Introduction to UML

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- Introduction
- UML 1.x Diagrams
- UML Views
- Where to start?
- Tools

Introduction

- So you have done Java A&B
- Brainwashing
- UML: why yet another language?
- UML History
- Standardization: OMG
- General Goals of UML
- Overview of UML 2.0

 So you have done Java A&B

Owning a hammer doesn't make one an architect.

- You learnt Object-oriented *Programming*.
- You have encountered/mastered the following concepts:
  - Encapsulation
  - Class/Object
  - Composition/Aggregation
  - Generalization/Inheritance
  - Polymorphism
  - Messages
- Useful for *decomposing/modeling/understanding* the complexity
- From a craftsman to a designer:

  One level up: Forget about Java, think about object oriented *Analysis/Design*
  Even higher: pattern oriented *Anaysis/Design*

 Brainwashing

Please forget about the following first:

- int i = 0;
- if {...} else {...}
- System.out.print("hello, hell");
- while(true){
  if(Sensor.A.readValue()==1) Sound.playTune(extremely, happy);
  }

 Brainwashing

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- while(true){
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  }

Lets pick up the terms that you prefer as a designer:
• product • system • things • scenario • user, consumer, people • parents, children • relationship • communication • competencies • ...

 UML: why yet another language?

- Object oriented analysis and design models are to
  - Communicate
  - Specify
  - Define Software architecture
  - Manage complexity
  - Facilitate reuse

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  - In 1994, more than 50 OO methods:
    Fusion, Shlaer-Mellor, ROOM, Class-Relation, Wirfs-Brock, Coad-Yourdon, MOSES, Syntropy, BOOM, OOSD, OSA, BON, Catalysis, COMMA,HOOD, Ooram, DOORS

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  - Graphical notations differ
  - The process differs or remains vague
  - But: Industry needs standards!


 UML History

- To stop the OO method wars, UML was invented by "3 Amigos":


Grady Booch


Ivar Jacobson


James Rumbaugh

Grady Booch: The Booch Method (*Conception, Architecture*)
Ivar Jacobson: Object Object-Oriented Software Engineering (OOSE) (*Use Cases*)
James Rumbaugh: Object Modeling Technique (OMT) (*Analysis*)

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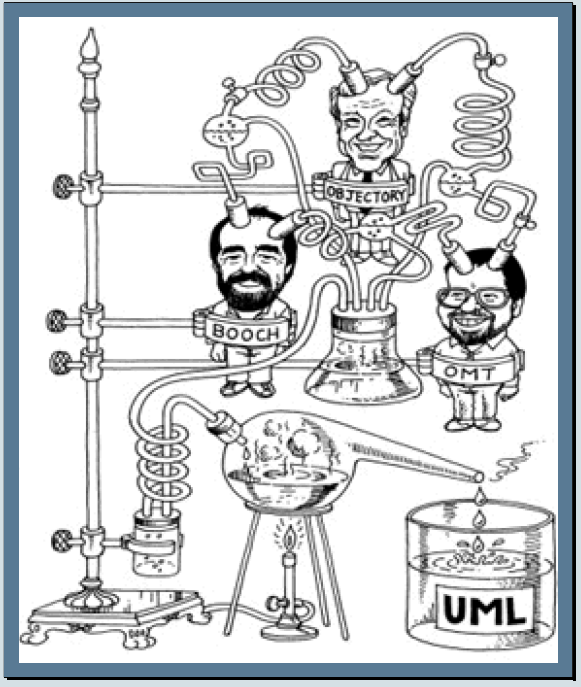
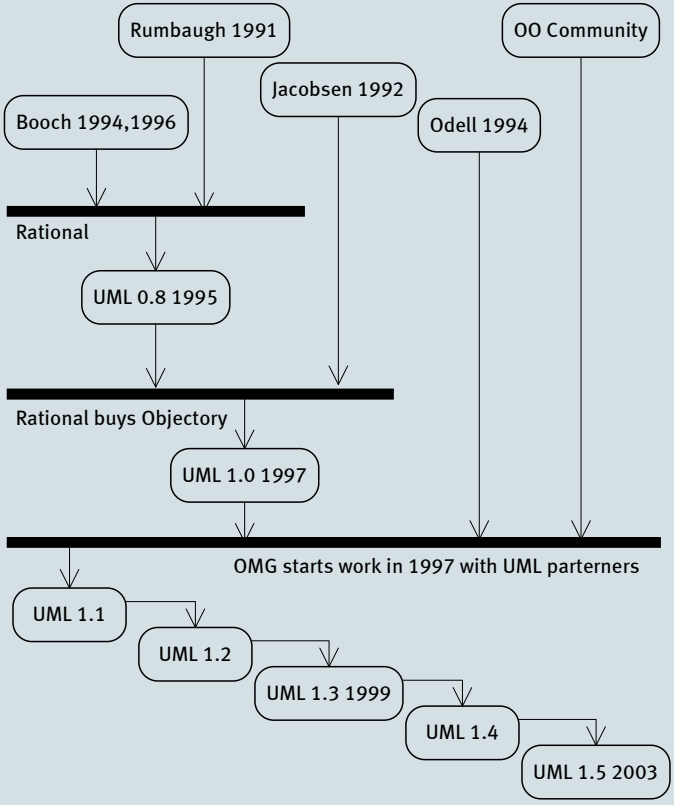
- UML standardization
  - Started in 1994 by putting aside their own methods and notations
  - Version 1.0 published in 1997
  - Version 2.0 published in 2005
  - It has become the formal and ***de facto*** standard

▶ Introduction ▶ UML History (2)





 Standardization: OMG

- OMG = Object Management Group
  - Non-profit organization founded in 1989
  - Over 700 linked companies
  - Usually known for CORBA (IDL, IIOP · · ·)

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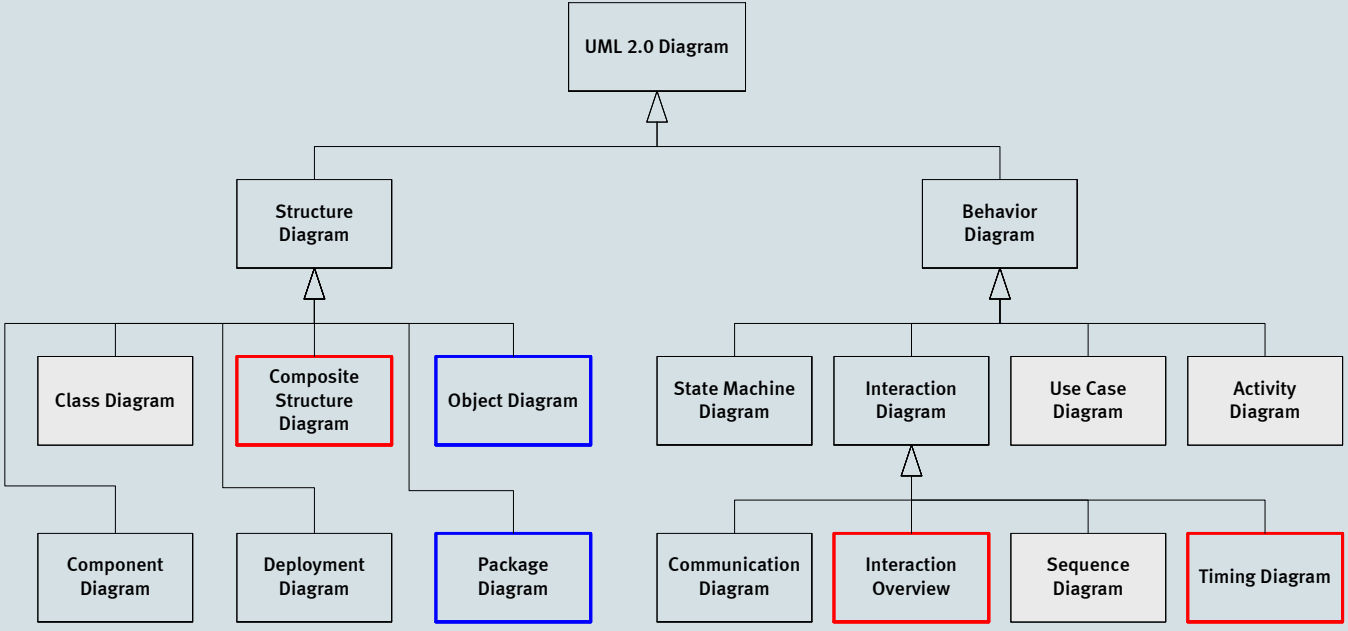
- June 1996 : Task Force Object Analysis & Design
  - Definition of a standard model form
  - Definition of a “Meta-model” standard
  - Definition of a graphical notation (optional)

 General Goals of UML

- Model systems using OO concepts
  - express object-oriented designs visually
  - programming language independent
  - provide high-level documentation
  - communicate, evaluate, and reuse designs
  - can think about design, before coding
- Establish an explicit coupling to conceptual as well as executable artifacts
- To create a modeling language usable by both humans and machines
- Models different types of systems

  information systems, technical systems, embedded systems, realtime systems, distributed systems, system software, business systems, UML itself, ...

▶ Introduction ▶ Overview of UML 2.0



UML 1.x Diagrams

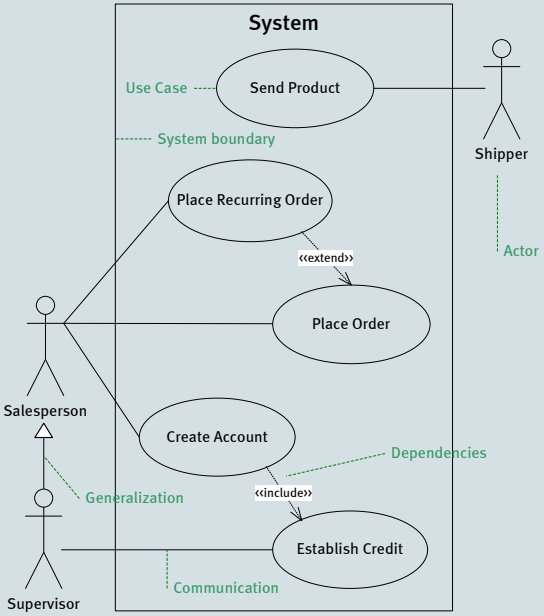
- ♡ Use Case Diagrams
- ♡ Class Diagrams
- Object Diagrams & Filmstrips
- ♡ Sequence Diagrams
- Collaboration Diagrams
- ♡ Activity Diagrams
- State Diagrams
- Component Diagrams
- Package Diagrams
- Deployment Diagrams

 ♡ Use Case Diagrams

- Overview
- What is a use case?
- Actors In Use Cases
- Example of a use case
- A POS example (1)
- A POS example (2)
- Use Case Best Practices
- Common Use Case Pitfalls

Specifies participants in a use case and the relationships between use cases.

