OO concepts
UML representation

- Objects, Classes, Messages/Methods
- Inheritance, Polymorphism, Dynamic Binding
- Abstract Classes, Abstract Coupling

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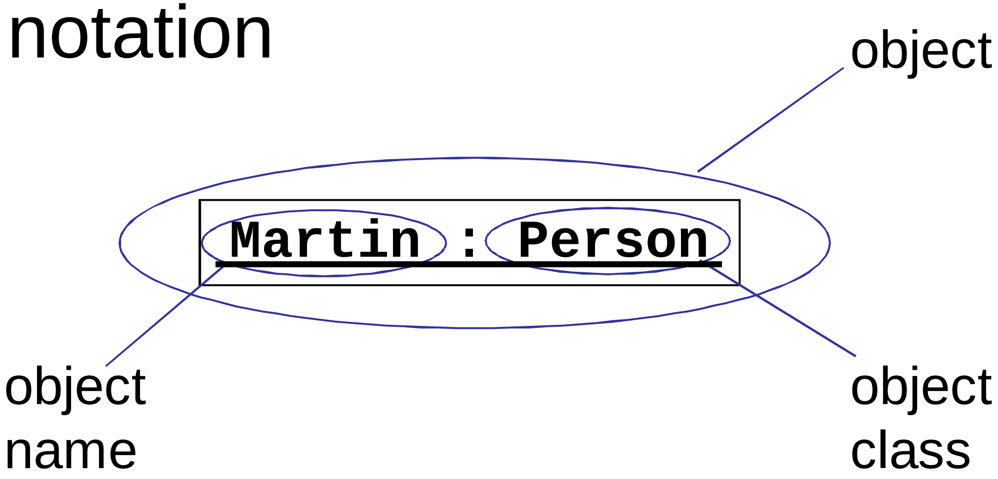
- Lecture notes at:

http://www.softwareresearch.net/index.php?id=220

Objects in UML

- Object notation



An object diagram provide a run time snapshot of the system, representing objects and the connections between them

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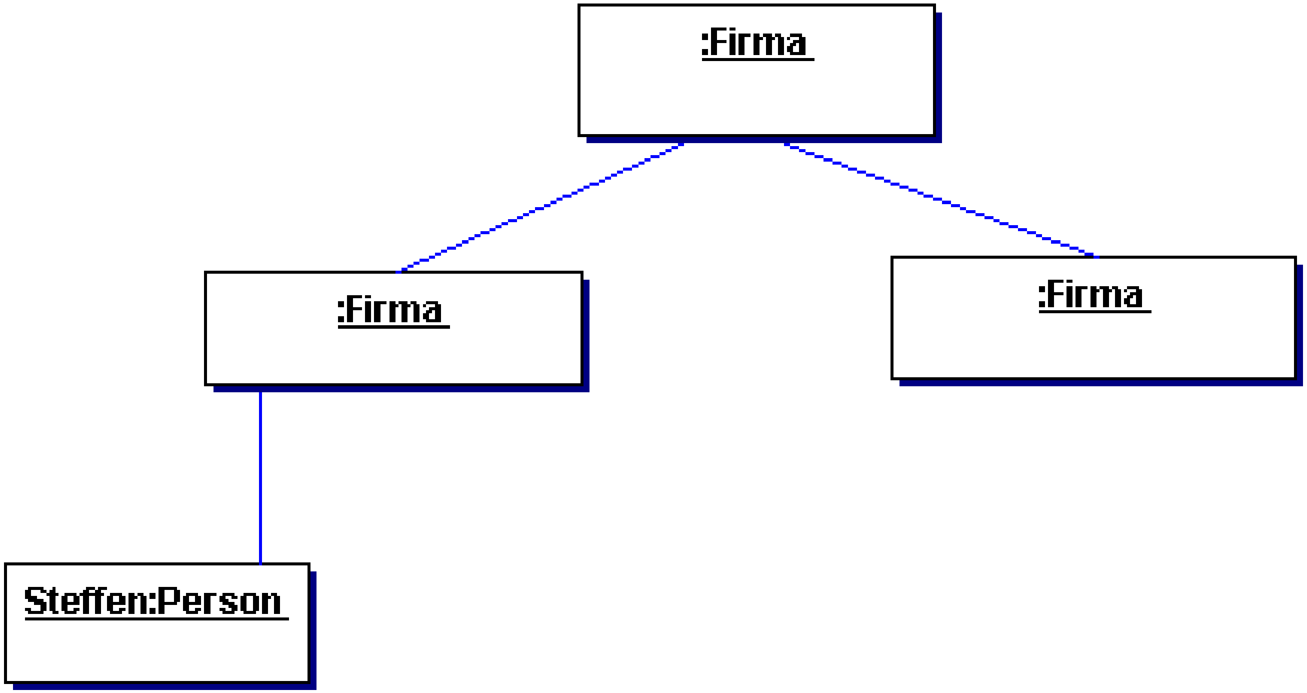
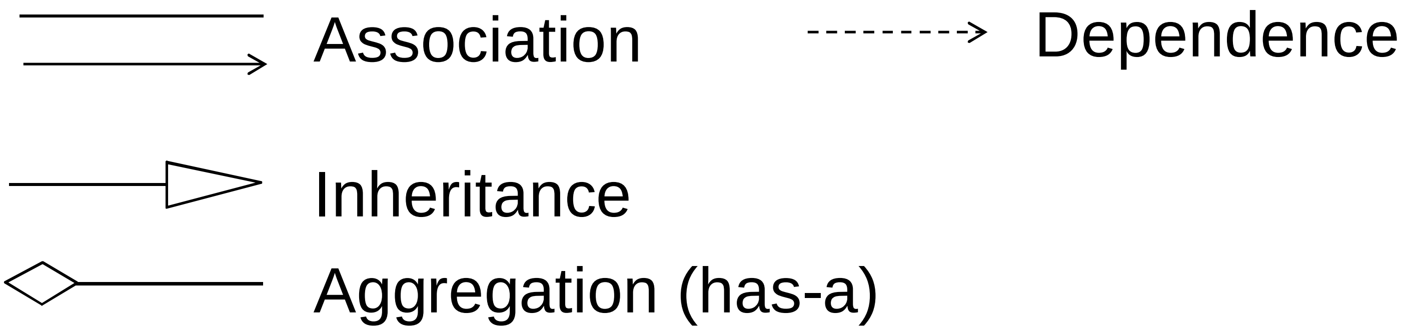
Object diagram



Class relationships (I)



Association

Dependence

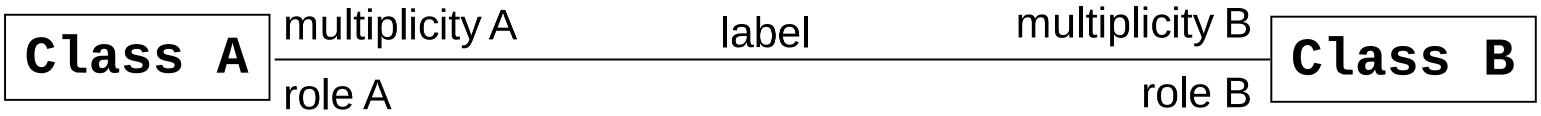
Inheritance

Aggregation (has-a)

