Basics of programming 3

Java and UML

Steps of SW development

- Requirements
  - goal: defining what is expected
- Analysis
  - goal: understanding problem domain
- Design
  - goal: closing on implementation decisions
- Implementation
  - goal: creating formal, machine language description
- Testing
  - goal: assessing adherence to requirements

Models in SW development

- Analysis
  - focus on responsibilities and interactions
    - public method are defined
    - attributes (if any) only specify responsibility
- Design
  - focus on internal structures
    - protected, package, private members
    - high-level structures (e.g. list, set) concretized
- Implementation
  - programming language constraints considered
    - implementation decisions only

Modelling

- High level description
  - details are neglected on purpose
    - essence of good modelling: what is relevant?
    - flexibility and universality are important
  - must maintain abstraction level
    - don’t dive into details
    - knowing capabilities is still a must
- Formal language is needed
  - to understand each other
  - to understand past self

OO concepts in modelling

- Objects and classes
  - static and dynamic views
  - class level and object level views
- Types (“dumb objects”)
  - primitive and complex
  - abstraction is needed
- Associations and Inheritance
  - connections have abstraction level too

Static and dynamic views

- Static view
  - all or relevant components and their relationships
  - describes all kinds of connections
    - temporary connection (dependency)
    - constant (association, aggregation, inheritance, etc)
    - instance or class level
- Dynamic view
  - temporal behaviour of components
- Views are related
  - must be consistent

Modelling attributes (types)

- Abstract types
  - name
  - address
  - age
  - coordinates
  - …
- Java types
  - String name
  - class Address
  - int age
  - class Coord
- C++ types
  - char* (string) name
  - struct (class) address
  - int age
  - struct coord

Modelling attributes (types)

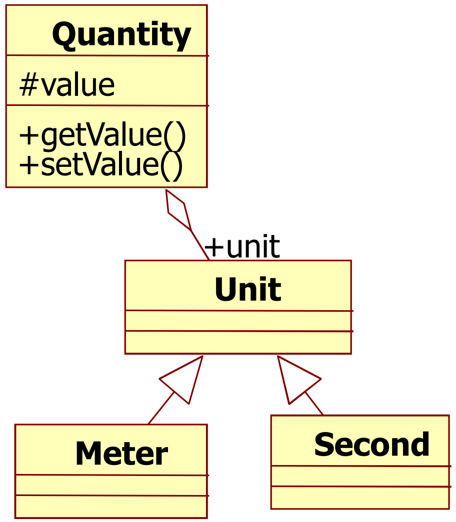
- Keep abstraction level high
  - e.g. use coordinates as type, not class
- Hide attributes
  - private or protected
  - use getter/setter methods for access
    - enables additional behaviour
- Type representation should be shy
  - should only consider internal consistency

Visibility in UML, Java and C++

- Similar concepts with small differences
  - private (-)
    - access for defining class only
  - package (~)
    - not in C++ (namespaces have “public” visibility)
    - no explicit notation in Java, access for package members
  - protected (#)
    - access for subclasses
    - in Java access for package members
  - public (+)
    - access for everybody

Handling Units

- Classic approach
  - implicit units
    - e.g. `double speed // [m/s]`
    - good documentation is needed (c.f. mars probe)
    - even in API: `Thread.sleep(long)`
- Sophisticated approach
  - explicit units
  - helps conversion, logging, etc
  - might be overkill



Associations between classes

- Dependency
  - temporal, lasts a single method call
- Association
  - long term, lasts multiple method calls
  - reference is stored
- Aggregation / Composition
  - life long
  - lifecycle management is needed

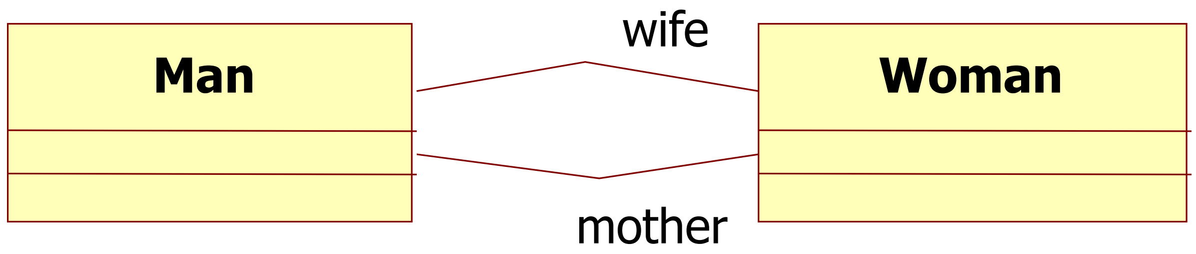
Dependency

- Notation
  - dashed line - - - - - - - - - ->
- In Java
  - method parameter or return value
  - methods doesn’t remember reference
- In C++
  - method parameter or return value
  - pointer, reference?
    - pointer params need life cycle hints (orphan, adopt)

Association

- Notation
  - solid line
  - arrows and crosses show navigability
- In Java
  - Storing reference
  - Lifecycle is taken care of by GC
- In C++
  - Storing pointer to object
  - Lifecycle is taken care of by others
    - no delete in destructor

Association

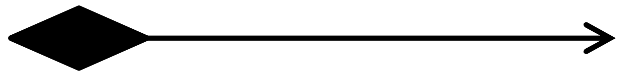



```
// JAVA
class Woman {}
class Man {
   Woman wife;
   Woman mother;
}
```

```
// C++
class Woman {}
class Man {
    Woman* wife;
    Woman& mother;
  public:
    ~Man() {}
}
```

