Software Engineering I (02161)

Week 11

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Contents

What does this function do?

```
public List<Integer> qsort(List<Integer> list) {
   if (list.size() <= 1) return list;

   int k = list.elementAt(0);

   List<Integer> l1 = new ArrayList<Integer>();
   List<Integer> l2 = new ArrayList<Integer>();
   List<Integer> l3 = new ArrayList<Integer>();

   partition(k,list,l1,l3,l2);

   List<Integer> r = f(l1);

   r.addAll(l3);
   r.addAll(f(l2));
   return r;
}

public void partition(int k, List<Integer> list,
                      List<Integer> l1, List<Integer> l2, List<Integer> l3) {
   for (int i : list) {
      if (i < k) l1.add(i);
      if (i == k) l3.add(i);
      if (i > k) l2.add(i);
   }
}
```

qsort

qsort

What does this function do?

```
public void testEmpy() {
  int[] a = {};
  List<Integer> r = qsort(Array.asList(a));
  assertTrue(r.isEmpty());
}

public void testOneElement() {
  int[] a = { 3 };
  List<Integer> r = qsort(Array.asList(a));
  assertEquals(Array.asList(3),r);
}

public void testTwoElements() {
  int[] a = {2, 1};
  List<Integer> r = qsort(Array.asList(a));
  assertEquals(Array.asList(1,2),r);
}

public void testThreeElements() {
  int[] a = {2, 3, 1};
  List<Integer> r = qsort(Array.asList(a));
  assertEquals(Array.asList(1,2,3),r);
}
...
```

What does this function do?

```
List<Integer> sort(List<Integer> a)
```

Contract of funct. sort

Precondition: *a* is not **null**

Postcondition: For all *result*, $a \in$ List<Integer>:

result == *f*(*a*) (sort)

if and only if

isSorted(result) and sameElements(a,result)

where

isSorted(a) if and only if

for all $0 \leq i, j < a.size()$**:**

$i \leq j$ **implies** $a.get(i) \leq a.get(j)$

and

sameElements(a,b) if and only if

for all $i \in Integer$**:** $count(a, i) = count(b, i)$

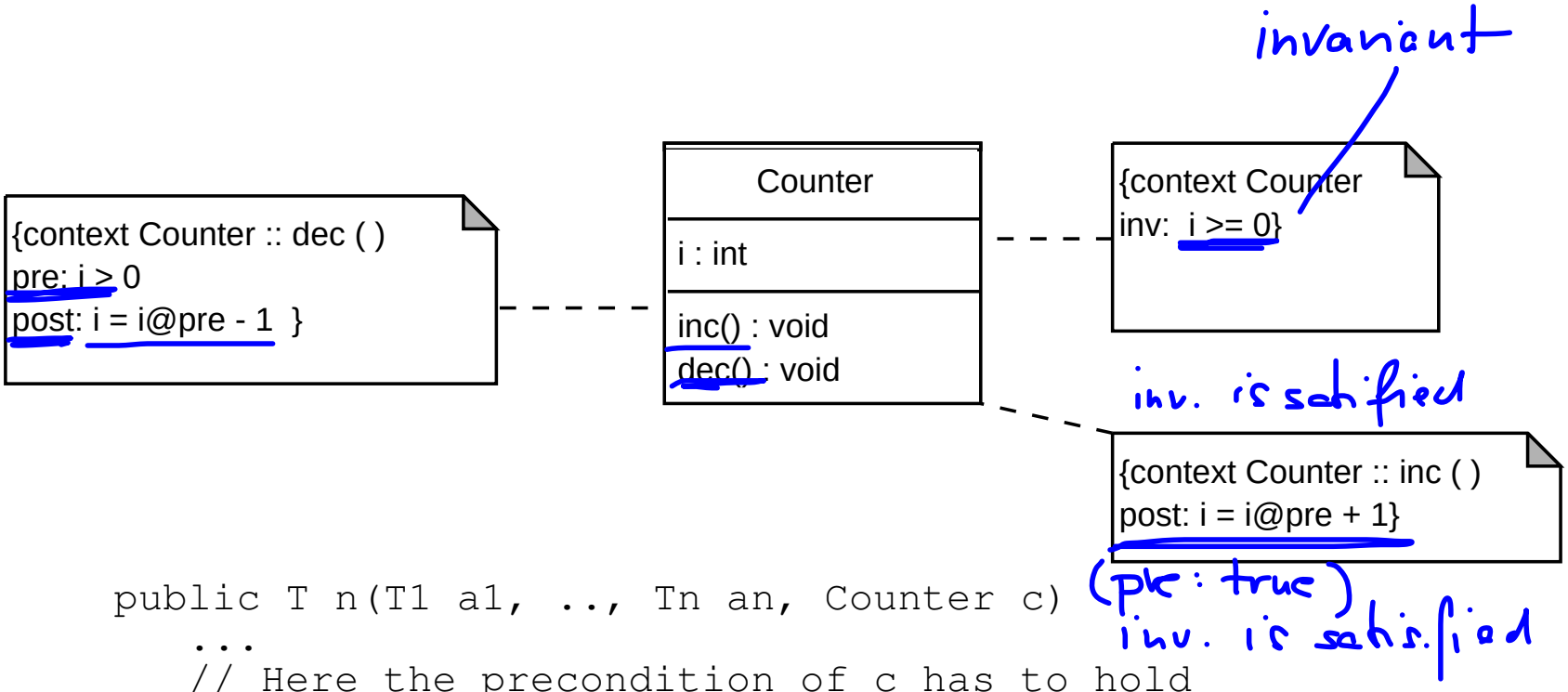
Design by contract

Contract between Caller and the Method

- Caller ensures precondition
- Method ensures postcondition

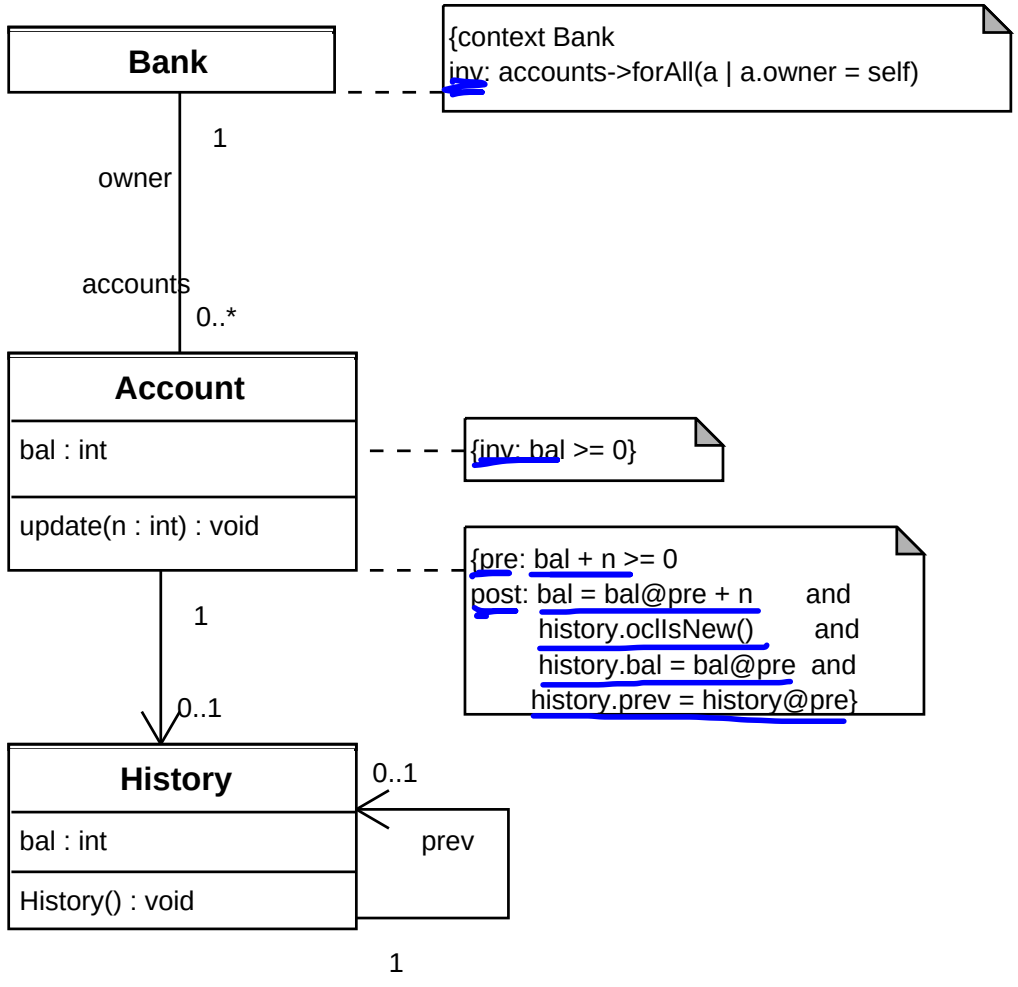
- Contracts spefify *what* instead of *how*

Example Counter




```
public T n(T1 a1, .., Tn an, Counter c)
   ...
   // Here the precondition of c has to hold
   // to fulfil the contract
   c.dec();
   // Before returning from dec, c has to ensure the
   // postcondition of dec
   ...
```

Bank example with constraints

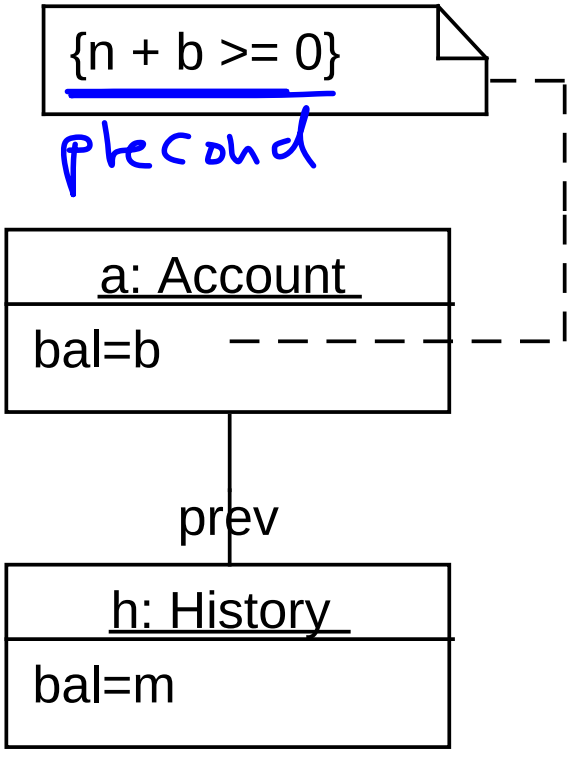


Update operation of Account

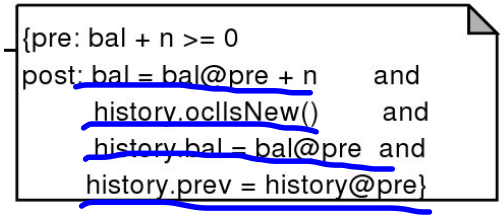
{pre: bal + n >= 0
post: bal = bal@pre + n and
history.oclIsNew() and
history.bal = bal@pre and
history.prev = history@pre}