- Use cases
- Actors (or roles)
- Communication associations between actors and use cases
- Specialization/Generalization between actors/roles
- Use case dependencies:
  - «extend»
  - «include»




 What is a use case?

Describes a functional requirement of the system as a whole from an external perspective:

- Library Use Case: *Borrow book*
- VCR Use Case: *Set Timer*
- Top1Toy's Use Case: *Buy cheap plastic toy*
- IT Help Desk Use Case: *Log issue*

 Actors In Use Cases

- Actors are external roles
- Actors initiate (and respond to) use cases
  - *Sales rep* logs call
  - *Driver* starts car
  - Alarm system alerts *duty officer*
  - *Timer* triggers email

 Example of a use case

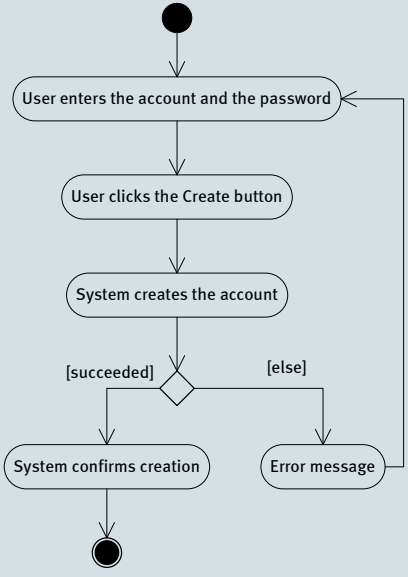
A use case can be specified textually:

Use case: **Create account**
Involved actor(s): Salesperson

1. Salesperson enters the account name and password
2. Salesperson clicks the Create button
3. The system creates an account
4. The system confirms the created account

Error Case 1: Creation Failed
If the system fails at 3, then the system shows a message about the failure and redirects the user back to the step 1

Or using activity diagrams:



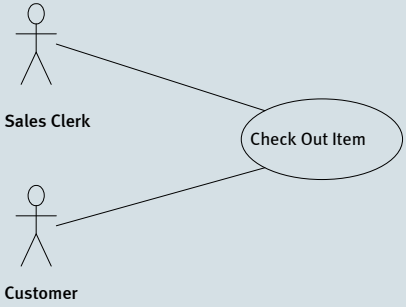
► UML 1.x Diagrams ► ♡ Use Case Diagrams ► A POS example (1)

Use Case 1: Sales Clerk checks out an item
Involved actor(s): Customer, Sales Clerk

1. Customer sets item on counter.
2. Sales Clerk swipes UPC reader across UPC code on item
3. System looks up UPC code in database procuring item description and price
4. System emits audible beep.
5. System announces item description and price over voice output.
6. System adds price and item type to current invoice.
7. System adds price to correct tax subtotal

Error case 1: UPC code unreadable
If after step 2, the UPC code was invalid or was not properly read, emit an audible 'bonk' sound.

Error case 2: No item in database
If after step 3 no database entry is found for the UPC flash the 'manual entry' button on the terminal. Accept key entry of price and tax code from Sales Clerk. Set Item description to "Unknown item". Go to step 4.



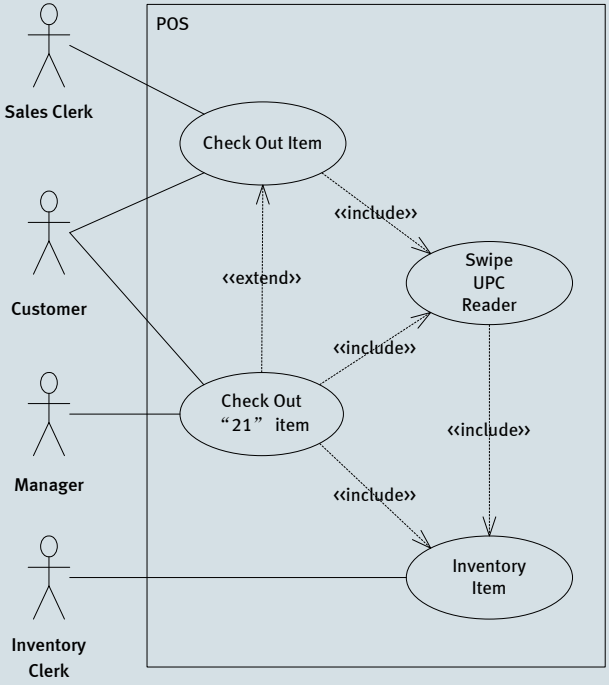
A POS example (2)

Use Case 1: Check out item
Involved actor(s): Customer, Sales Clerk

1. Customer sets item on counter.
2. XP21: Sales clerk swipes UPC reader («include» Swipe UPC Reader) across UPC code on item.
3. System looks up UPC code in database procuring item description and price.
4. System emits audible beep.
5. System announces item description and price over voice output.
6. System adds price and item type to current invoice.
7. System adds price to correct tax subtotal.

Use Case 2: Check Out "21" Item
Involved actor(s): Sales Clerk, Manager

2. Replace XP21 of extended use case with:
2.1. Sales Clerk calls "21" over P.A. System
2.2. Waits for manager
2.3. Manager swipes UPC reader («include» Swipe UPC Reader)



 Use Case Best Practices

- Keep them simple & succinct
- Don't write all the use cases up front - develop them incrementally
- Revisit all use cases regularly
- Prioritise your use cases
- Ensure they have a single tangible & testable goal
- Write them from the user's perspective, and write them in the language of the business
- Set a clear system boundary and do not include any detail from behind that boundary
- Look carefully for alternative & exceptional flows

 Common Use Case Pitfalls

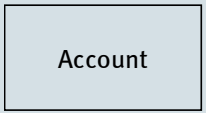
- The system boundary is undefined or inconstant
- The use cases are written from the system's (not the actors') point of view
- The actor names are inconsistent
- There are too many use cases
- The use-case specifications are too long
- The customer doesn't understand the use cases
- The use cases are never finished

 ♡ Class Diagrams

- Classes
- Attributes
- Operations
- Visibility
- Class & Instance Scope
- Bi-directional Associations
- Association names & role defaults
- Multiplicity & Collections
- Aggregation & Composition
- Generalization
- Overriding Operations
- Interface & Realization
- Abstract Classes & Abstract Operations
- More on Generalization
- Dependencies
- Qualified Associations
- Association Classes
- Associations, Visibility & Scope
- Information Hiding
- Exercise

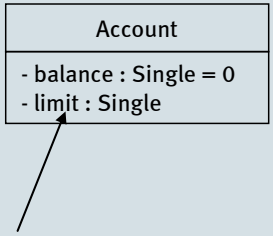
Classes

```
class Account {
}
```



 Attributes

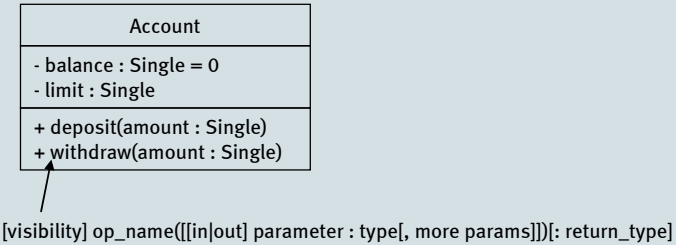
```
class Account {
  private float balance = 0;
  private float limit;
}
```



[visibility] [/] attribute_name[multiplicity] [: type [= default_value]]

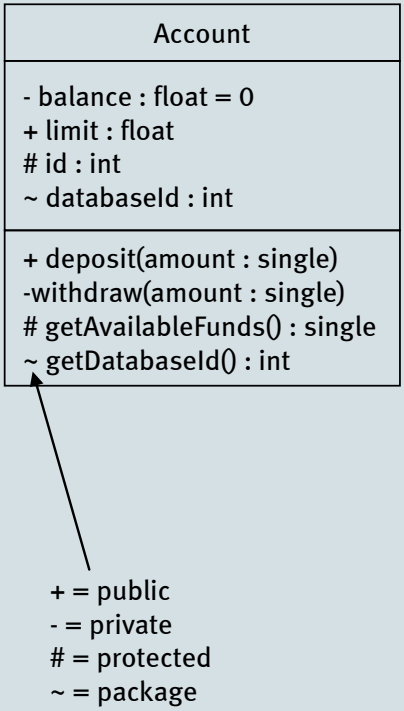
 Operations

```
class Account{
  private float balance = 0;
  private float limit;

  public void deposit(float amount){
    balance = balance + amount;
  }

  public void withdraw(float amount){
    balance = balance – amount;
  }
}
```



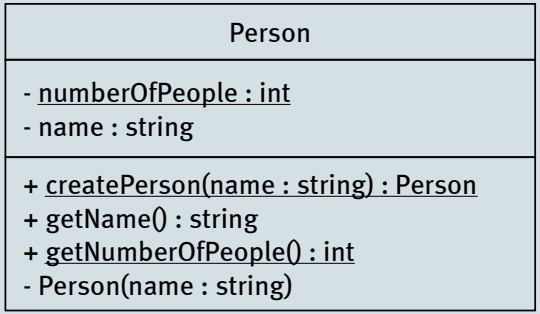
 ▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶ Visibility

```
class Account{
  private float balance = 0;
  public float limit;
  protected int id;
  int databaseId;

  public void deposit(float amount){
    balance = balance + amount;
  }

  private void withdraw(float amount){
    balance = balance – amount;
  }

  protected int getId(){
    return id;
  }

  int getDatabaseId(){
    return databaseId;
  }
}
```



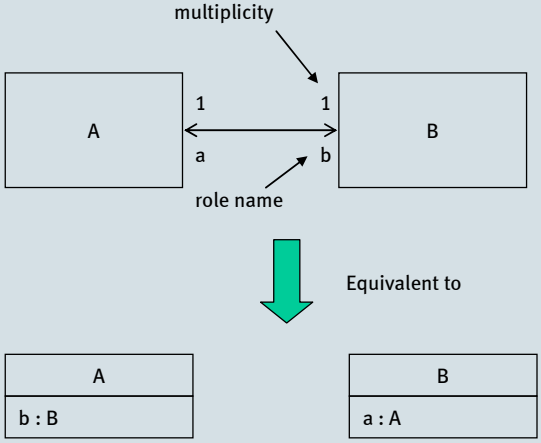
▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶ Class & Instance Scope

```
class Person {
  private static int numberOfPeople = 0;
  private String name;

  private Person(string name){
    this.name = name;
    numberOfPeople++;
  }

  public static Person createPerson(string name){
    return new Person(name);
  }

  public string getName(){
    return this.name;
  }

  public static int getNumberOfPeople(){
    return numberOfPeople;
  }
}

/*-------------------------------------------------*/
int  numOfPeople = Person.getNumberOfPeople();
Person p = Person.createPerson("Jun Hu");
```



