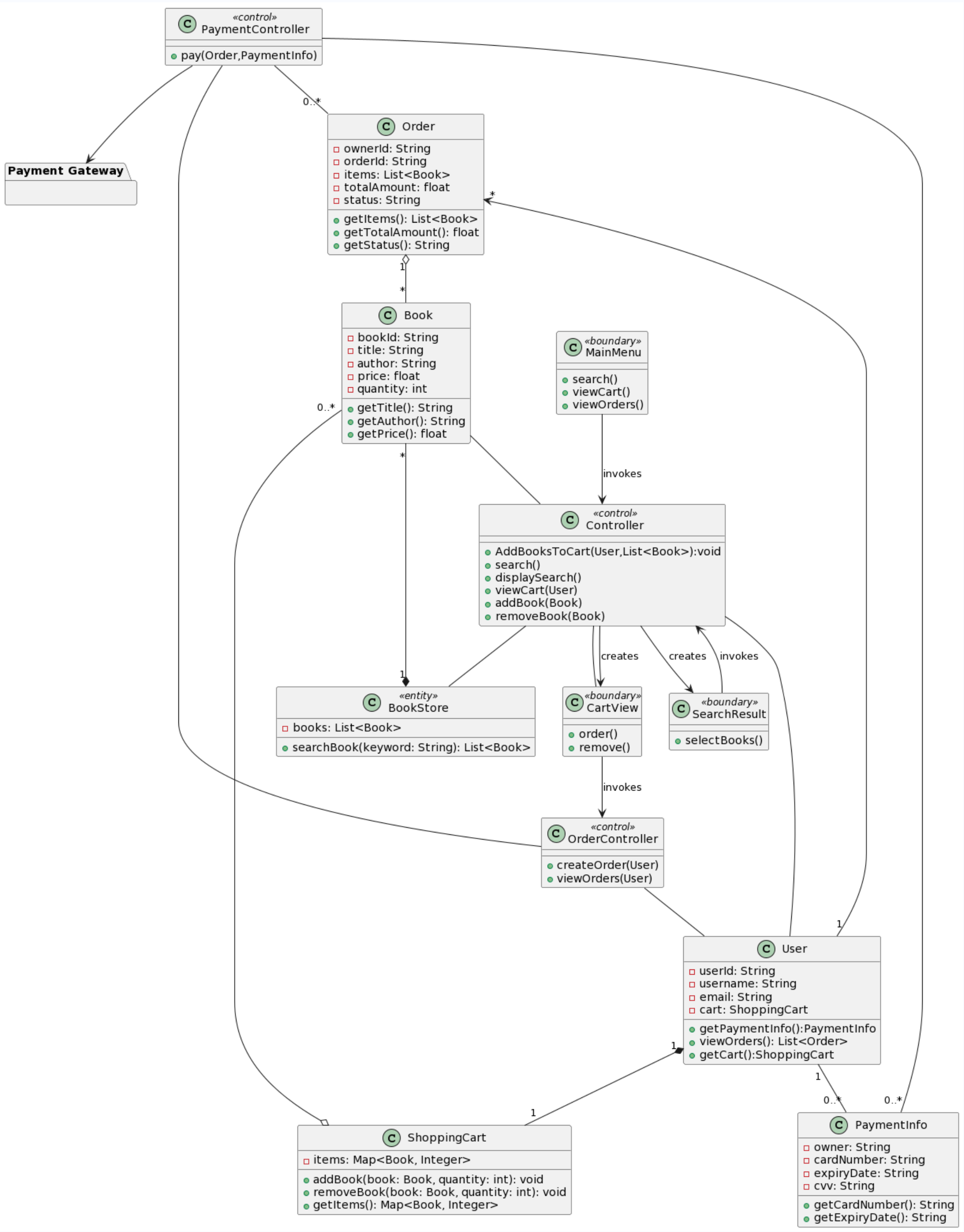
discover classes

An Online Bookstore – Activity diagram (partial)



function of the this

A more detailed Class Diagram



combine architecture and pattern to invent classes

Another scenario – Course registration

- A university makes its course offering accessible online and allows students to add and drop courses as well as view the list of offered courses. T
- o access the system a student must supply a valid username/password.
- Provide a detailed design to the above system