State **before** executing

`update(n)`



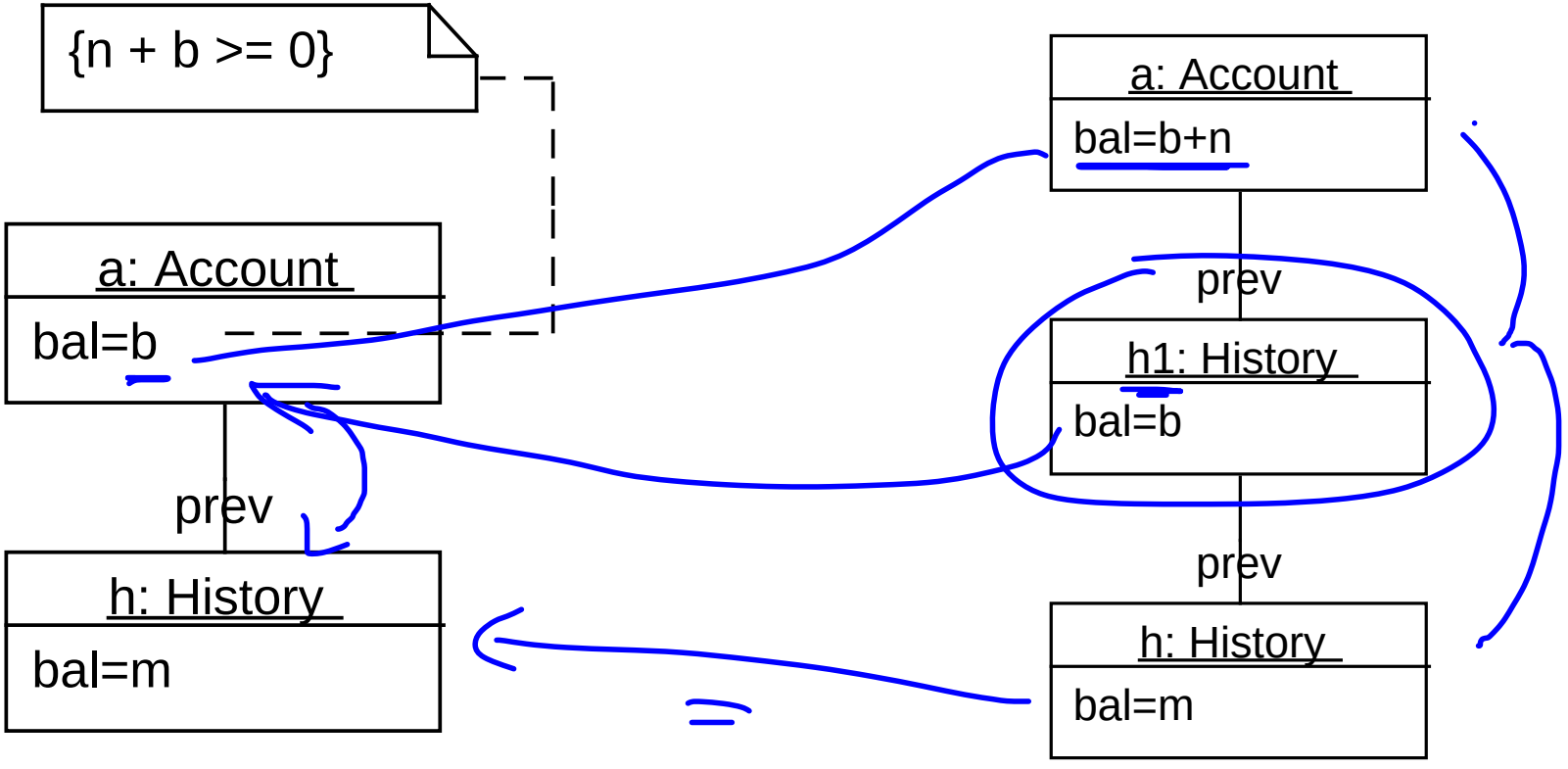
Update operation of Account



OCL (Object Constraint Language)

State **before** executing `update(n)`

State **after** executing `update(n)`



Example

```
LibraryApp::addMedium(Medium m)
pre: adminLoggedIn
post: medium@pre = medium->including(m) and
        medium.library = this)
```

```
LibraryApp::search(String string) : List<Medium>
post: result = medium->select(m |
                    m.title.contains(string) or
                    m.autor.contains(string) or
                    m.signature.contains(string))
   medium = medium@pre
```

```
User::borrowMedium(Medium m)
pre: borrowedMedium->size < 10
         and m != null
         and not(borrowedMedium->exists(m' | m'.isOverdue))
post: m.borrowDate = libApp.getDate() and
      borrowedMedium->includes(m)
```

Postcondition

Assume that `result` denotes the result of the function $f(x : double)$.

1) post: $\texttt{result}^2 = x$
2) post: $\texttt{result} = x^2$
3) post: $x^2 = \texttt{result}$
4) post: $x = \texttt{result}^2$

Which statements are correct: (multiple answers are possible)

a) 2 + 3 is the postcondition for the function computing the square of a number

b) Only 2 is the postcondition for the function computing the square of a number

c) 3 is the postcondition of the square root function

e) 1 is the postcondition of the square root function

Precondition

- Given the contract for a method *minmax*(*int*[]*array*) in a class which has instance variables *min* and *max* of type int:

  pre: $array \neq null$ and $array.length > 0$
  post: $\forall i \in array : min \leq i \leq max$

- Which of the following statements is true: if the client calls *minmax* such the precondition is not satisfied
  a) A NullPointerException is thrown
  b) An IndexOutOfBoundsException is thrown
  c) Nothing happens
  d) What happens depends on the implementation of minmax

Implementing DbC with assertions

- Many languages have an assert construct: assert bexp;
- Contract for Counter::dec(i:int)

  Pre: $i > 0$

  Post: $i = i@pre - 1$

Implementing DbC with assertions

- Many languages have an assert construct: assert bexp;
- Contract for Counter::dec(i:int)

  Pre: $i > 0$

  Post: $i = i@pre - 1$

```
void dec() {
   assert i > 0; // Precondition
   int prei = i; // Remember the value of the counter
                 // to be used in the postcondition
   i--;
   assert i == prei-1; // Postcondition
}
```

Implementing DbC with assertions

- Many languages have an assert construct: assert bexp;
- Contract for Counter::dec(i:int)

  Pre: $i > 0$

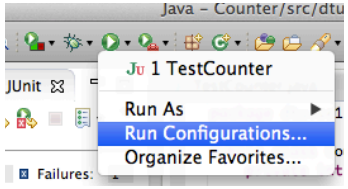
  Post: $i = i@pre - 1$

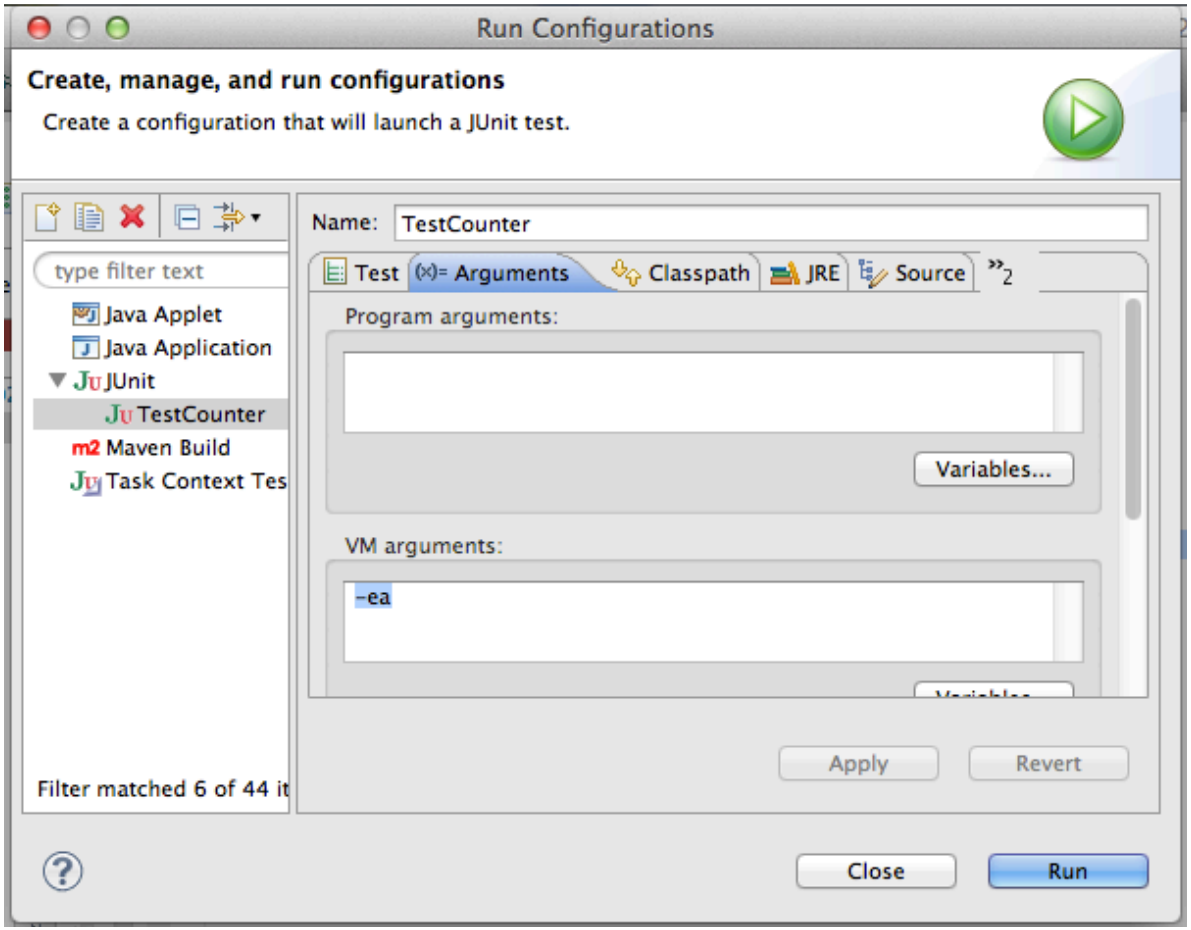
```
void dec() {
   assert i > 0; // Precondition
   int prei = i; // Remember the value of the counter
                 // to be used in the postcondition
   i--;
   assert i == prei-1; // Postcondition
}
```