An association can be refined by other relations

Often one models first only the fact that two classes are related and refines later this general notation element

Class relationships (II)



- Each association can be named with a text label (like in the ER-model)
- Role names can be specified at association ends
- Multiplicity can be marked at association ends
- A class can have an association with itself, expressing a relationship between objects of the same class

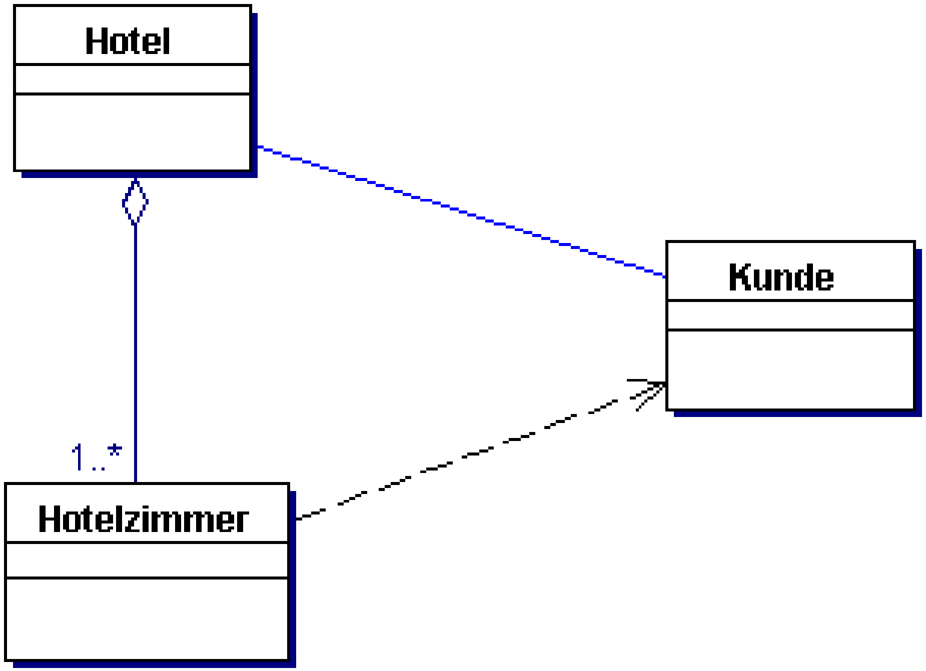
Class relationships (III)

Multiplicity specification:

1	exactly one
*	any (0 or more)
0..*	any (0 or more)
1..*	1 or more
0..1	0 or 1
2..5	range of values
1..5, 9	range of values or nine

Class relationships (IV)

Example:



Inheritance

Polymorphism

Dynamic Binding

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Inheritance (I)

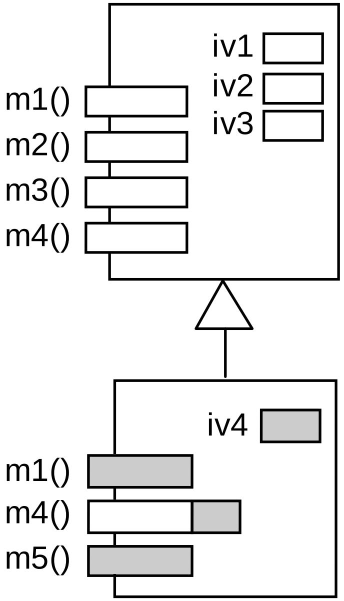
- A class defines the type of an object
- If one models for example a class **Customer** and a class **CorporateCustomer**, one expects that each object of type **CorporateCustomer** to be also of type **Customer**. The type **CorporateCustomer** is a subtype of **Customer**.

Inheritance (II)

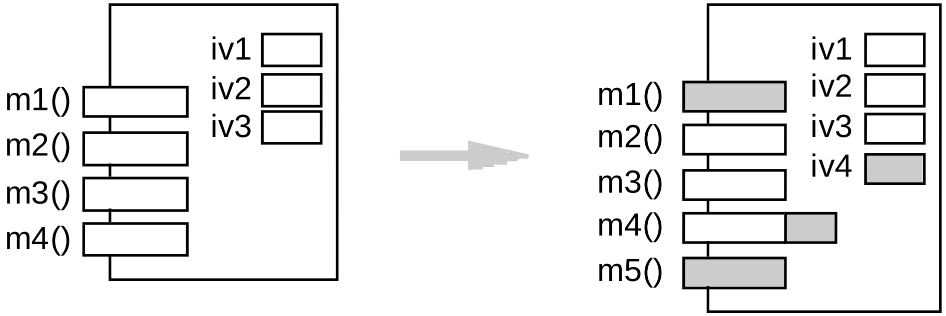
- A superclass generalizes a subclass
- A subclass specializes a superclass
- A subclass **inherits** methods and attributes of its superclass

Inheritance(III)

- A subclass has the following possibilities to specialize its behavior:
  - Defining new operations and attributes
  - Modifying existing operations (overwriting methods of the superclass)



Flatten view:



