Evolving mutation from objects to the cloud

MUTATION workshop, Berlin, March 2011

Benoit Baudry

INSTITUT NATIONAL
DE RECHERCHE
EN INFORMATIQUE
ET EN AUTOMATIQUE

INRIA

centre de recherche RENNES - BRETAGNE ATLANTIQUE

Outline

- A perspective on testing in evolving software construction paradigms
- A methodological pattern: question-learn-test-feedback
- An illustration: aspect-oriented programming

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The scope of software testing practice and research is broadening

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purpose

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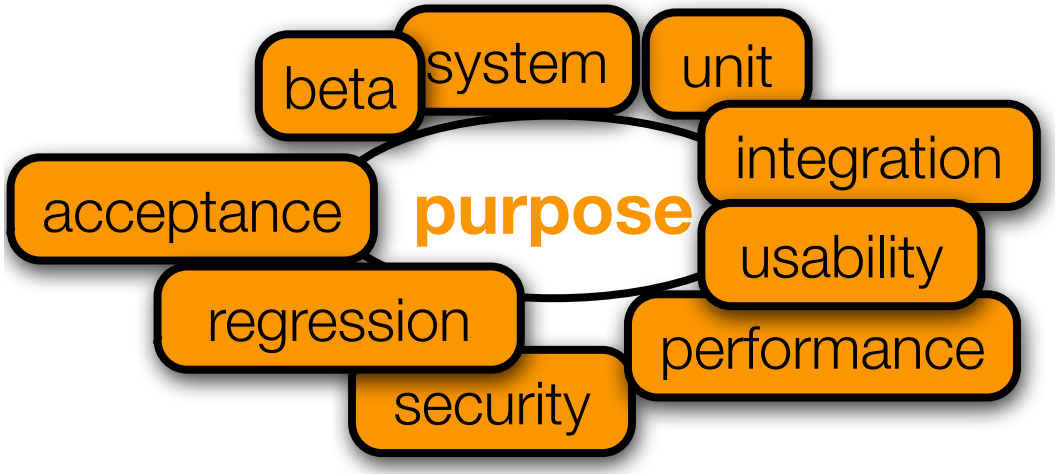
The scope of software testing practice and research is widening



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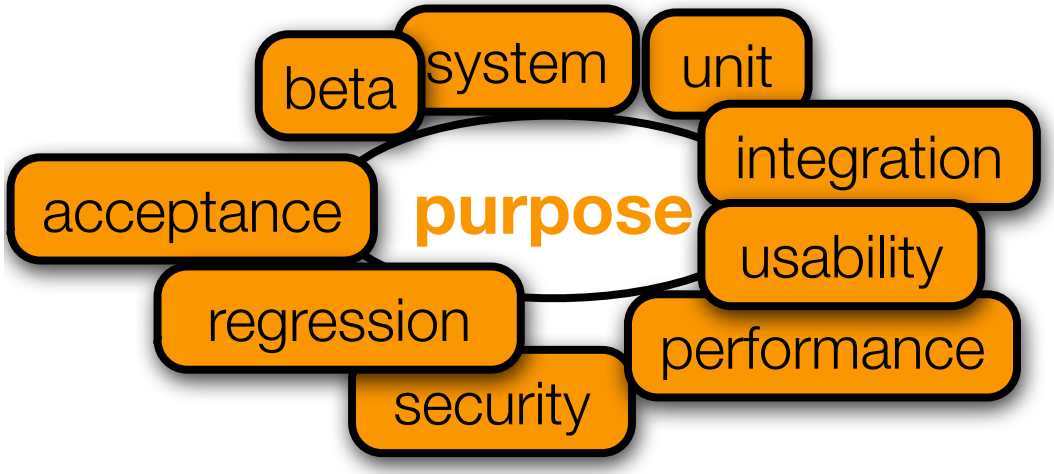

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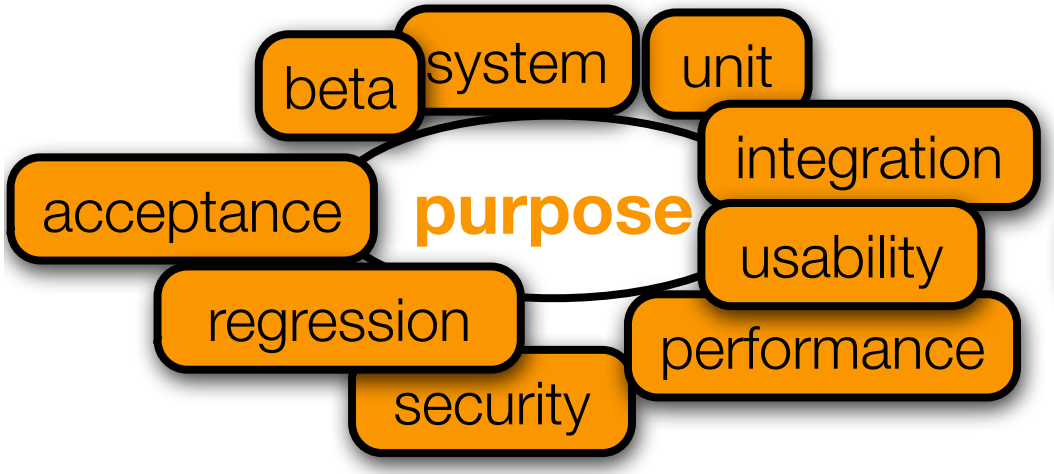

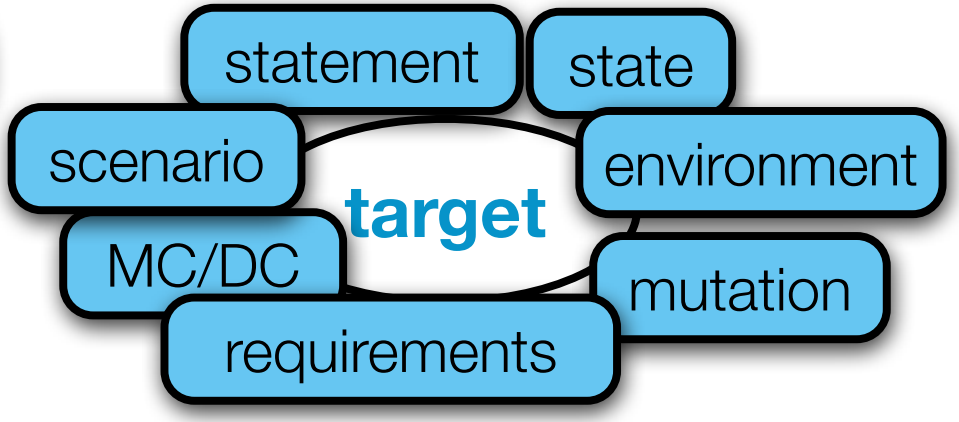

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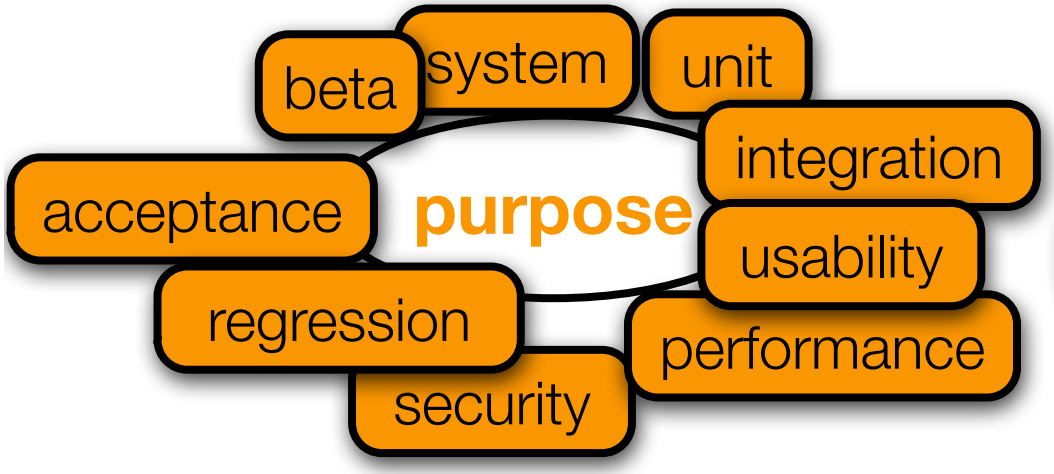

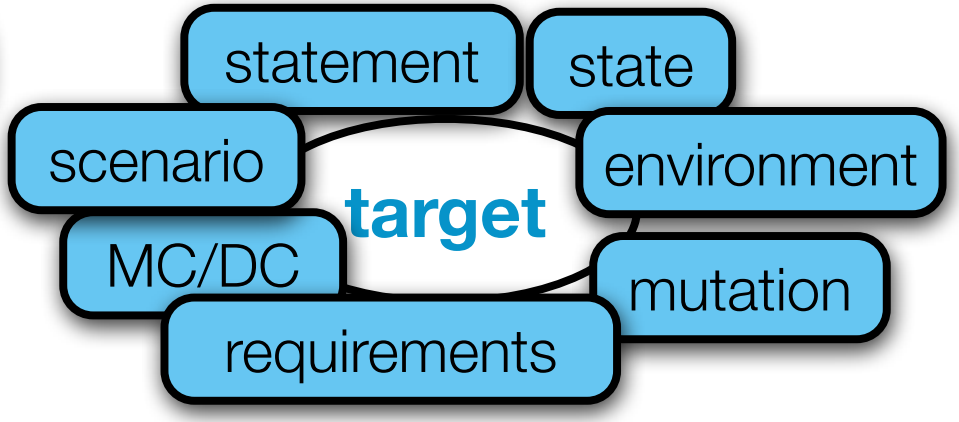

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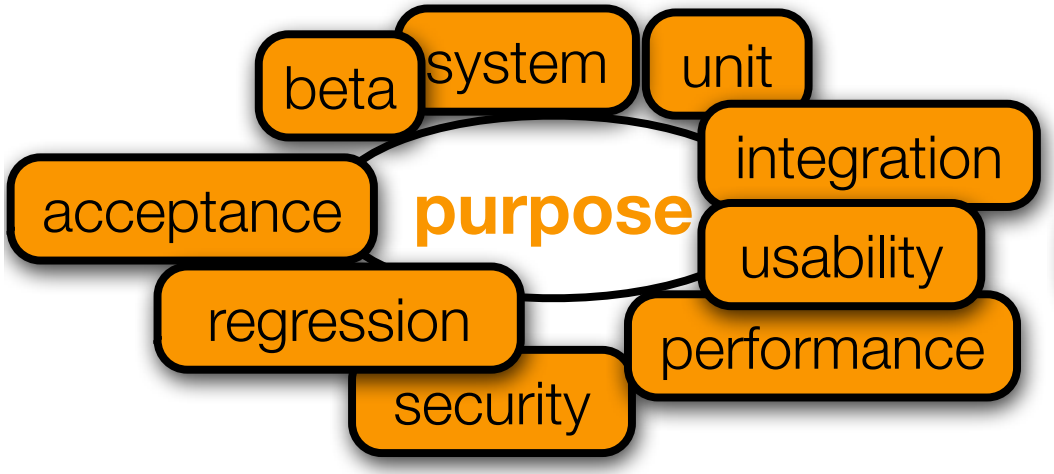

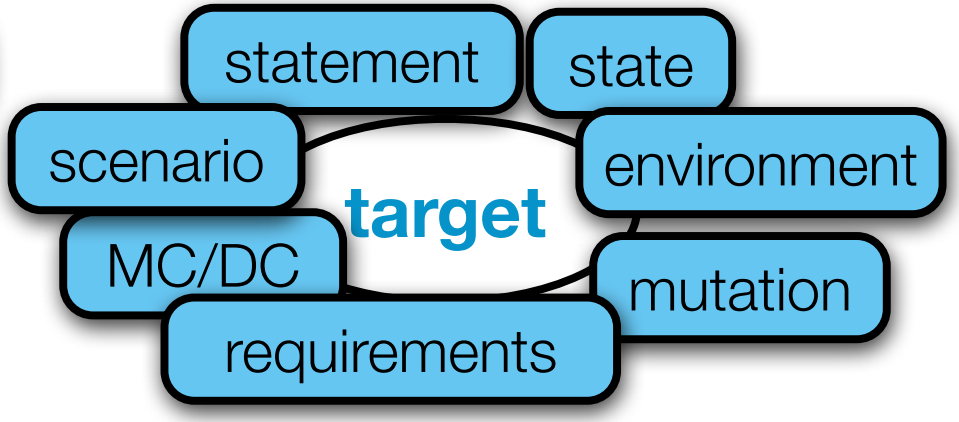

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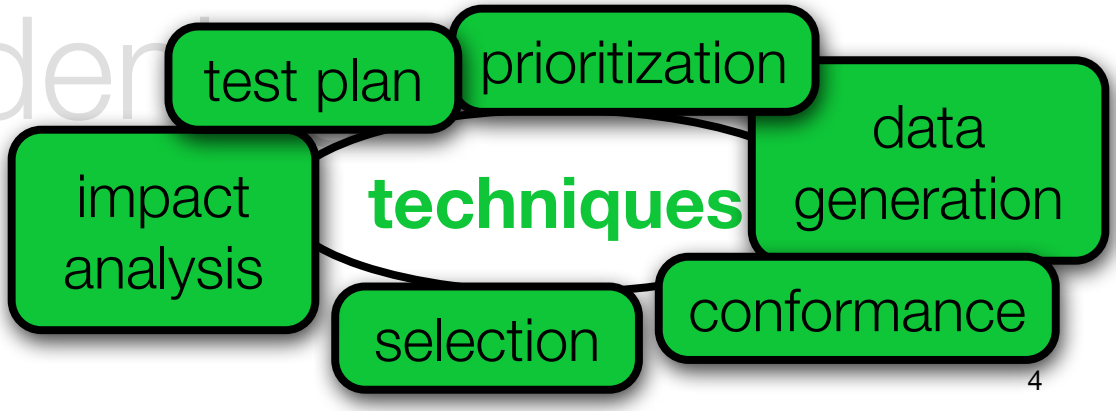

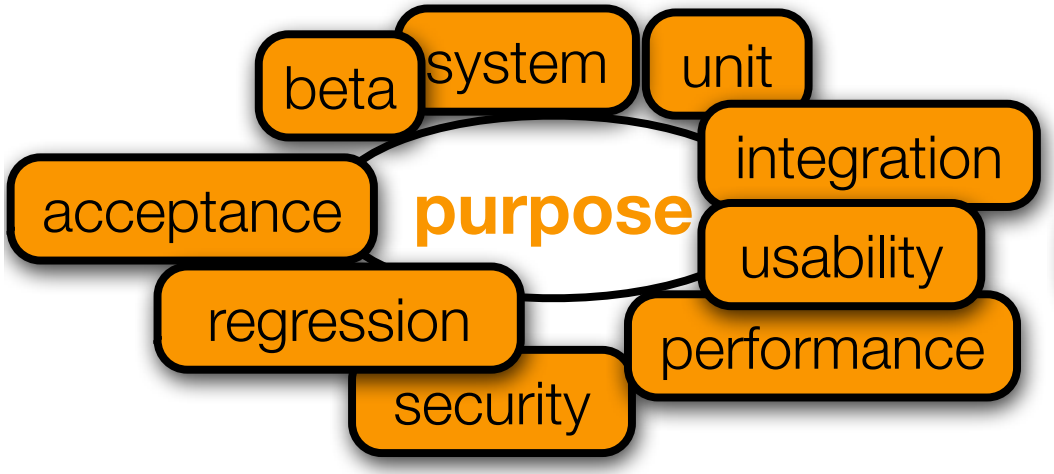

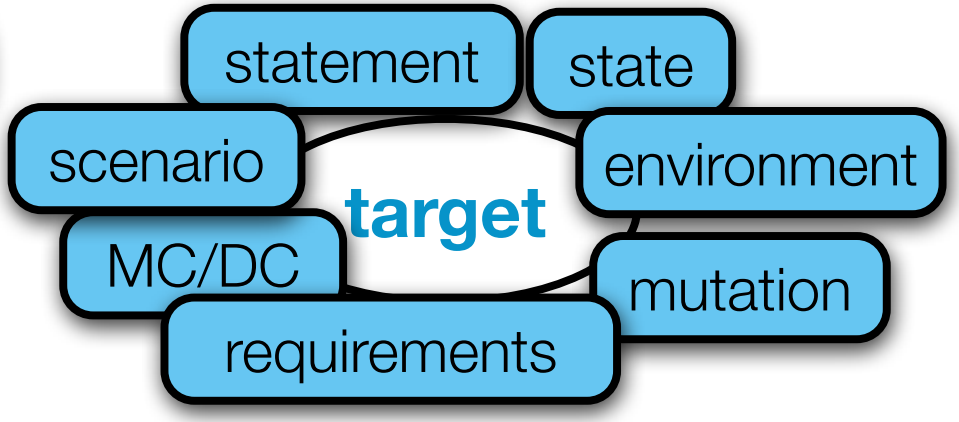

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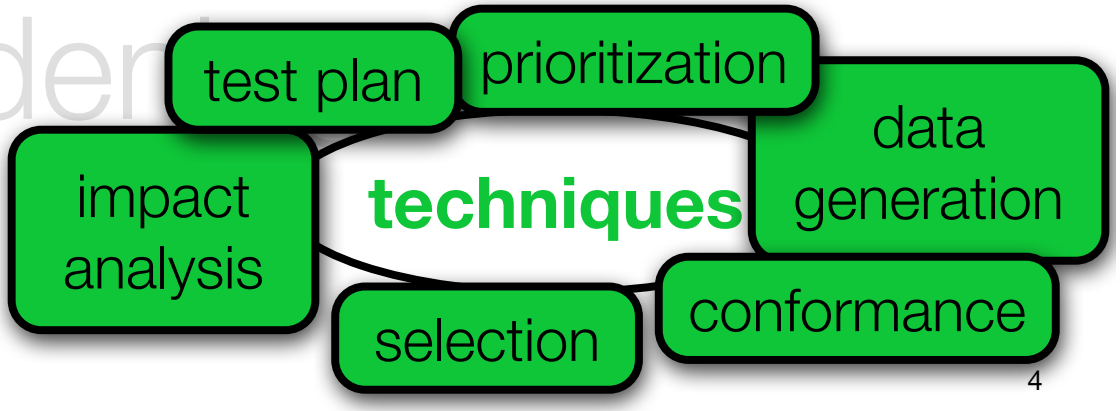