- assert $\neq$ assertTrue

Important

- Assertion checking is switched off by default in Java
  1) `java -ea Main`
  2) In Eclipse





Implementing DbC in Java

Pre: $args \neq null$ and $args.length > 0$

Post: $\forall n \in args : min \leq n \leq max$

```
public class MinMax {
  int min, max;

  public void minmax(int[] args) throws Error {
    assert args != null && args.length != 0;
    min = max = args[0];
    for (int i = 1; i < args.length; i++) {
      int obs = args[i];
      if (obs > max)
        max = obs;
      else if (min < obs)
        min = obs;
    }
    assert isBetweenMinMax(args);
  }

  private boolean isBetweenMinMax(int[] array) {
    boolean result = true;
    for (int n : array) {
      result = result && (min <= n && n <= max);
    }
    return result;
  }
```

Assertions

- Advantage
  - Postcondition is checked for each computation
  - Precondition is checked for each computation
- Disadvantage
  - Checking that a postcondition is satisfied can take as as much time as computing the result

  $\rightarrow$ Performace problems
  - Solution:
    - Assertion checking is switched on during debugging and testing and switched off in production systems
    - Only make assertions for precondition

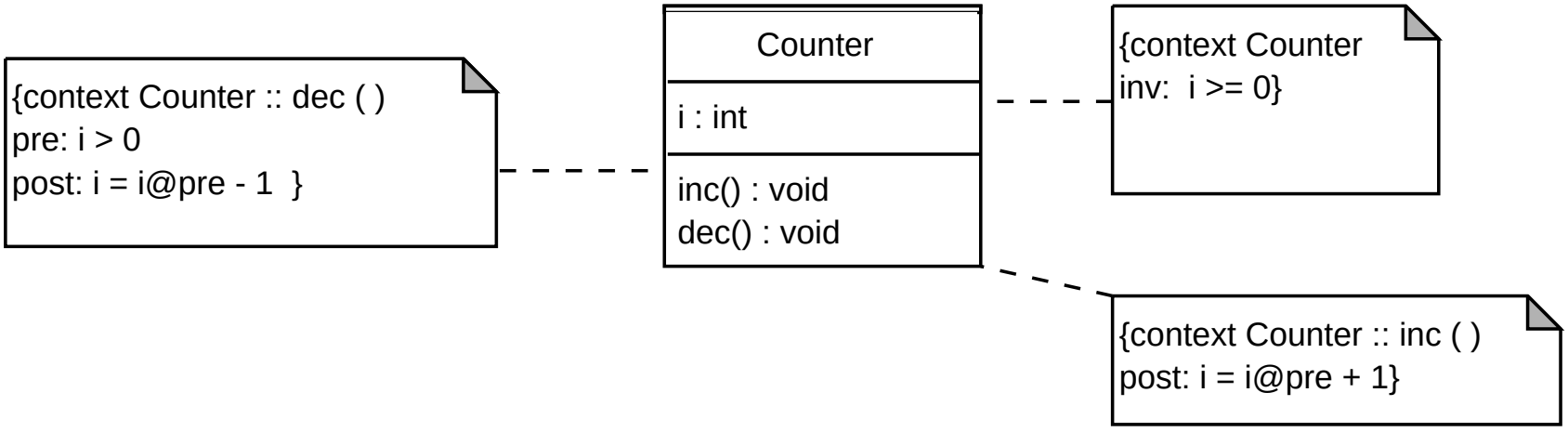
    $\rightarrow$ Preconditions are usually faster to check

    $\rightarrow$ Contract violations by the client are more difficult to find than postcondition violations (c.f. assertions vs tests)

Assertion vs. Tests

- Assertion
  - Check all computations (as long as assertion checking is switched on)
  - Check also for contract violations from the client (i.e. precondition violations)
- Tests
  - Only check test cases (conrete values)
  - Cannot check what happens if the contract is violated by the client

Counter



- Methods
  - assume that invariant holds
  - ensure invariants
- When does an invariant hold?
  - After construction
  - After each *public* method

Invariants

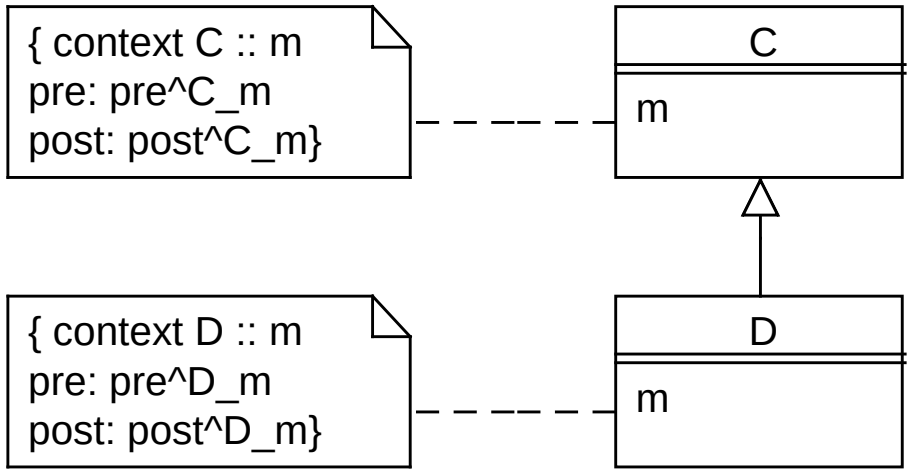
- Contstructor has to ensure invariant

```
public Counter() {
   i = 0;
   assert i >= 0;  // Invariant
}
```

- Operations ensure and assume invariant

```
void dec() {
   assert i >= 0; // Invariant
   assert i > 0; // Precondition
   int prei = i; // Remember the value of the counter
                 // to be used in the postcondition
   i--;
   assert i == prei-1; // Postcondition
   assert i >= 0; // Invariant
}
```

Contracts and inheritance

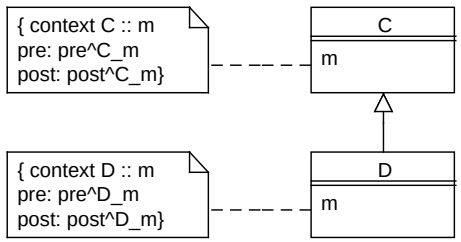


Contracts and Inheritance

Liskov / Wing Substitution principle:

At every place, where one can use objects of the superclass C, one can use objects of the subclass D

```
public T n(C c)
    ...
    // has to ensure PreˆC_m
    c.m();
    // n can rely PostˆC_m
    ...
```



- Compare $t.n(newC())$ with $t.n(newD())$.

→ $Pre_m^C \implies Pre_m^D$ *weaker* precondition

→ $Post_m^D \implies (Pre_m^C \implies Post_m^C)$ *stronger* postcondition

Counter vs. Counter1

Counter and Counter1 are identical with the exception of operation dec:

- Counter::dec

  pre: $i > 0$
  post: $i = i@pre - 1$

- Counter1::dec

  pre: true
  post: $(i@pre > 0) \implies i = i@pre - 1$ and
  $(i@pre \leq 0) \implies i = 0$

Which statement is true?

a) Counter is a subclass of Counter1

b) Counter1 is a subclass of Counter

c) There is no subclass relationship between Counter and Counter1

Defensive Programming

- Can one trust the client to ensure the precondition?

Defensive Programming

- Can one trust the client to ensure the precondition?
- Defensive Programming: don't trust the client

```
void dec() { if (i > 0) { i--; } }
```

Defensive Programming

- Can one trust the client to ensure the precondition?
- Defensive Programming: don't trust the client

```
void dec() { if (i > 0) { i--; } }
```

- New Contract: No requirement for the client
  - Method has to ensure it works with any argument

  pre: true

  post: $(i@pre > 0) \implies (i = i@pre - 1)$ and
  $(i@pre \leq 0) \implies (i = 0)$

↳ because of invariant.