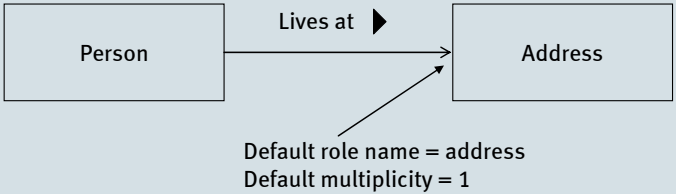
 # Bi-directional Associations

```
class A
{
  public B b;
  public A(){
    b = new B(this);
  }
}

/*-------------------*/
class B{
  public A a;
  public B(A a)
  {
    this.a = a;
  }
}

/*-------------------*/
A a = new A();
B b = a.b;
A a1 = b.a;
assert a == a1;
```



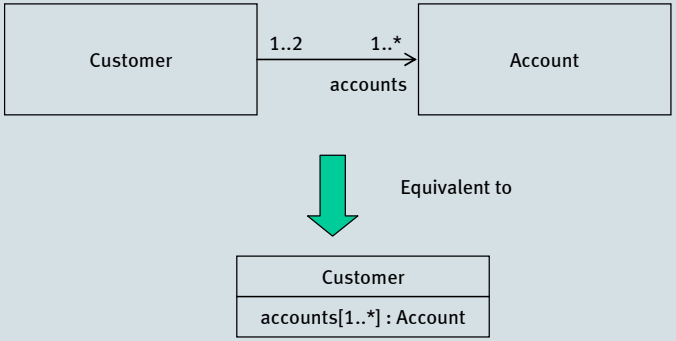
Association names & role defaults

```
class Person
{
    // association: Lives at
    public Address address;

    public Person(Address address)
    {
        this.address = address;
    }
}
```



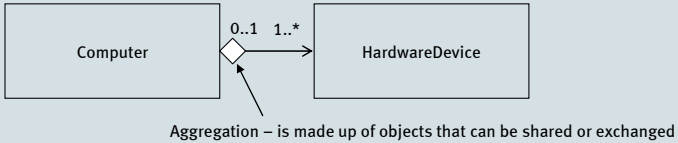
 Multiplicity & Collections

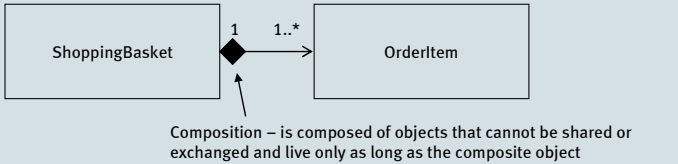
```
class Customer
{
  // accounts[1..*] : Account
  ArrayList accounts = new ArrayList();

  public Customer()
  {
    Account defaultAccount = new Account();
    accounts.add(defaultAccount);
  }
}
```



Aggregation & Composition

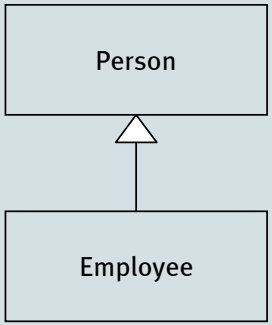
```
/********** Aggregation ***********/
public class ClassA{
  private Class b;

  public classA(ClassB b){
    this.b = b;
  }
}

/********** Composition ***********/
public class ClassA {
  private ClassA b = new ClassB();
}
```





 ▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶ Generalization

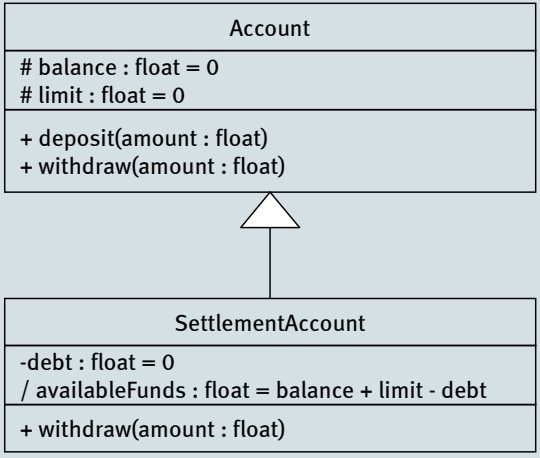
```
class Person{
}

class Employee extends Person{
}
```



 ▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶

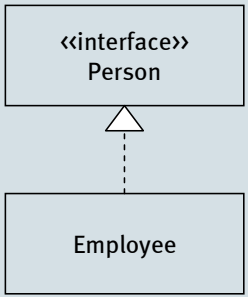
Overriding Operations

```
class Account
{
  protected float balance = 0;
  protected float limit = 0;

  public void deposit(float amount){
    balance = balance + amount;
  }

  public void withdraw(float amount){
    balance = balance – amount;
  }
}

class SettlementAccount extends Account{
  private float debt = 0;

  float availableFunds(){
    return (balance + limit – debt);
  }

  public void withdraw(float amount){
    if (amount › this.availableFunds()){
      throw new InsufficientFundsException();
    }
    base.withdraw(amount);
  }
}
```

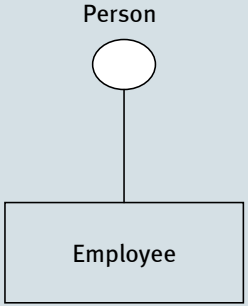


 Interface & Realization

```
interface Person{
}

class Employee implements Person{
}
```

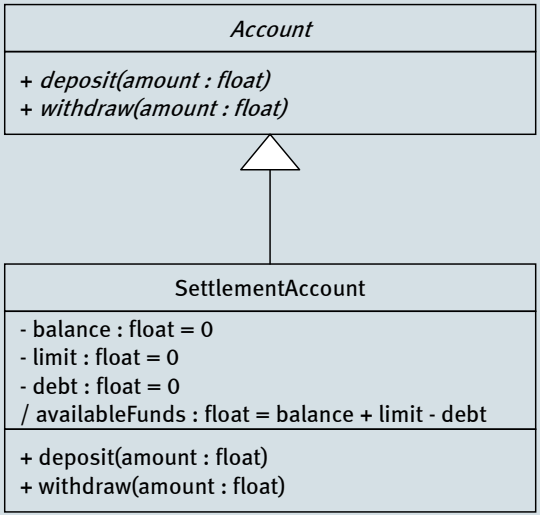


OR

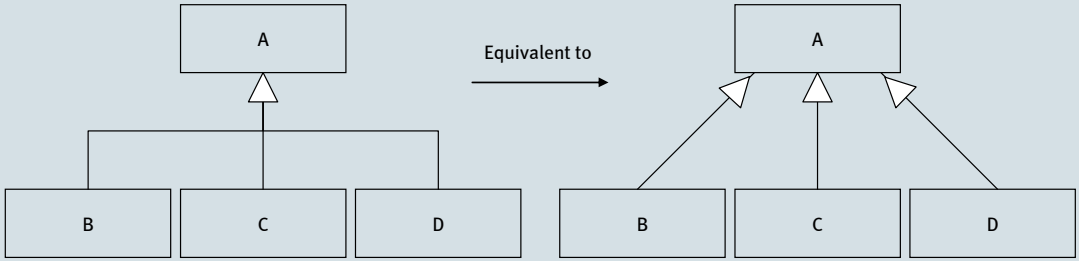


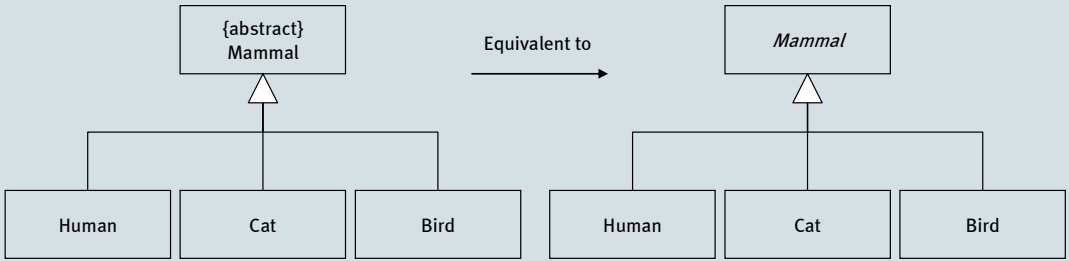
▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶ Abstract Classes & Abstract Operations

```
abstract class Account{
  public abstract void deposit(float amount);
  public abstract void withdraw(float amount);
}

class SettlementAccount extends Account{
  private float balance = 0;
  private float limit = 0;
  private float debt = 0;

  float availableFunds()  {
    return (balance + limit – debt);
  }

  public void deposit(float amount){
    balance = balance + amount;
  }

  public void withdraw(float amount){
    if (amount › this.availableFunds()){
      throw new InsufficientFundsException();
    }
    balance = balance – amount;
  }
}
```



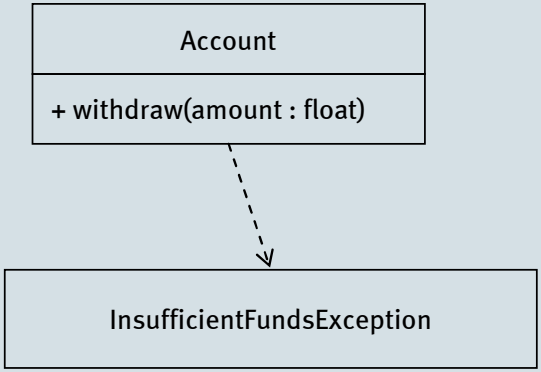
 More on Generalization





 ▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶ Dependencies

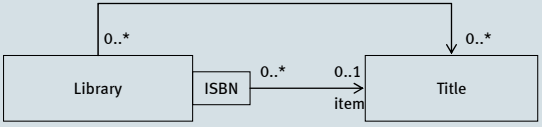
```
public class Account {

  public void withdraw(float amount)
    throws InsufficientFundsException{
  }

}
```



 Qualified Associations

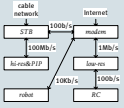
hash-table, associative array, “dictionary” . . .

```
class Library{
  private HashMap titles = new HashMap();

  public Title item(String isbn){
    return (Title)titles.get(isbn);
  }
}
```