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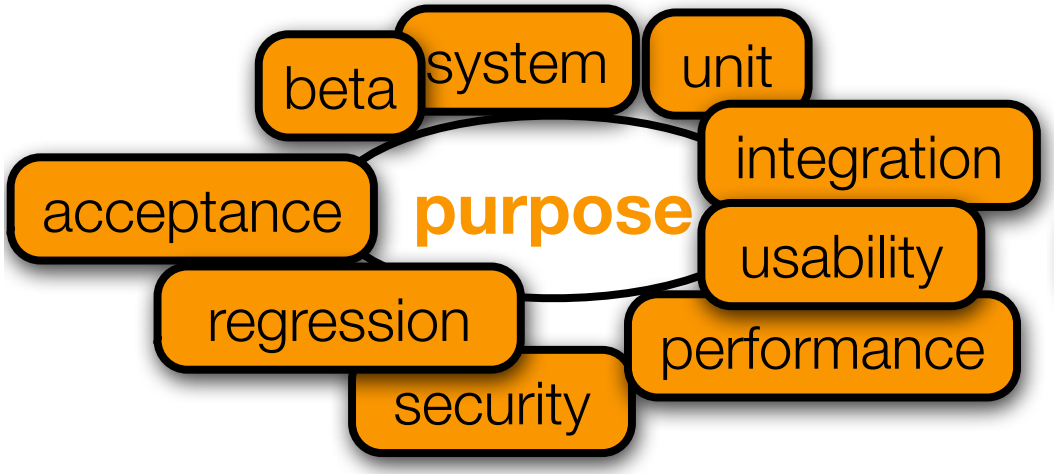
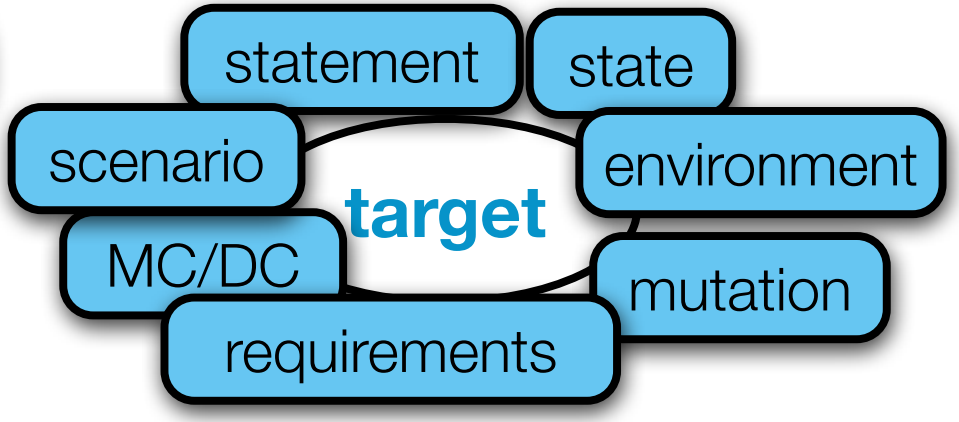
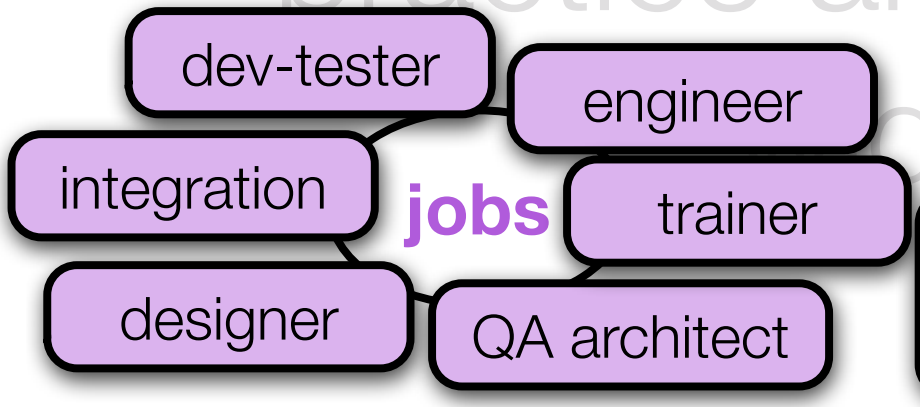
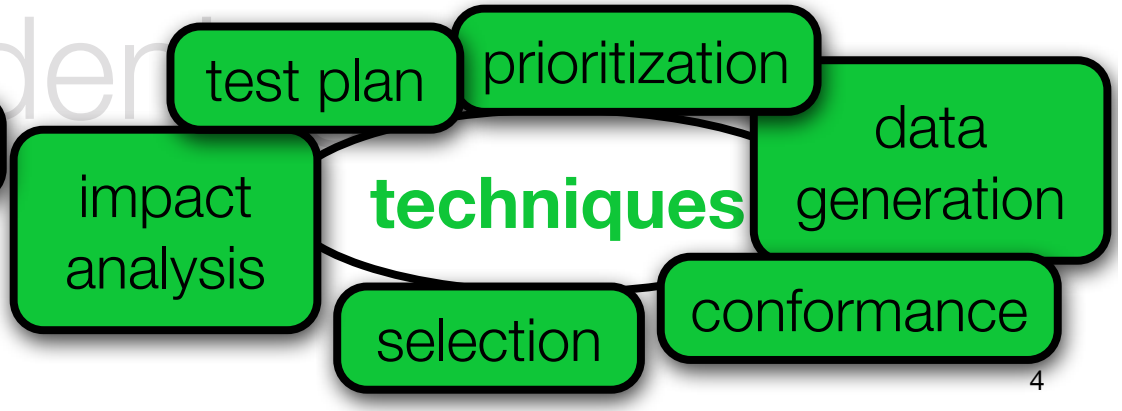
The scope of software testing practice and research is enormous









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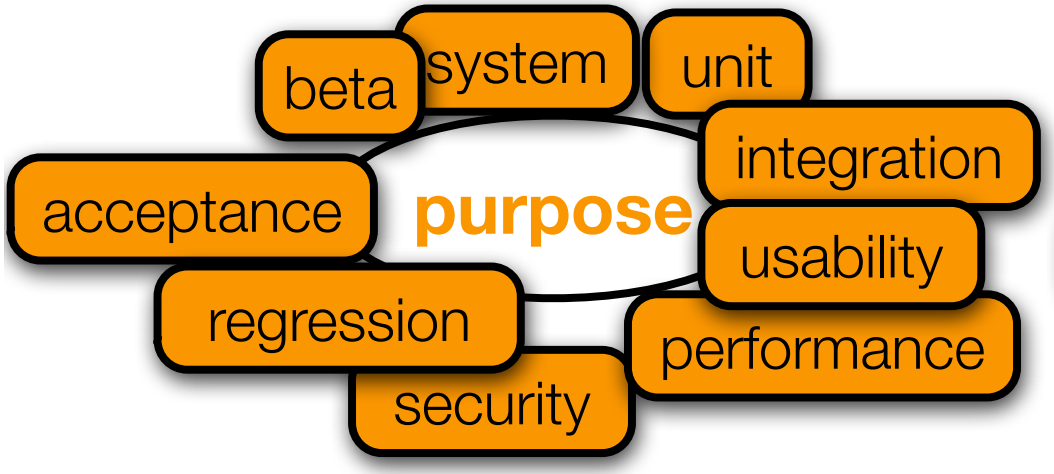

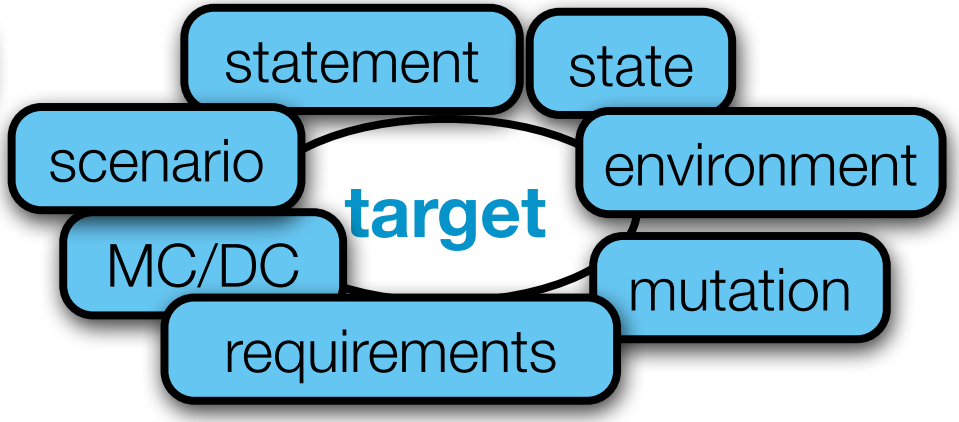

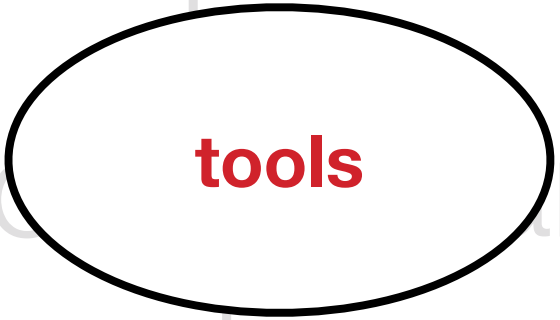

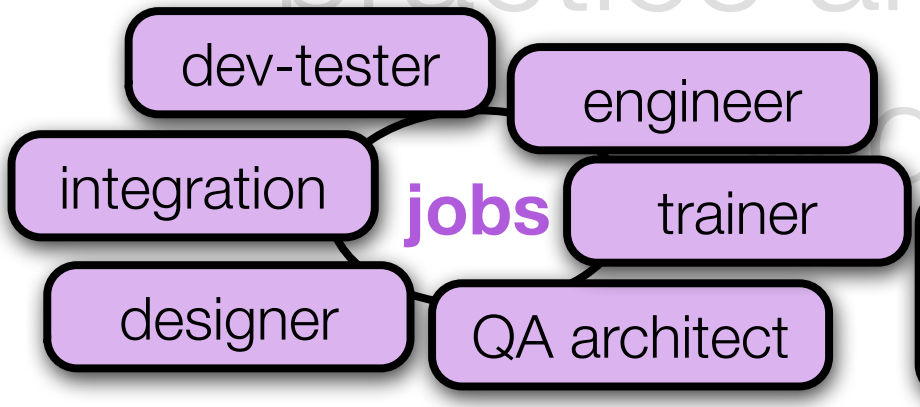

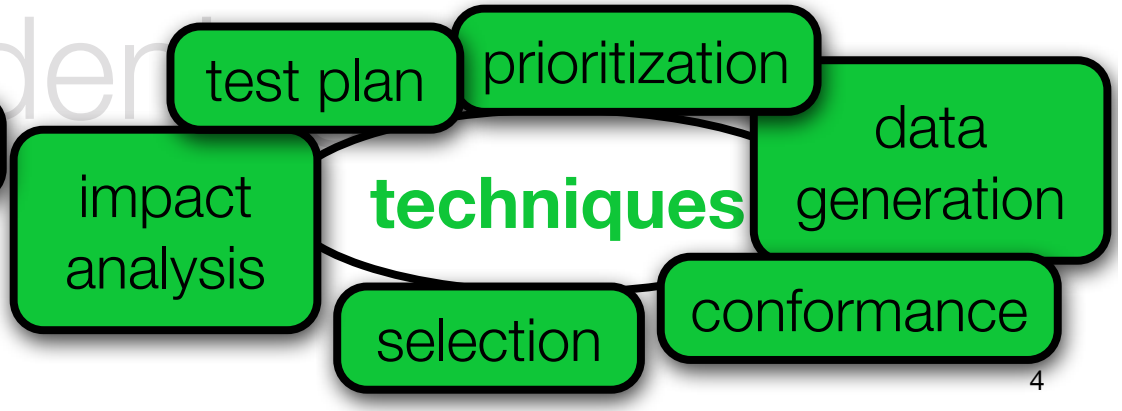

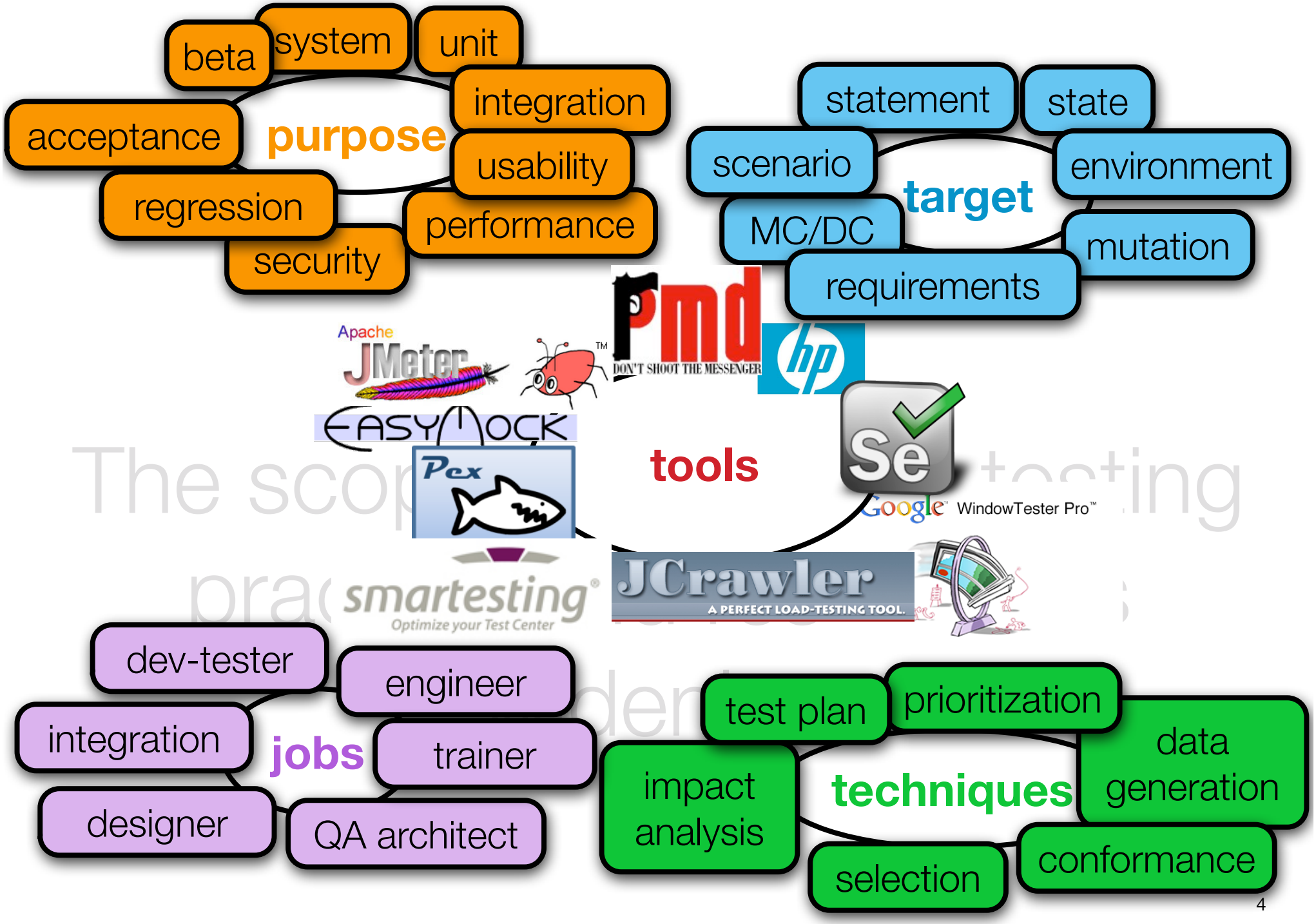
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acceptance
usability
regression
performance
security
target
statement
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requirements
tools
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pmd
DON'T SHOOT THE MESSENGER
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Pex
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smartesting
Optimize your Test Center
JCrawler
A PERFECT LOAD-TESTING TOOL.
jobs
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engineer
integration
trainer
designer
QA architect
techniques
test plan
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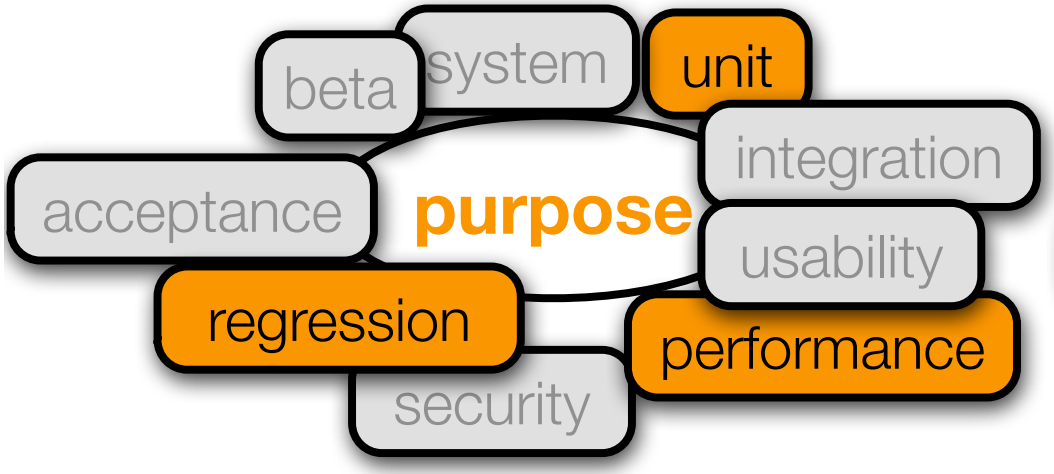
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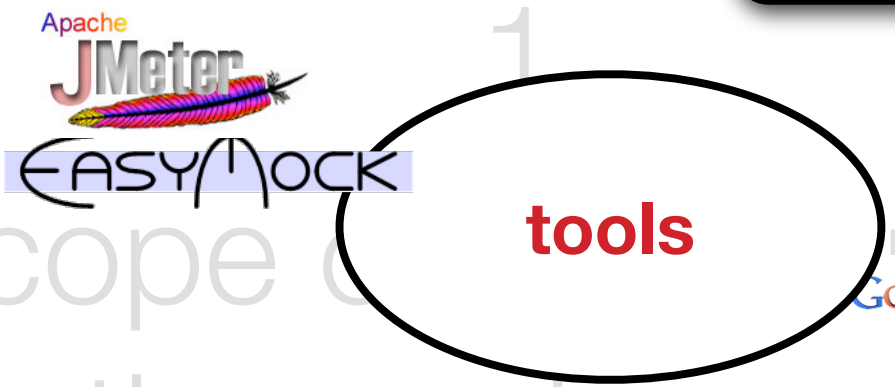
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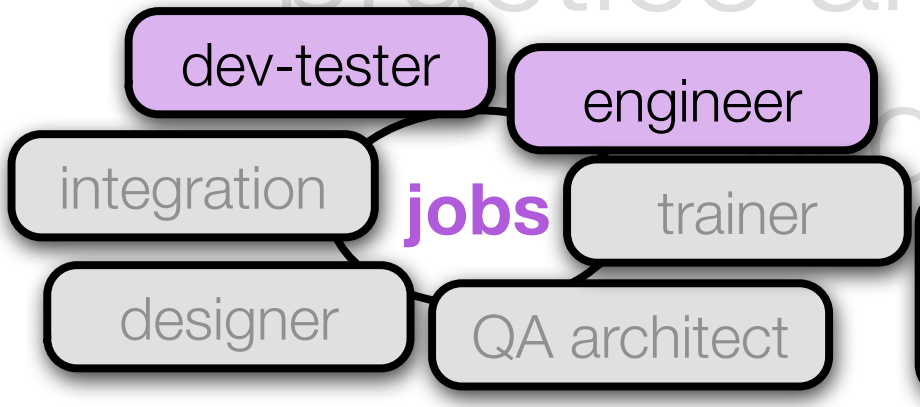
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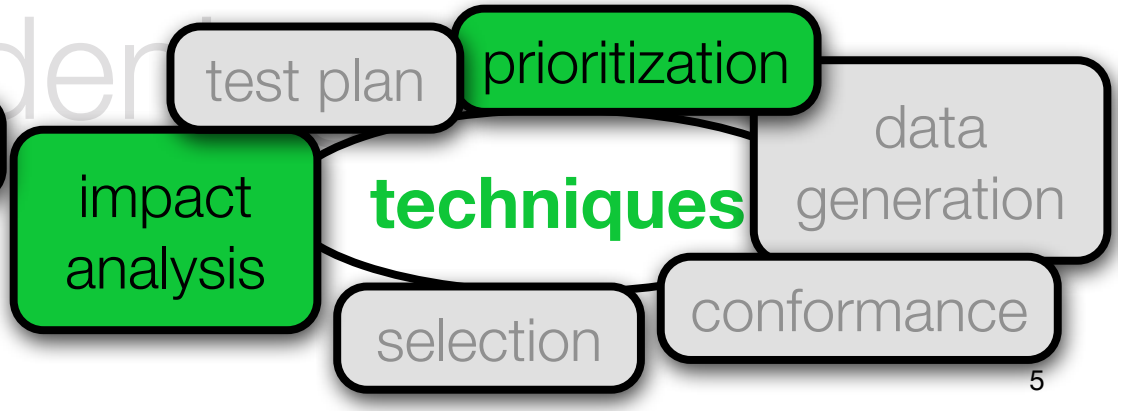
dev-tester
engineer
integration
trainer
designer
QA architect


techniques
test plan
prioritization
impact analysis
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conformance

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- system
- unit
- integration
- usability
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- security
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- statement
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- mutation
- requirements
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tools

jobs

- engineer
- trainer
- QA architect
- designer
- integration
- dev-tester

techniques

- test plan
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- conformance
- selection
- impact analysis

2.

because of (i) new ways of building software systems to (ii) face the growing diversity of applications and requirements for software systems

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processes

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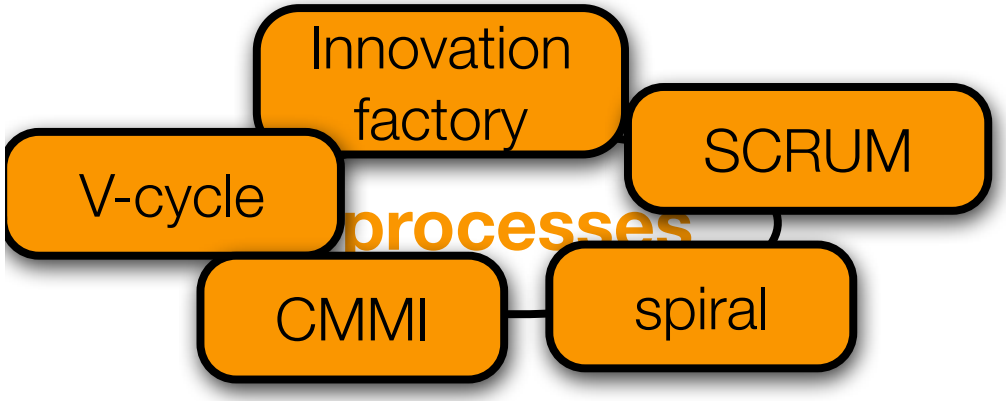