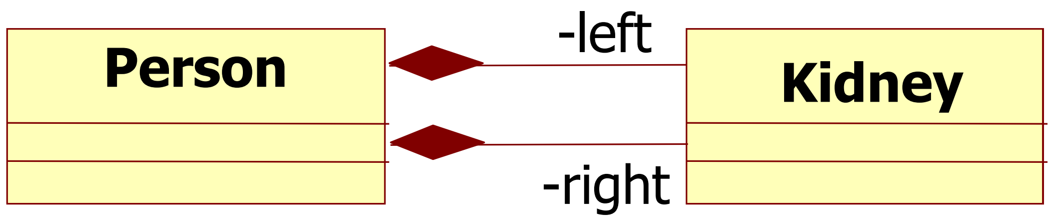
Aggregation / Composition

- Notation
  - solid line with diamond



- In Java
  - Storing reference
  - Lifecycle is taken care of by GC
- In C++
  - Storing pointer to object
    - Lifecycle must be taken care of
      - delete in destructor
  - Storing object directly

Aggregation / Composition




```
// JAVA
class Kidney {}
class Person {
  Kidney left;
  Kidney right;
}
```

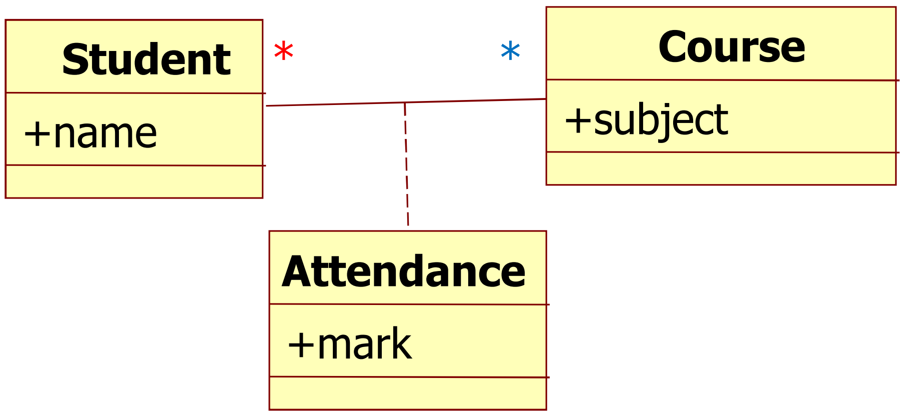
```
// C++
class Kidney {}
class Person {
   Kidney* left;
   Kidney  right;
  public:
   ~Y() {delete left;}
}
```

Association vs Aggregation

- Memory handling differ in implementations
  - pointers in C++
    - delete is needed somewhere ☹
  - references in Java
    - GC is our friend ☺
- Association vs. Aggregation
  - Java: no difference on code level
    - analysis and design concepts reduced
  - C++: difference in life cycle management
    - maintains analysis and design decisions

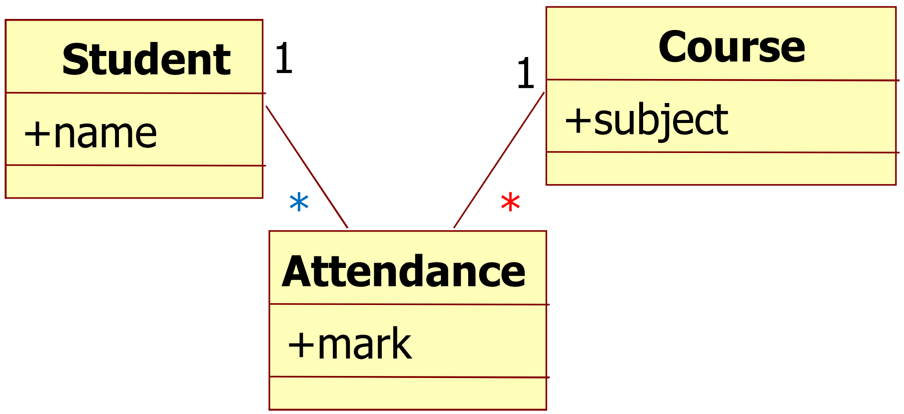
Association class

- Represents responsibilities of an association
  - not assignable to any party
  - *e.g. Student attends Course*
  - analysis level, OO languages usually do not support it