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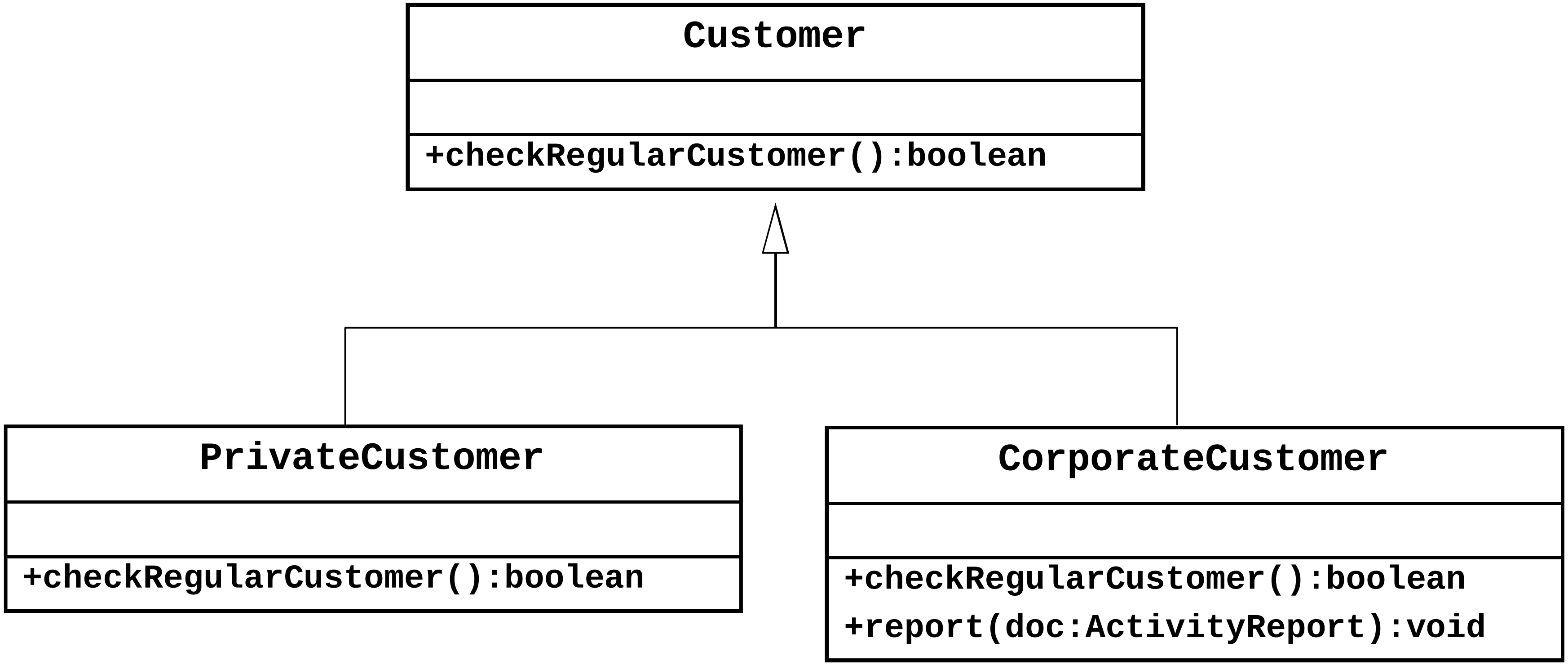
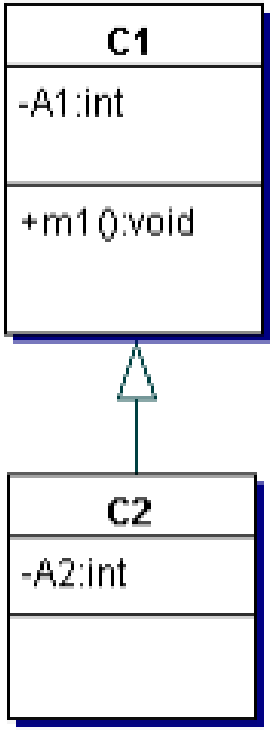
Inheritance (IV)

- UML Notation


Customer
+checkRegularCustomer():boolean
PrivateCustomer
+checkRegularCustomer():boolean
CorporateCustomer
+checkRegularCustomer():boolean
+report(doc:ActivityReport):void

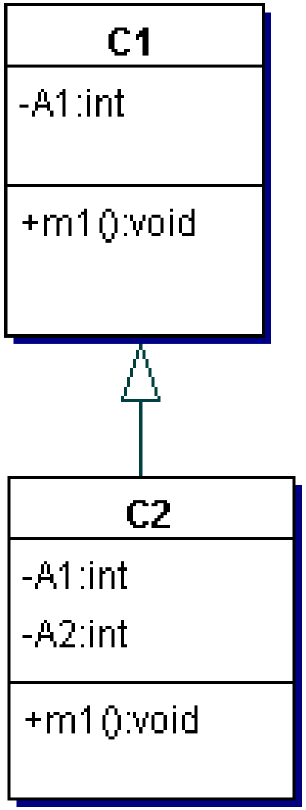
Inheritance (V)

„delta“ view



Flatten view

(not in standard UML!)



Inheritance and access rights

- Private members of a superclass are **not accessible** in subclasses
- Protected members of a superclass are accessible **only** in subclasses
- Public members are accessible **everywhere**
- Access rights can be specified globally for a superclass (C++):

```
class R : private A{ /* ... */ };
class S : protected A{ /* ... */ };
class T : public A{ /* ... */ };
```

Inheritance in Java

- Java supports single inheritance, where each class has at most one superclass
- The keyword is **`extends`**

Example:

```
public class CorporateCustomer extends Customer{
    ...
}
```

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Inheritance in C++

```
class Base {
  protected: int i;
};
class Derived : public Base {
  int f(Base* b) { return b->i; }
  int g(Derived* d) { return d->i; }
};
```

Inheritance

Polymorphism

Dynamic Binding

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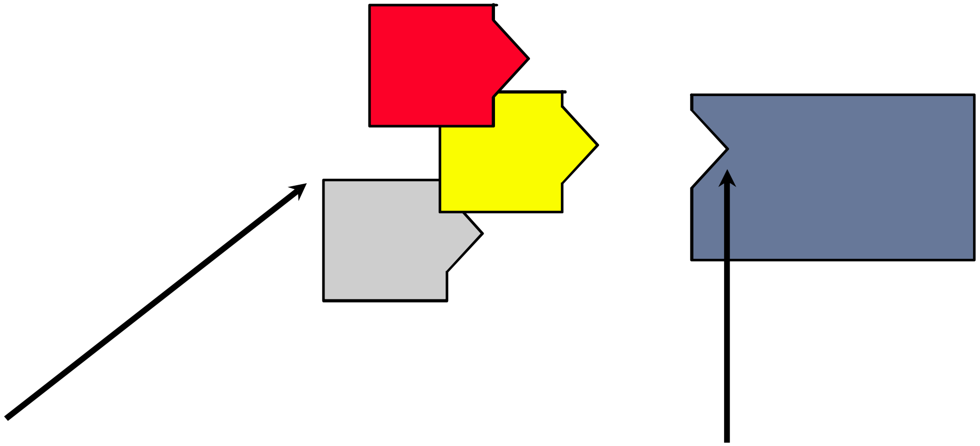
Polymorphism (I)

- An object type can be poly (=multiple) morph (=form). This can be depicted in the same way as plug-compatibility:



Objects compatible with the plug

„Plug“-Standard

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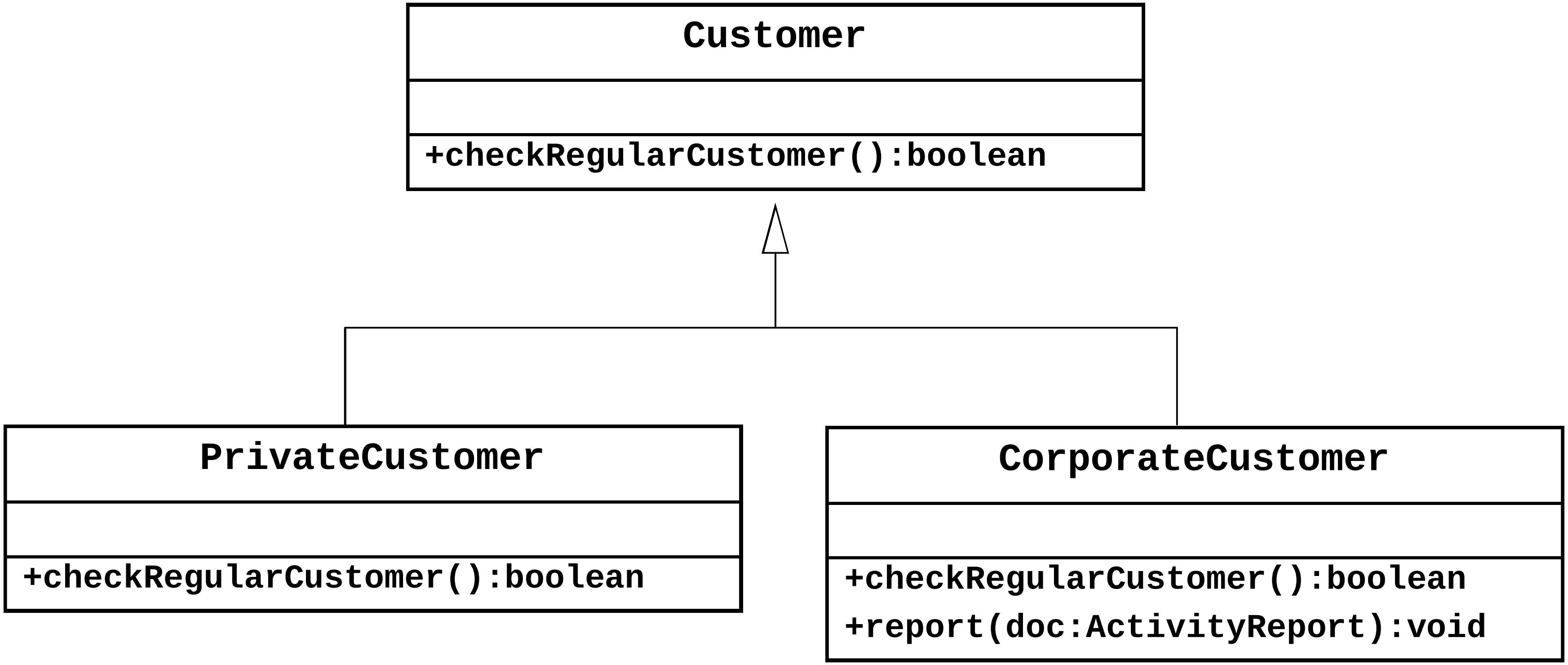
Inheritance example revisited



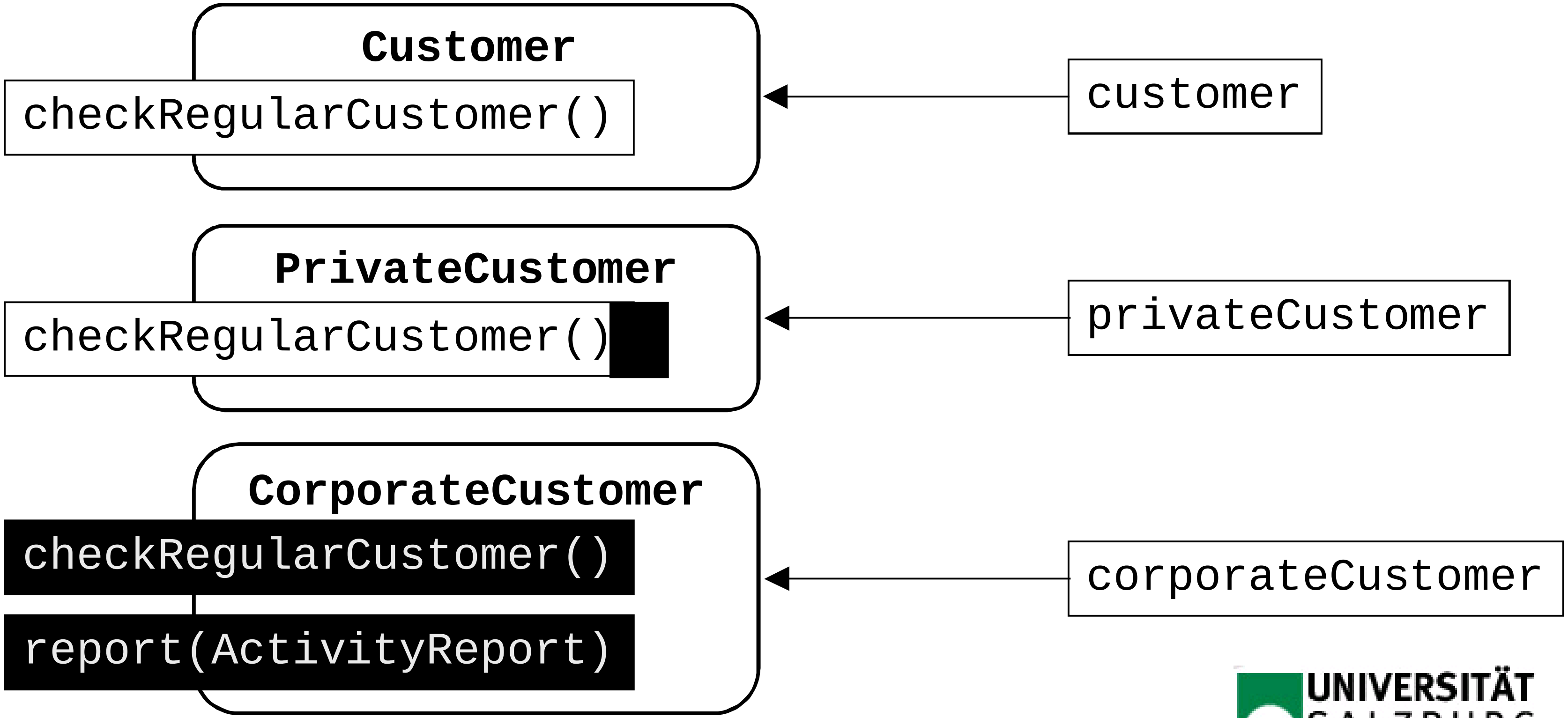
Customer
+checkRegularCustomer():boolean
PrivateCustomer
+checkRegularCustomer():boolean
CorporateCustomer
+checkRegularCustomer():boolean
+report(doc:ActivityReport):void

Polymorphism (II)

- Objects of type **CorporateCustomer** (subclass) keep at least the same contract as objects of type **Customer** (superclass).
- Therefore it is meaningful to consider that an object of class A_i, which is a subclass of class A, **is not only of type** A_i but also of the types given by all A_i‘s superclasses (starting with A).
- **An object has not only one type. It has multiple types**, and the number of types is given by the position of the class from which the object is generated in the class hierarchy.