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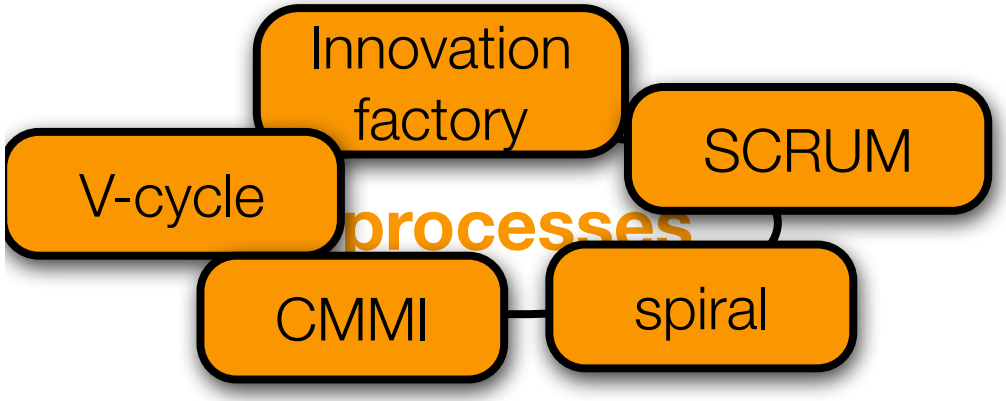

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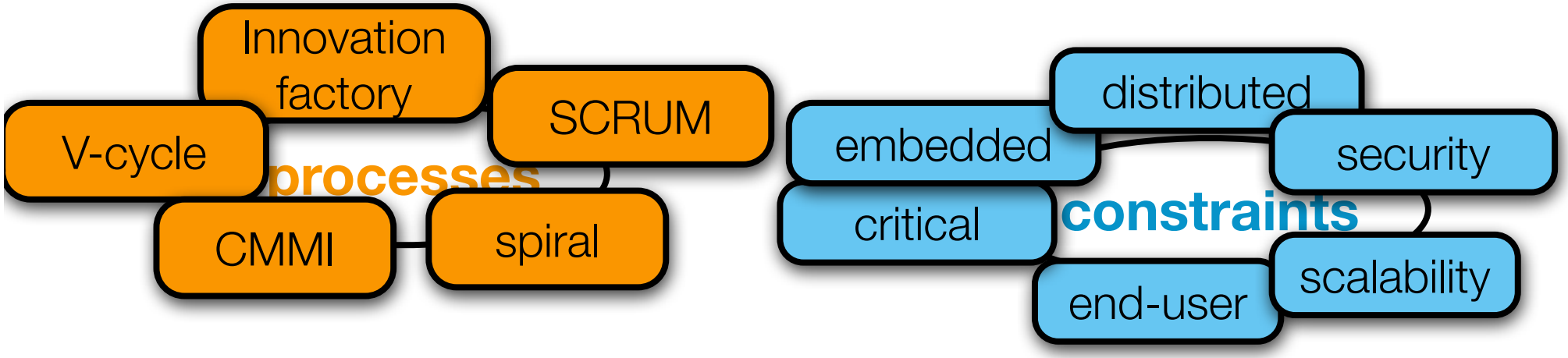

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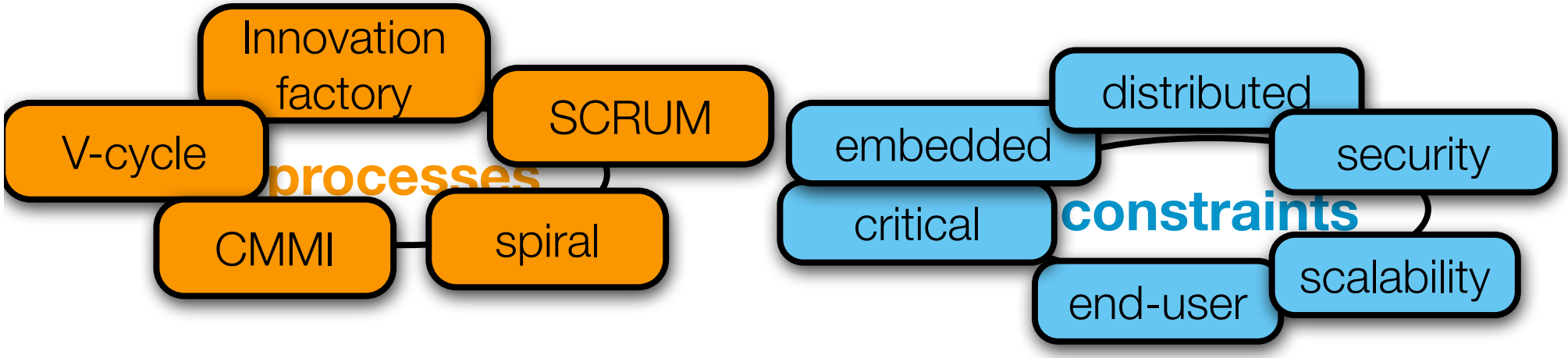

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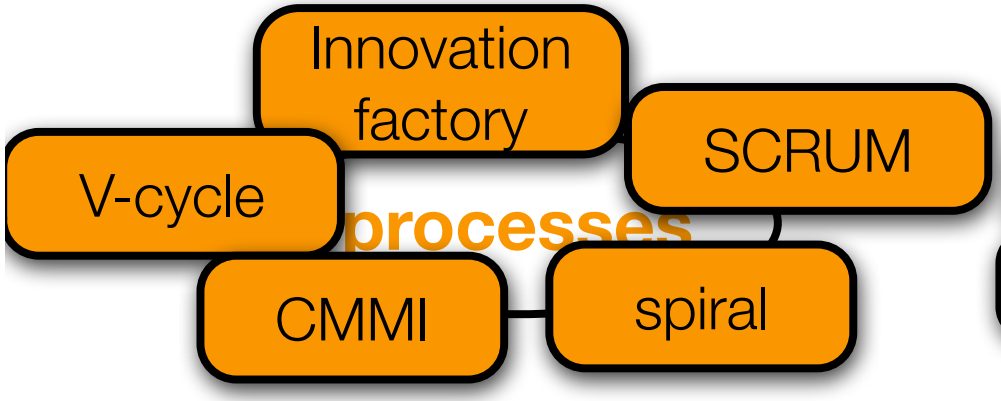

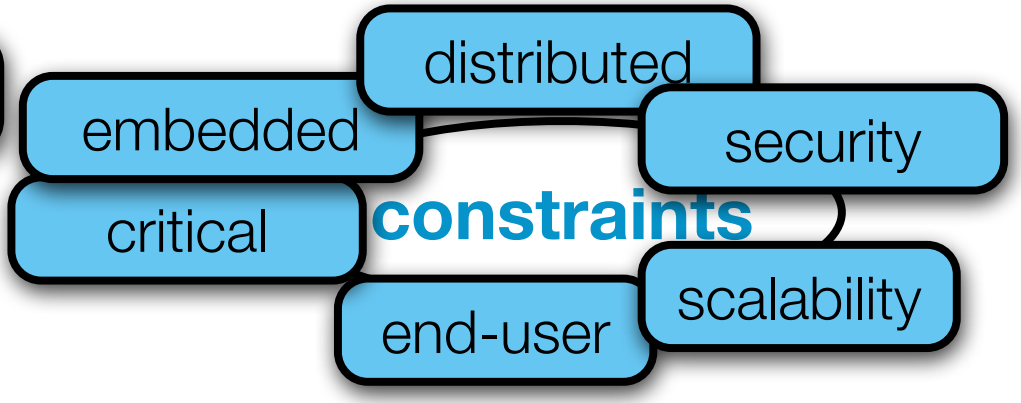

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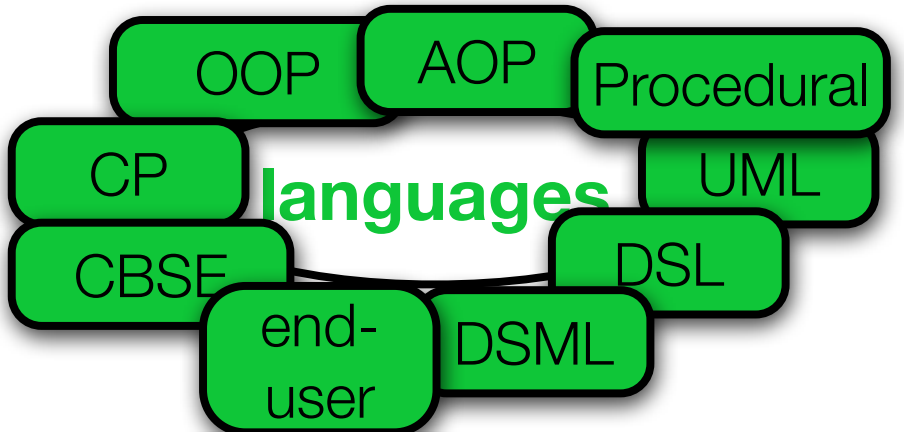

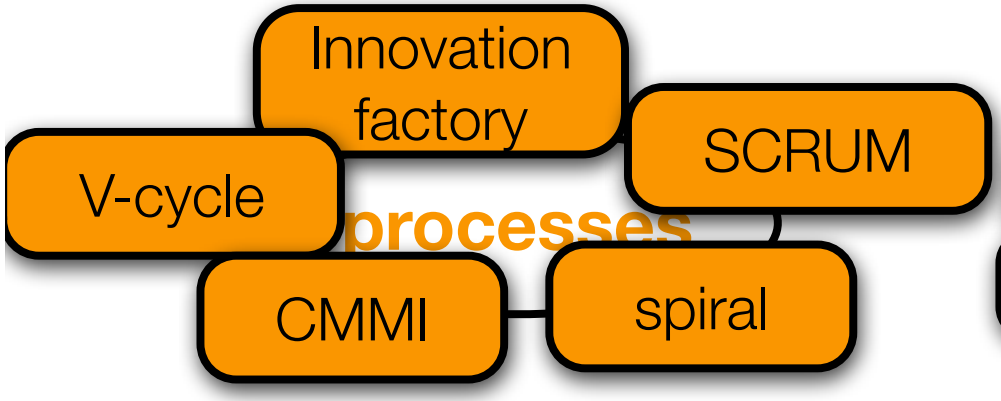

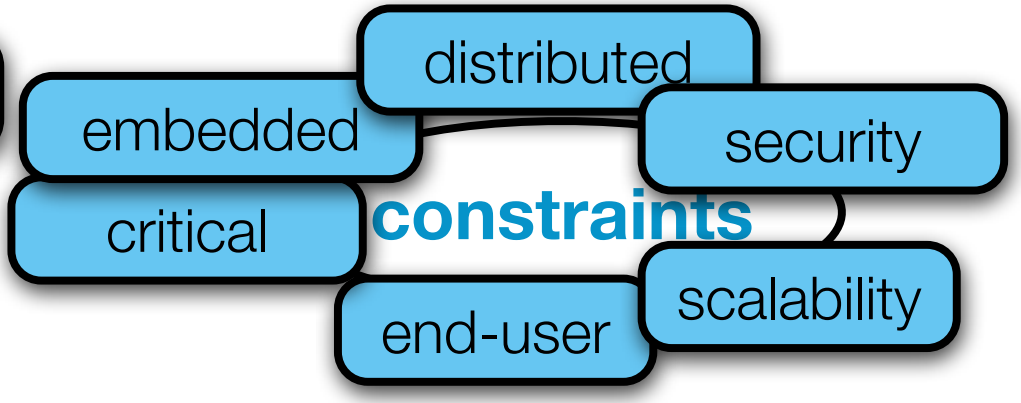

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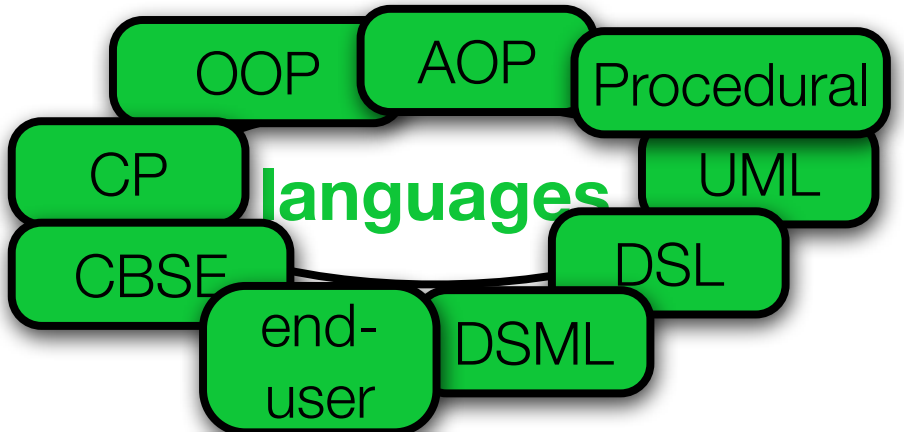

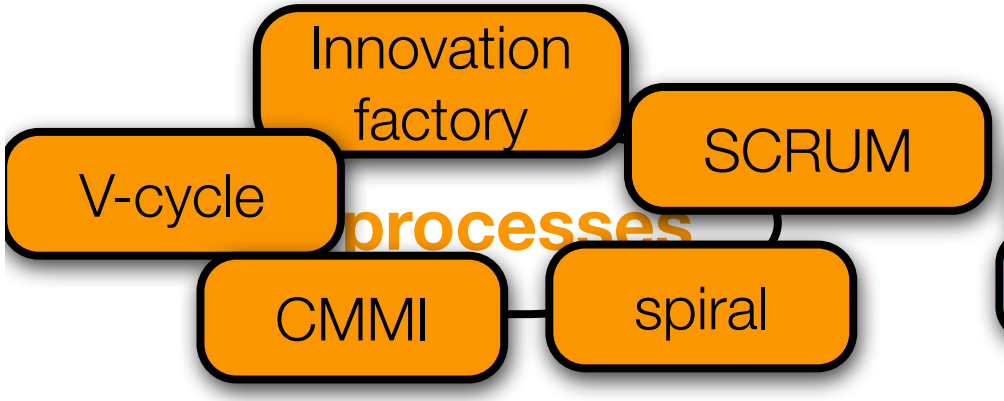

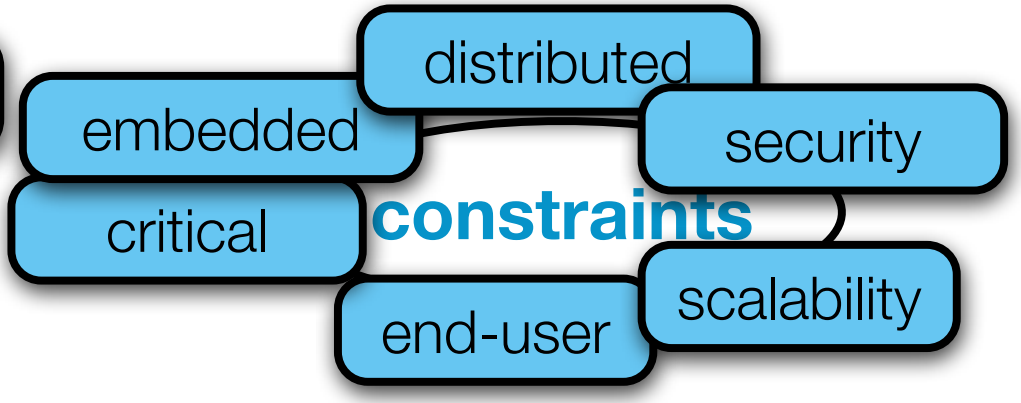

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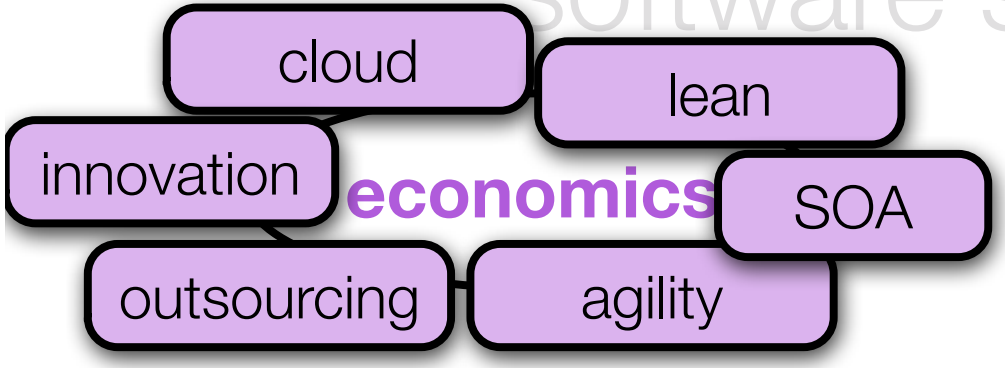

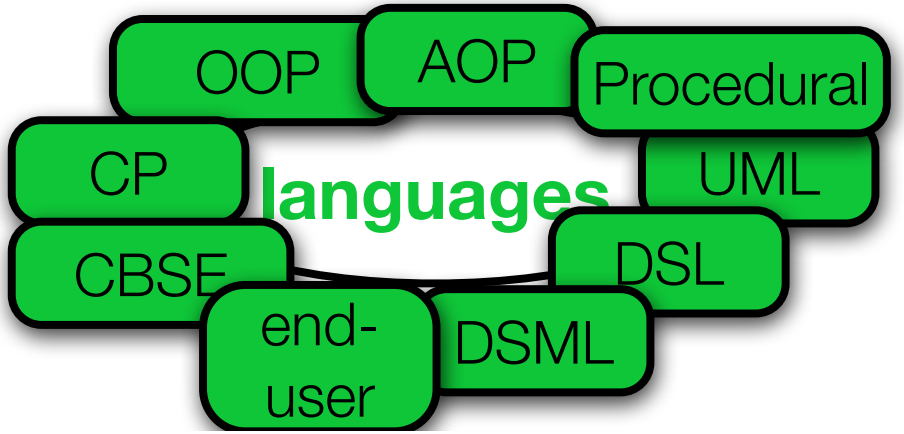

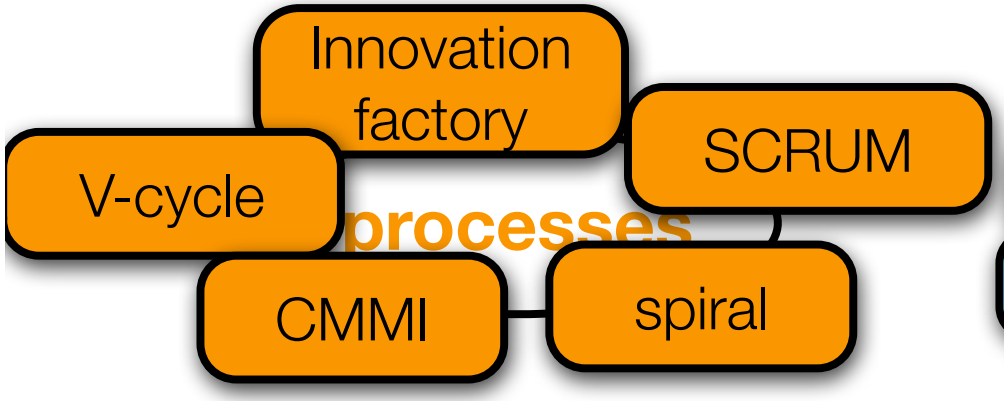

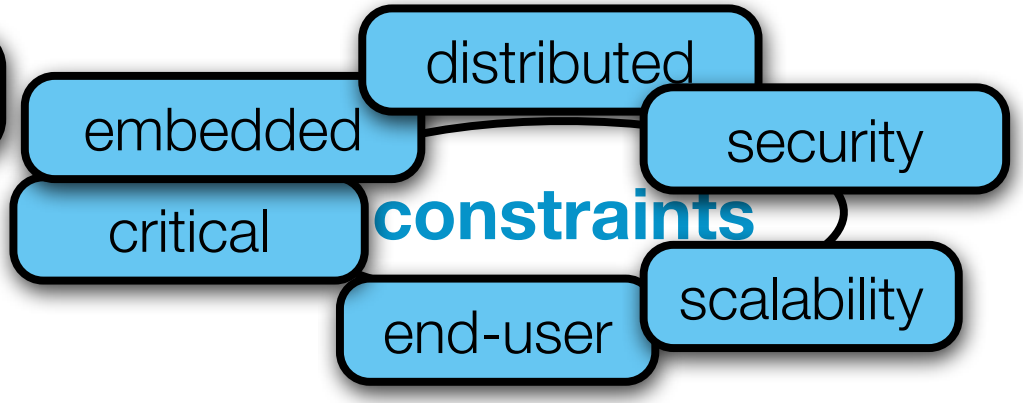

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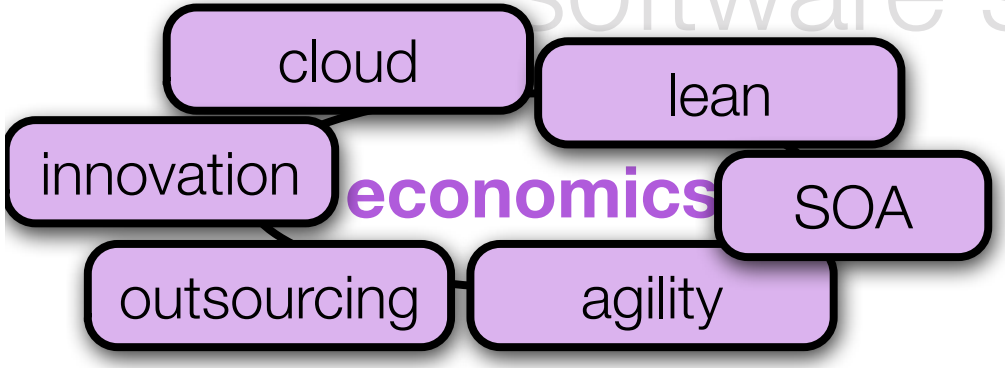