Association class

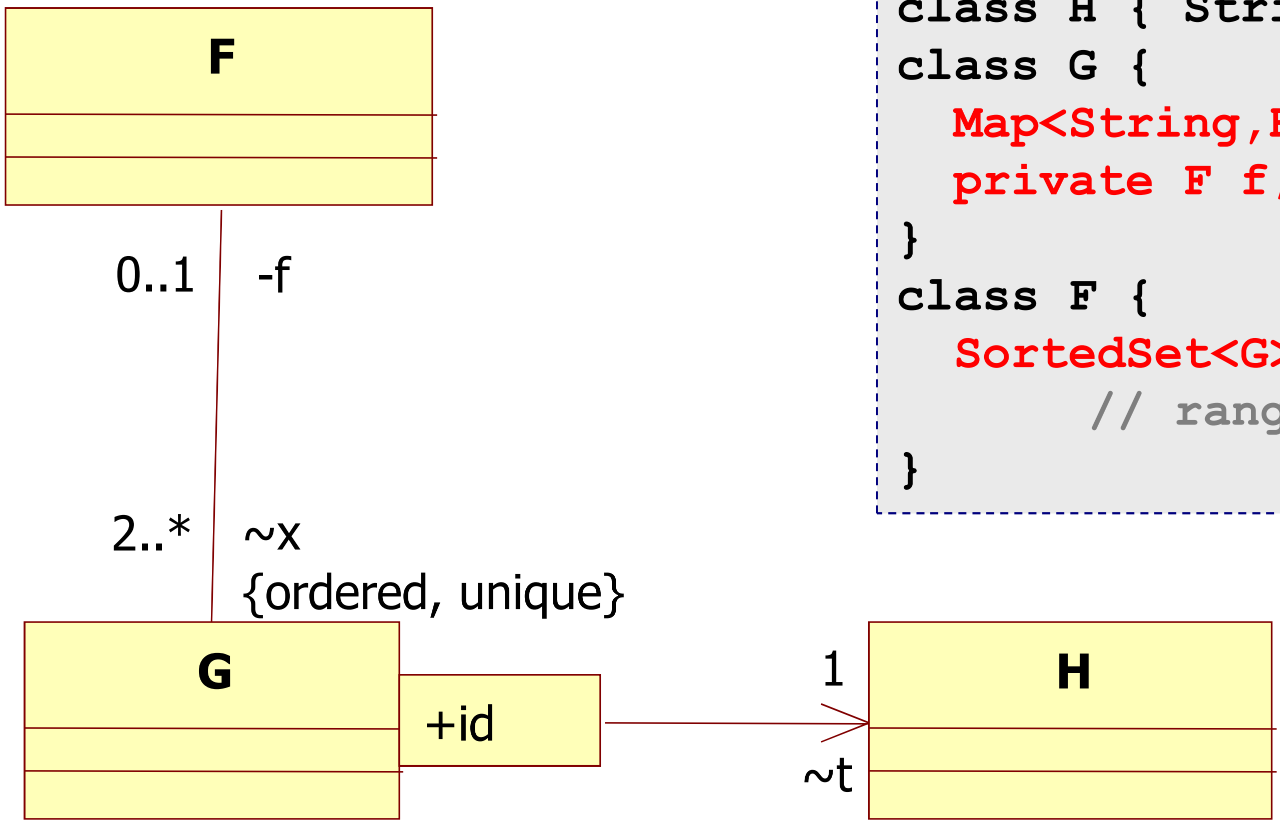
- Design and implementation
  - join class
  - 1-n multiplicity on Association class



Associations' attributes

- Cardinality (multiplicity)
  - ordinal: 1 — *reference*
  - optional: 0..1 — *reference*
  - range: 2..5 — *collection (range check?)*
  - unlimited: * — *collection*
- Qualifier — *associative array (map, etc)*
- Other
  - unique — *set*
  - ordered — *list*

Associations' attributes



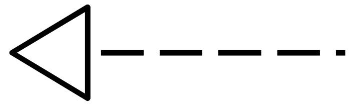

```java
// JAVA
class H { String id; }
class G {
  Map<String,H> t;
  private F f;
}
class F {
  SortedSet<G> x;
        // range check?
}
```

Inheritance

- Notation
  - solid line with triangle

- Java
  - single inheritance between classes
  - public inheritance only
- C++
  - multiple inheritance
    - virtual inheritance
  - public and private inheritance
    - in UML, for private use stereotypes

Interfaces

- Notation
  - stereotype <<interface>>
    - implementation: dashed line with triangle 
  - lollipop 
- Java
  - separate meta-type
  - multiple inheritance for interfaces
- C++
  - no separate meta-type
    - all methods pure virtual

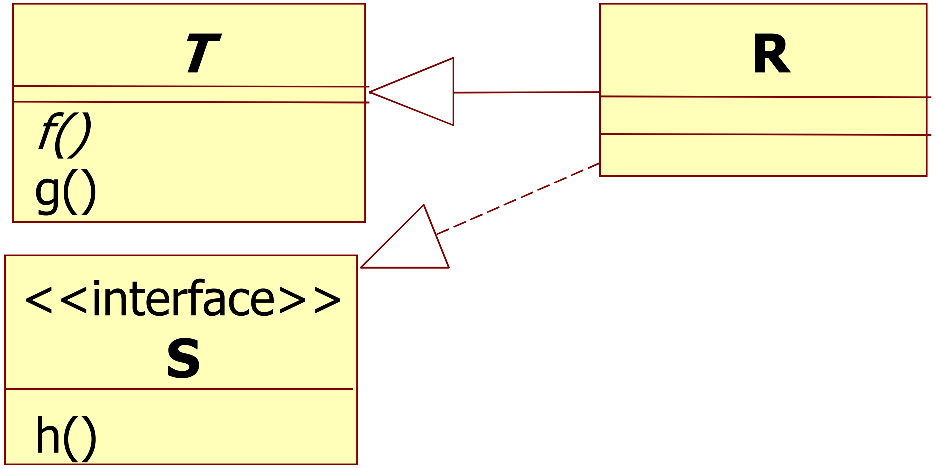
Abstract classes vs. Interfaces

- Interfaces
  - method signatures only
  - use when
    - implementations might vary, but are out of scope
    - access of functionality must be separated
- Abstract classes
  - might contain code
  - use when
    - default implementation is needed in superclass
    - hook methods are needed in subclasses