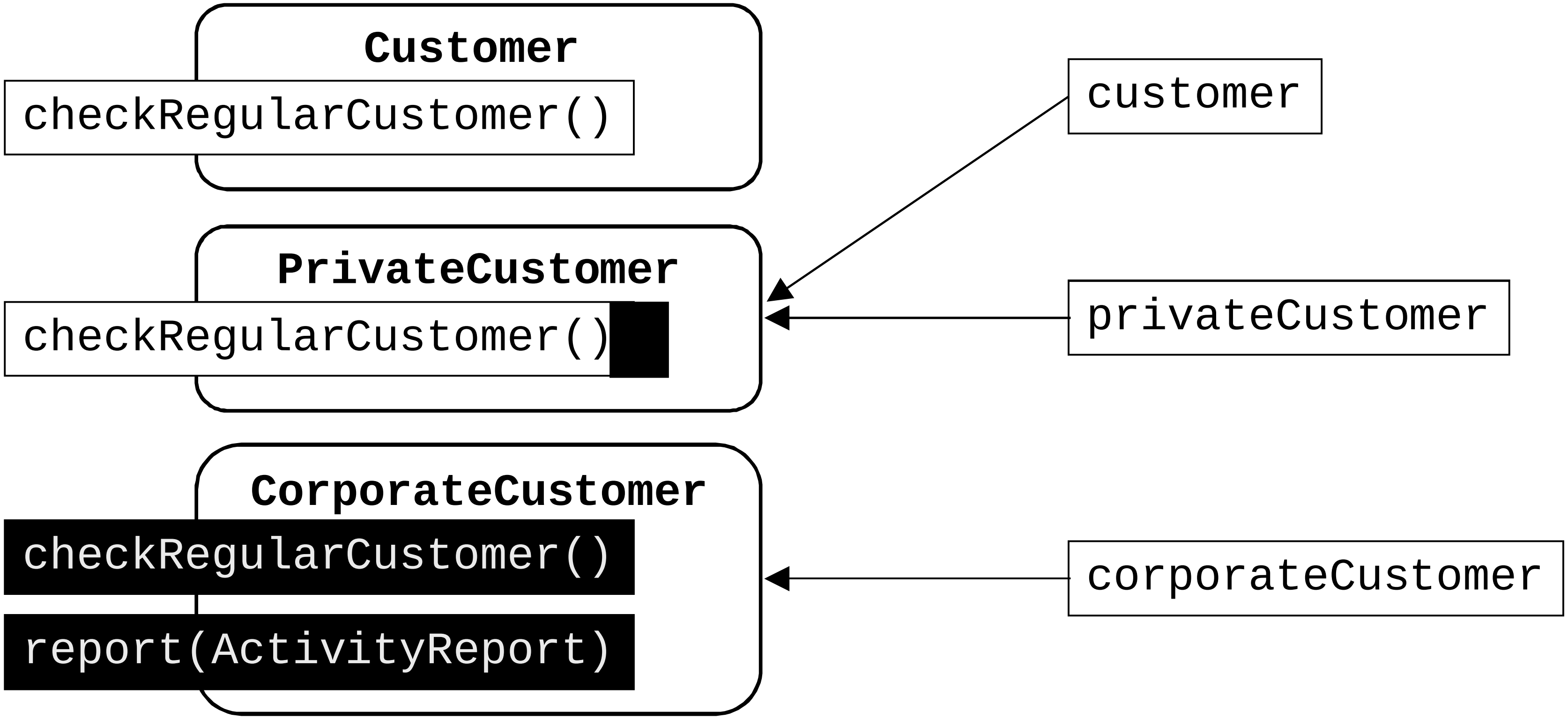
Polymorphism – Example (I)

```
Customer customer = new Customer();
PrivateCustomer privateCustomer = new PrivateCustomer();
CorporateCustomer corporateCustomer= new CorporateCustomer();
```



Polymorphism – Example (II)

customer = privateCustomer; // OK



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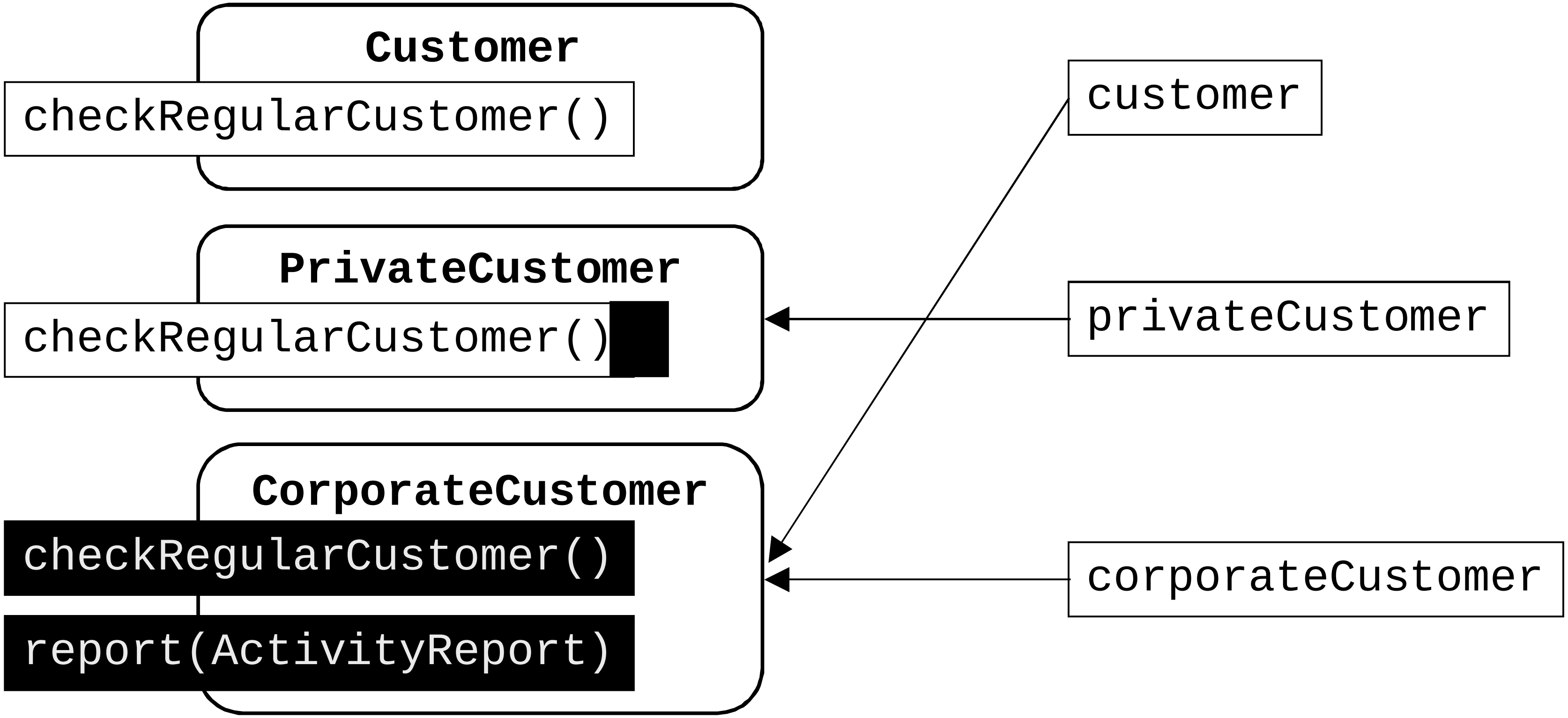
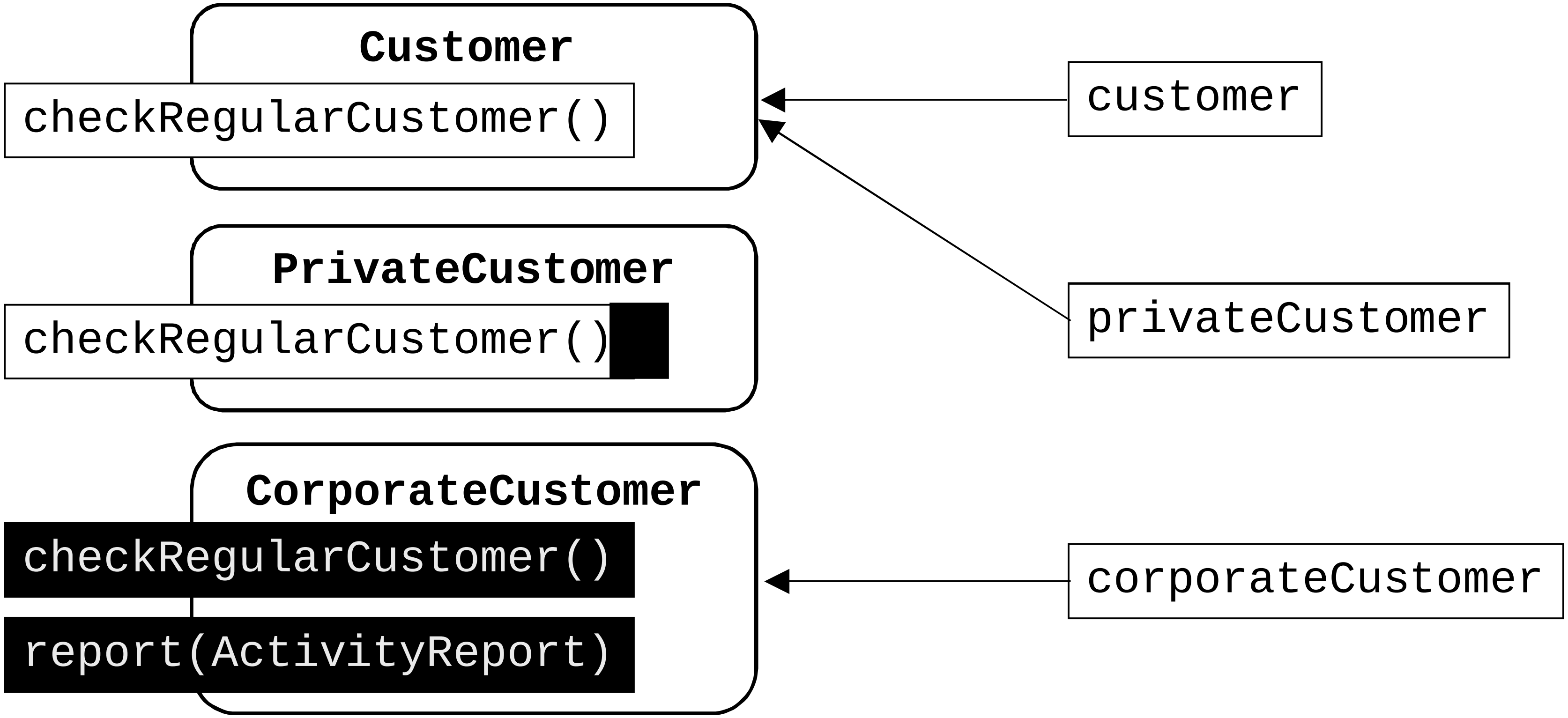
Polymorphism – Example (III)