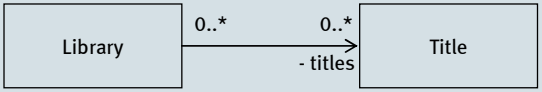
▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶ Association Classes

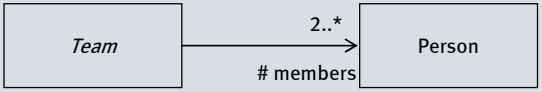
```
class Customer{
    ArrayList rentals = new ArrayList();
}

class Video{
    Rental rental;
}

class Rental{
    Customer customer;
    Video video;

    DateTime dateRented;

    public Rental(DateTime dateRented, Customer customer, Video video){
        this.dateRented = dateRented;
        video.rental = this;
        customer.rentals.add(this);
        this.customer = customer;
        this.video = video;
    }
}
```

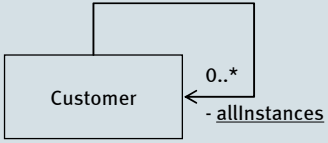


 Associations, Visibility & Scope

```
class Library{
     private Title[] titles;
}

class Team{
    protected Person[] members;
}


class Customer{
    private static Customer[] allInstances;
}
```

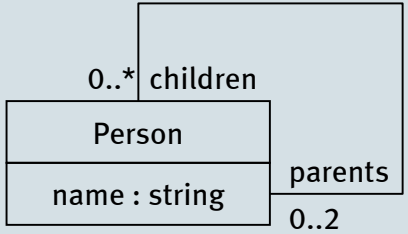






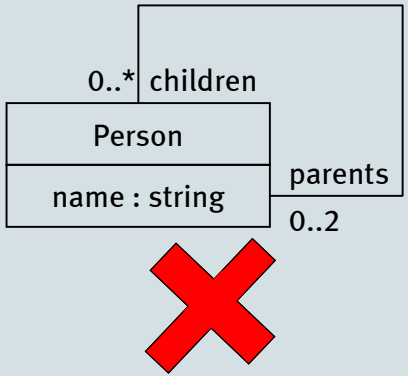
 ▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶ Information Hiding

```
class Person
{
    public String name;
    public Parent[] parents = new Parent[2];
    public ArrayList children = new ArrayList();
}

Person mary = new Person();
Person ken = new Person();
Person jason = new Person();
jason.parents[0] = mary;
jason.parents[1] = ken;
mary.children.add(jason);
ken.children.add(jason);
jason.name = "Jason";
```



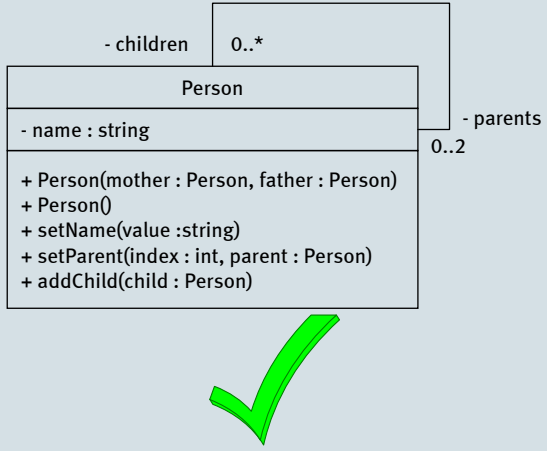
 ▶ UML 1.x Diagrams ▶ ♡ Class Diagrams ▶ Information Hiding

```
class Person
{
    public String name;
    public Parent[] parents = new Parent[2];
    public ArrayList children = new ArrayList();
}

Person mary = new Person();
Person ken = new Person();
Person jason = new Person();
jason.parents[0] = mary;
jason.parents[1] = ken;
mary.children.add(jason);
ken.children.add(jason);
jason.name = "Jason";
```

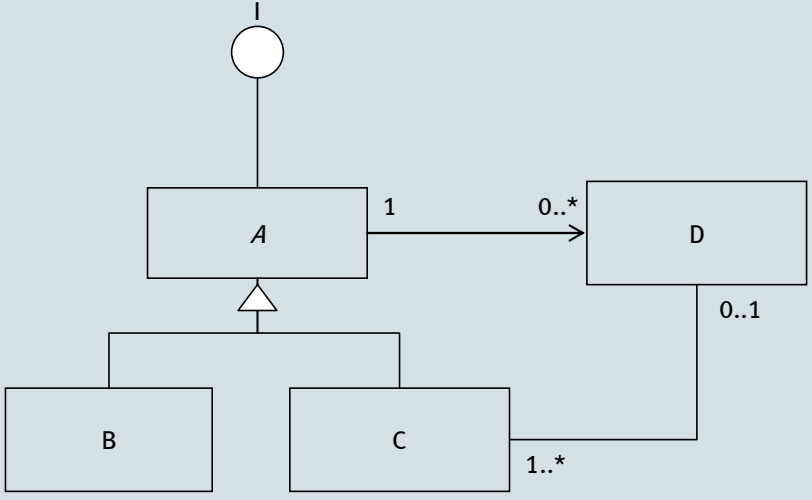


 # Information Hiding (2)

```
class Person{
    private String name;
    private Parent[] parents = new Parent[2];
    private ArrayList children = new ArrayList();

    public Person(Person mother, Person father){
        this.setParent(0, mother);
        this.setParent(1, father);
    }
    public void setName(String value){
        this.name = value;
    }
    public void setParent(int index, Person parent){
        parents[index] = parent;
        parent.addChild(this);
    }
    public void addChild(Person child){
        this.children.add(child);
    }
    public Person()
    {
    }
}

Person mary = new Person();
Person ken = new Person();
Person jason = new Person(mary, ken);
jason.setName("Jason");
```



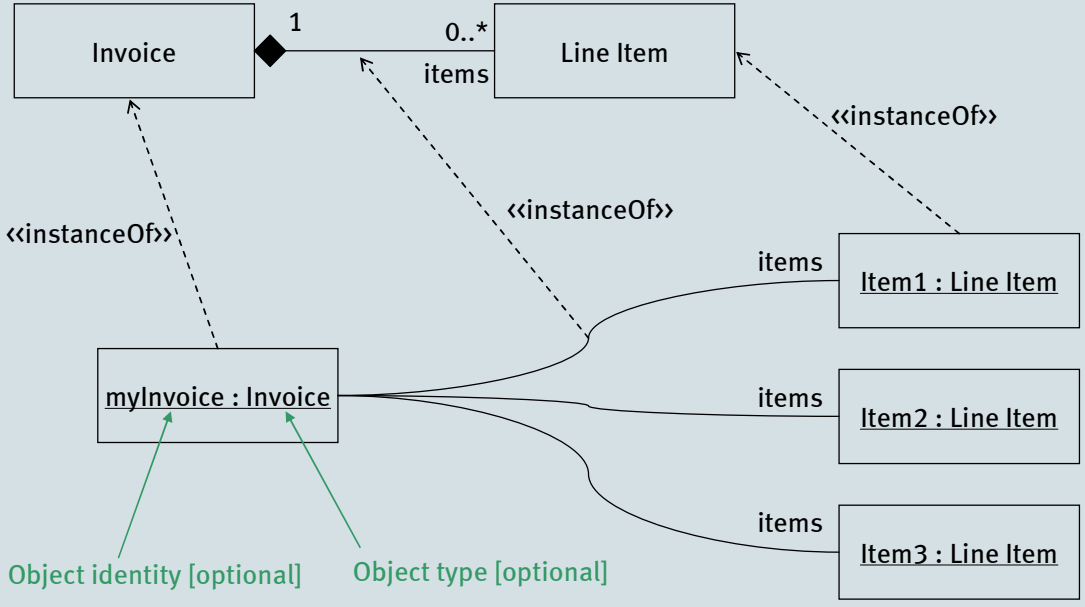
Write the Java code to implement the class diagram exactly as below:



 Object Diagrams & Filmstrips

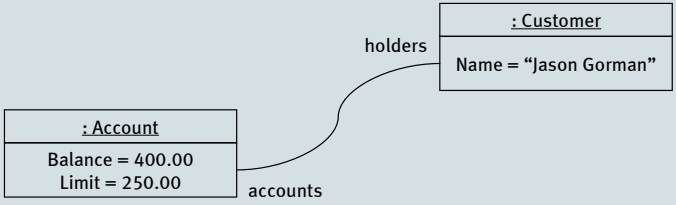
- Instances of Class Diagrams
- Object State
- Filmstrips

 Instances of Class Diagrams

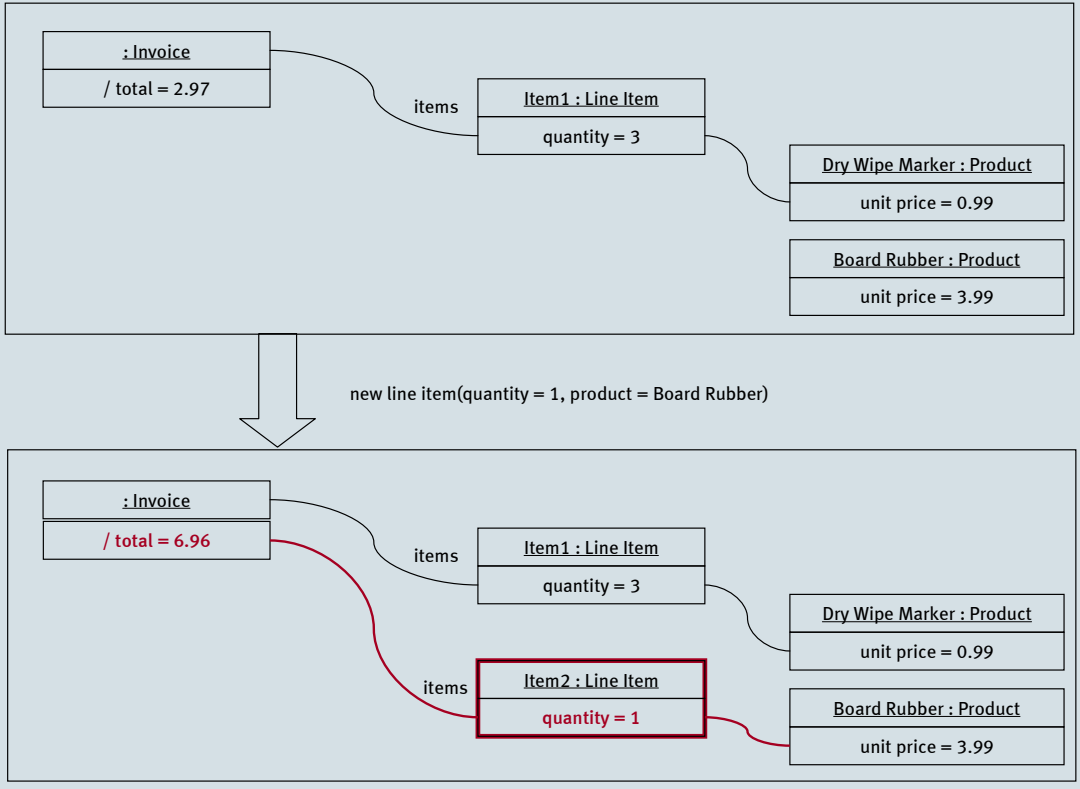


 Object State

- Object diagrams are *snapshots* of class diagrams in execution – that is, if we could execute a model (but that's another story...)
- We may use snapshots to model the *before* and *after* of tests cases to see what has changed and then assign responsibility for those changes in high-level design.
- We may also use snapshots to *debug* high-level designs in much the same way we use breakpoints to debug our code.