Abstract classes vs. Interfaces

- UML
  - abstract class (method): name in *italic*
  - interface: stereotype `<<interface>>` or lollipop
- Java
  - separate meta-types for abstract and interface
  - multiple inheritance for interfaces
    - separate expected functionality with interfaces
- C++
  - no explicit abstract or interface type
  - pure virtual methods, no distinction

Abstract classes and interfaces



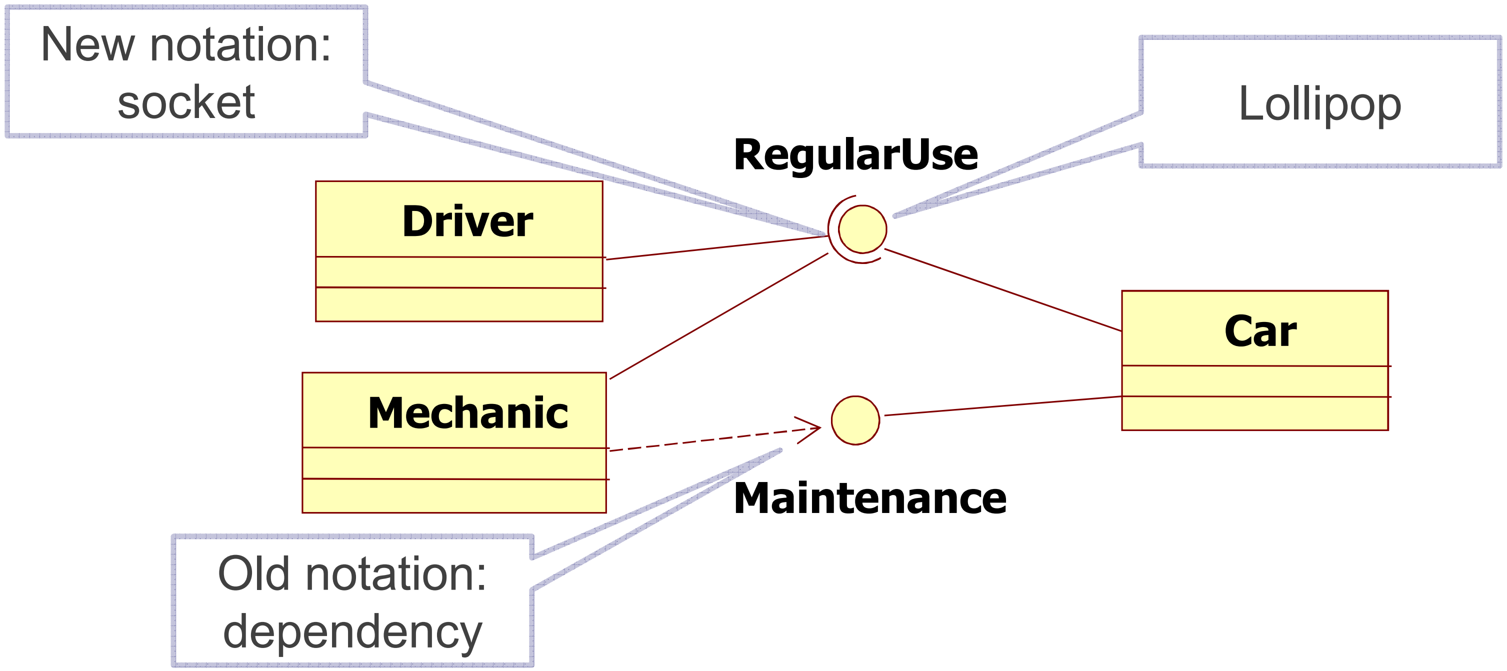
Visibility is omitted!

```
// JAVA
abstract class T {
  abstract void f();
  void g() { ... }
}
interface S { void h(); }
class R extends T
    implements S {...}
```

```
// C++
class T {
   virtual void f() = 0;
   void g() { ... }
}
class S {
   virtual void h() = 0;
}
class R : public T,
          public S {...}
```