Defensive Programming

- Can one trust the client to ensure the precondition?
- Defensive Programming: don't trust the client

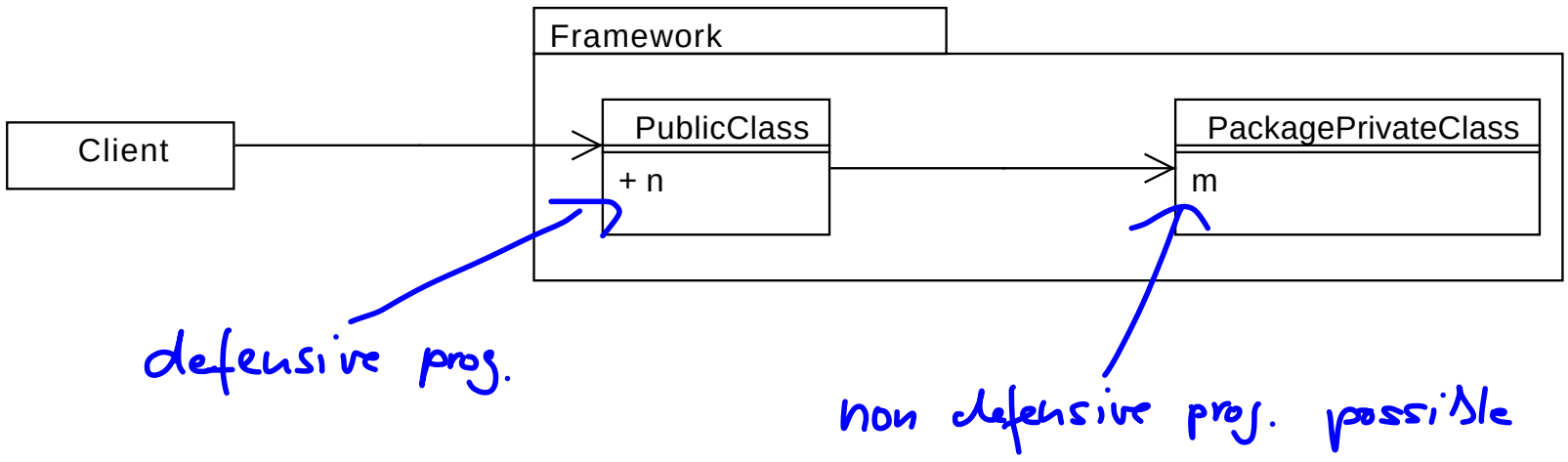
```
void dec() { if (i > 0) { i--; } }
```

- New Contract: No requirement for the client
  - Method has to ensure it works with any argument
    pre: true
    post: $(i@pre > 0) \implies (i = i@pre - 1)$ and
    $(i@pre \leq 0) \implies (i = 0)$
- Or, using *under specification*
    pre: true
    post: $(i@pre > 0) \implies (i = i@pre - 1)$

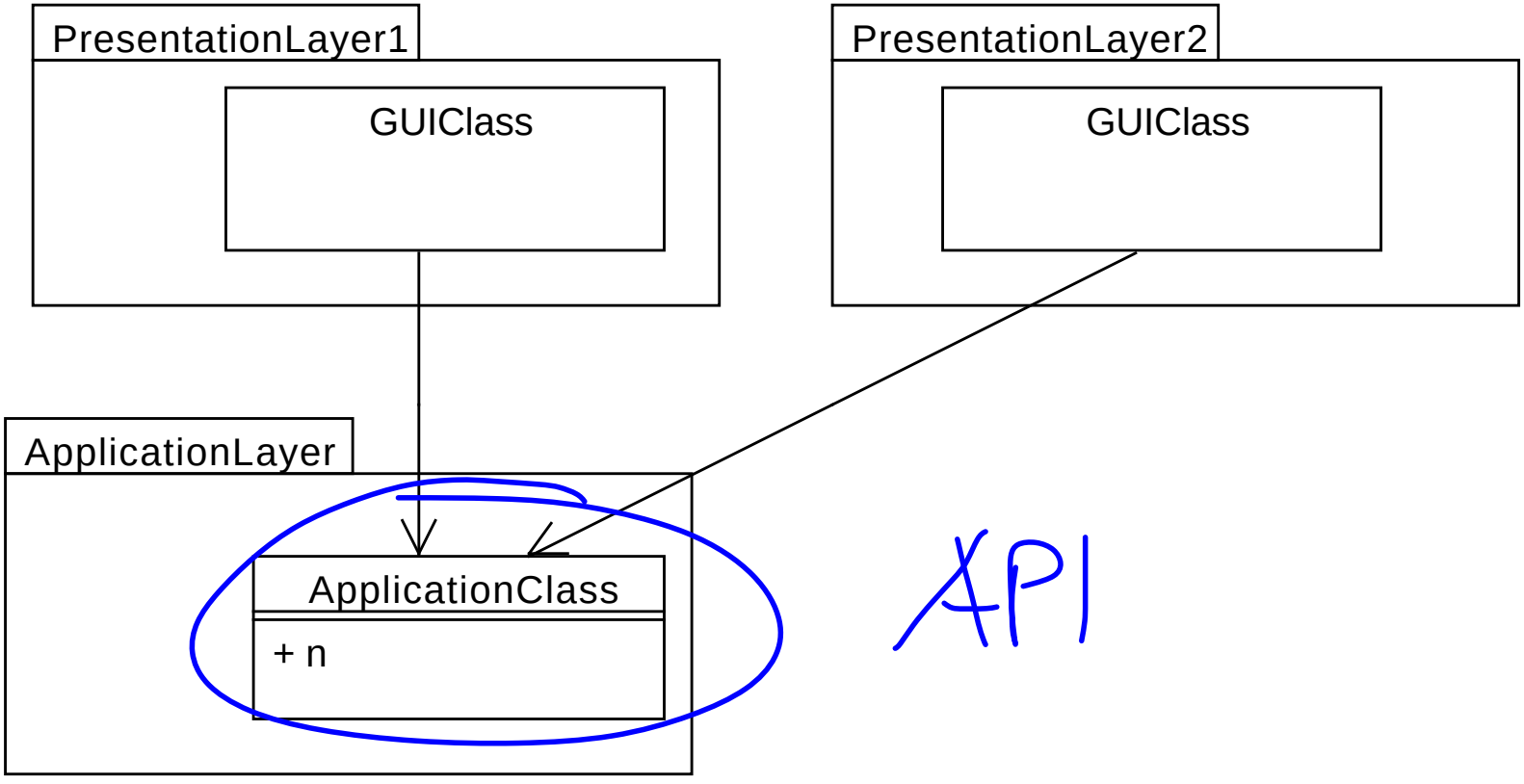
Defensive Programming

if you can't control the client

precond. if you can



Defensive Programming



Defensive Programming

Given method contracts 1)

```
LibraryApp::addMedium(Medium m)
pre: adminLoggedIn
post: medium@pre = medium->including(m) and
        medium.library = this)
```

and 2)

```
LibraryApp::addMedium(Medium m)
post: adminLoggedIn implies
            medium@pre = medium->including(m) and
           medium.library = this)
```

pre : true

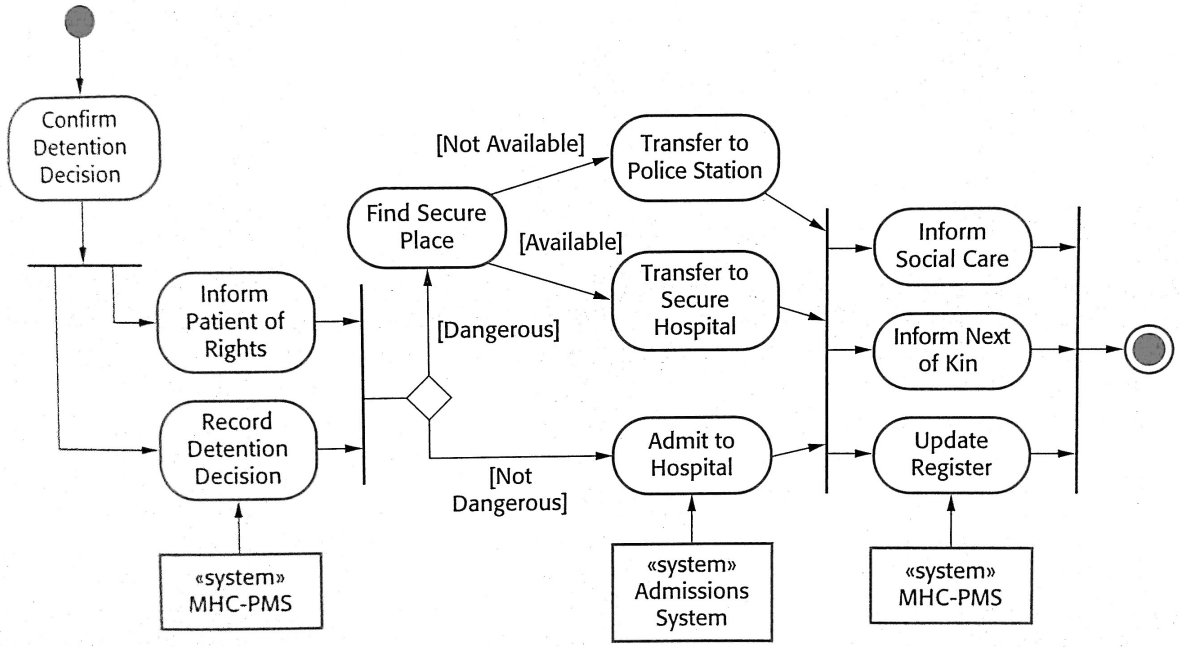
Which statement is correct?