Another scenario – Course registration

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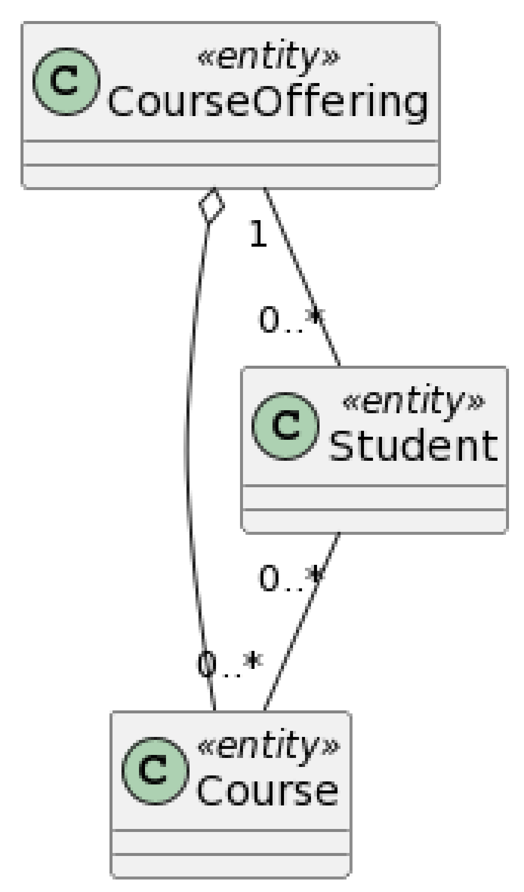