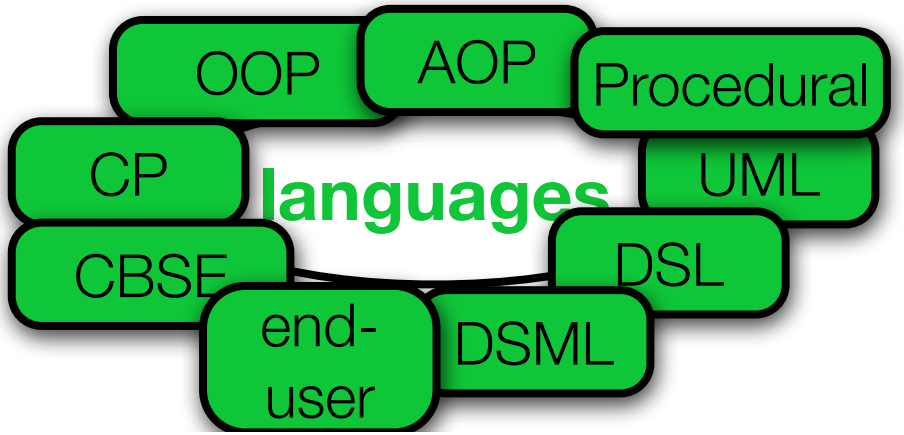

because our job is building software systems to

processes

Innovation factory
SCRUM
V-cycle
CMMI
spiral

constraints

distributed
embedded
security
critical
scalability
end-user

environments

J2EE Java 2 Platform Enterprice Edition
eclipse 2.1 The Eclipse Project
spring source
GWT
maven
ESTEREL Technologies
sonar
Cradle From concept to creation
MATLAB SIMULINK

economics

cloud
lean
innovation
SOA
outsourcing
agility

languages

OOP
AOP
Procedural
CP
UML
CBSE
DSL
end-user
DSML

Innovation factory

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(ii) face the growing diversity of applications and requirements for software systems

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+1.10
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AUTO CURTAIN
HOME ENTERTAINMENT
COMMUNICATION
MOODS
HOME AUTOMATION
GARAGE
AUTO SPRINKLERS
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AUTO LIGHTING
HOME BACK UP SYSTEM
SECURITY
eCAM


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AUTO CURTAIN
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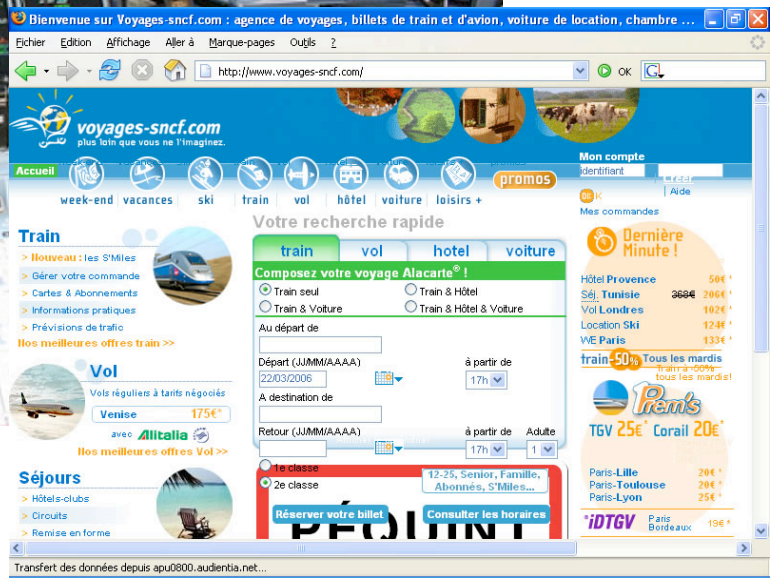
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Au départ de
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A destination de
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Venise 175€
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Nos meilleures offres Vol >>
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Circuits
Remise en forme
1e classe
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12-25, Senior, Famille, Abonnés, S'Miles...
Réserver votre billet
Consulter les horaires
Dernière Minute !
Hôtel Provence 50€
Séj. Tunisie 200€
Vol Londres 102€
Location Ski 124€
WE Paris 133€
train -50% Tous les mardis
Proms
TGV 25€ Corail 20€
Paris-Lille 20€
Paris-Toulouse 20€
Paris-Lyon 25€
iDTGV Paris Bordeaux 19€
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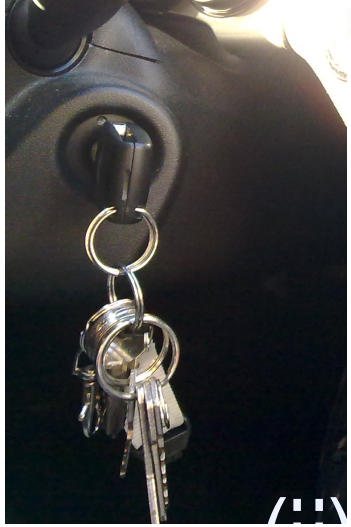


WEB 2.0 Landscape
WEB APPLICATION
Widget/ component
Aggregation/ recombination
CONTENT SHARING
RECOMMENDATIONS/ FILTERING
Rating/ Tagging
Collaborative filtering
SOCIAL NETWORK
FEUTURE EXPLORATION NETWORK
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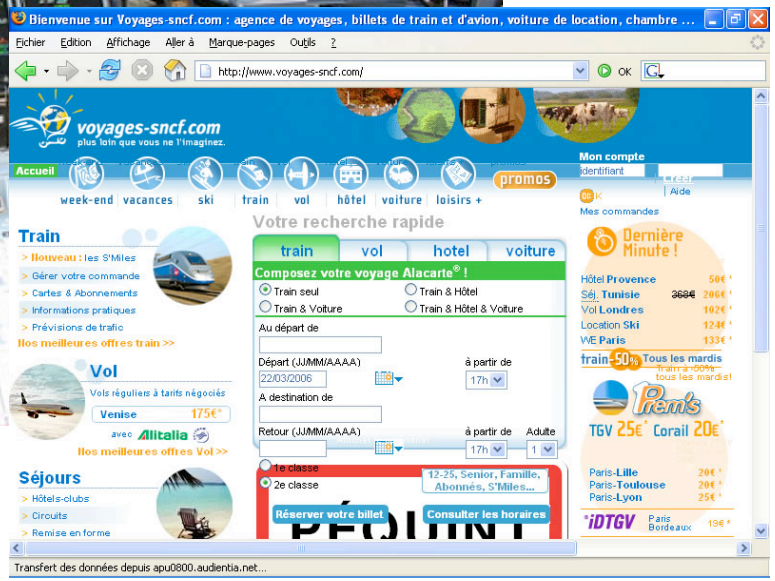
NASDAQ


AUTO CURTAIN
HOME ENTERTAINMENT
COMMUNICATION
MOODS
HOME AUTOMATION
GARAGE
AUTO SPRINKLERS
AUTO LIGHTING
HOME BACK UP SYSTEM
SECURITY
eCAM


Bienvenue sur Voyages-sncf.com : agence de voyages, billets de train et d'avion, voiture de location, chambre ...
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à partir de
17h
A destination de
Retour (JJ/MM/AAAA)
Adulte
1e classe
2e classe
12-25, Senior, Famille, Abonnés, S'Miles...
Réserver votre billet
Consulter les horaires
Train
Nouveau : les S'Miles
Gérer votre commande
Cartes & Abonnements
Informations pratiques
Prévisions de trafic
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Vols réguliers à tarifs négociés
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Location Ski 124€
WE Paris 133€
train -50% Tous les mardis
Proms
TGV 25€ Corail 20€
Paris-Lille 20€
Paris-Toulouse 20€
Paris-Lyon 25€
iDTGV Paris Bordeaux 19€
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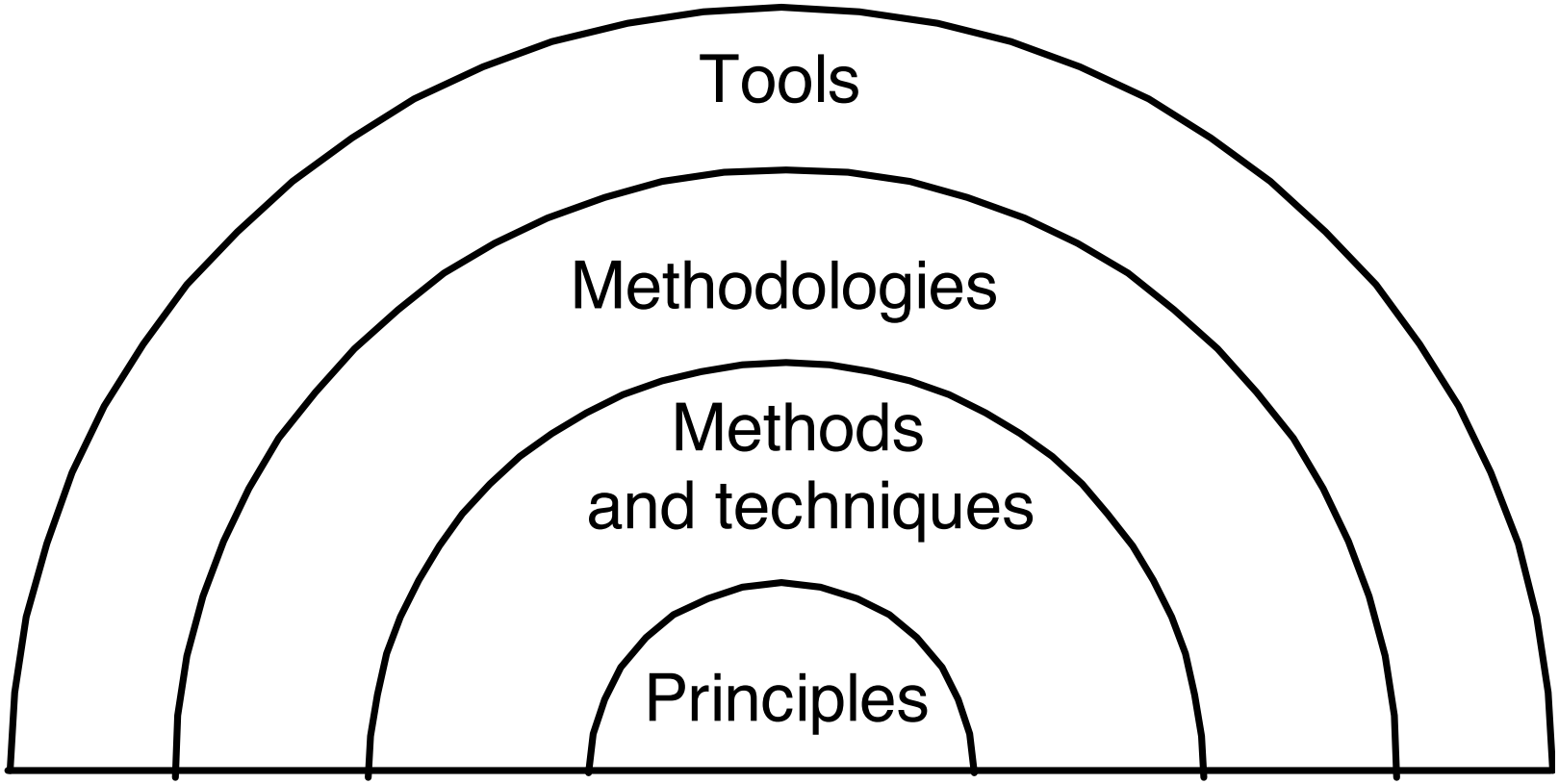
3.

The identification of core principles underlying this apparent seething landscape is a major challenge for research in software engineering.

A visual representation

Carlo Ghezzi, Mehdi Jazayeri, and Dino Mandrioli.
Fundamentals of Software Engineering, 2nd edition. 2002.



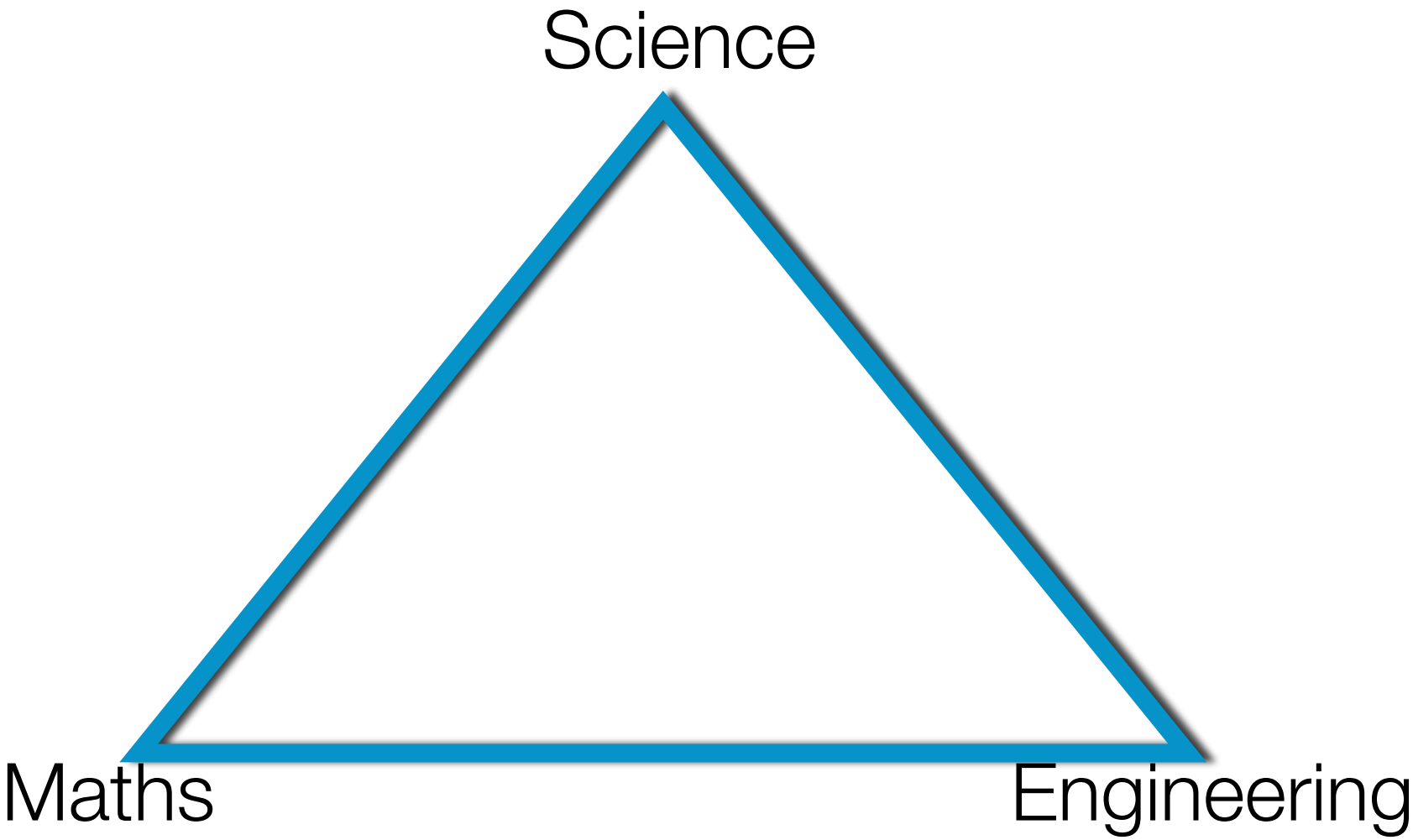
Key principles

Carlo Ghezzi, Mehdi Jazayeri, and Dino Mandrioli.
Fundamentals of Software Engineering, 2nd edition. 2002.

- Rigor and formality
- Separation of concerns
- Modularity
- Abstraction
- Anticipation of change
- Generality
- Incrementality

Research in Software Engineering

Peter J. Denning: Is computer science science?. *Communications of the ACM, 2005.* ***48****(4): p. 27 – 31.*



Research in Software Engineering

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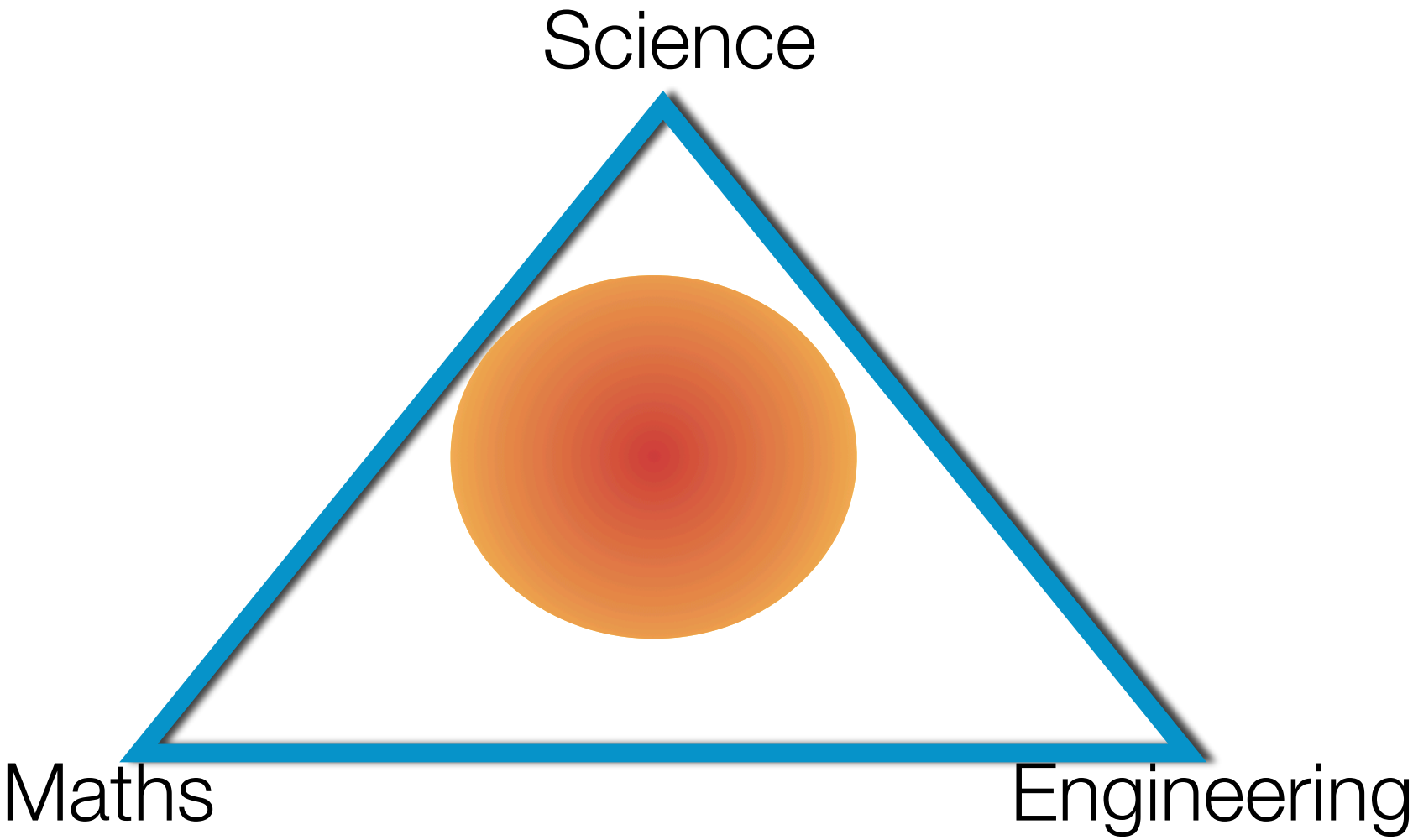
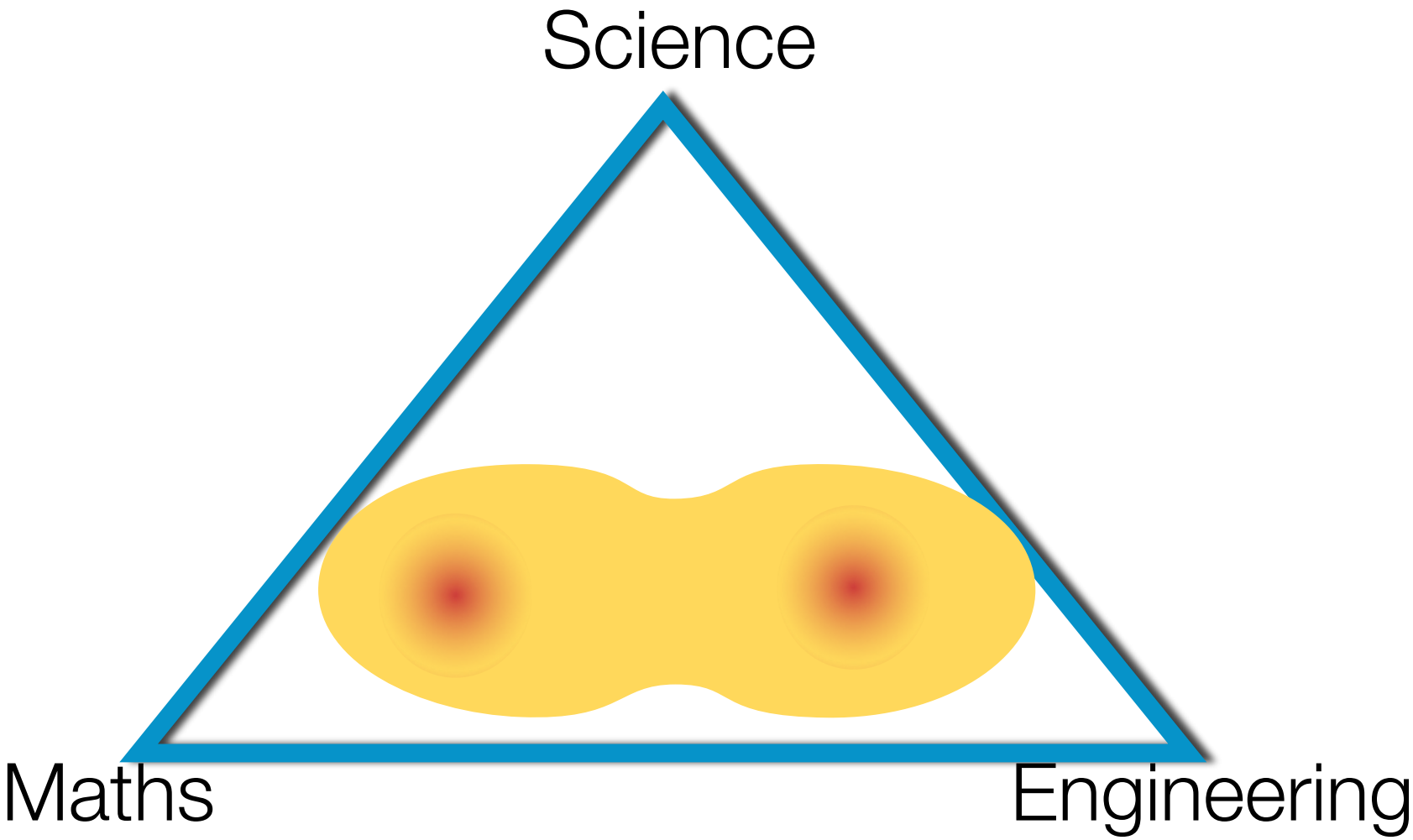


Research in Software Engineering

Peter J. Denning: Is computer science science?. *Communications of the ACM, 2005.* ***48****(4): p. 27 – 31.*



4.