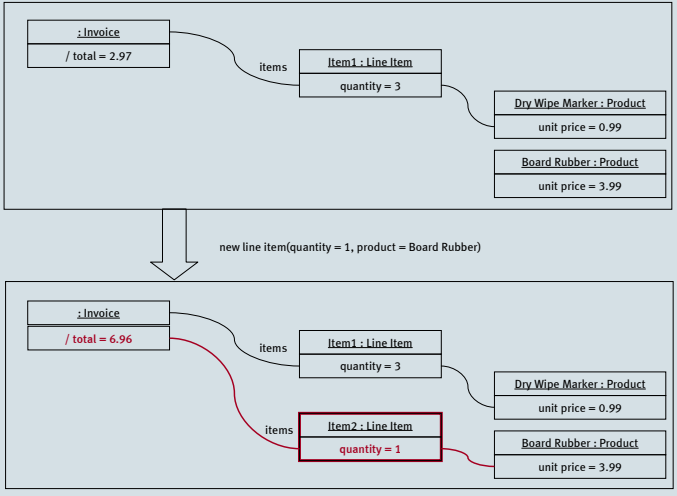


 # Filmstrips


: Invoice
/ total = 2.97
items
Item1 : Line Item
quantity = 3
Dry Wipe Marker : Product
unit price = 0.99
Board Rubber : Product
unit price = 3.99
new line item(quantity = 1, product = Board Rubber)
: Invoice
/ total = 6.96
items
Item1 : Line Item
quantity = 3
Dry Wipe Marker : Product
unit price = 0.99
items
Item2 : Line Item
quantity = 1
Board Rubber : Product
unit price = 3.99

 Filmstrips (2)

- We can animate the effect of an operation using a pair of snap-shots
- Change are highlighted so they are easy to spot.
- There are several effects we need to note in a filmstrip:
  - Changes to attribute values
  - Object creation
  - Link creation
  - Link destruction



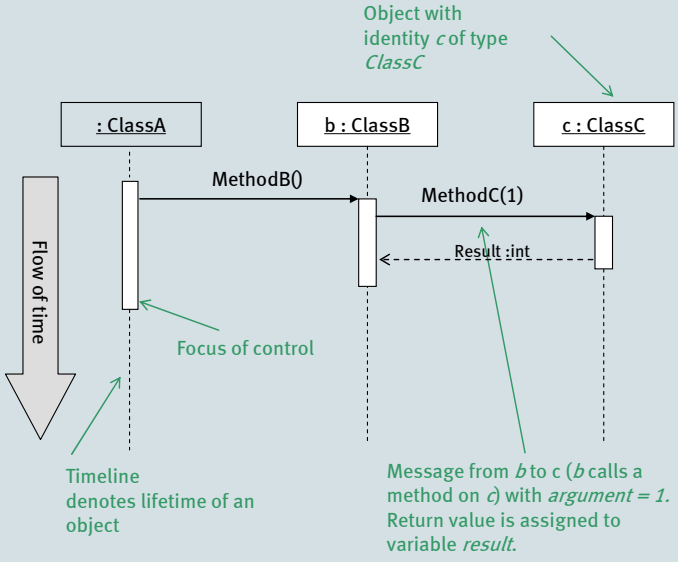
 ♡ Sequence Diagrams

- Why sequence diagrams
- Messages & Timelines
- Object Creation & Destruction
- Collections and Iterations
- Conditional Messages
- Class Operations
- Recursion

- In OO analysis & design, the real objective is to dream up ways in which groups of objects can collaborate together to complete some useful task.
- In OO terms, we say that objects interact with each other by sending messages (in the form of method calls or events).

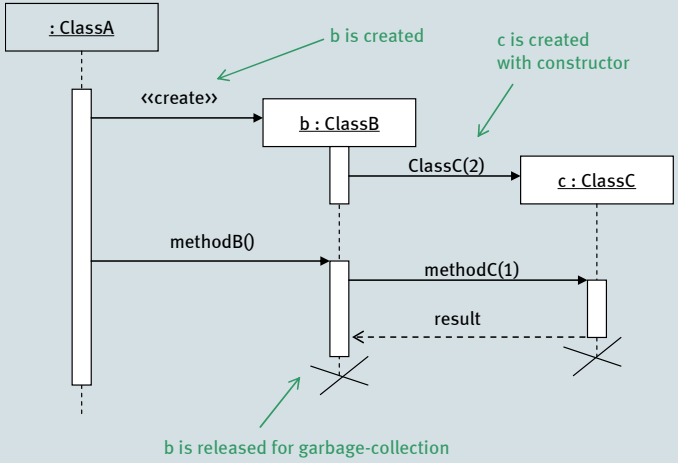
 # Messages & Timelines

```
public class ClassA{
  private ClassB b = new ClassB();

  public void methodA() {
    b.methodB();
  }
}

public class ClassB{
  private ClassC c = new ClassC();

  public void methodB(){
    int result = c.methodC(1);
  }
}

public class ClassC{
  public int methodC(int argument) {
    return argument * 2;
  }
}
```



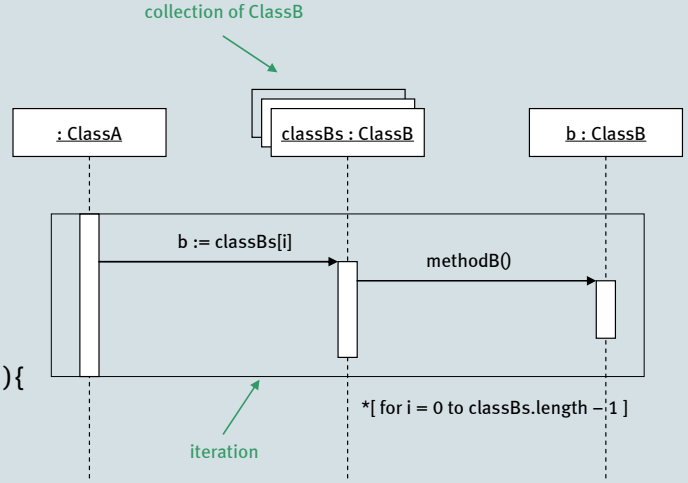
 # Object Creation & Destruction

```
public class ClassA{
    public void methodA()    {
        ClassB b = new ClassB();
        b.methodB();
    }
}

public class ClassB{
    private ClassC c = new ClassC(2);

    public void methodB(){
        int result = c.methodC(1);
    }
}

public class ClassC{
    private int factor = 0;
    public ClassC(int factor){
        this.factor = factor;
    }
    public int methodC(int argument){
        return argument * factor;
    }
}
```



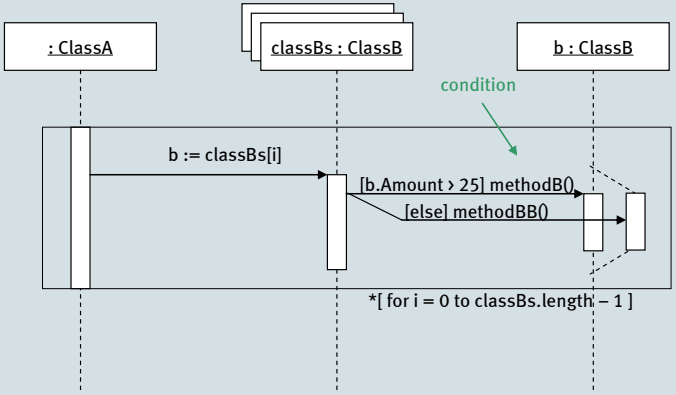
Collections and Iterations

```
public class ClassA
{
  //a collection of ClassB objects
  private ClassB[] classBs
    = new ClassB[]
      { new ClassB(),
        new ClassB(),
        new ClassB()
      };

  public void methodA(){
    //iteration
    for(int i = 0; i < classBs.length; i++){
      ClassB b = classBs[i];
      b.methodB();
    }
  }
}
```



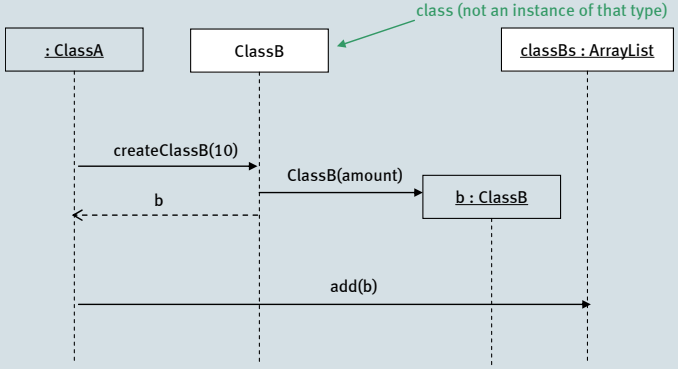
 Conditional Messages

```
public void methodA(){
  for(int i = 0; i < classBs.length; i++){
    ClassB b = classBs[i];

    if(b.Amount > 25){
      b.methodB();
    }
    else{
      b.methodBB();
    }
  }
}
```



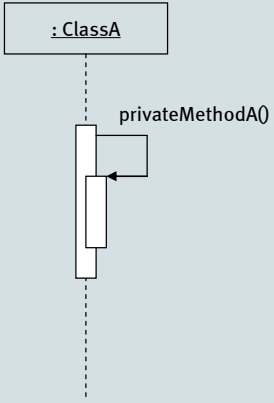
▶ UML 1.x Diagrams ▶ ♡ Sequence Diagrams ▶ Class Operations

```
public class ClassA{
  private ArrayList classBs
    = new ArrayList();

  public void methodA(){
    ClassB b = ClassB.createClassB(10);
    classBs.add(b);
  }
}
```