Interface for separating access

- Car is accessed differently by people
  - driver must not maintain car ☹



Interface for separating access

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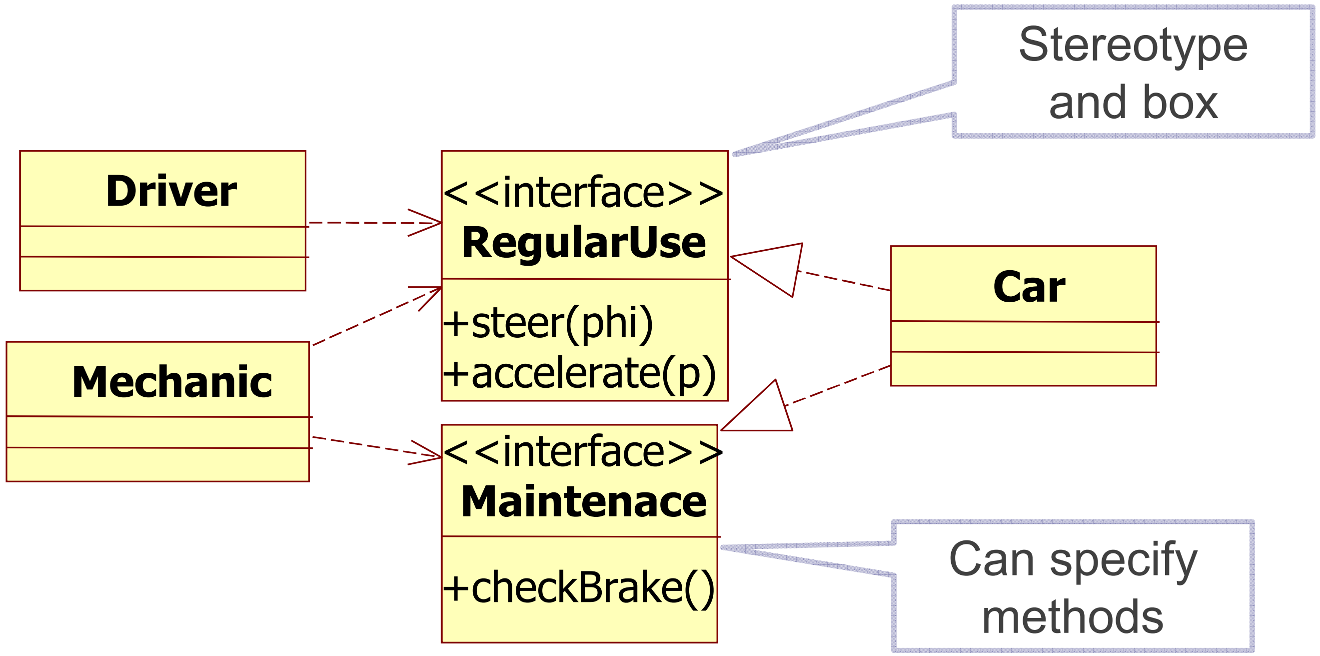


Inheritance: method override

- Overriding methods
  - modifies inherited behaviour
- UML best practice
  - in subclasses only show overridden methods
    - when superclass is visible on diagram
- Java best practice
  - use `@Override` annotation in subclass
- C++
  - method must be *virtual* in superclass