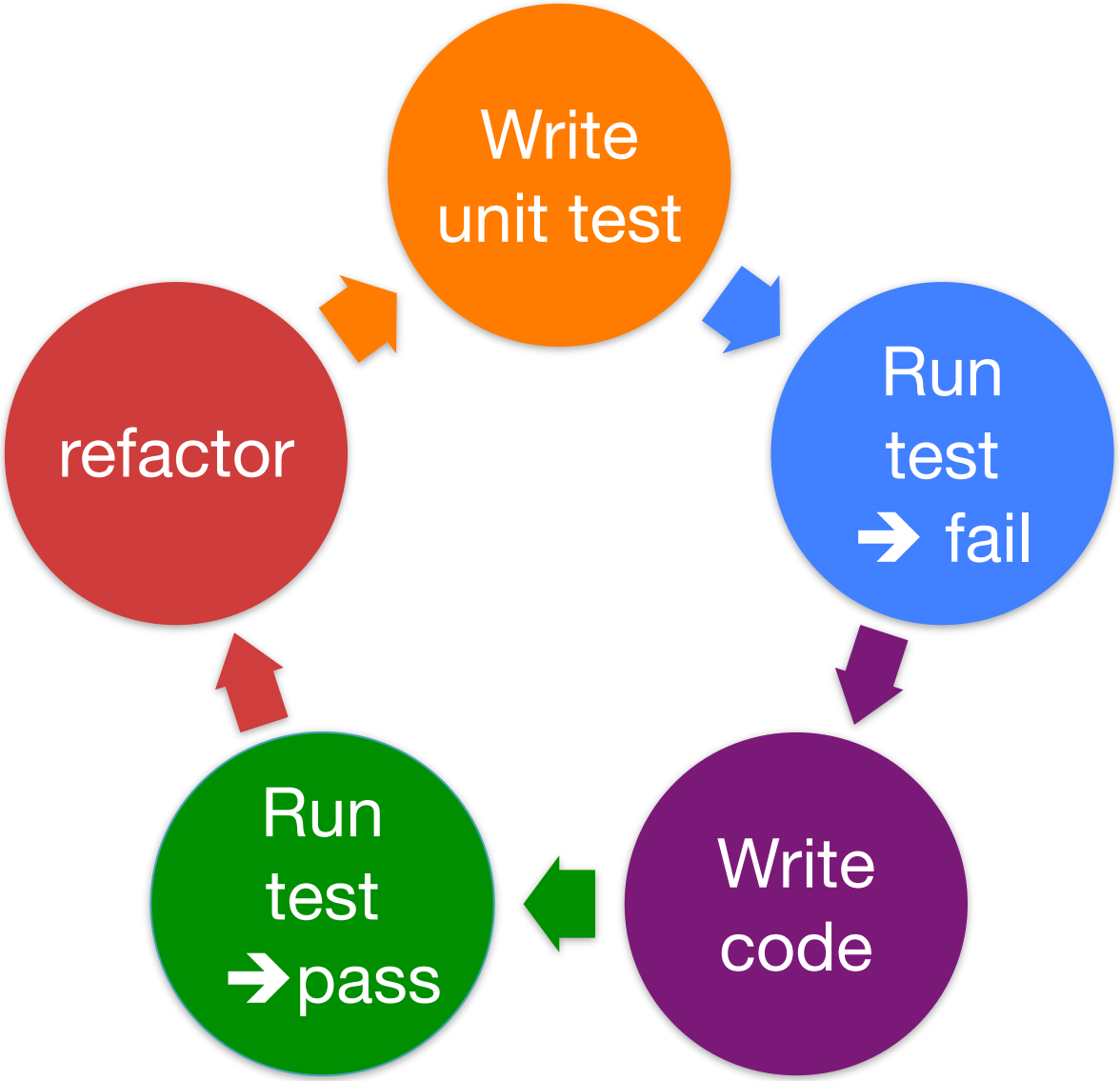
The confrontation of these core principles with the broadening scope of software leads to the emergence of new software construction paradigms

Software construction paradigms

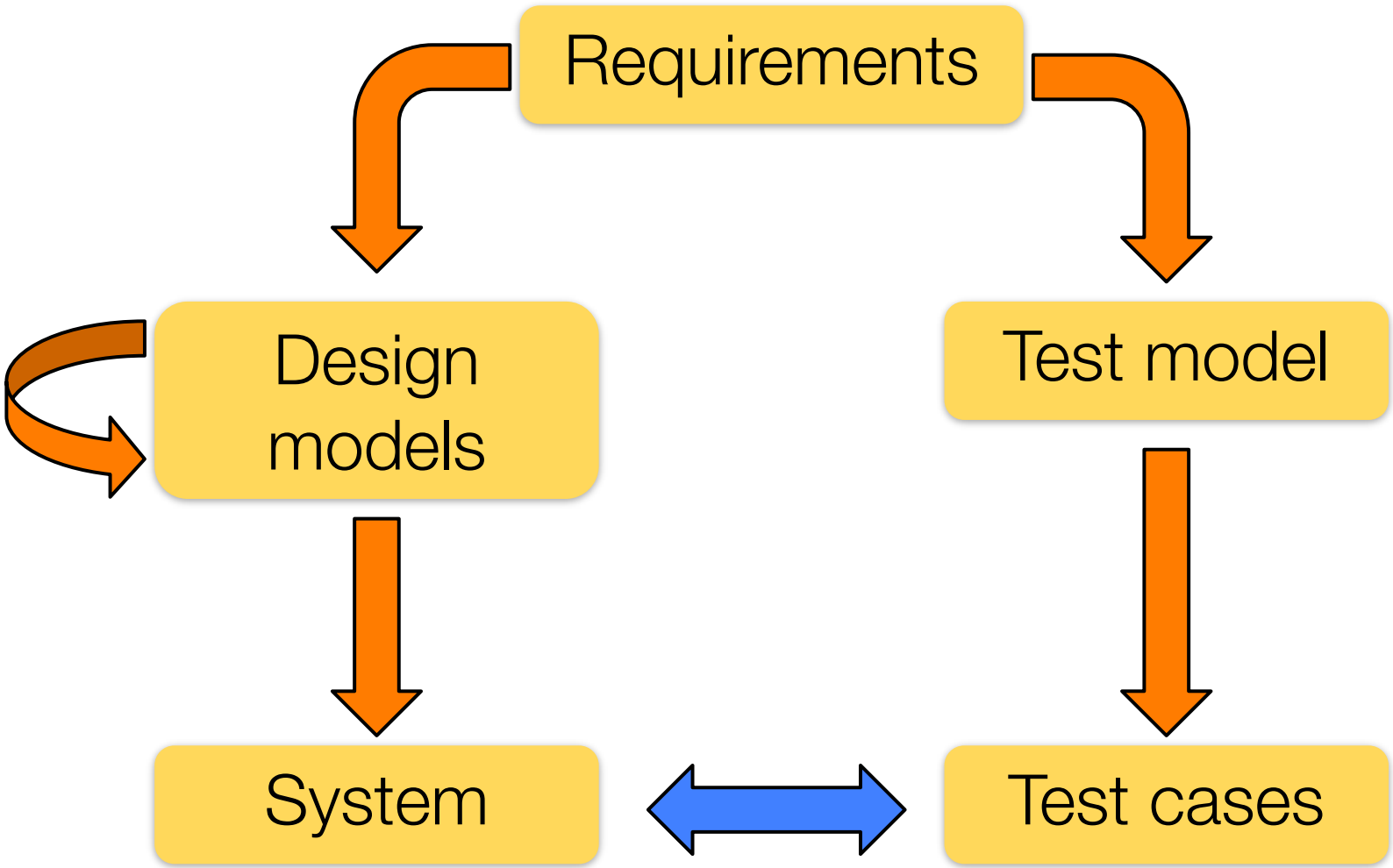
- Object-oriented programming
- Aspect-oriented programming
- Model-driven development
- Aspect-oriented modelling
- Multi-paradigm modelling

Software testing research for emerging paradigms extends beyond error detection to analyze and include the context imposed by these paradigms

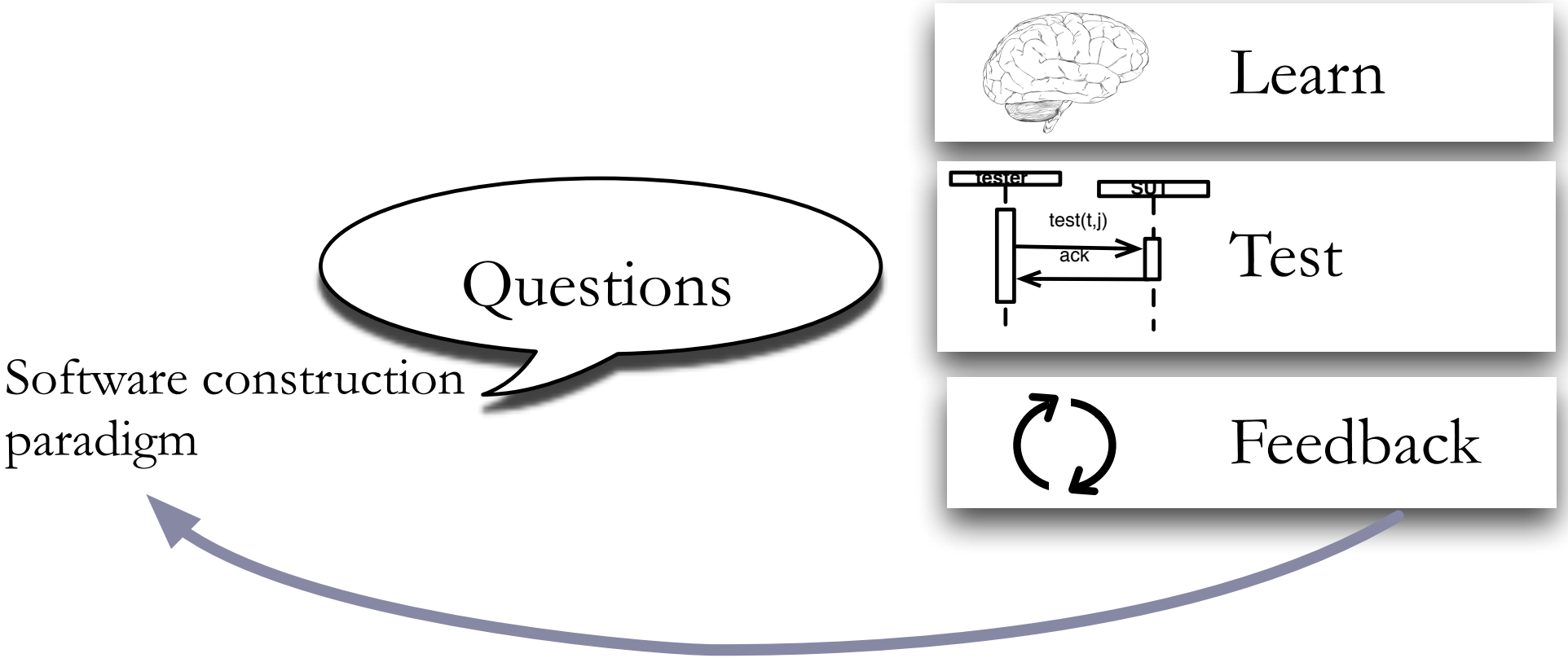
Agility and Test Driven Development



MDD and MBT

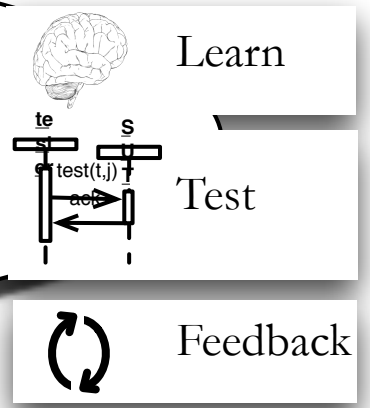


QLTF pattern



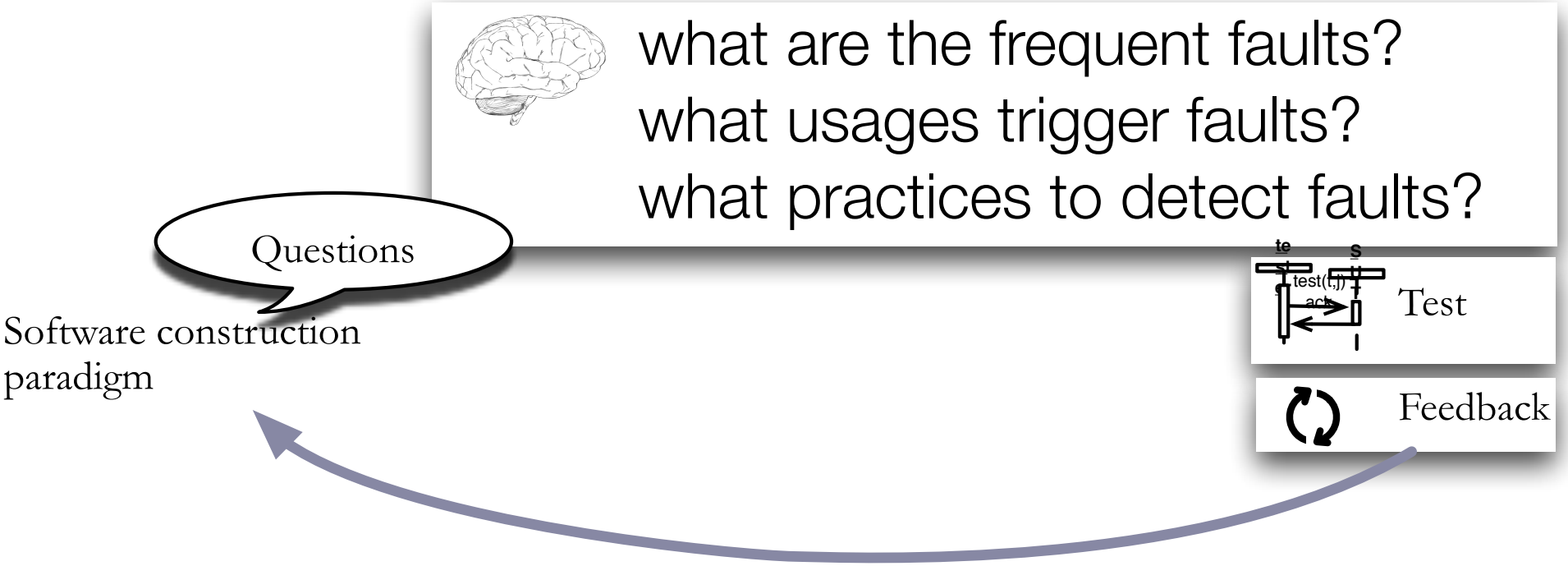
Mutation in QLTF

what can go wrong?
what type of errors are we looking for?
what can mitigate/increase error risks?

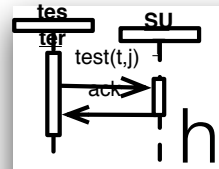


Software construction paradigm

Mutation in QLTF



Mutation in QLTF



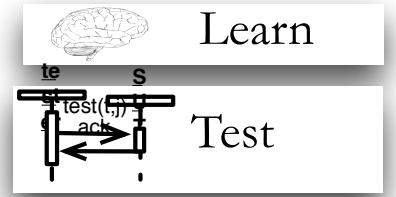
how can we assist fault detection?
do our techniques detect faults?
are new adequacy criteria adequate?

Questions

Software construction paradigm

Feedback

Mutation in QLTF

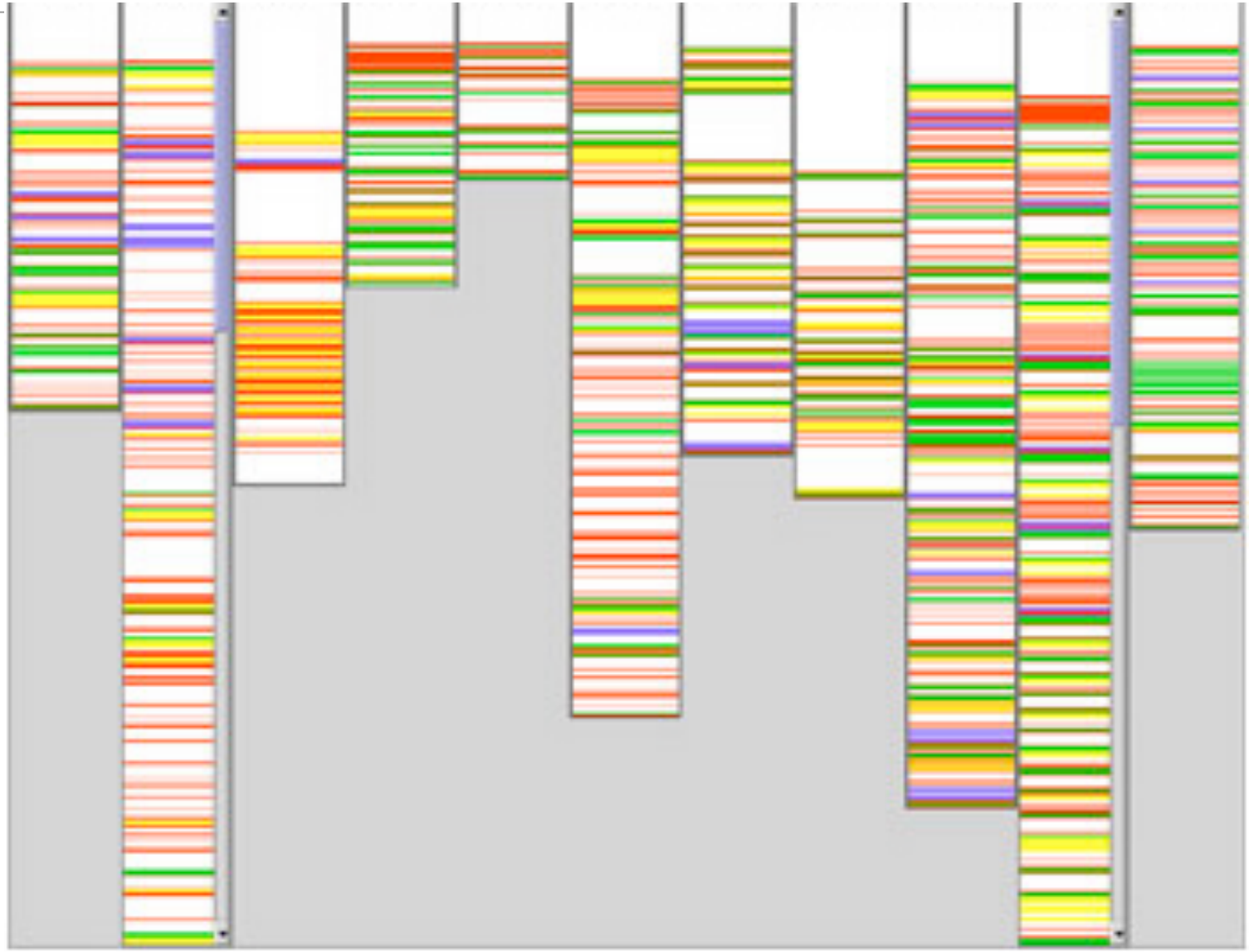


Questions

how can we prevent faults?
how can testability be improved?
how can test be integrated in dev. processes?