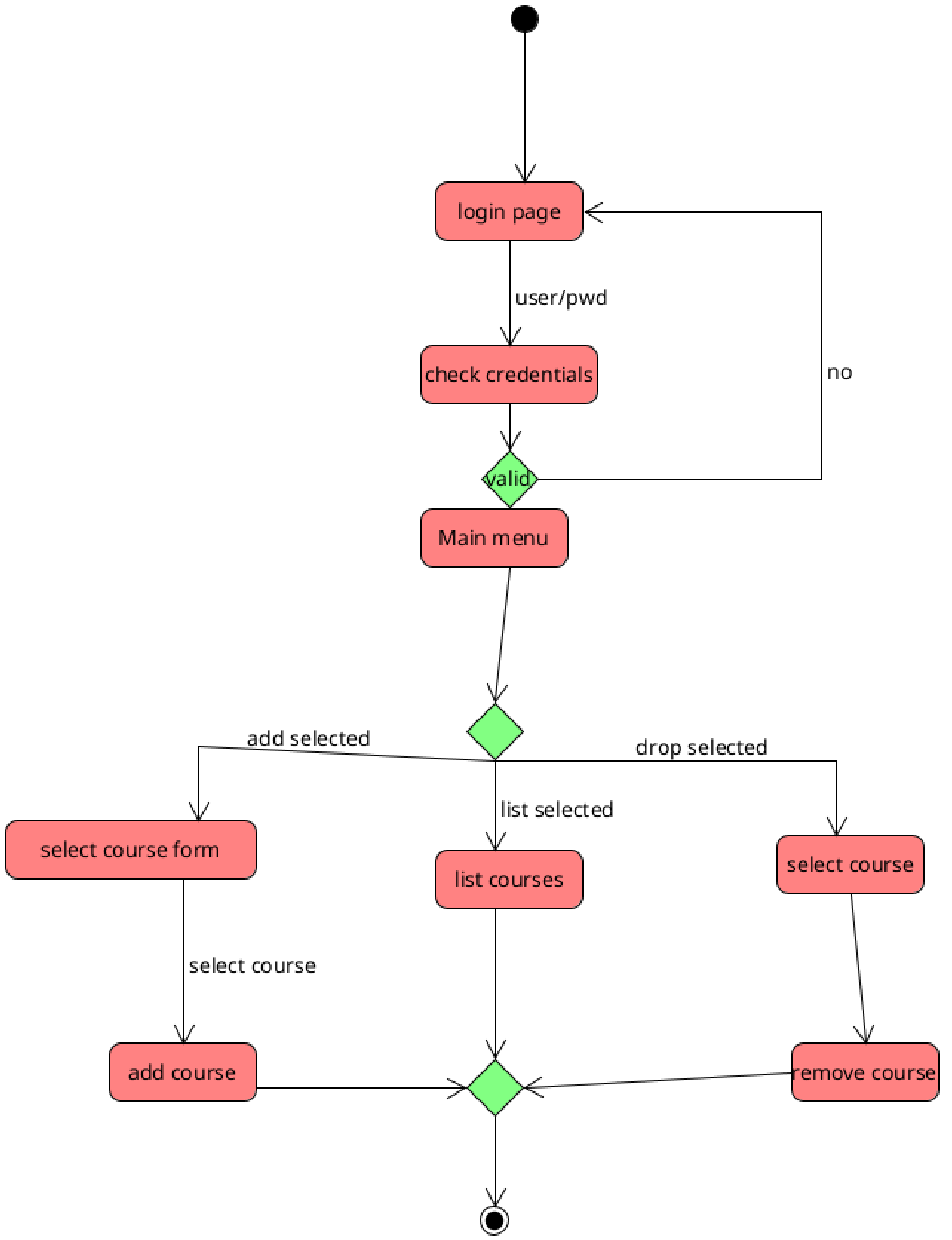
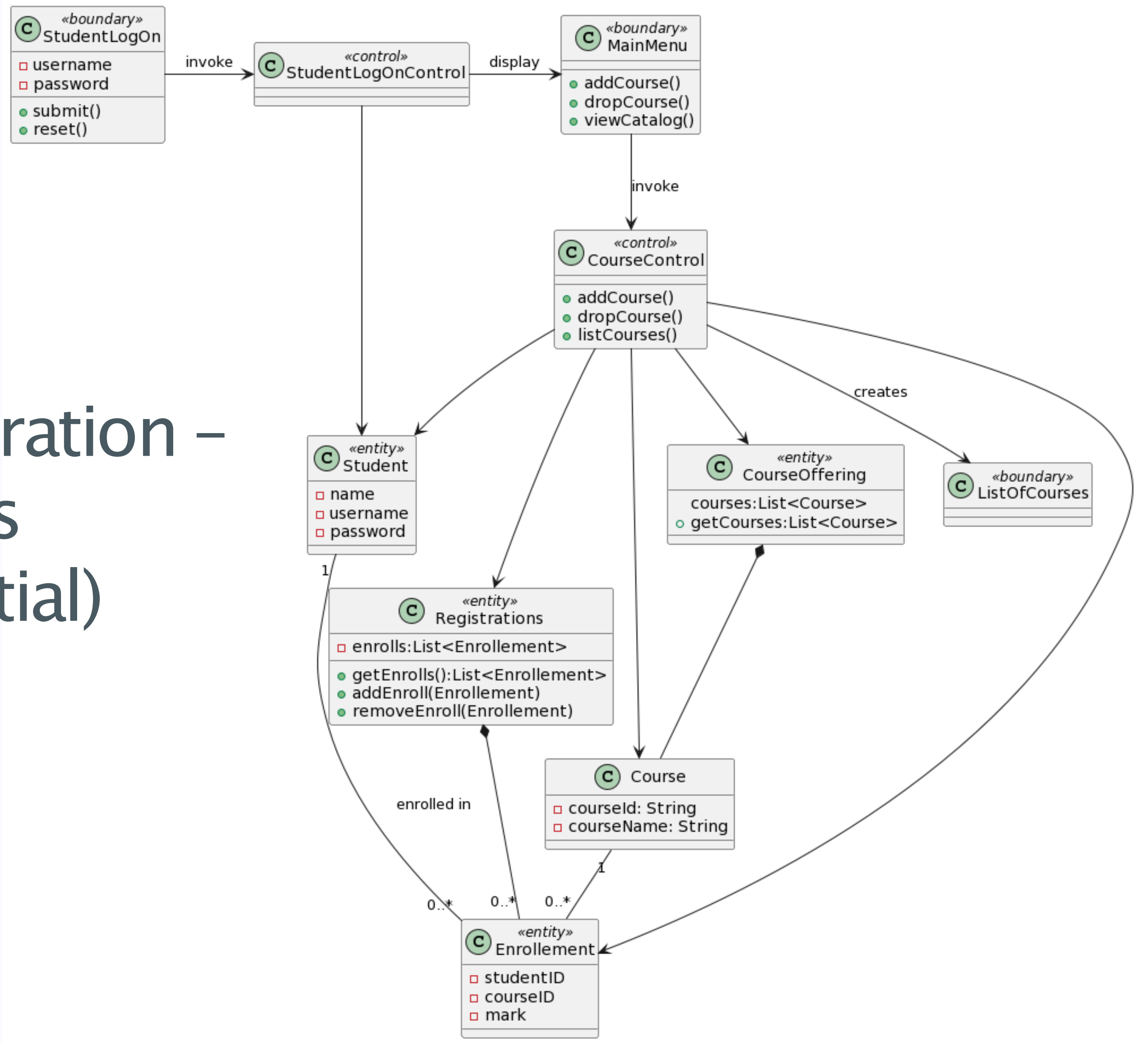
Initial class diagram