a) 1) uses defensive programming

b) 2) uses defensive programming

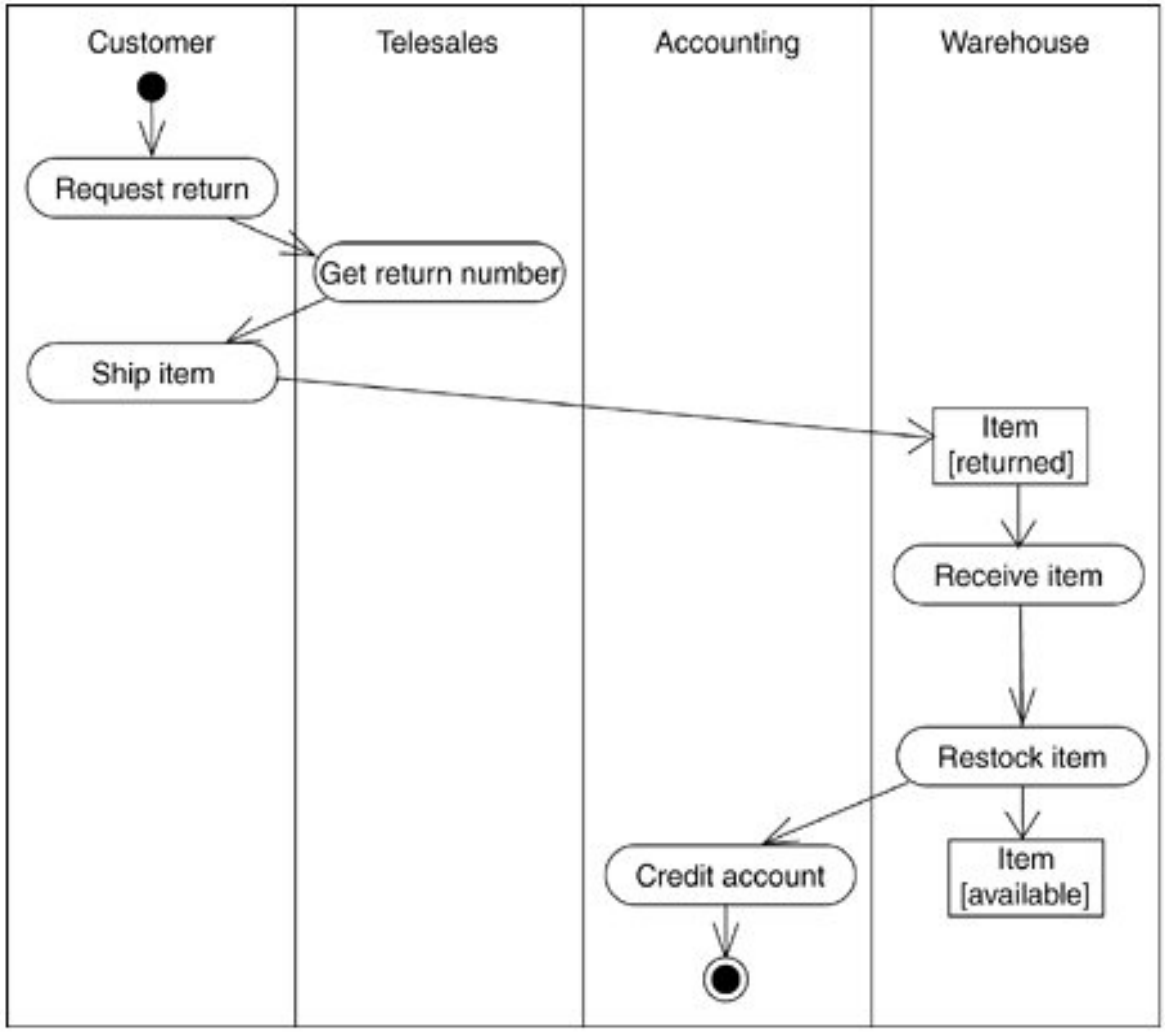
Contents

Activity Diagram: Business Processes

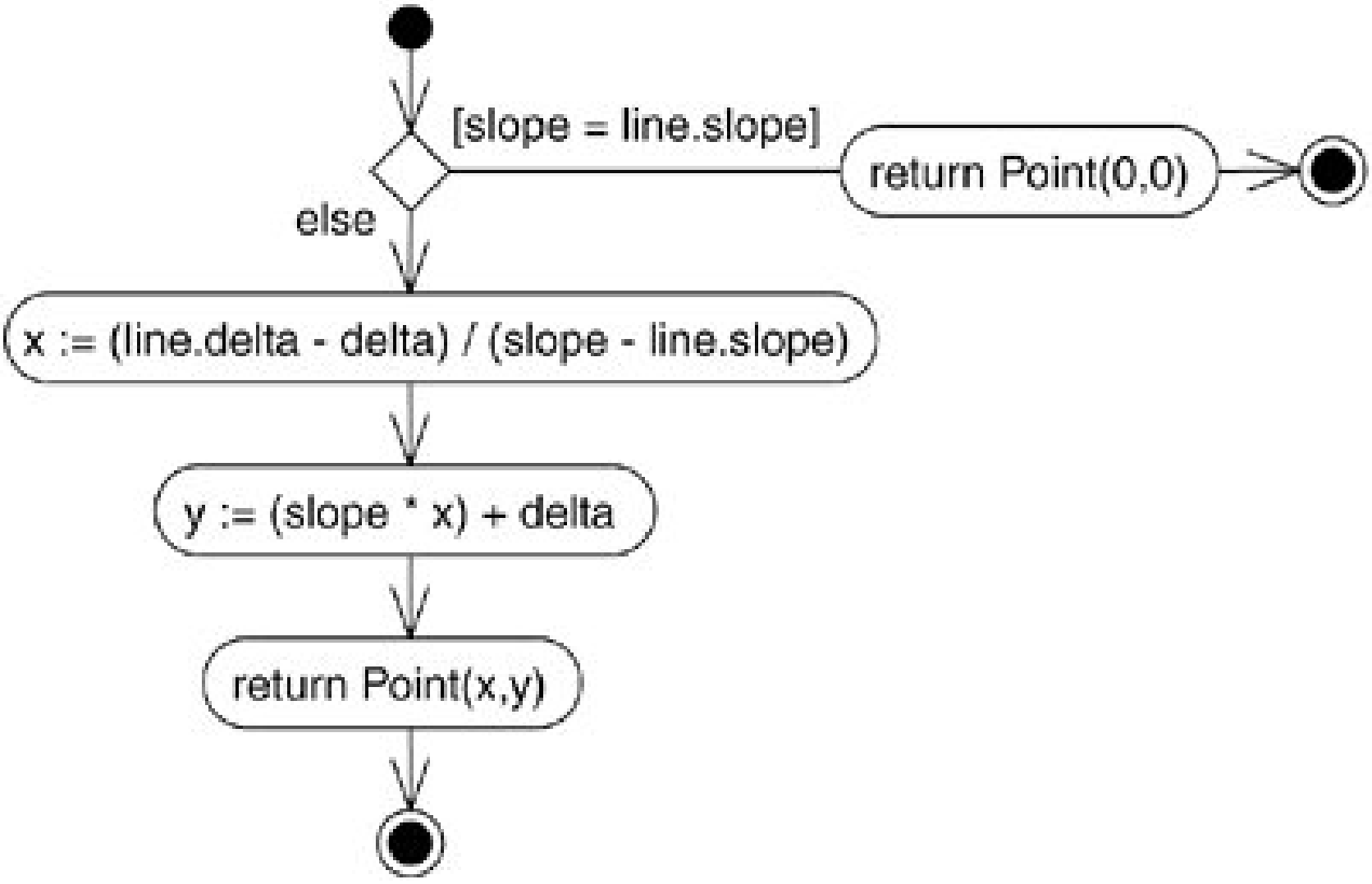


- Describe the *context* of the system
- Helps finding the requirements of a system
  - modelling business processes leads to suggestions for possible systems and ways how to interact with them
  - Software systems need to fit in into existing business processes

Activity Diagram Example Workflow



Activity Diagram Example Operation

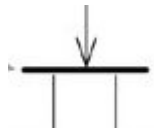
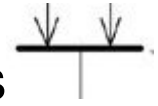
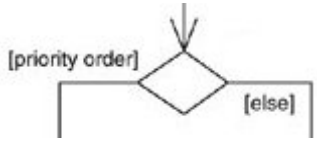


UML Activity Diagrams

- Focus is on *control flow* and *data flow*
- Good for showing *parallel/concurrent* control flow
- Purpose
  - Model business processes
  - Model workflows
  - Model single operations
- Literature: UML Distilled by Martin Fowler

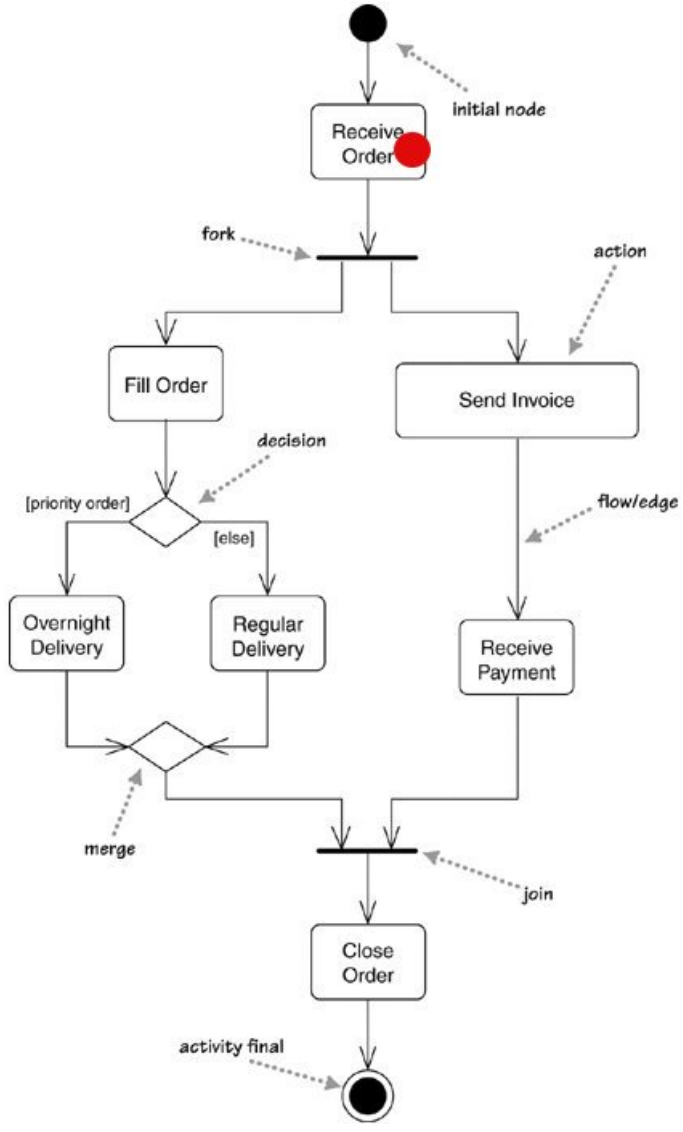
Activity Diagram Concepts

- *Actions* 

  - Are atomic
  - E.g Sending a message, doing some computation, raising an exception, . . .
    - UML has approx. 45 Action types
- *Concurrency*
  - Fork: Creates concurrent flows 
    - Can be true concurrency
    - Can be interleaving
  - Join: Synchronisation of concurrent activities 
    - Wait for all concurrent activities to finish (based on token semantics)
- *Decisions* 

  - Notation: Diamond with conditions on outgoing transitions
  - `else` denotes the transition to take if no other condition is satisfied