Software construction paradigm

Aspect oriented programming



An example: AOP

```
class Point implements FigureElement {
  private int x = 0, y = 0;

   int getX() { return x; }
   int getY() { return y; }
   void setX(int x) {
        this.x = x;
   }
   void setY(int y) {
        this.y = y;
   }
   void moveBy(int dx, int dy) {
        ...
   }
}
 class Line implements FigureElement{
    private Point p1, p2;

     Point getP1() { return p1; }
     Point getP2() { return p2; }
     void setP1(Point p1) {
          this.p1 = p1;
     }
     void setP2(Point p2) {
          this.p2 = p2;
     }
     void moveBy(int dx, int dy) {
          ...
     }
 }
```

```
aspect DisplayUpdating {
    pointcut move():
         call(void FigureElement.moveBy(int, int))||
         call(void Line.setP1(Point))             ||
         call(void Line.setP2(Point))             ||
         call(void Point.setX(int))               ||
         call(void Point.setY(int));
    after(): move() {
         Display.update();
    }
}
```

An example: AOP

```
class Point implements FigureElement {
  private int x = 0, y = 0;

   int getX() { return x; }
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          this.p2 = p2;
     }
     void moveBy(int dx, int dy) {
          ...
     }
 }
```

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}
```

Advice

An example: AOP

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class Point implements FigureElement {
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   }
   void moveBy(int dx, int dy) {
        ...
   }
}

 class Line implements FigureElement{
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          this.p1 = p1;
     }
     void setP2(Point p2) {
          this.p2 = p2;
     }
     void moveBy(int dx, int dy) {
          ...
     }
 }
```

Pointcut descriptor (PCD)

```
aspect DisplayUpdating {
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        call(void Line.setP1(Point))             ||
        call(void Line.setP2(Point))             ||
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    }
}
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Advice

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   }
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        this.y = y;
   }
   void moveBy(int dx, int dy) {
        ...
   }
}

 class Line implements FigureElement{
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     }
     void setP2(Point p2) {
          this.p2 = p2;
     }
     void moveBy(int dx, int dy) {
          ...
     }
 }
```

JoinPoint

Pointcut descriptor (PCD)

```
aspect DisplayUpdating {
    pointcut move():
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        call(void Line.setP1(Point))             ||
        call(void Line.setP2(Point))             ||
        call(void Point.setX(int))               ||
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    }
}
```

Advice

An example: AOP

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   }
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        ...
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 class Line implements FigureElement{
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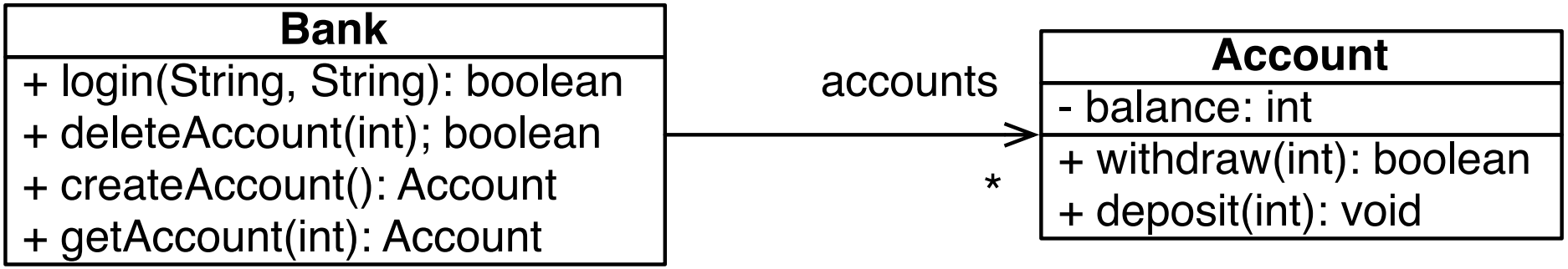
     void setP2(Point p2) {
          this.p2 = p2;
     }
     void moveBy(int dx, int dy) {
          ...
     }
 }
```

JoinPoint

Pointcut descriptor (PCD)

```
aspect DisplayUpdating {
    pointcut move():
        call(void FigureElement.moveBy(int, int))||
        call(void Line.setP1(Point))             ||
        call(void Line.setP2(Point))             ||
        call(void Point.setX(int))               ||
        call(void Point.setY(int));
    after(): move() {
        Display.update();
    }
}
```

Advice

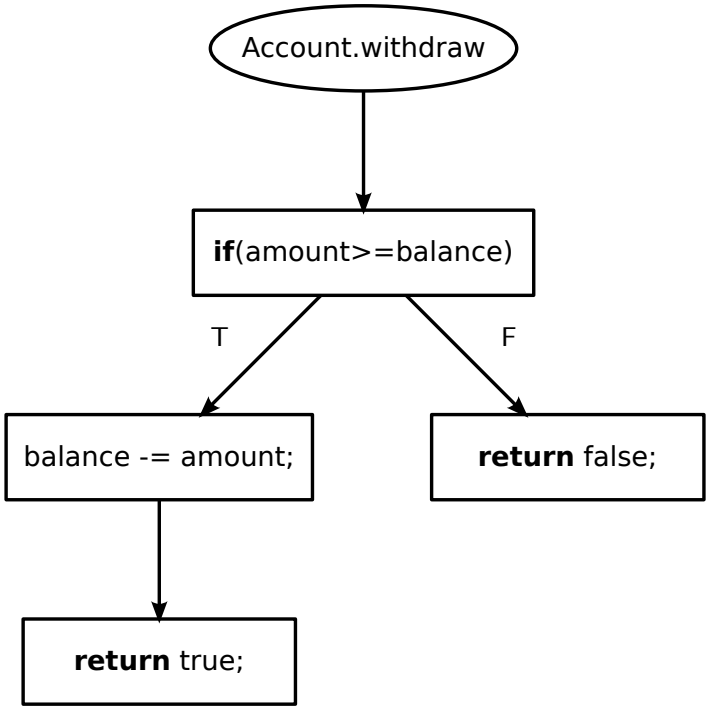



```
public aspect AccessControl {
    pointcut controlledAccess():
      execution(* Account.*(int));

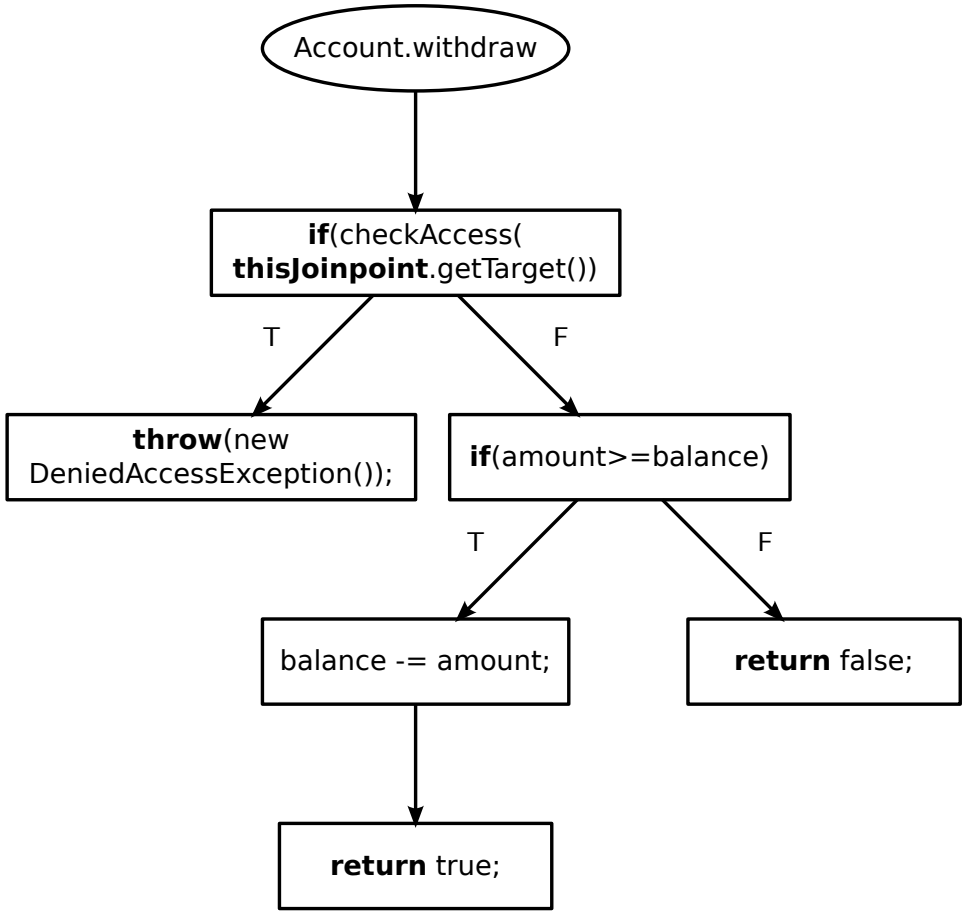
    @AdviceName("AccessControl")
    before(): controlledAccess() {
        if(!checkAccess(thisJoinPoint.getTarget()))
            throw new DeniedAccessException();
    }
}
```

- A fault in the PCD can have a ripple effect and result in many different faults

Withdraw

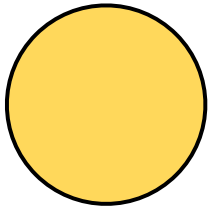

Account.withdraw
if(amount>=balance)
T
F
balance -= amount;
return false;
return true;

(a)


Account.withdraw
if(checkAccess(
thisJoinpoint.getTarget())
T
F
throw(new
DeniedAccessException());
if(amount>=balance)
T
F
balance -= amount;
return false;
return true;

(b)

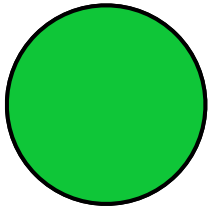
Faults in PCD



Intended

Matched

Faults in PCD

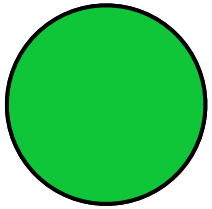


correct PCD

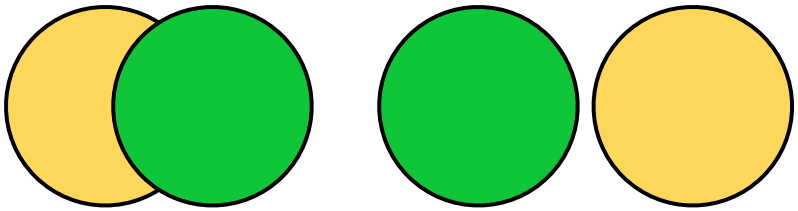
Intended

Matched

Faults in PCD



correct PCD

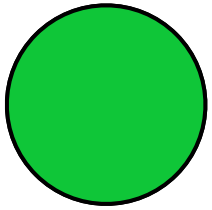


both neglected and unintended

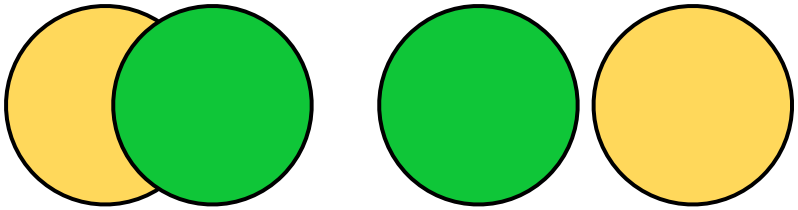
Intended

Matched

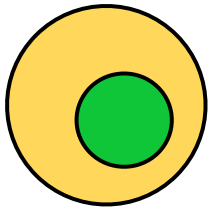
Faults in PCD



correct PCD



both neglected and unintended

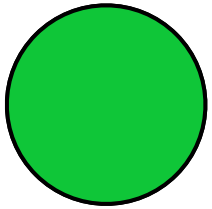


neglected joinpoints

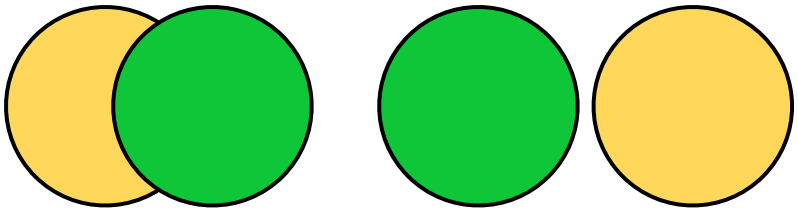
Intended

Matched

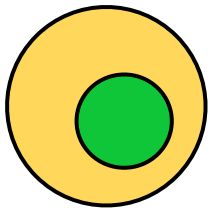
Faults in PCD



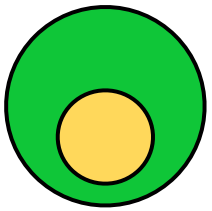
correct PCD



both neglected and unintended



neglected joinpoints



unintended joinpoints

- both neglected and unintended

```
pointcut controlledAccess(): execution(* Bank.*(int));
```

matches `deleteAccount()` and `getAccount()`

```
pointcut controlledAccess(): execution(boolean Bank.*(int));
```

matches `deleteAccount()` and `login()`

- neglected joinpoints

```
pointcut controlledAccess(): execution(* Account.*(int));
```

matches `withdraw()` and `deposit()`

```
pointcut controlledAccess(): execution(boolean Account.*(int));
```

matches `withdraw()`

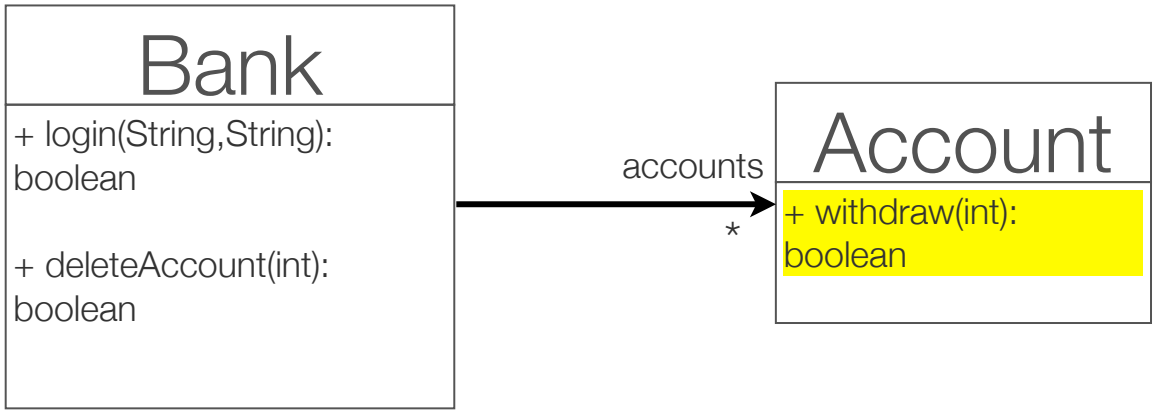
Mutant PCD

- A PCD where a fault has been inserted
  - Selects a different set of joinpoints
- Equivalent mutant
  - Mutant that matches the same set of joinpoint
  - Equivalent mutants can be detected statically

Mutation Operators

Operator	Description
PCCC	Replaces a `cflow` by a `cflowbelow`, or the contrary
PCCE	Replaces a `call` by an `execution`, or the contrary
PCGS	Replaces a `get` by a `set`, or the contrary
PCLO	Changes the logical operators in a composition of PCDs
PCTT	Replaces a `this` by a `target`, or the contrary
POEC	Adds, removes or changes throwing clauses
POPL	Changes the parameter list
PSWR	Removes wildcards
PWAR	Removes annotation from type, field or method patterns
PWIW	Adds wildcards

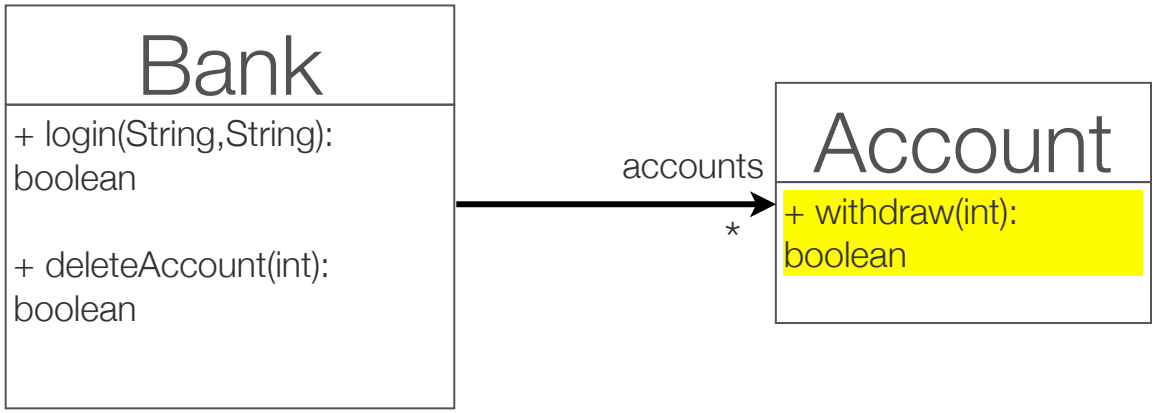
Testing the PCD: an example – 1




```
public aspect AccessControl {
    pointcut controlledAccess(): execution(* Account.*(int))

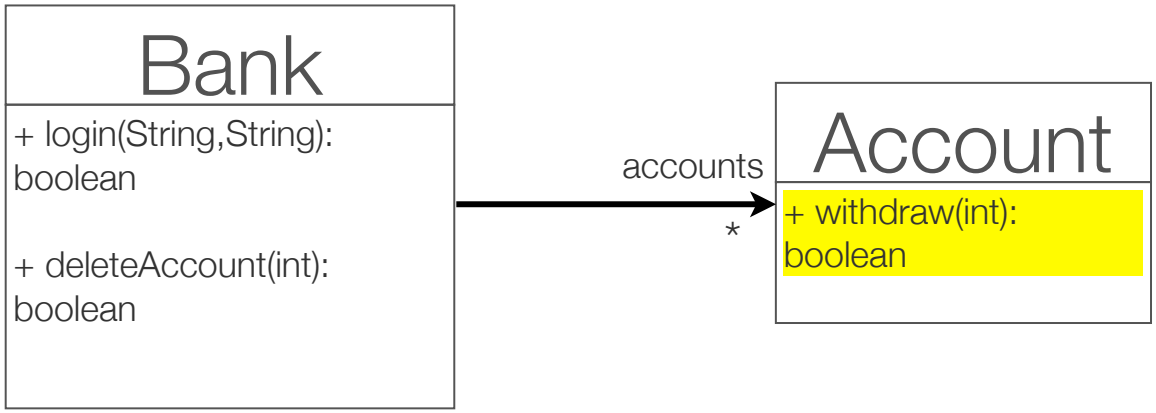
    @AdviceName("AccessControl")
    before(): controlledAccess() {
        if(!checkAccess(thisJoinPoint.getTarget()))
            throw new DeniedAccessException();
    }
}
```

Testing the PCD: an example – 1




```
public void testAccessControlDelete() {
    bank.login(nonAuthorizedUser,password);
    try {
        account.withdraw(30);
        fail("Access should not be authorized");
    } catch(DeniedAccessException() {}
}
```

Testing the PCD: an example – 1

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    try {
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        fail("Access should not be authorized");
    } catch(DeniedAccessException() {}
}
```
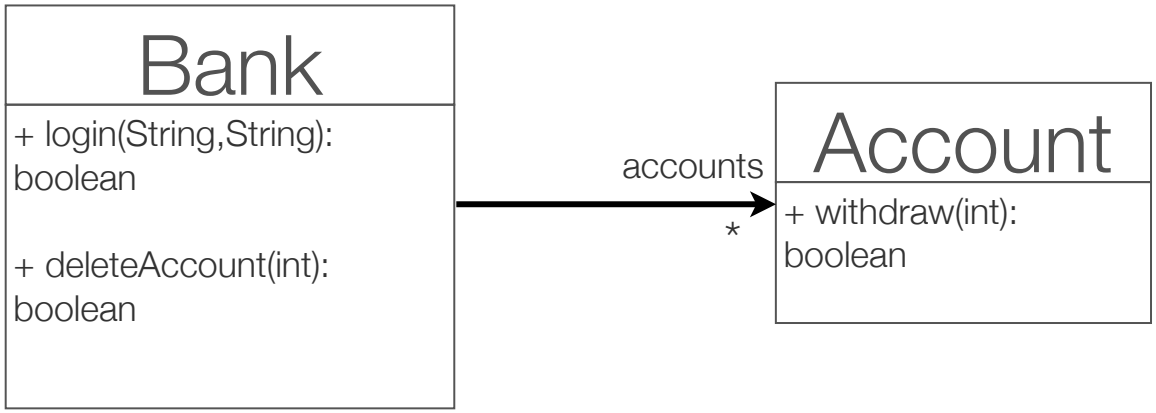