Course registration – Activity diagram



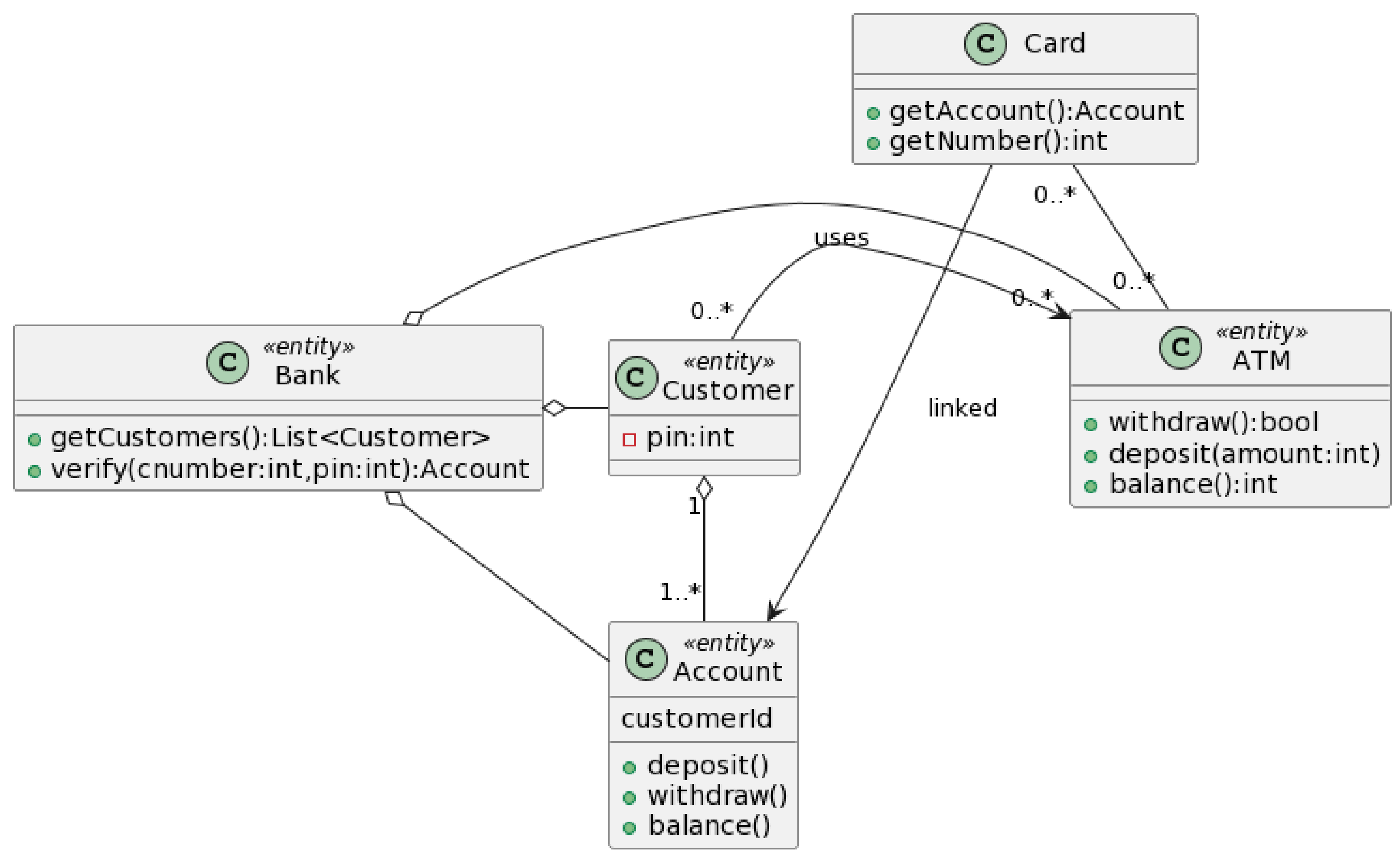
Course registration – Detailed Class Diagram (partial)



ATM example

- A bank issues cards for its customers to be used to withdraw and deposit cash from ATM machines. Each card is linked to a customer account.
- Provide domain class diagram and activity diagram.