customer = corporateCustomer;   // OK



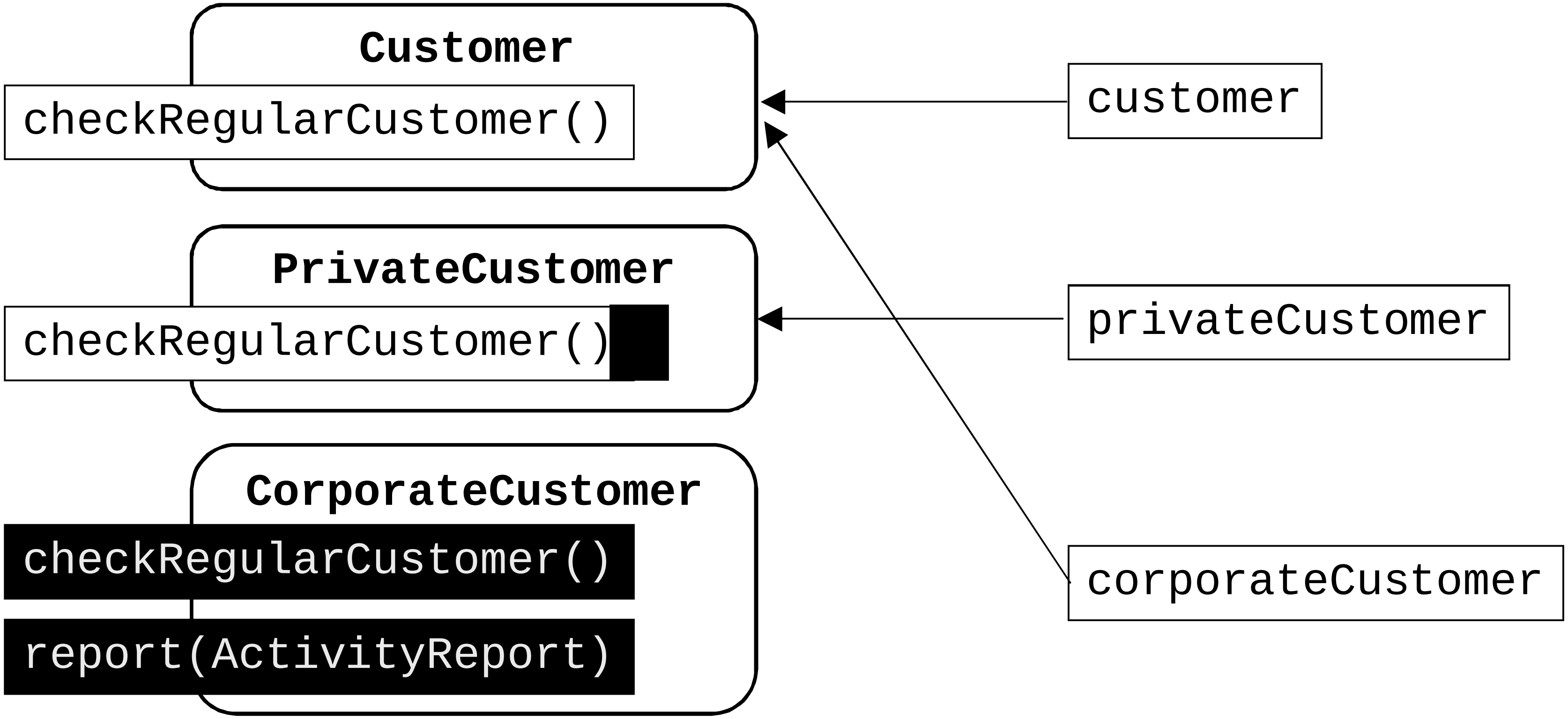
Polymorphism – Example (IV)

privateCustomer = customer;   // wrong



Polymorphism – Example (V)

corporateCustomer = customer;   // wrong



Polymorphism – Example (VI)