Testing the PCD: example – 2

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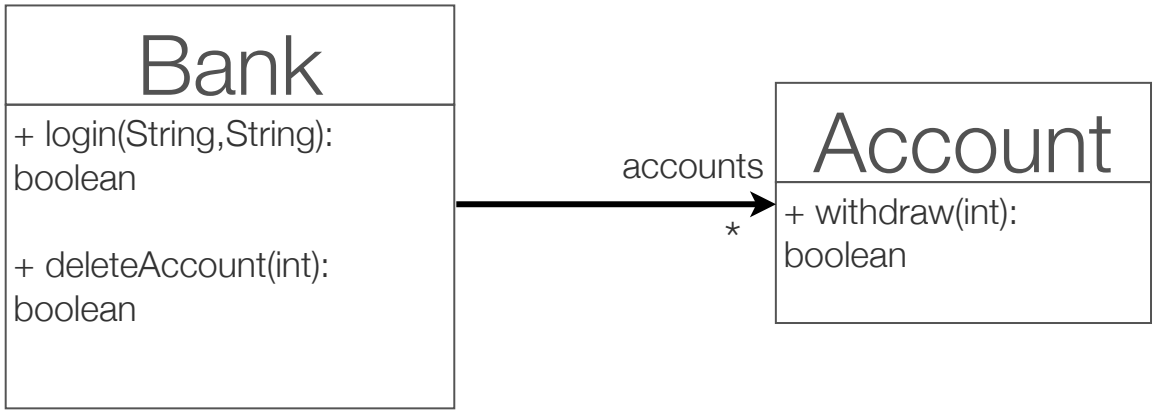


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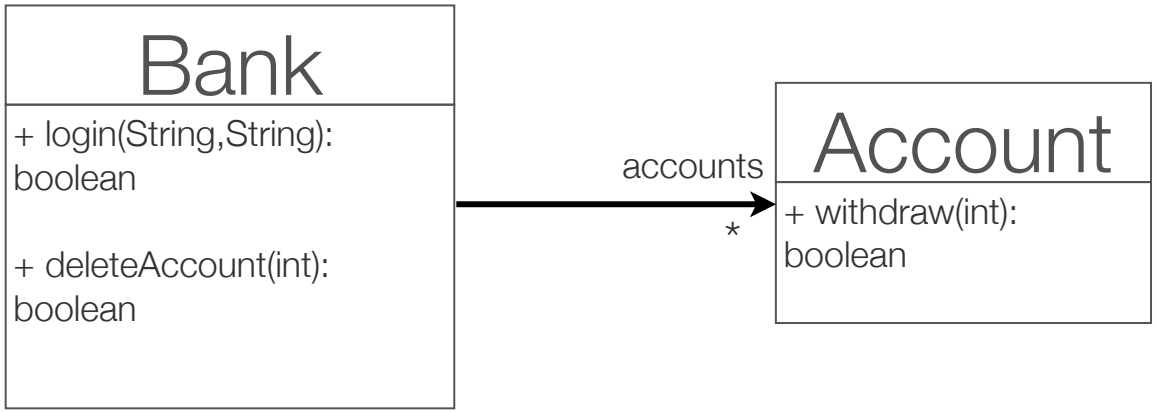


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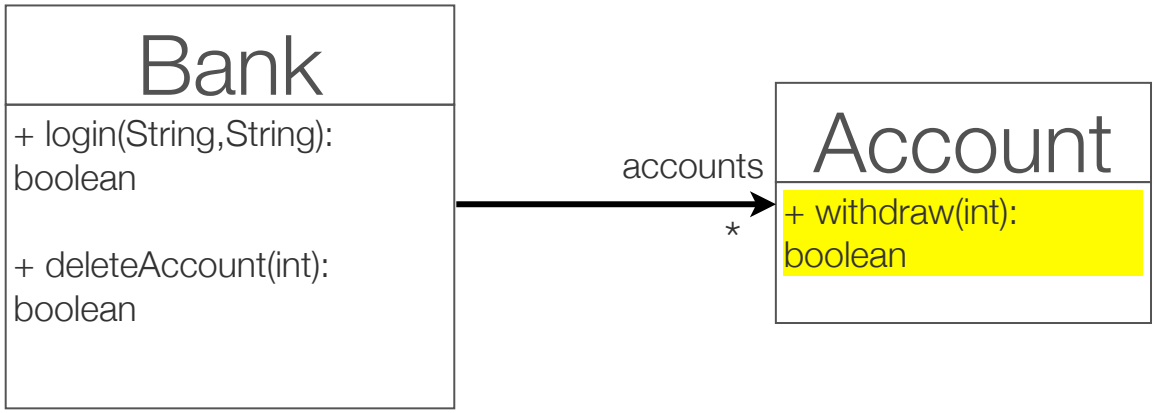


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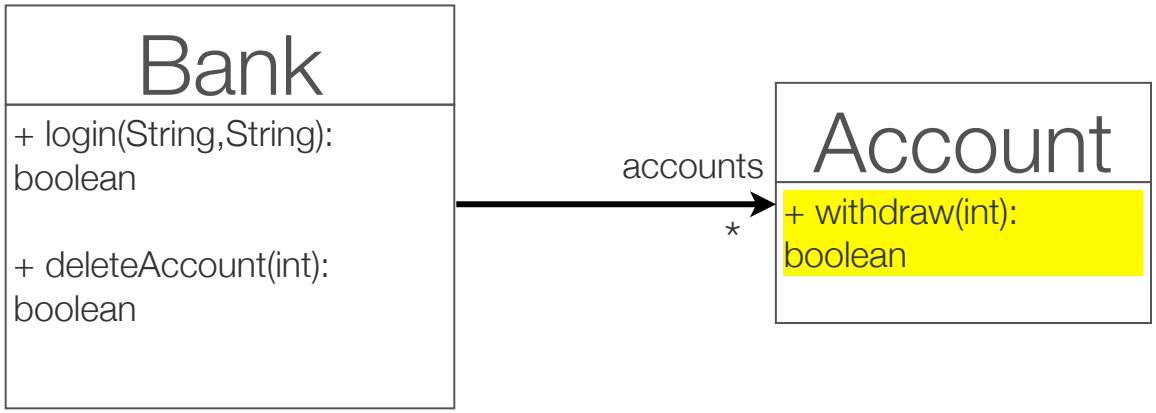


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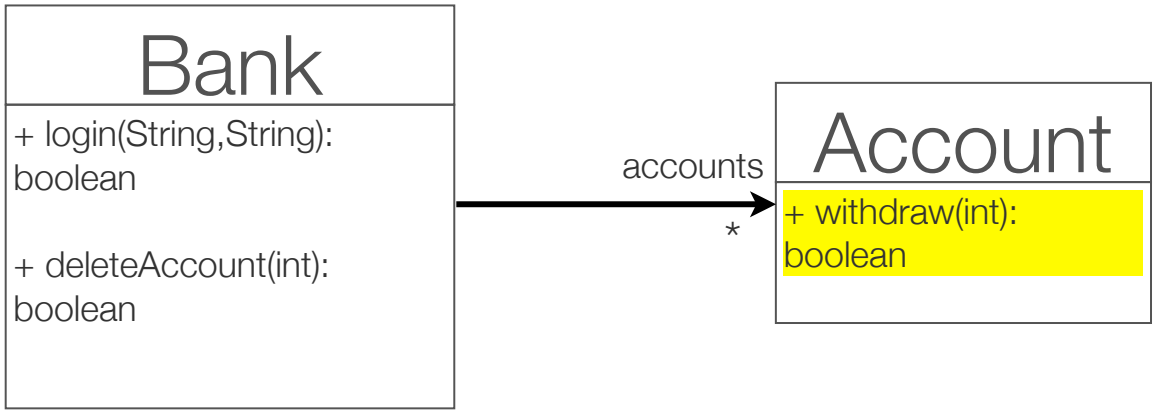


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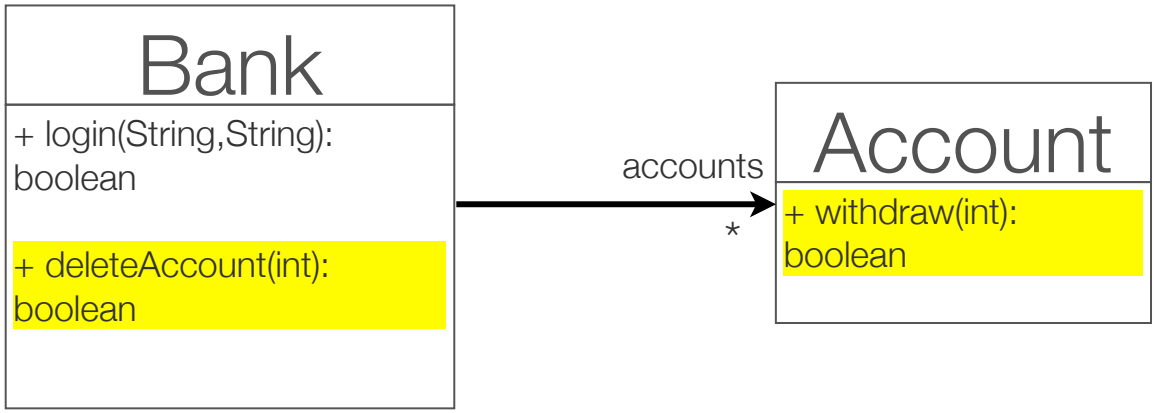


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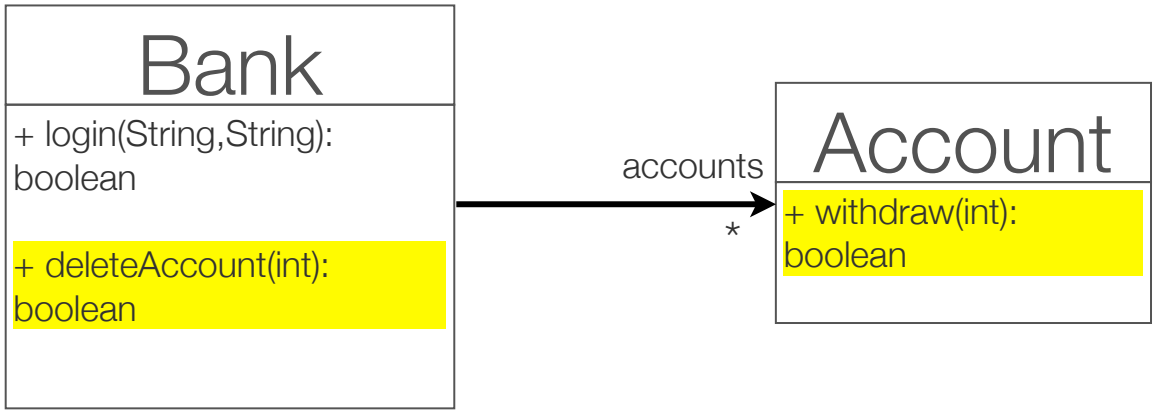


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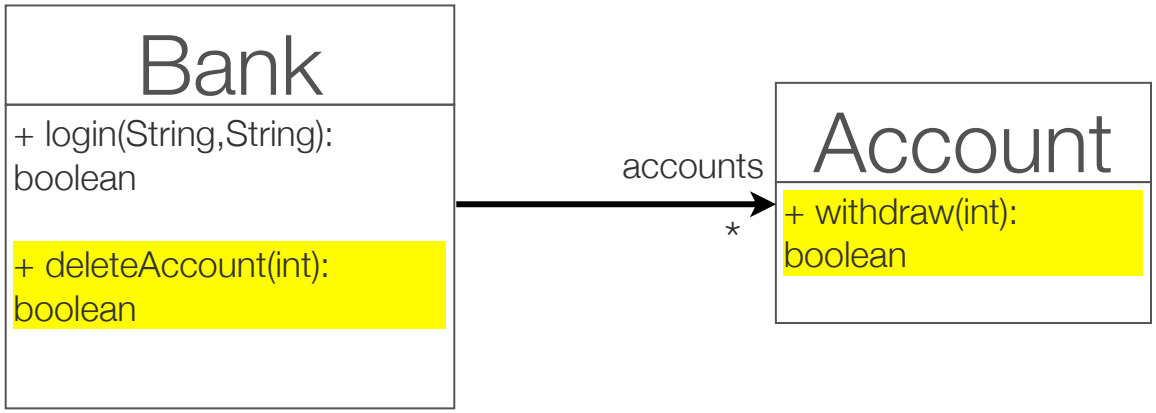


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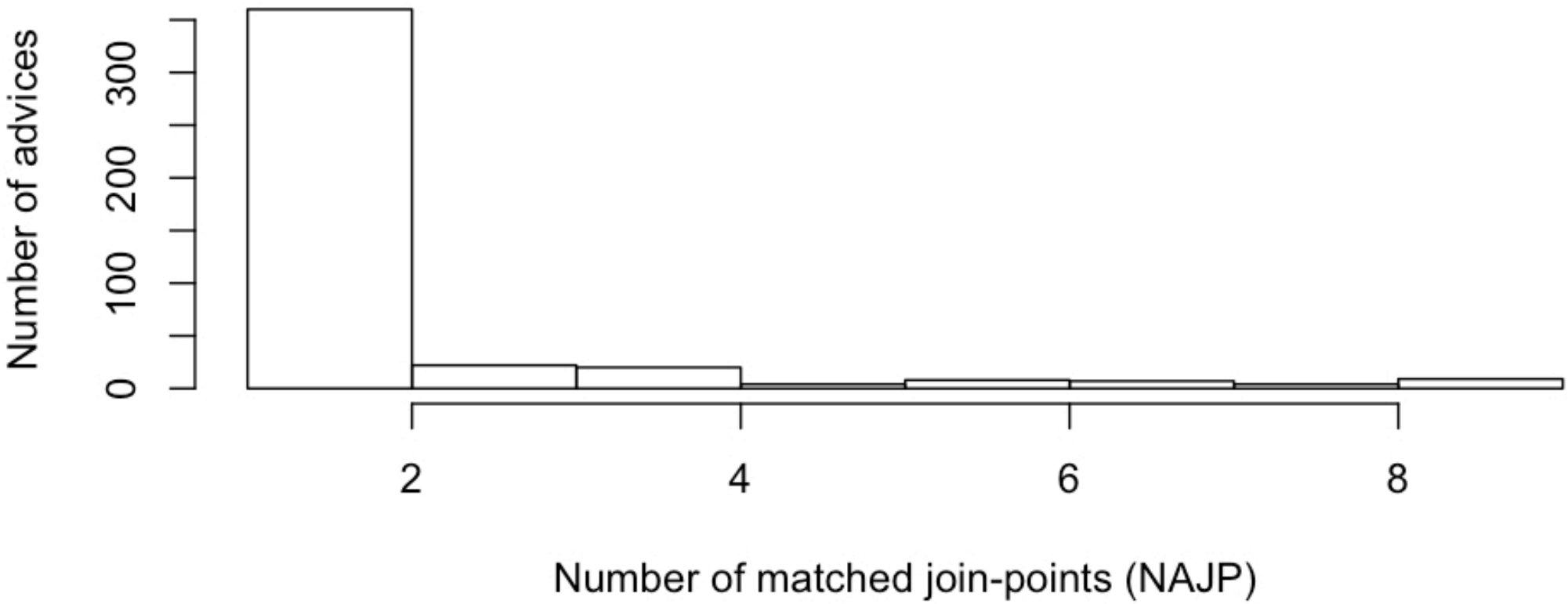
Crosscutting aspects

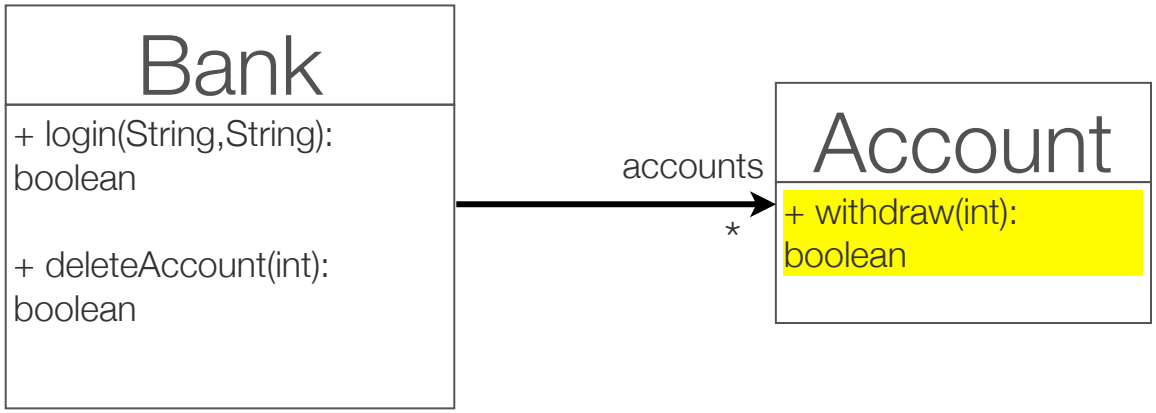


38 open source projects:
479 aspects, 522 advices in 21245 join-points

AdviceTracer: writing PCD specific Oracles

- AdviceTracer: AspectJ library to write oracles that specifically target the PCD
- Oracles written with AdviceTracer for one PCD are:
  - Independent from the advices
  - Independent from other PCDs

AdviceTracer: example – 1

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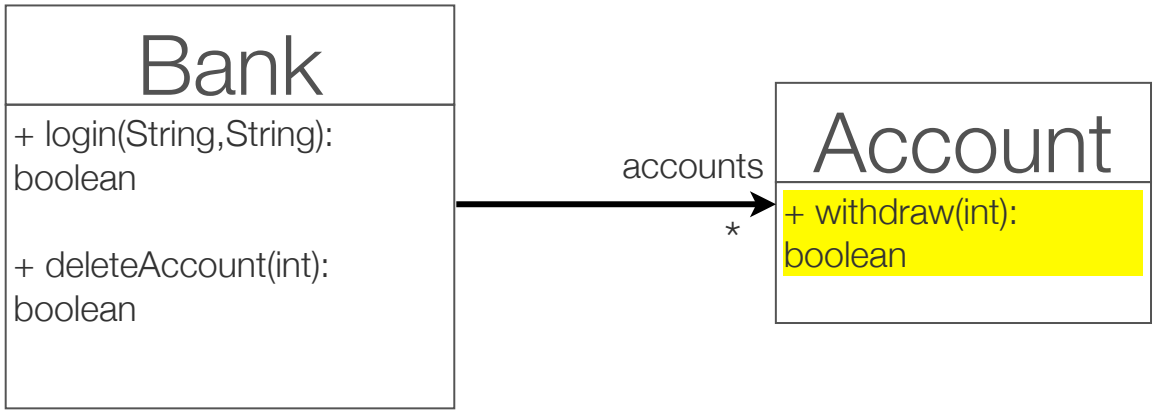


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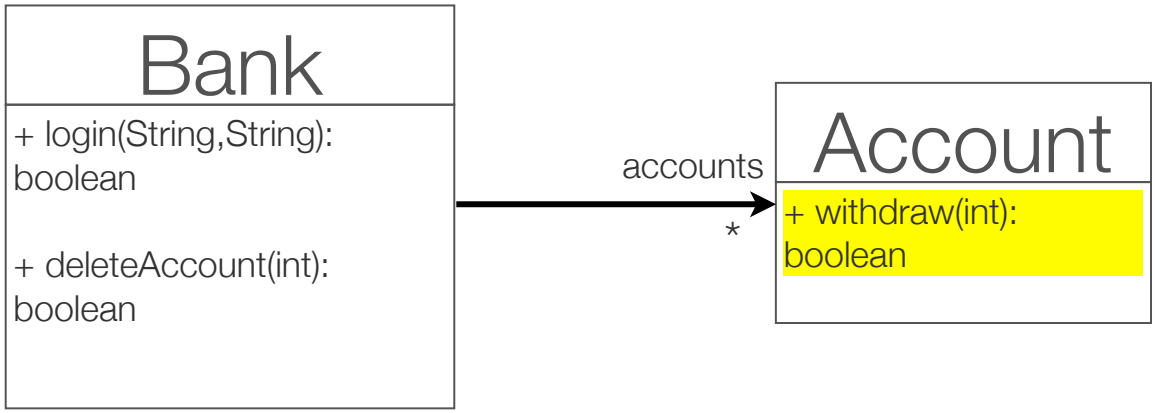