Activity Diagrams Execution



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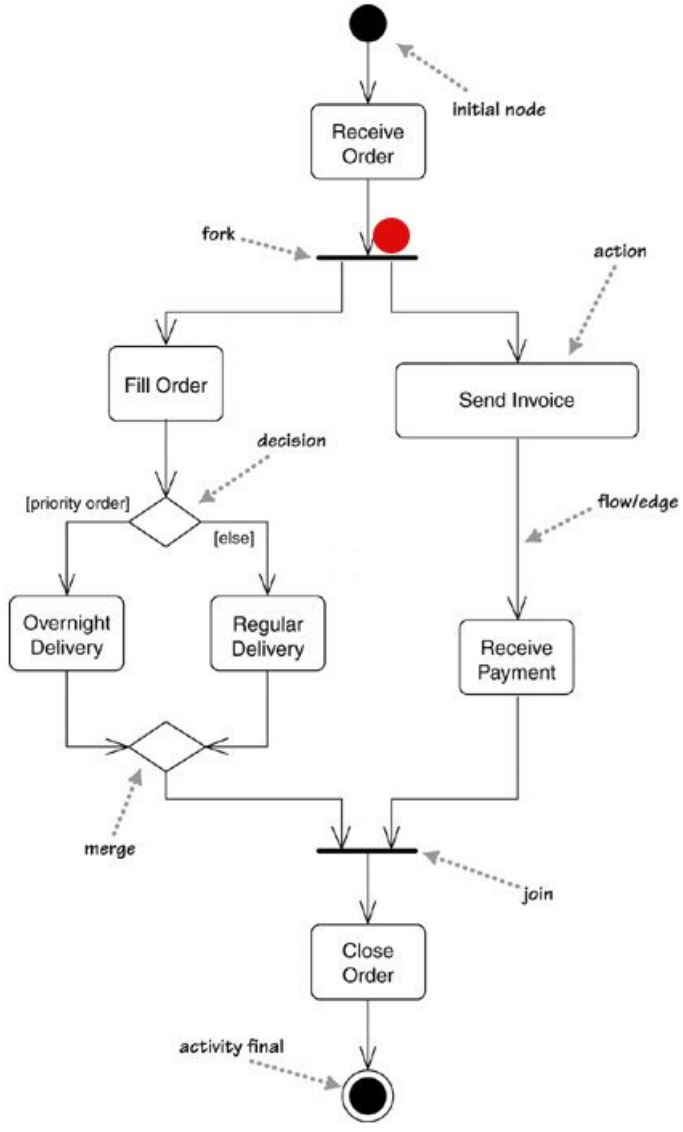

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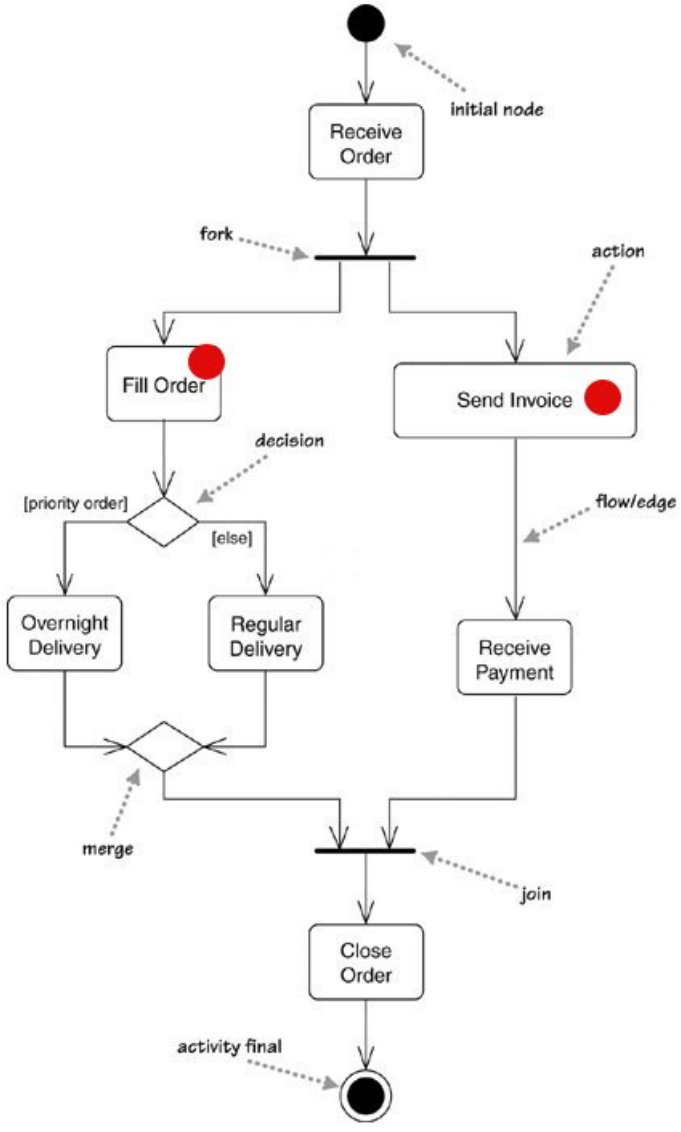

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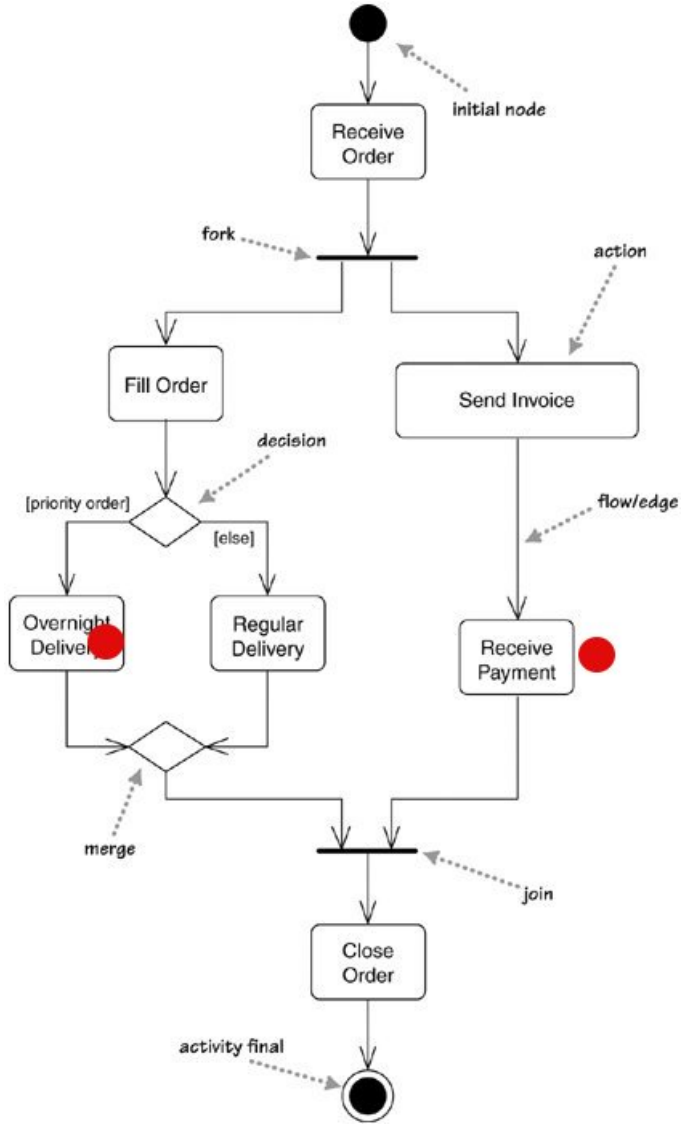

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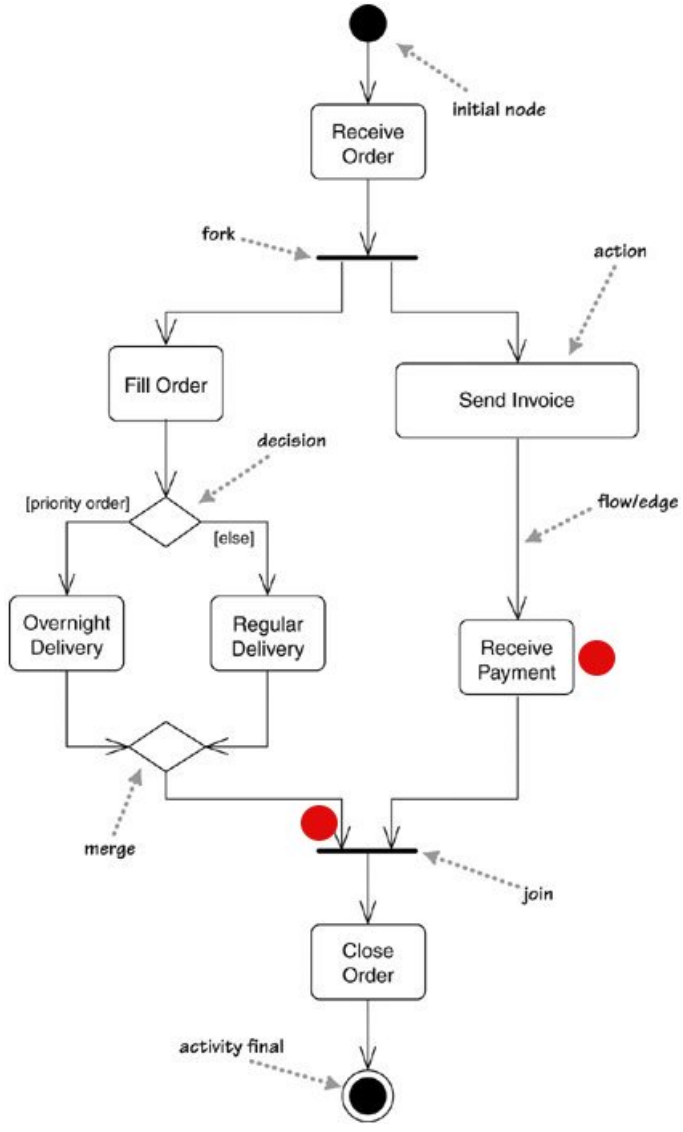
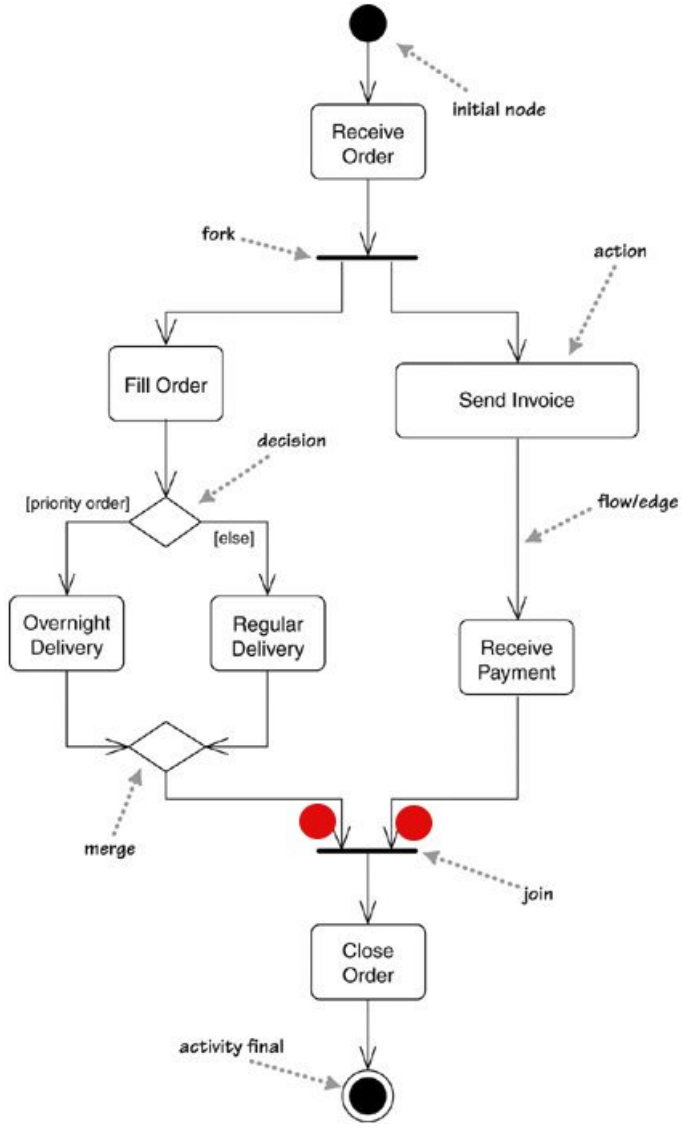