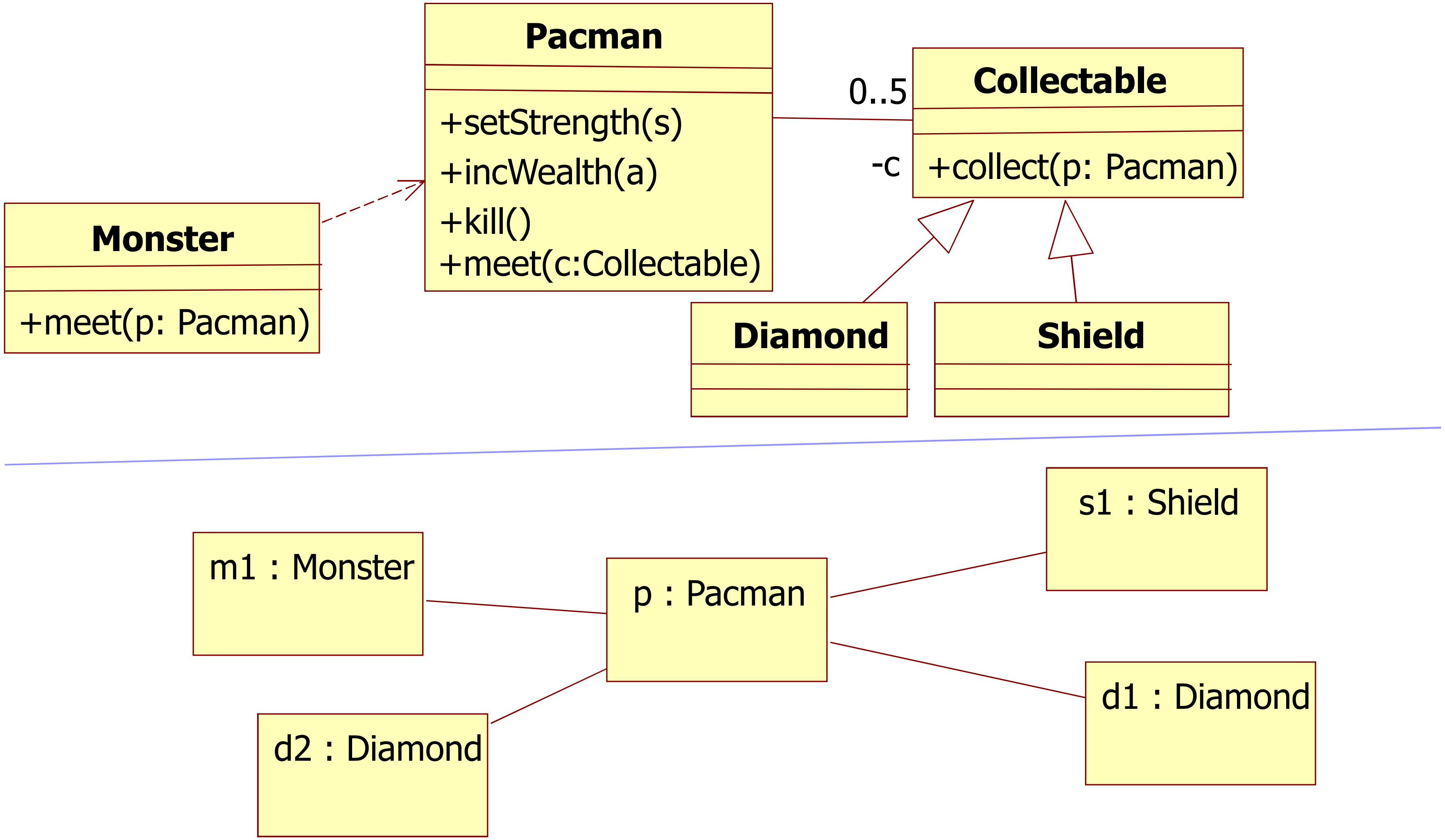
Behaviour

- Static structure is captured by class diagrams
  - show all connections
  - closely related to source code
- Behaviour is implemented in methods
  - methods are executed during runtime
  - method bodies are omitted from class diagram
- Internal behaviour (intra-object)
  - mostly state chart, seldom activity diagram, etc.
- External behaviour (inter-object)
  - interaction diagrams (sequence and communication)

Modelling behaviour

- Communication diagram
  - represents objects
  - and relationships between objects
    - relationship is static
    - if no communication, called object diagram
  - and communication between objects
    - communication is dynamic
- Objects are instances of classes
  - object diagram is an instance of class diagram

Class and Object diagram



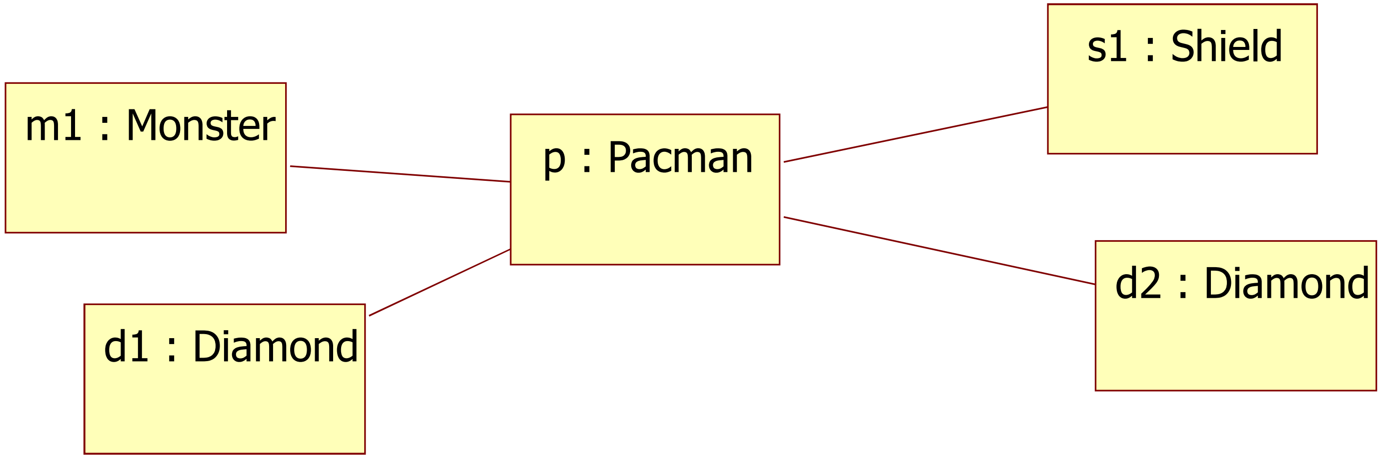
Java implementation (partial)

```
class Monster {
  public void meet(Pacman p) {
    p.kill();
  }
}
interface Collectable {
  boolean collect(Pacman p);
}
class Diamond implements Collectable
{
  double value;
  public boolean collect(Pacman p) {
      p.incWealth(value);
  }
}
class Shield implements Collectable
  {...}
```

```
class Pacman {
  double strength;
  double wealth;
  public void
  meet(Collectable c){
    if (n<5) if
       (c.collect(this))
        n++;
  }
  public void
  intWealth(double w) {
    wealth += w;
  }
  ...
}
```