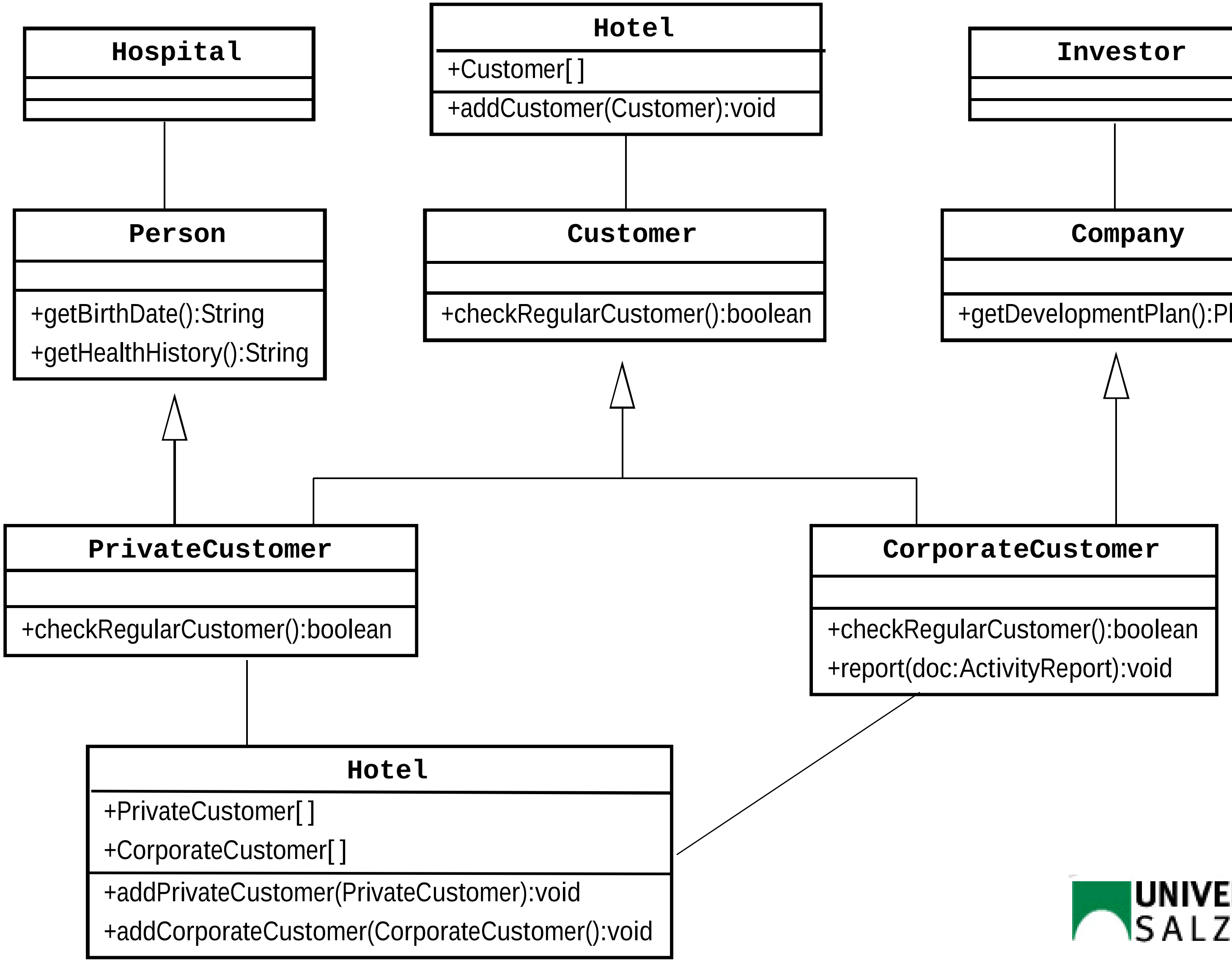
- The reason for failure is that an object which is an instance of class `Customer` does not understand all method calls that an object which is an instance of class `CorporateCustomer` understands.

```
(1) corporateCustomer = customer;
(2) corporateCustomer.report(monthlyReport);
```

(1) Type mismatch: cannot convert from `CorporateCustomer` to `Customer`

(2) The method `report(activityReport)` is undefined for the type `Customer`.

Polymorphism – Example (VII)


Hospital
Hotel
+Customer[ ]
+addCustomer(Customer):void
Investor
Person
+getBirthDate():String
+getHealthHistory():String
Customer
+checkRegularCustomer():boolean
Company
+getDevelopmentPlan():Plan
PrivateCustomer
+checkRegularCustomer():boolean
CorporateCustomer
+checkRegularCustomer():boolean
+report(doc:ActivityReport):void
Hotel
+PrivateCustomer[ ]
+CorporateCustomer[ ]
+addPrivateCustomer(PrivateCustomer):void
+addCorporateCustomer(CorporateCustomer():void

Static and dynamic type

- Static type
  - Accurately given by the declaration in the program text
  - Example: **`customer`** is of static type **`Customer`**

- Dynamic type
  - The type of the referenced object at runtime
  - Example: after **`customer=corporateCustomer`**, the dynamic type of **`customer`** is **`CorporateCustomer`**

- A variable with a static type can have several dynamic types during its lifetime, depending of the width and depth of the class hierarchy

Dynamic binding (I)

Dynamic binding: The compiler **does not specify which method is called at runtime .** The method is determined at runtime based on

- The method name
- The variable‘s dynamic type

```
Customer c;
if (i > 0) then
      c = new CorporateCustomer();
else
      c = new PrivateCustomer();
...
c.checkRegularCustomer();
```

Dynamic binding (II)

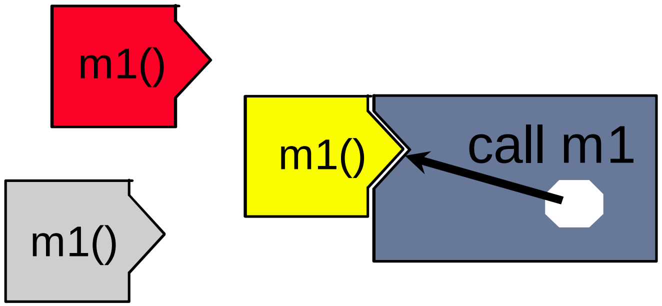
When **`(i > 0)`** is true, the variable **`c`** references an object generated from the class **`CorporateCustomer`** (and thus has the dynamic type **`CorporateCustomer`**). Hence, the call to **`checkRegularCustomer()`** is linked to the method as implemented in **`CorporateCustomer`**.

- In Java, all methods are dynamically bound, except for the ones explicitly marked by using the keyword **`static`**.
- In C++, by contrast, methods must be explicitly marked as dynamically bound by using the keyword **`virtual`**.