Activity Diagrams Execution



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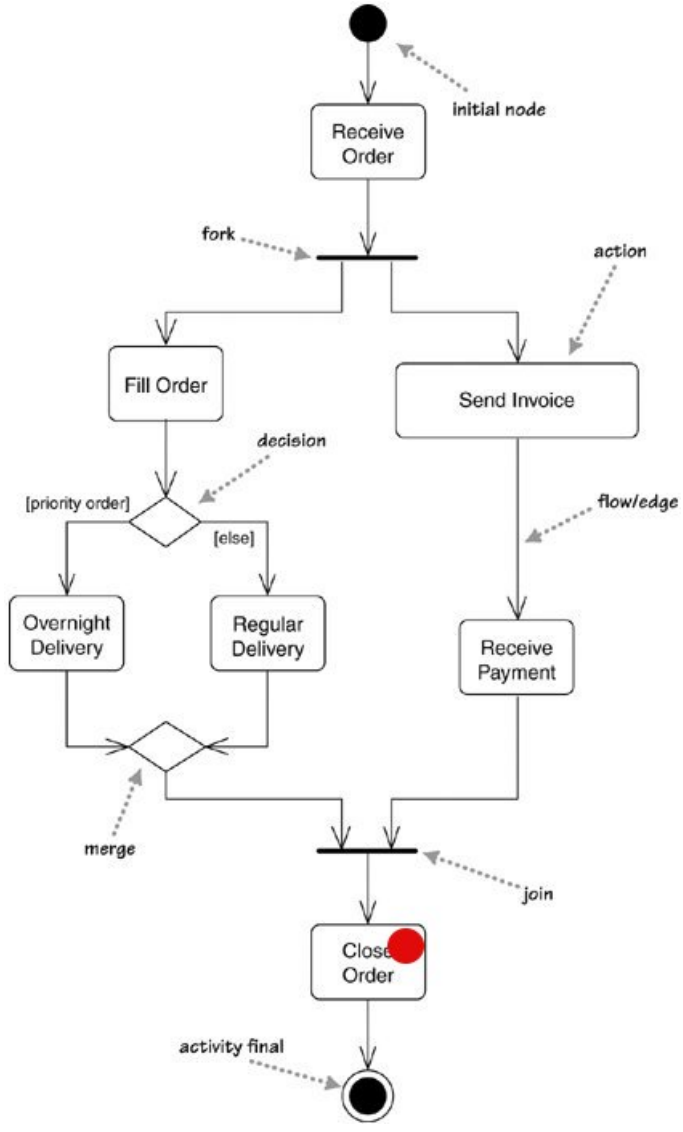

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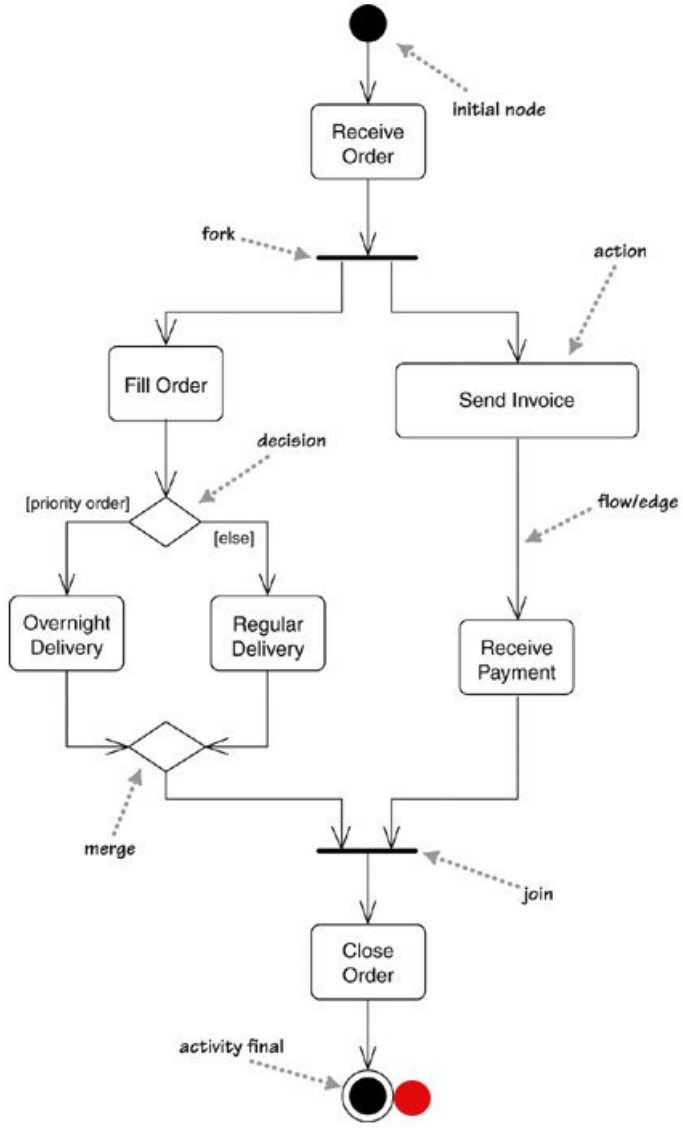
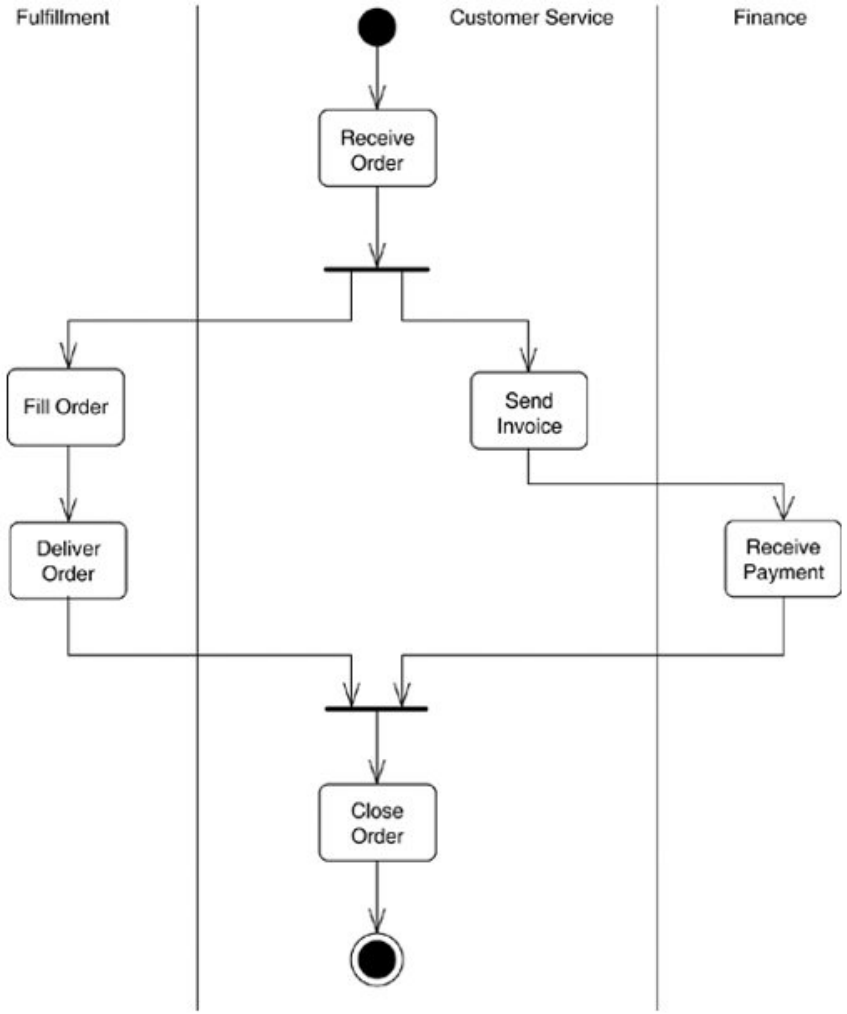
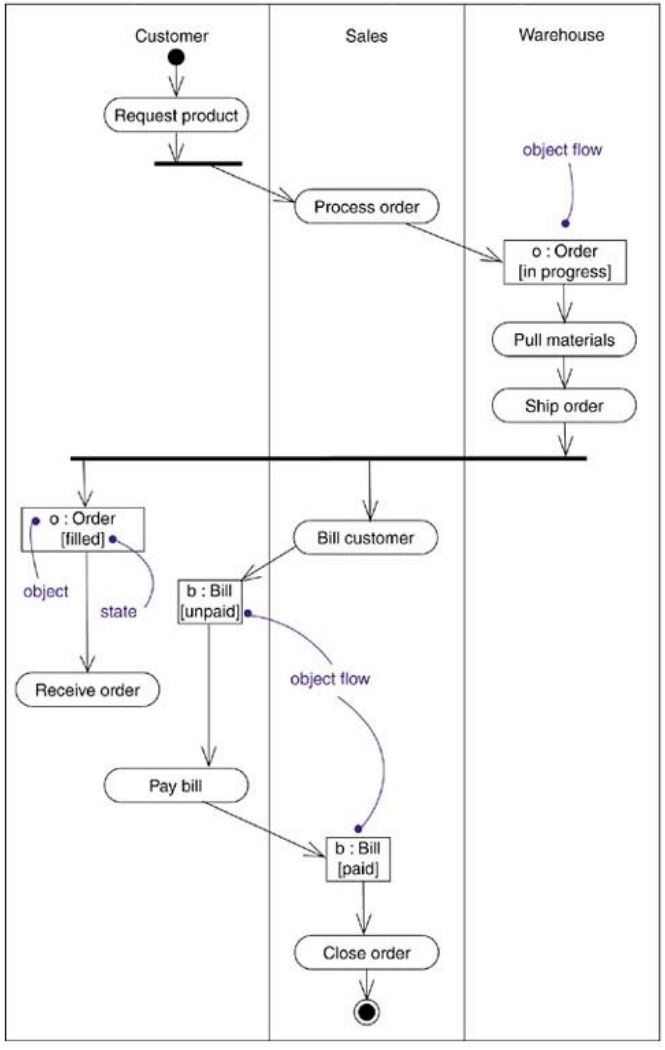