ATM – Domain class diagram



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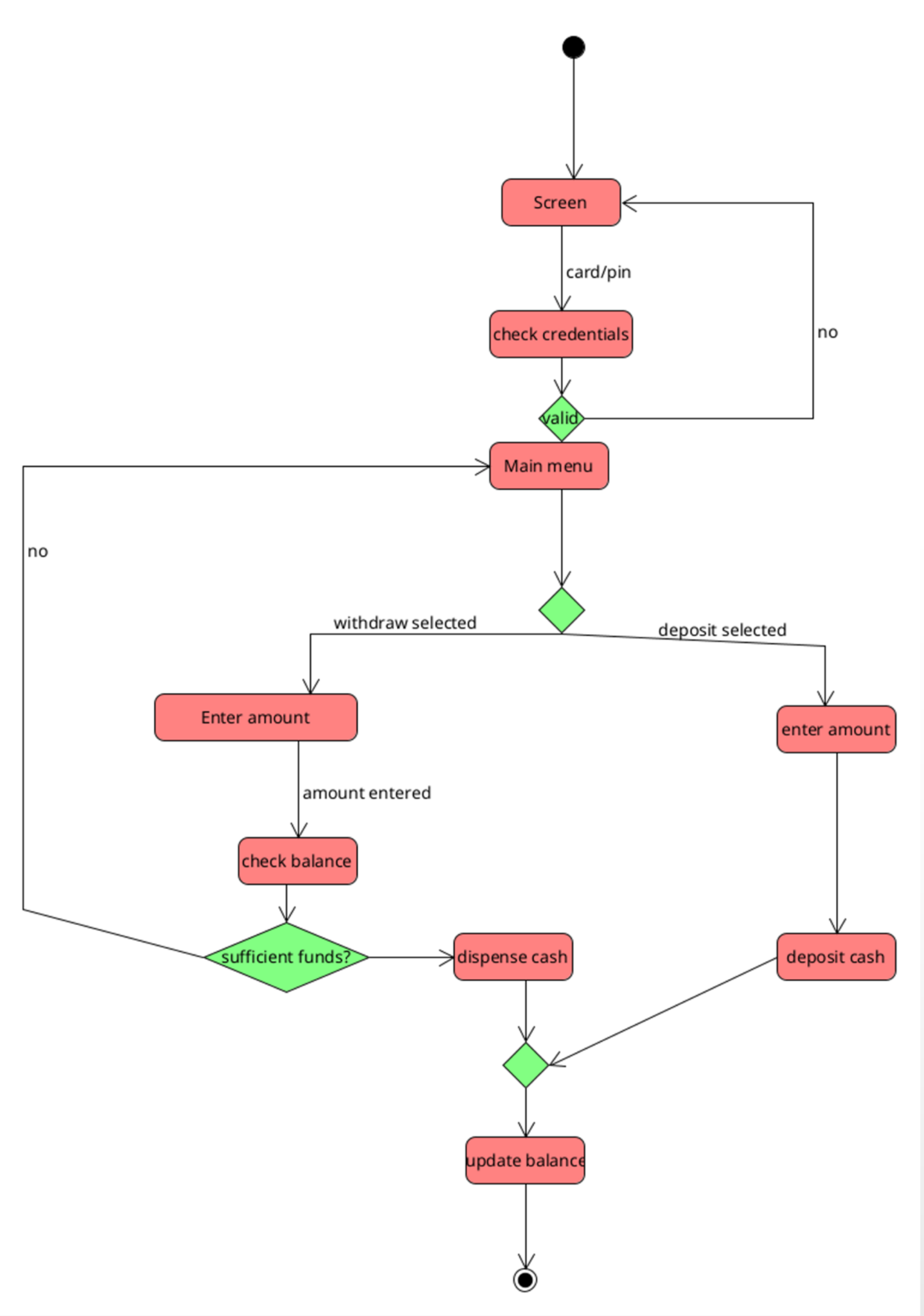
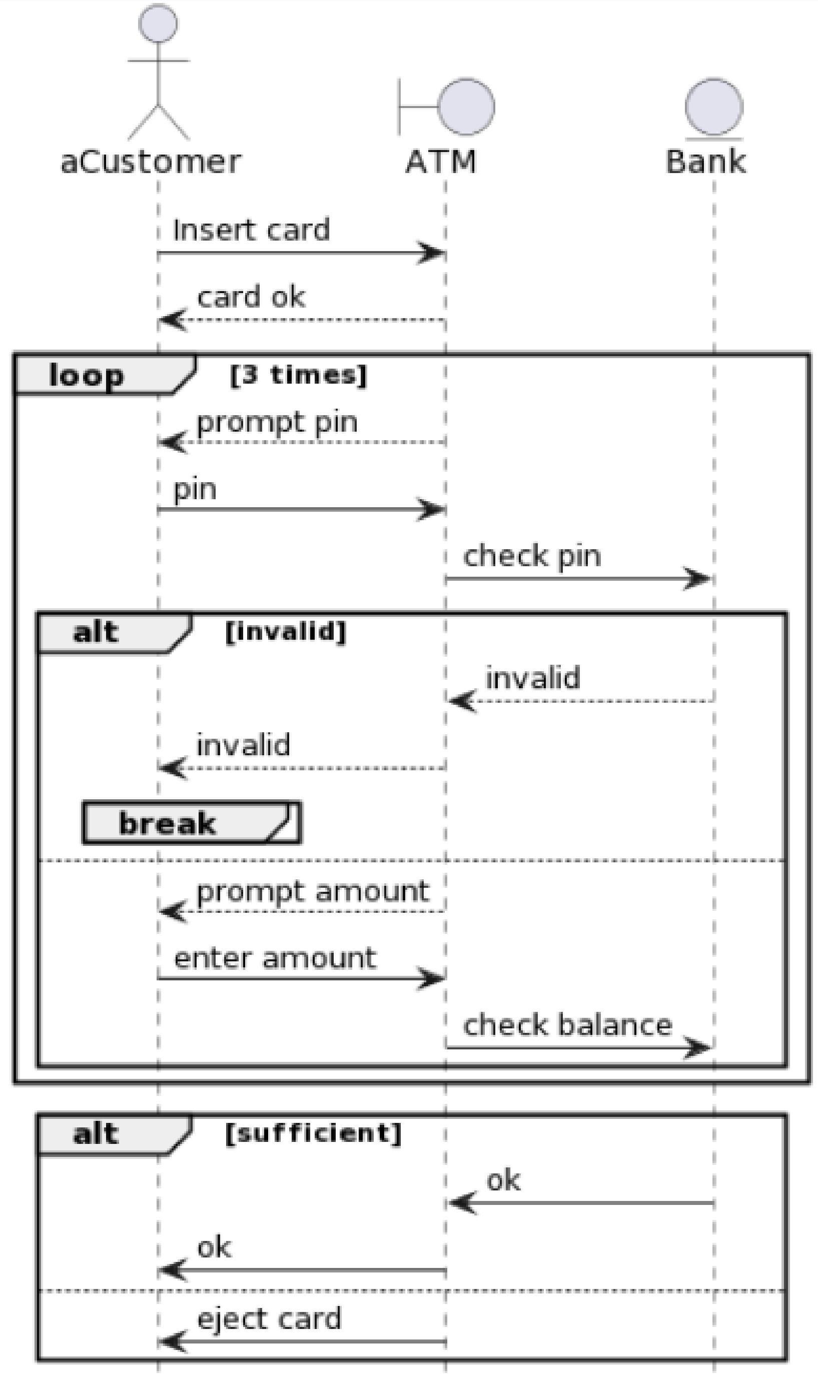
ATM – Activity diagram



ATM – Sequence diagram



- Based on this Sequence can you provide a design class diagram?
- Is a state diagram to model the behavior of the ATM necessary?

Key points

- Modelling is particularly a **difficult** skill
  - Even excellent programmers have difficulty thinking at the appropriate level of abstraction
  - Education traditionally focus more on programming than design and modelling
  - How would you go about refining the design?
- Resolution:
  - Ensure that team members have adequate training
  - Have experienced modeller as part of the team
  - Review all models thoroughly

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Key points

- Design is *empirical*. There is ***no single correct design***.
- During the design process:
  - Eliding (Omitting): Elements are hidden to simplify the diagram
  - Incomplete: During the early part of the design process, elements may be missing.
  - Inconsistency: During the early part of the design process, the model may not be consistent
- The diagram is not the whole design. Diagrams must be backed up with specifications.

Resources

- The Unified Modeling Language

  https://www.uml-diagrams.org/

- Software Engineering, 10th edition, Ian Sommerville, Chap. 7
- Software Engineering Design: Theory and Practice , Carlos E. Otero Chap. 5
- Software Engineering: Principles and Practice, Hans van Vliet Chap. 12

YOUR QUESTIONS