Dynamic binding (III)

Dynamic binding can be used for the plug-in concept

For example, the yellow object may implement m1() differently than the red object



Inheritance exercise

```
public class BaseTest {

    protected int protMember;

    BaseTest(int i){
        protMember = i;
    }
}
```

```
public class DerivedB extends BaseTest {

    DerivedB(int i) {
        super(i);
    }
}
```

```
public class DerivedA extends BaseTest{

    DerivedA(int i) {
        super(i);
    }

    public void printProt(BaseTest bt){
        System.out.println("Value in base class is " + bt.protMember);
    }

    public void printProt(DerivedB db){
        System.out.println("Value in derived class is " + db.protMember);
    }
}
```

```
public class Worker {

    DerivedA da;
    DerivedB db;
    BaseTest bt;

    public void work(){
        db = new DerivedB(2);
        da = new DerivedA(1);
        da.printProt(db);
        bt = db;
        da.printProt(bt);
    }

    public static void main(String[] args) {
        Worker wk = new Worker();
        wk.work();
    }
}
```

Inheritance exercise

```
public class BaseTest {

    protected static int protMember;

    BaseTest(int i){
        protMember = i;
    }
}
```

```
public class DerivedB extends BaseTest {

    DerivedB(int i) {
        super(i);
    }
}
```

```
public class DerivedA extends BaseTest{

    DerivedA(int i) {
        super(i);
    }

    public void printProt(BaseTest bt){
        System.out.println("Value in base class is " + bt.protMember);
    }

    public void printProt(DerivedB db){
        System.out.println("Value in derived class is " + db.protMember);
    }
}
```

```
public class Worker {

    DerivedA da;
    DerivedB db;
    BaseTest bt;

    public void work(){
        db = new DerivedB(2);
        da = new DerivedA(1);
        da.printProt(db);
        bt = db;
        da.printProt(bt);
    }

    public static void main(String[] args) {
        Worker wk = new Worker();
        wk.work();
    }
}
```

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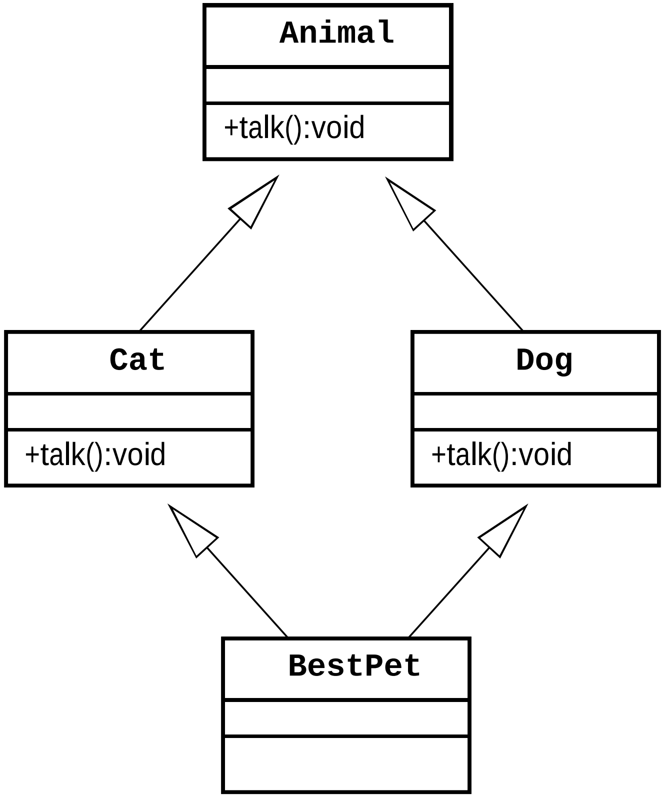
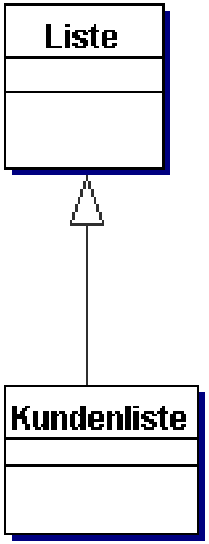
The diamond problem

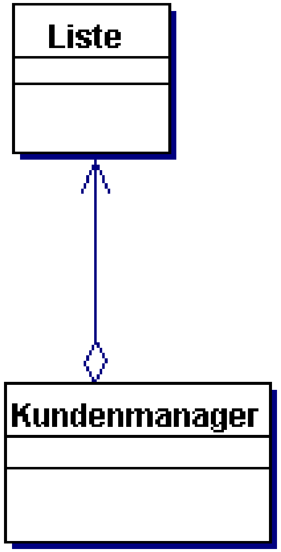
```
Animal myPet = new BestPet();
myPet.talk();
```

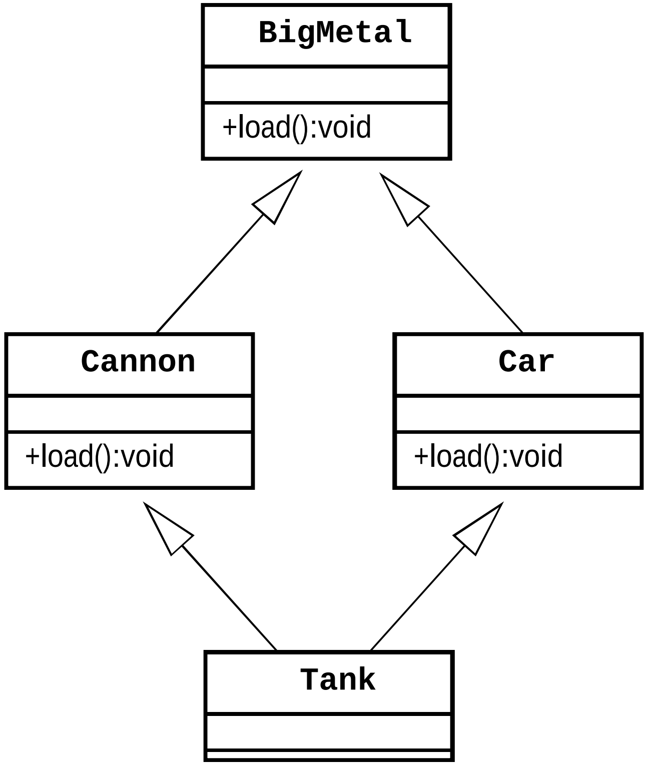
This problem does not occur in Java



Is-A and Has-A







Typical error: Is-A instead of Has-A

Type test and type guard in Java

- **Type test:** Inquiry of the dynamic type
- **Type guard:** runtime checking of type casting

Example:

```
if(customer instanceof CorporateCustomer){          // test
   CorporateCustomer corpCust = (CorporateCustomer)customer; //guard
   ...
}

if(customer instanceof CorporateCustomer)
   ((CorporateCustomer)customer).report(monthlyReport);
```

Understanding Interactions Between Objects

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Object Game

Play a hotel room reservation scenario