Swimlanes / Partitions

- Swimlanes show **who** is performing an activity

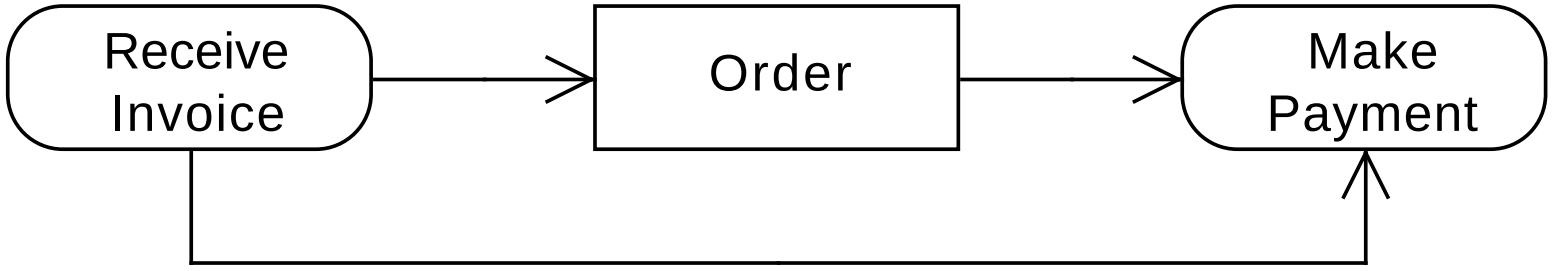


Objectflow example



Data flow and Control flow

- *Data flow* and *control flow* are shown:

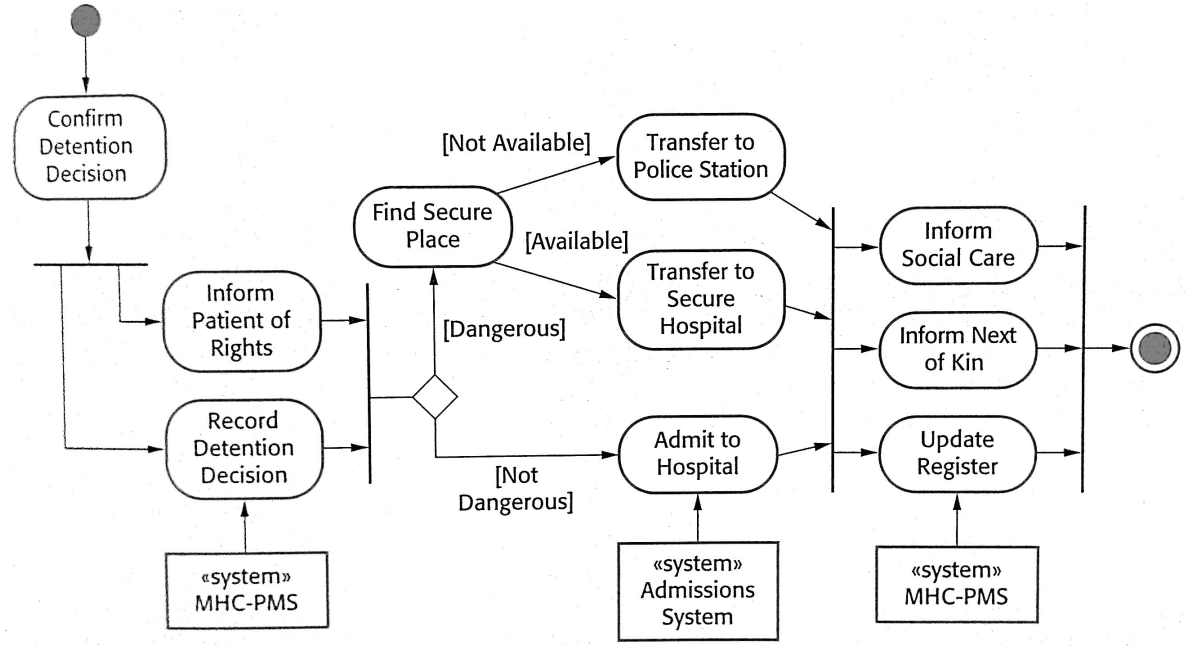


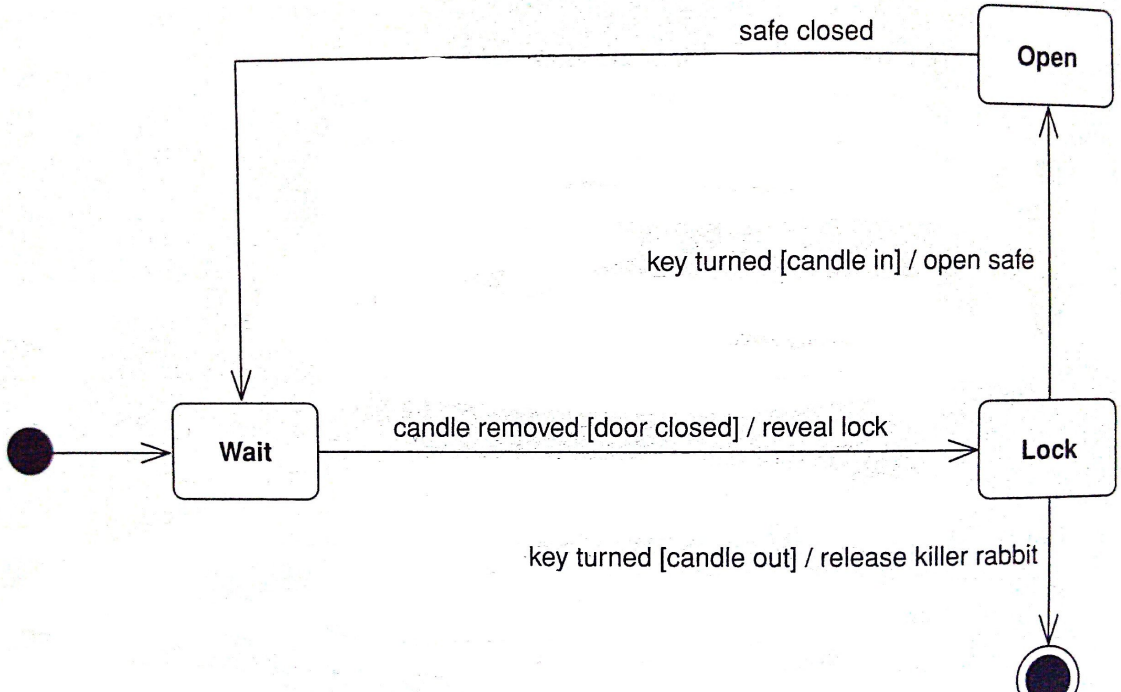
- Control flow can be omitted if implied by the data flow:

Use of Activity Diagrams

- Emphasise on concurrent/parallel execution
- Requirements phase
  - To model business processes / workflows to be automated
- Design phase
  - Show the semantics of one operation
    - Close to a graphic programming language

Activity Diagram vs State Machines





Contents

What did you learn?

- Requirements: Use Cases, User Stories, Use Case Diagrams
- Testing: Systematic Tests, Test-Driven Development
- System Modelling: Class Diagram, Sequence Diagrams, State Machines, Activity Diagrams
- Design: CRC cards, Refactoring, Layered Architecture, Design Principles, Design Patterns
- Software Development Process: Agile Processes, Project Planning
- Design by Contract

What did you learn?

- Requirements: Use Cases, User Stories, Use Case Diagrams
- Testing: Systematic Tests, Test-Driven Development
- System Modelling: Class Diagram, Sequence Diagrams, State Machines, Activity Diagrams
- Design: CRC cards, Refactoring, Layered Architecture, Design Principles, Design Patterns
- Software Development Process: Agile Processes, Project Planning
- Design by Contract

- Don’t forget the course evaluation

Plan for next weeks

- Next week:
  - Guest lecture by Miracle Systems A/S about how the do software development
  - Exercises from 15:00 – 17:00 as usual
- Week 13: 13.5., 13:00 – 17:00: 10 min demonstrations of the software
  1. Show that all automatic tests run
  2. TA chooses one use case
     - 2.a Show the systematic tests for that use case
     - 2.b Execute the systematic test manually
  - Schedule will be published this week
- In Next Week Exercises and Project Demonstrations
  - Visit of a film team
  - Just say no if you don't want to be filmed