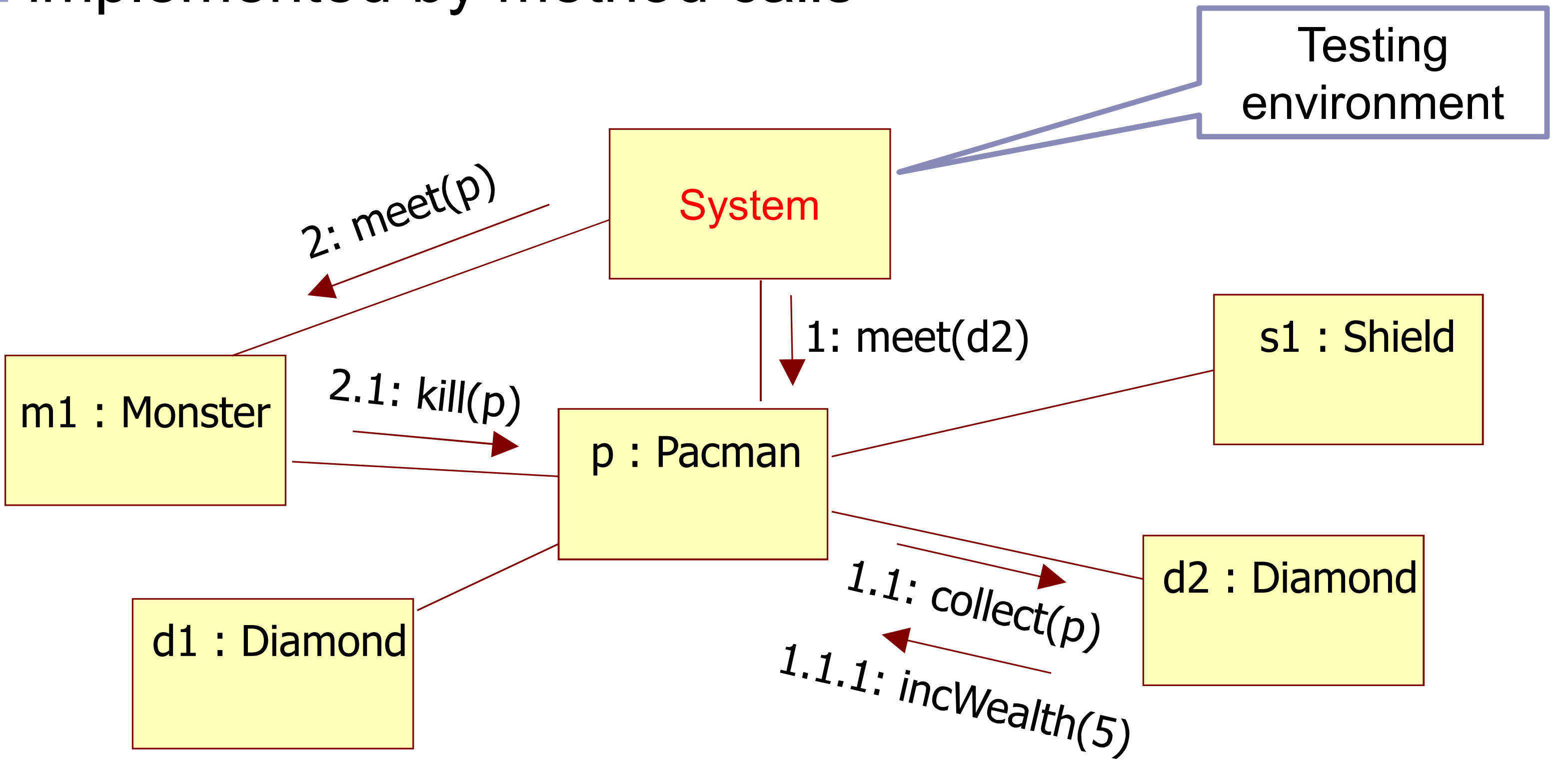
Java implementation (objects)

```java
Monster m1 = new Monster();
Diamond d1 = new Diamond();
Diamond d2 = new Diamond();
Shield s1 = new Shield();
Pacman p = new Pacman();
// setting up connections is omitted here
```



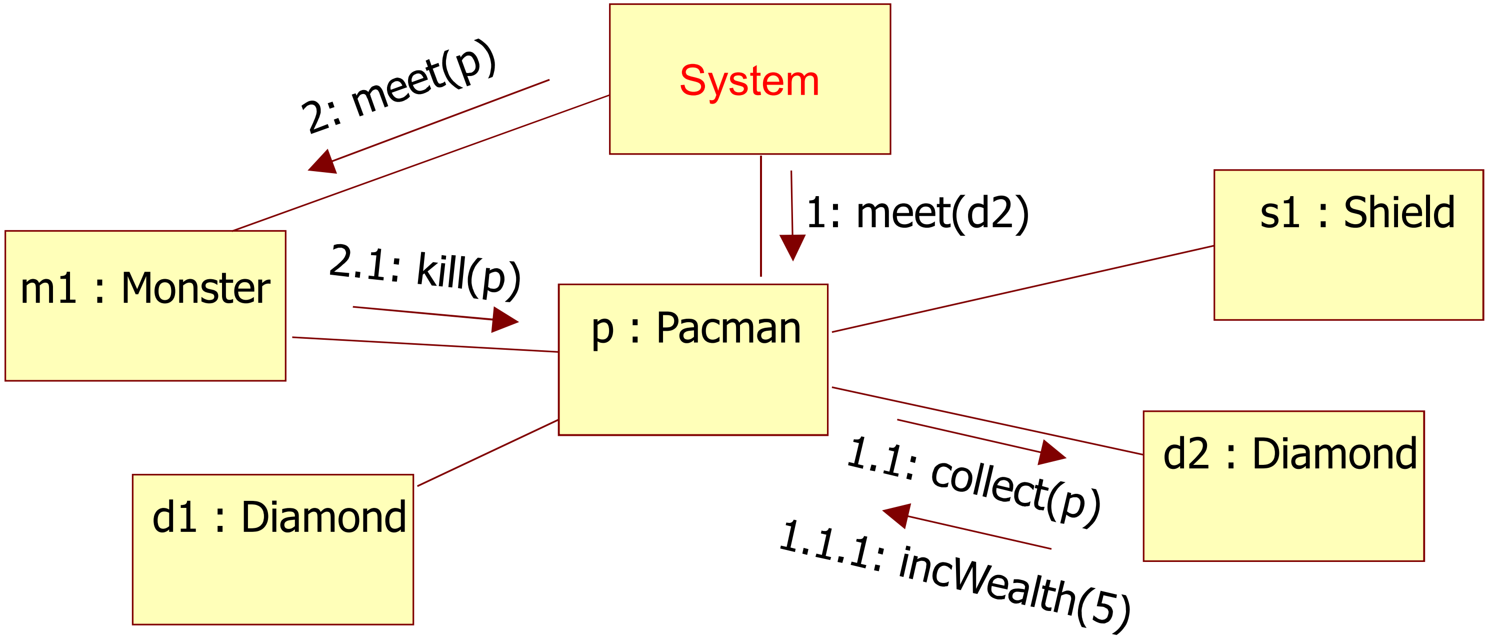
Communication (collaboration)