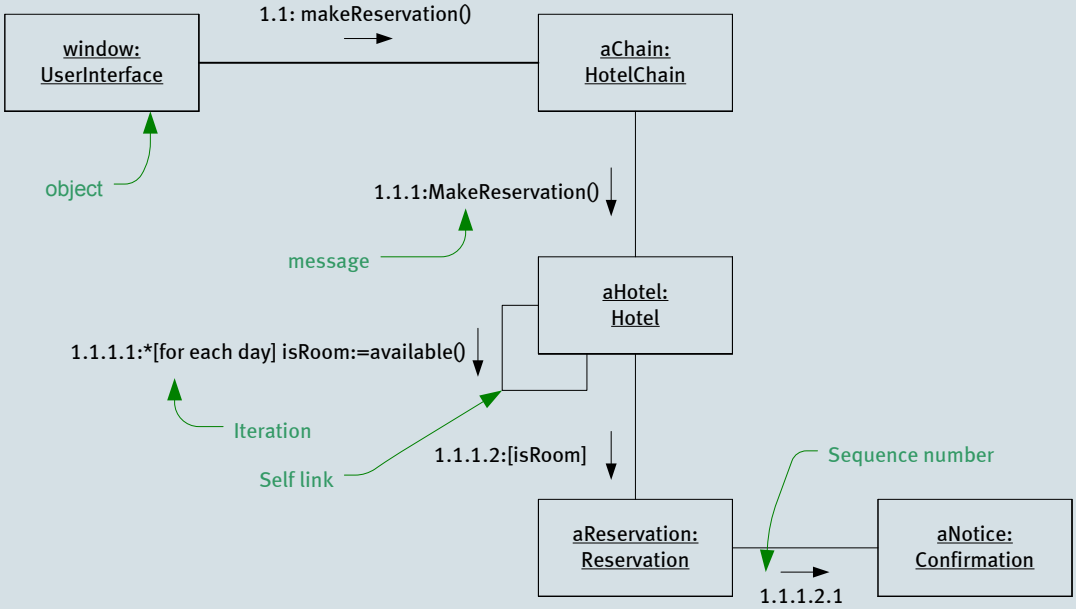
 ▶ UML 1.x Diagrams ▶ ♡ Sequence Diagrams ▶ Recursion

```
public class ClassA
{
  public void methodA()  {
      this.privateMethodA();
  }

  private void privateMethodA()  {
  }
}
```



▸ UML 1.x Diagrams ▸ Collaboration Diagrams

= Communication Diagrams in UML 2.x

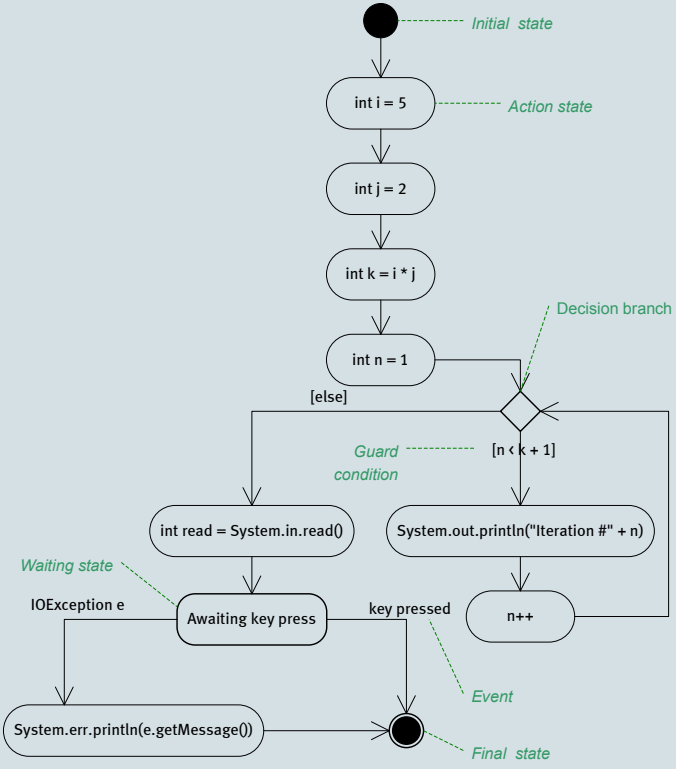


 ♡ Activity Diagrams

- Process Flow
- Concurrency
- Swim lanes
- Signals and Exceptions

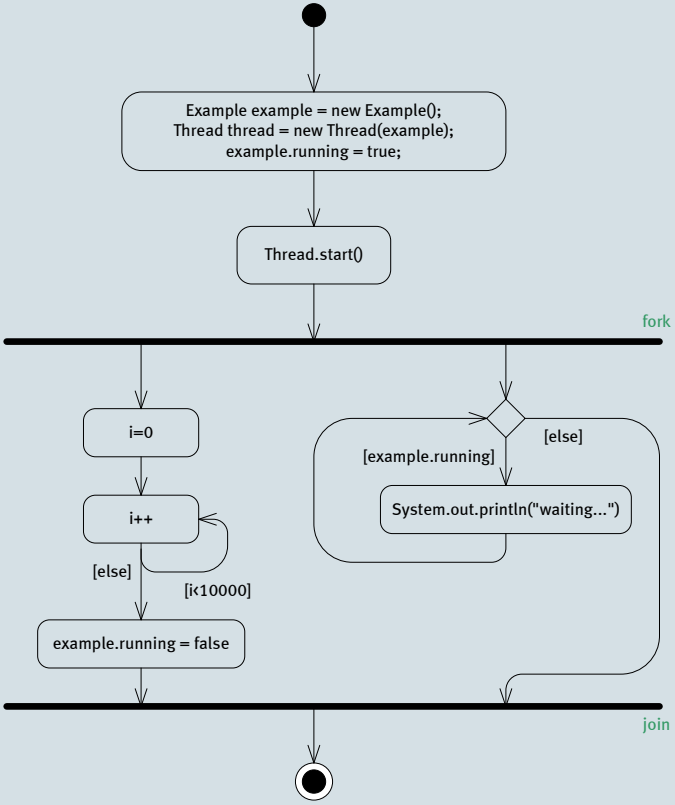
► UML 1.x Diagrams ► ♡ Activity Diagrams ► Process Flow

```
int i = 5;
int j = 2;
int k = i * j;

for(int n = 1; n < k + 1; n++) {
    System.out.println("Iteration #" + n);
}

try {
    int read = System.in.read();
} catch(IOException e) {
    System.err.println(e.getMessage());
}
```



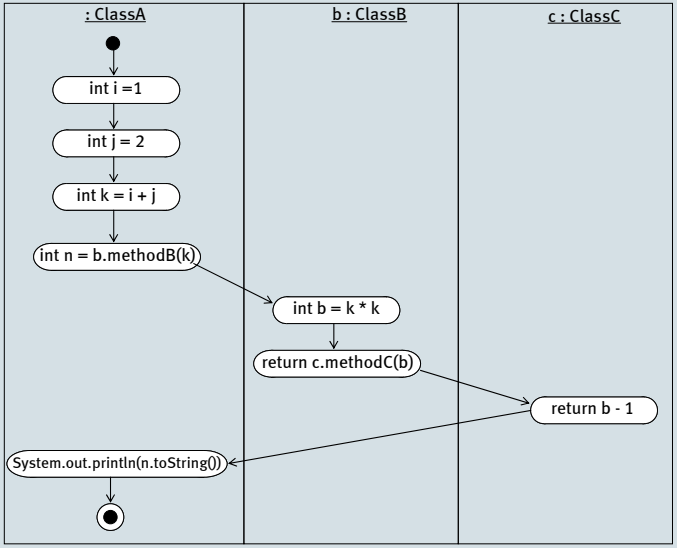
Concurrency

```
public class Example
    implements Runnable {

  private boolean running;

  public static void main(String[] args) {

    Example example = new Example();
    Thread thread = new Thread(example);
    example.running = true;
    thread.start();
    while (example.running) {
      System.out.println("waiting...");
    }
  }

  public void run() {
    for (int i = 1; i < 10000; i++) {}
    running = false;
  }
}
```



 ▶ UML 1.x Diagrams ▶ ♡ Activity Diagrams ▶ Swim lanes

```
public class ClassA{
  private ClassB b = new ClassB();

  public void methodA(){
    int i = 1;
    int j = 2;
    int k = i + j;

    int n = b.methodB(k);
    System.out.println(n.toString());
  }
}

public class ClassB{
  private ClassC c = new ClassC();

  public int methodB(int k){
    int b = k * k;
    return c.methodC(b);
  }
}

public class ClassC{
  public int methodC(int b){
    return b - 1;
  }
}
```

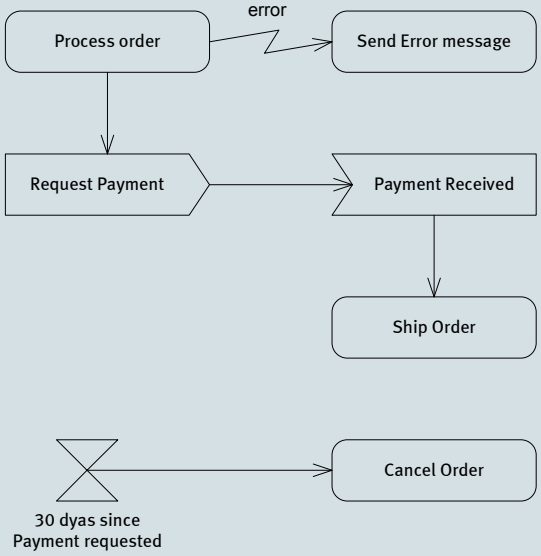


 Signals and Exceptions

- Signals

  Generating signals: sent to outside process (Request Payment at left).
  Accepting signals: received from outside process (Payment Received at left).
  Timer signals: received when time elapses or a set time arrives (30 days . . . at left).