- Links may have messages
  - implemented by method calls



Communication implemented

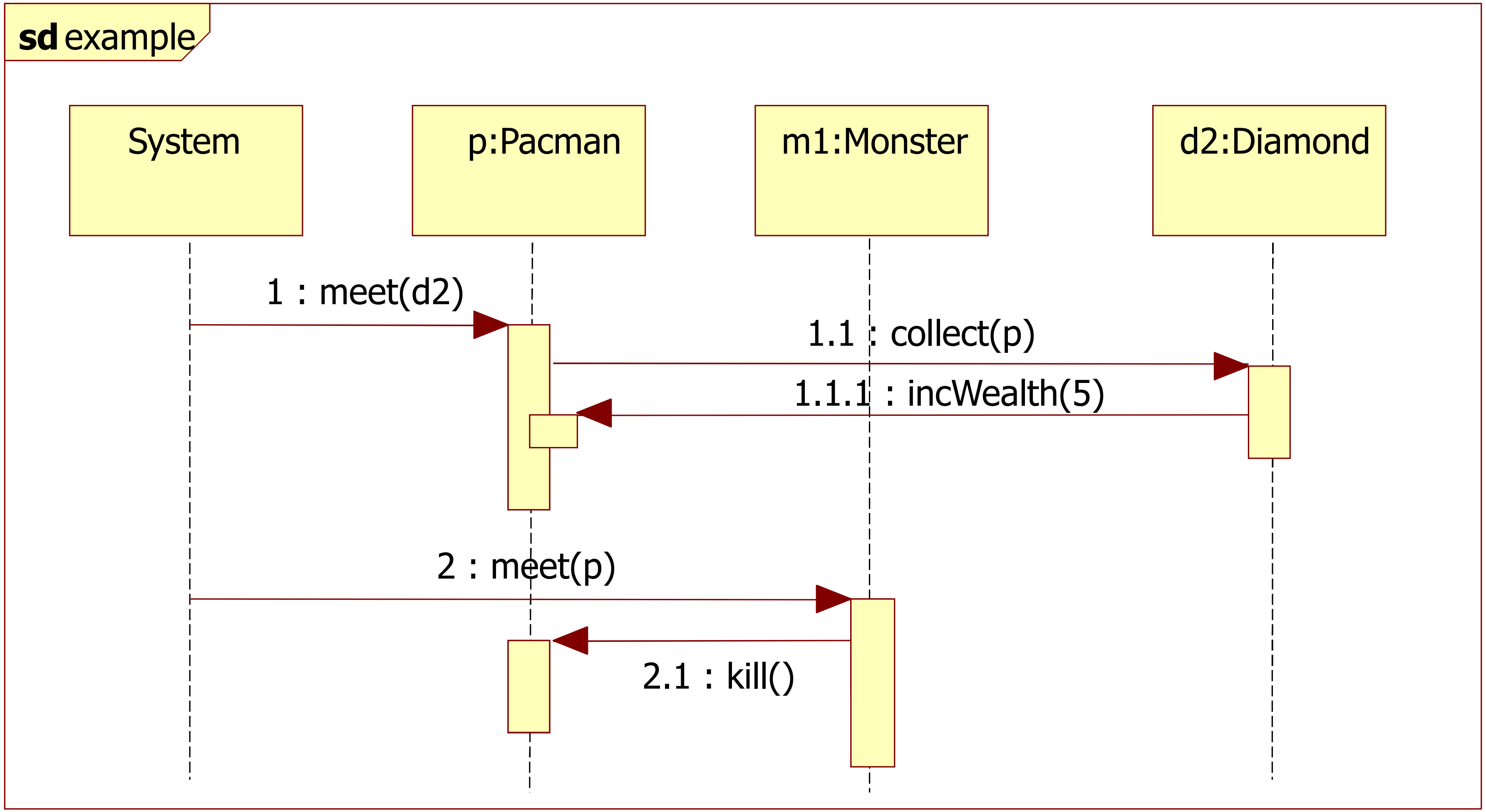
```
// objects created, links initialized, then ...
p.meet(d2);
       // p.meet(d2) calls d2.collect(this)
              // d2.collect(this) calls p.incWealth(5)
m1.meet(p);
       // m1.meet(p) calls p.kill();
```



Modelling behaviour 2

- Sequence diagram
  - represents object life-lines
  - sequence of communication between objects
- Activity diagram
  - describes external and internal behaviour
- State chart
  - represent internal behaviour
  - stimuli are mostly method calls
  - state representation is arbitrary

Sequence diagram



How concepts correlate

- Class diagram
  - all methods should appear on interaction diagrams
- Sequence and communication diagrams
  - all messages should appear on class diagrams
- Source code
  - class structure resembles class diagram
    - method signatures, attributes, inheritance, associations
  - method bodies implement dynamics
    - interaction diagrams represent the execution of methods
    - state-charts and activity diagrams mostly for internals