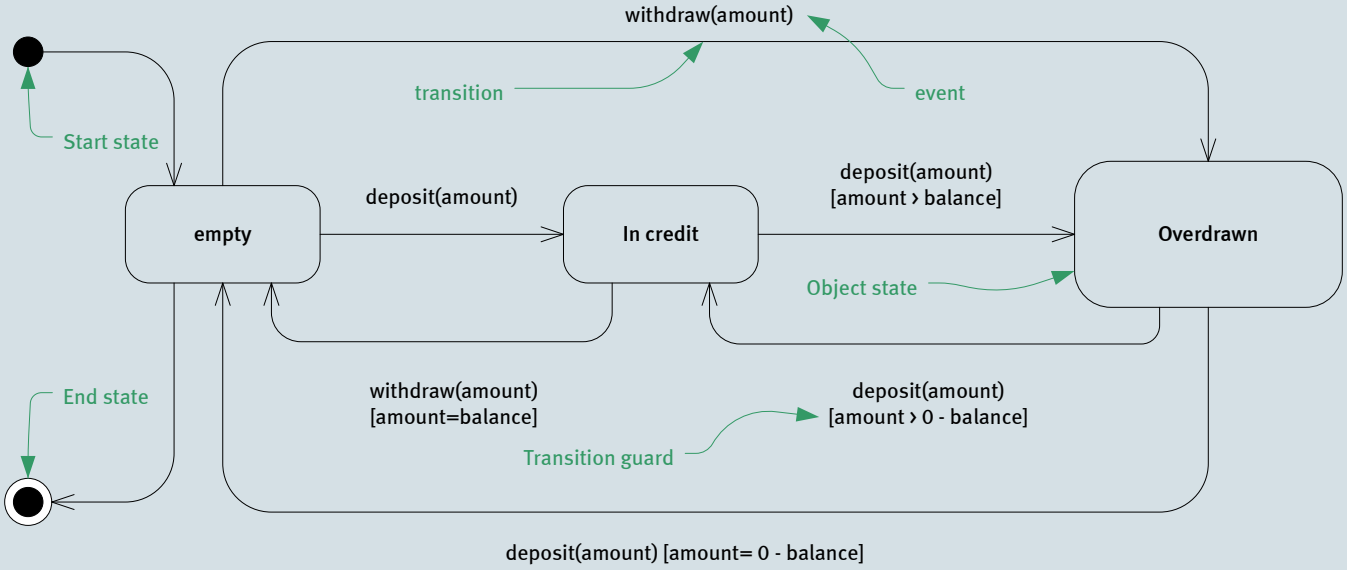
- Exceptions. Extraordinary errors that you typically don't detect with explicit tests are indicated with a "lightning bolt."



= State Machine Diagrams in UML 2.0

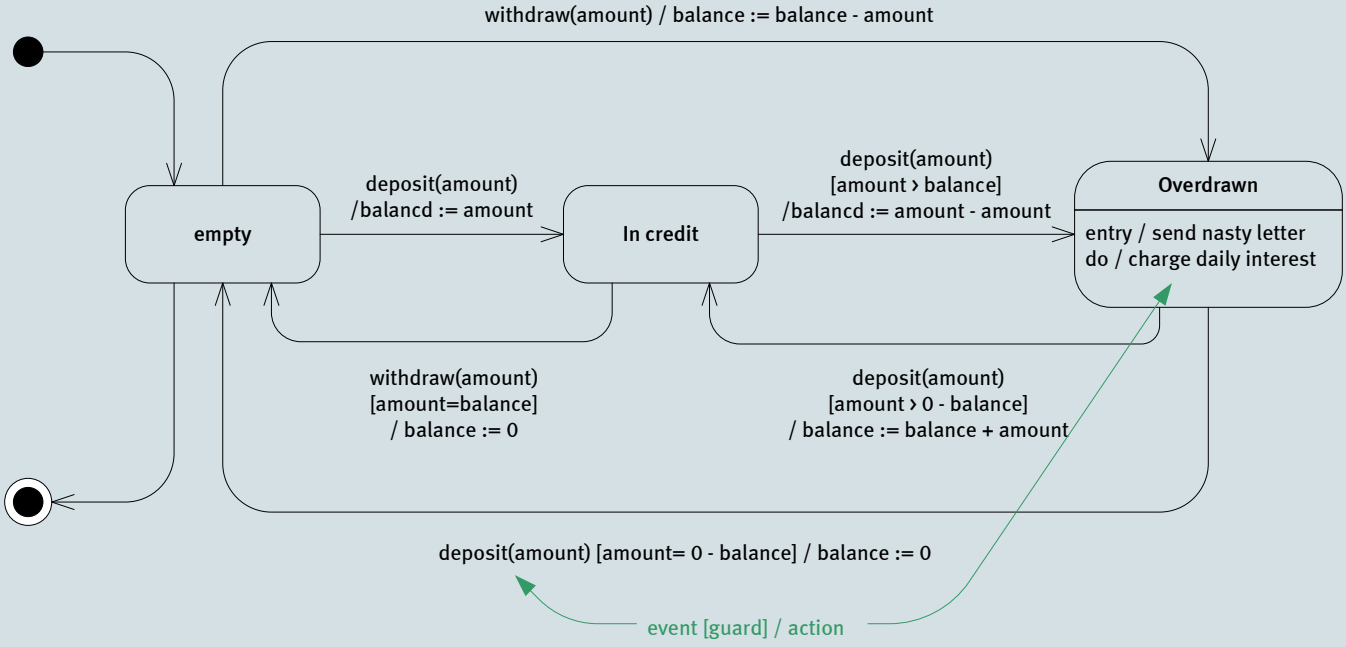
- State transitions
- Transitions and Actions
- Sub States & History States

State transitions

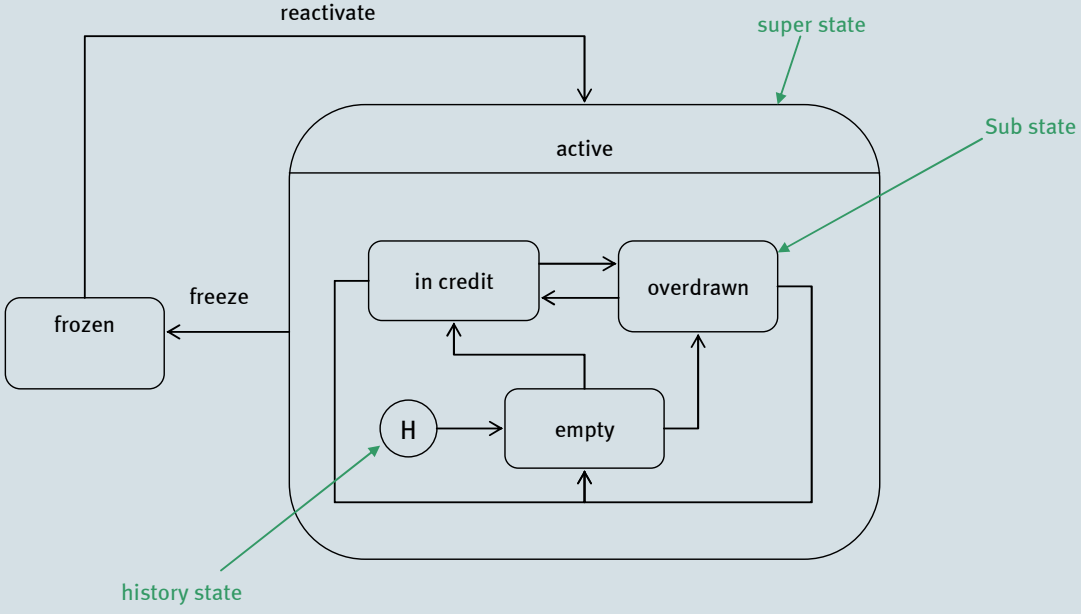


Account
Balance: float = 0
deposit(amount:float) withdraw(amount:float)

Transitions and Actions



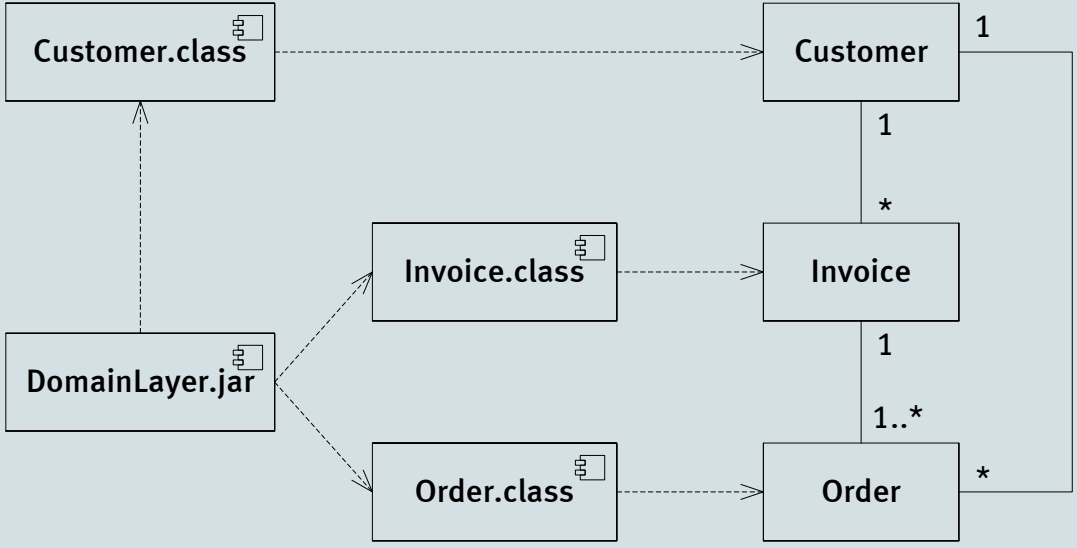
 # Sub States & History States



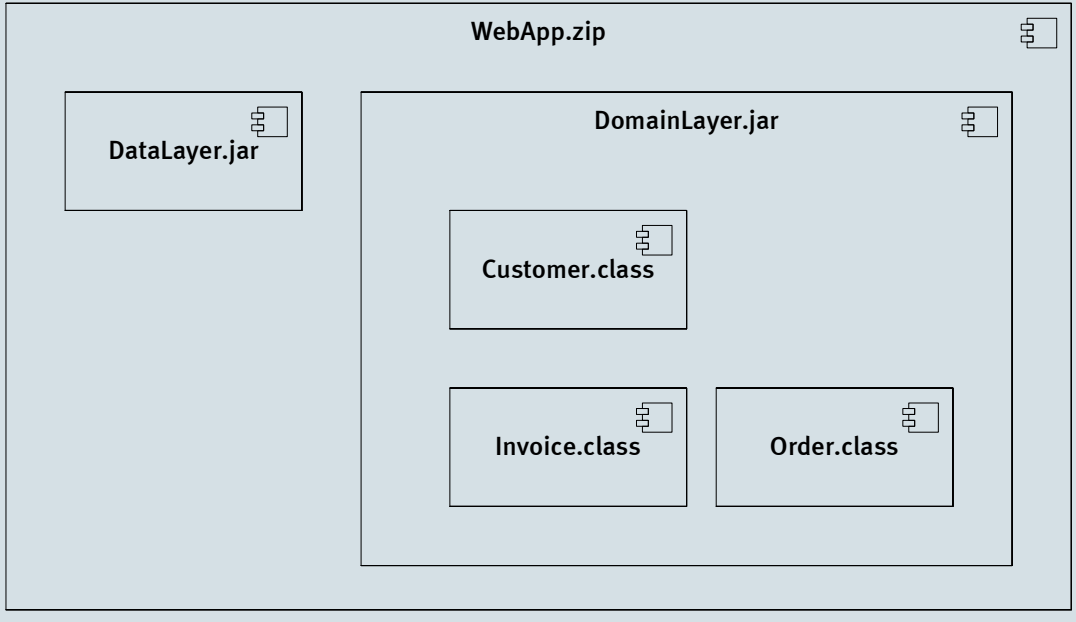
 Component Diagrams

- Components and Dependencies
- Components Can Contain Components

 Components and Dependencies

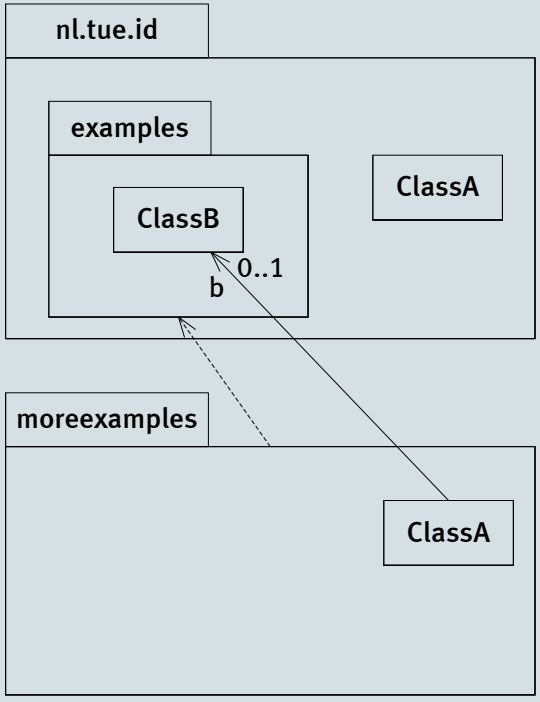


 Components Can Contain Components



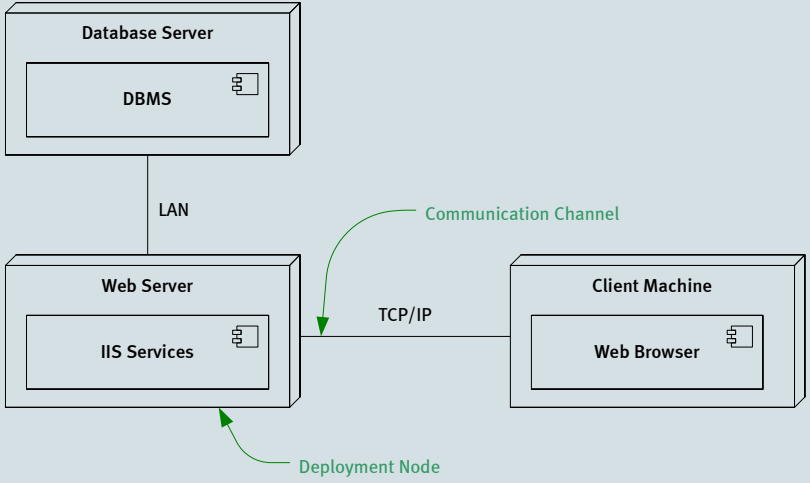
▶ UML 1.x Diagrams ▶ Package Diagrams

```
/*================================*/
package nl.tue.id;

class ClassA{
}

/*================================*/
package nl.tue.id.examples;

class ClassB{
}

/*================================*/
package moreexamples;

import nl.tue.id.examples.*;

class ClassA{
    private ClassB b;
}
```



▸ UML 1.x Diagrams ▸ Deployment Diagrams

We can use deployment diagrams to show how in the physical system components are deployed on different machines (called “nodes” in UML)



UML Views

- Use Case View
- Logical View
- Component View
- Concurrency View
- Deployment View

UML Views (2)

- Each view is a projection of the complete system
- Each view highlights particular aspects of the system
- Views are described by a number of diagrams
- No strict separation, so a diagram can be part of more than one view

UML Views (2)

- Each view is a projection of the complete system
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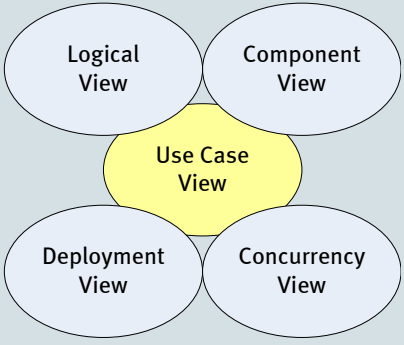
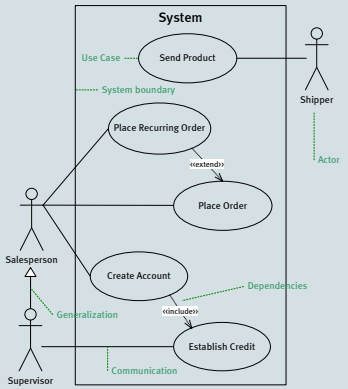
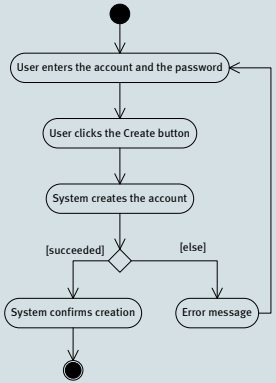


 Use Case View

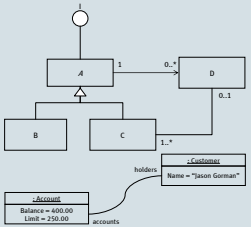
- Shows the functionality of the system as perceived by external actors.
- Actors can be users or other systems.
- Described by use case and activity diagrams.
- The central view which drives the development of other views.
- Used by customers, designers, developers, testers.

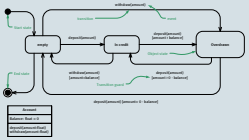


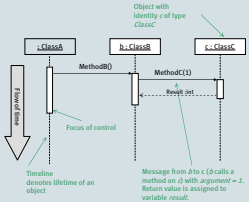


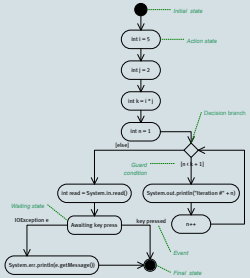
▸ UML Views ▸ Logical View

- Shows how the functionality of the system is designed / provided.
- Uses class and object diagrams to represent the static structure.
- Uses state, sequence, collaboration, and activity diagrams for dynamic behavior.
- Used by designers and developers.



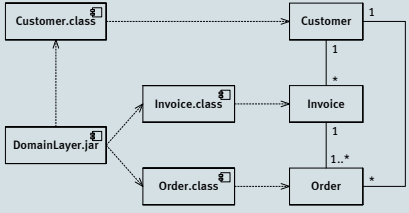


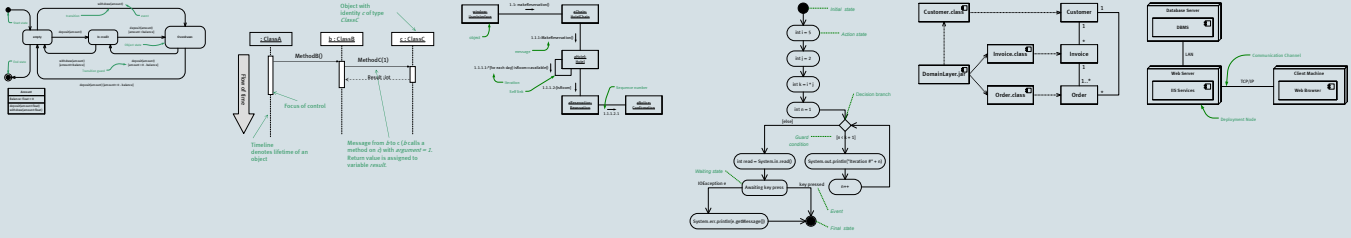




▶ UML Views ▶ Component View

- Shows the organization of the code components and their dependencies.
- Described by component diagrams.
- Used by developers.



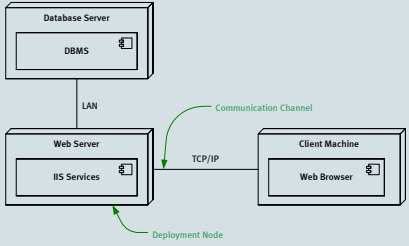


UML Views ▸ Concurrency View

- Addresses the problems with communication and synchronization for a concurrent system.
- Described by state, sequence, collaboration, activity, deployment, and component diagrams.
- Used by developers and system integrators.

 Deployment View

- Shows the deployment of the system into the physical architecture with computers and devices.
- Represented by the deployment diagram.
- Used by developers, system integrators, and testers.



Where to start?

Must:

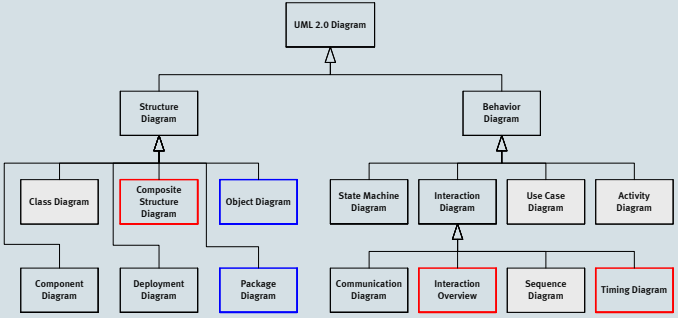
- User case diagrams
- Class diagrams
- Sequence diagrams
- Activity diagrams

Optional:

- Object diagrams
- State diagrams
- Collaboration diagrams

Gadgets:

- Component diagrams
- Deployment diagrams



Tools

- ***Microsoft*® *Visio*®** (with UML stencils), available as campus software.
- ArgoUML: open source software.
- IBM® Rational Rose®
- Borland® Together®
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- The last, the cheapest, the fastest, the most convenient tools are ...

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