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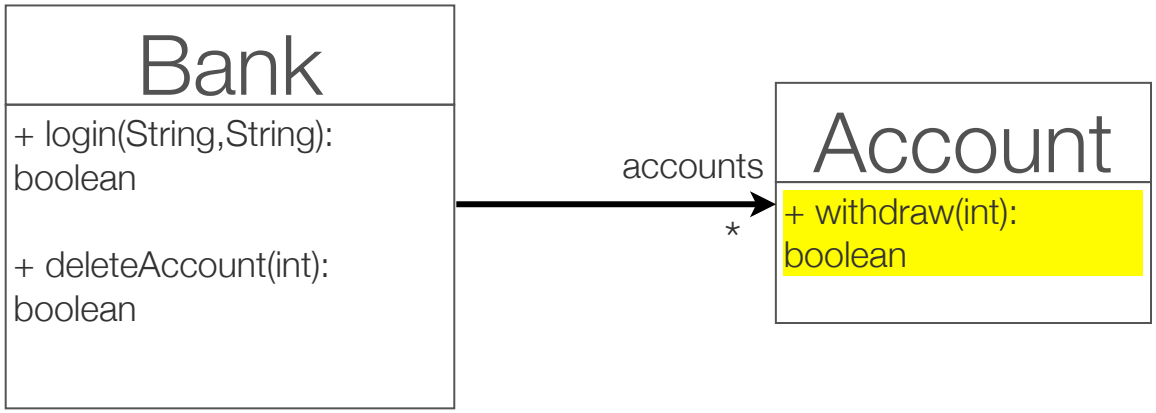


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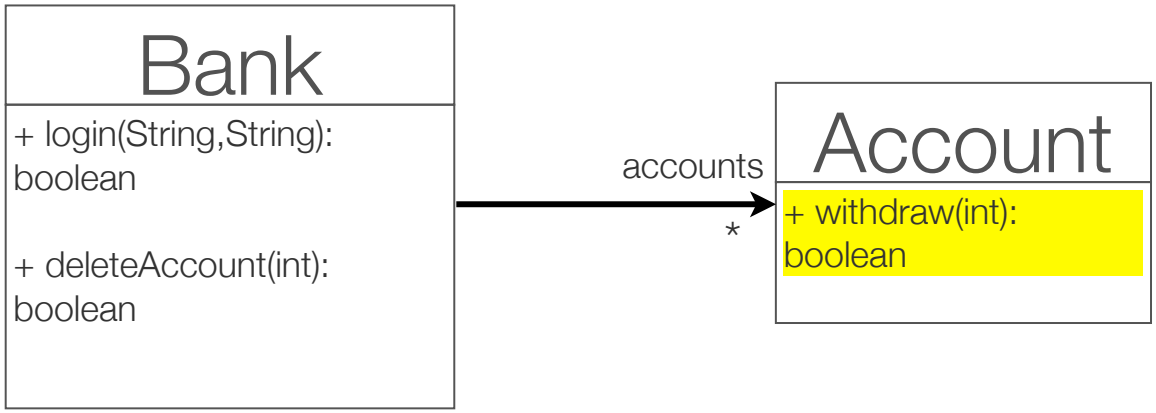


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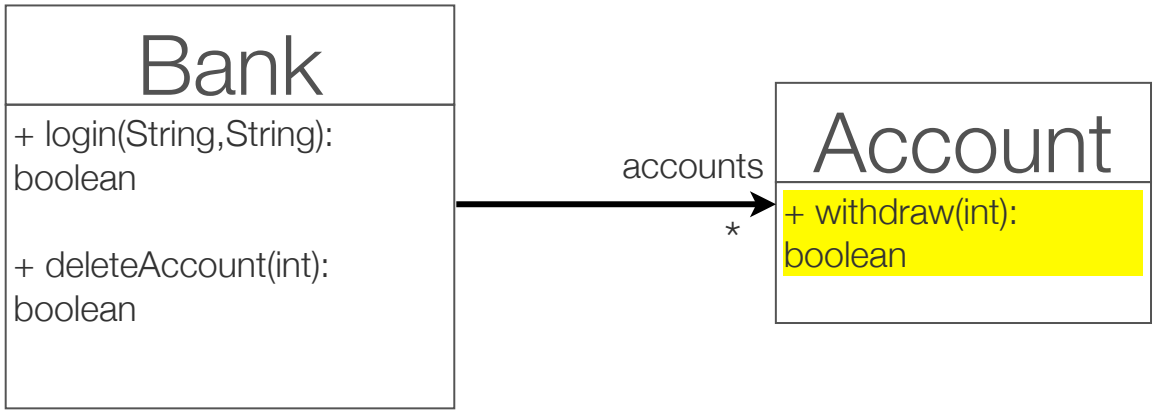


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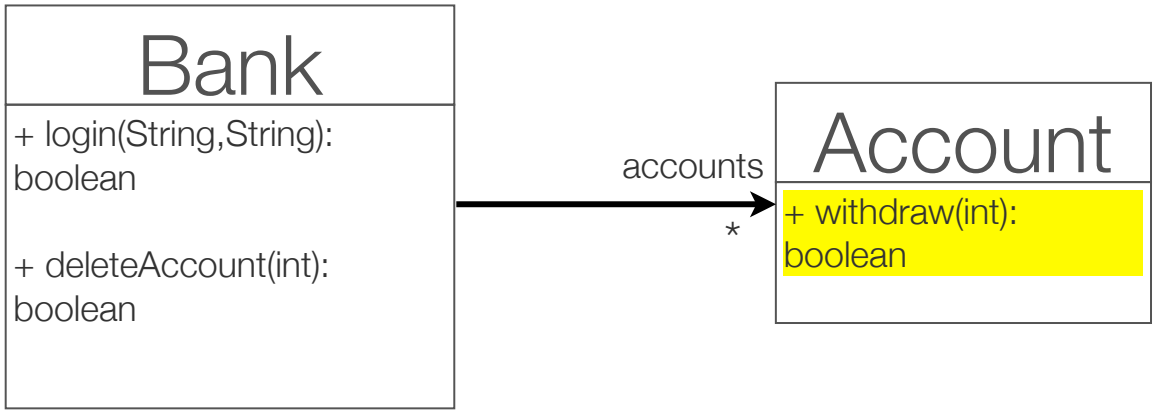


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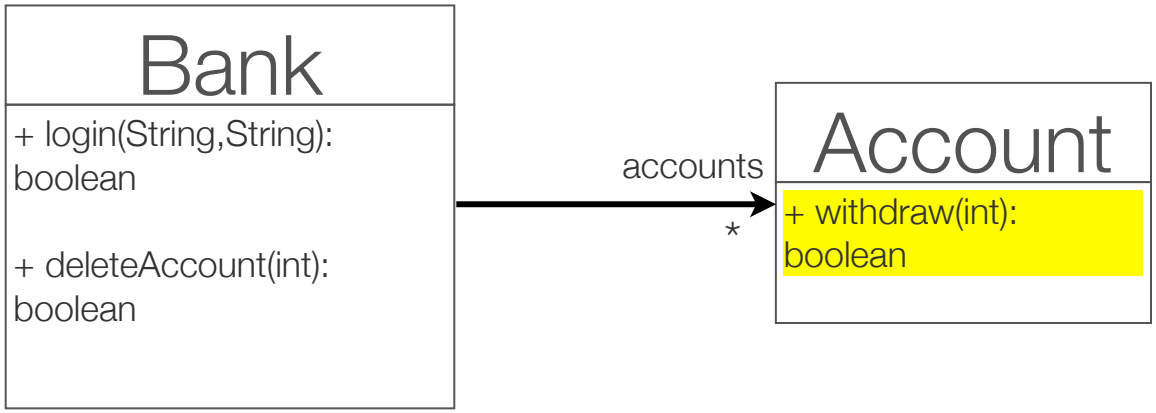


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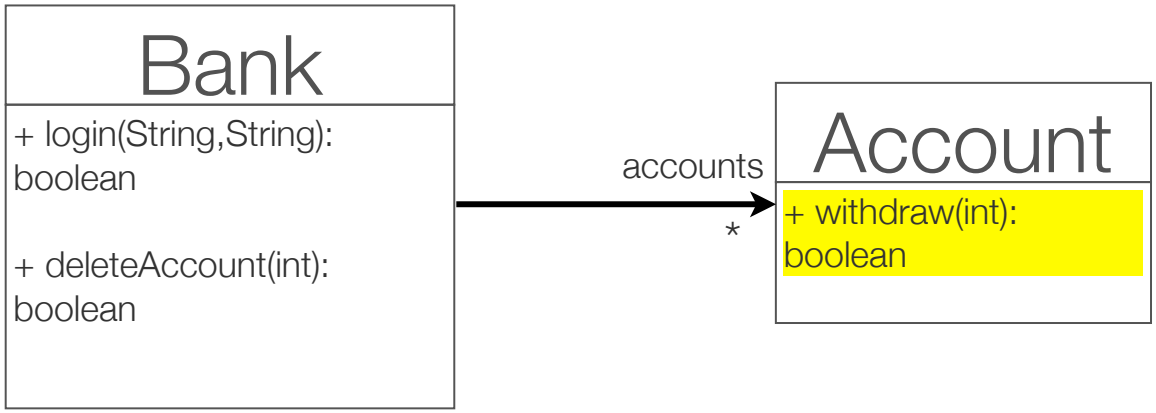


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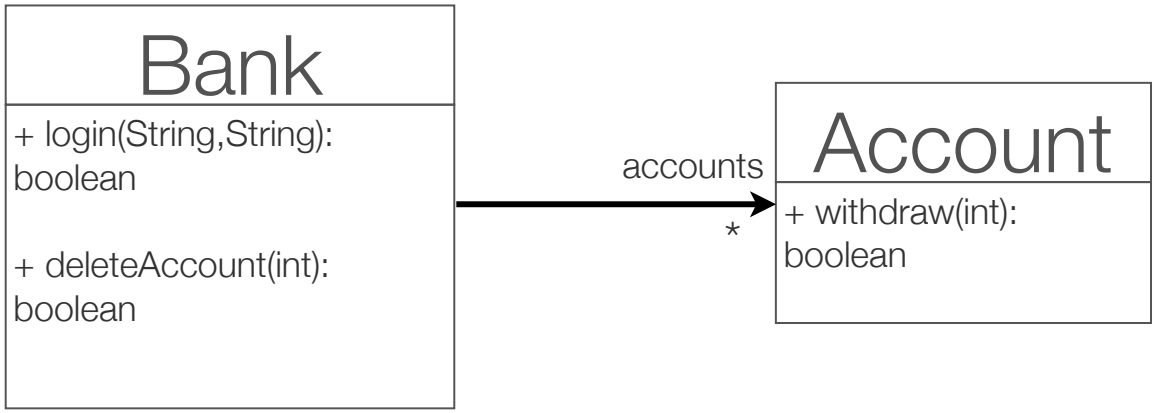


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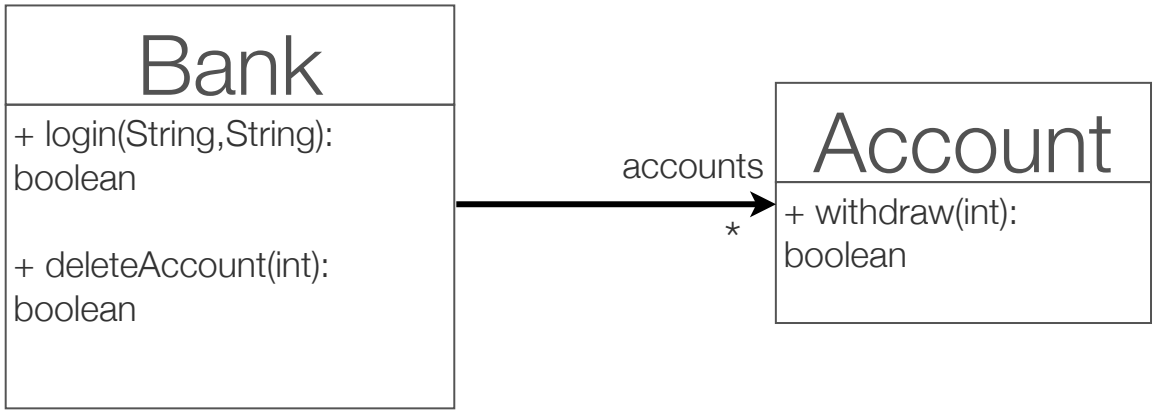


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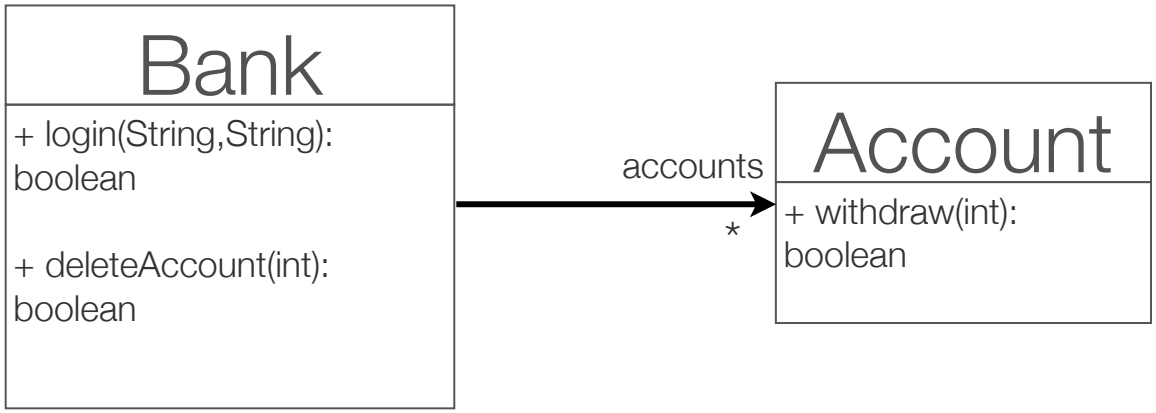


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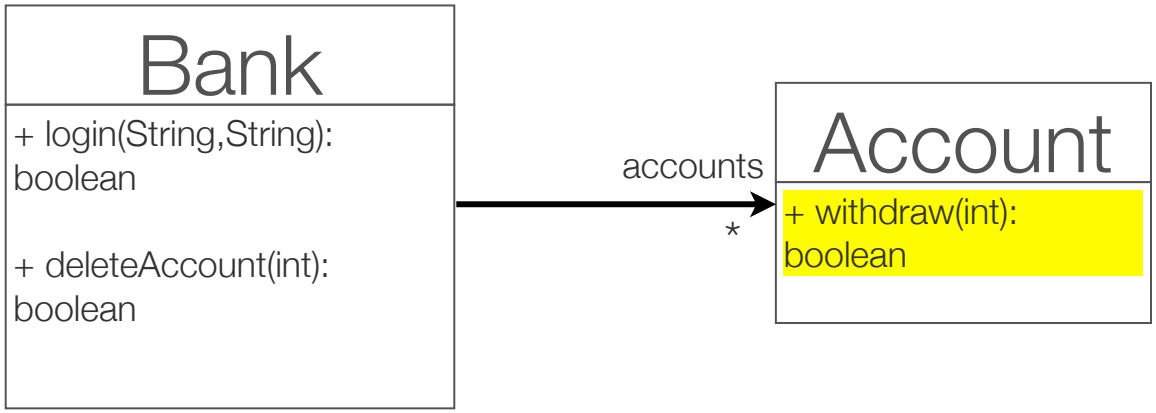


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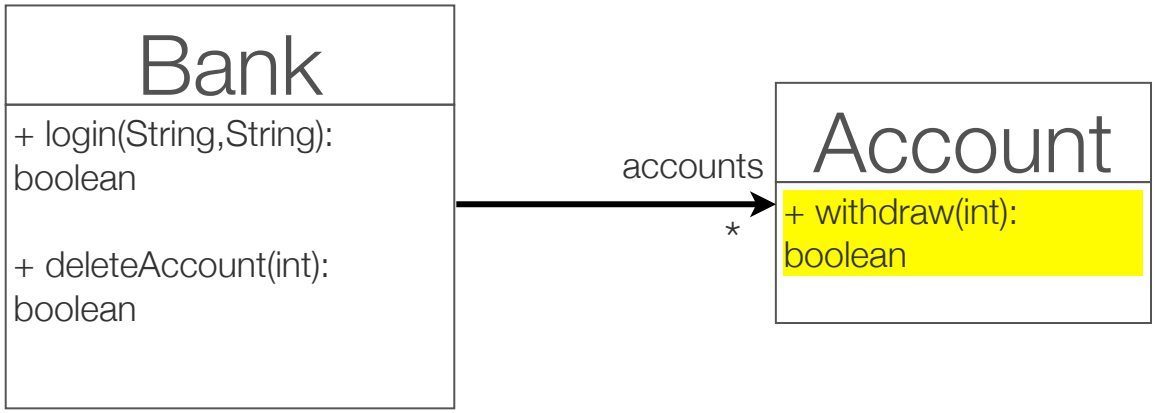


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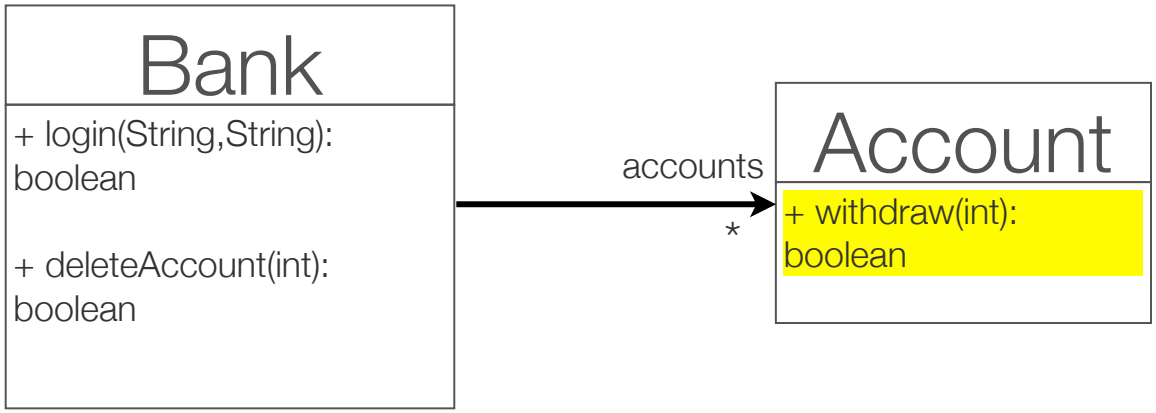


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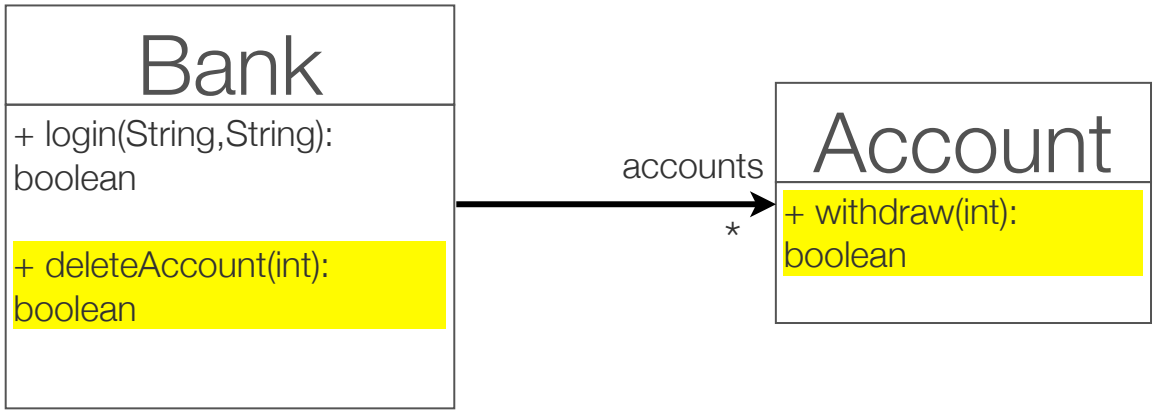


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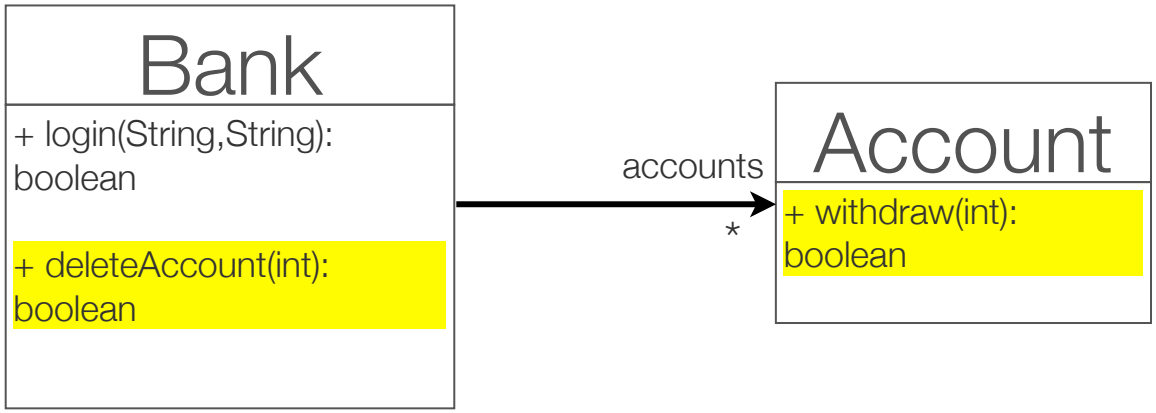


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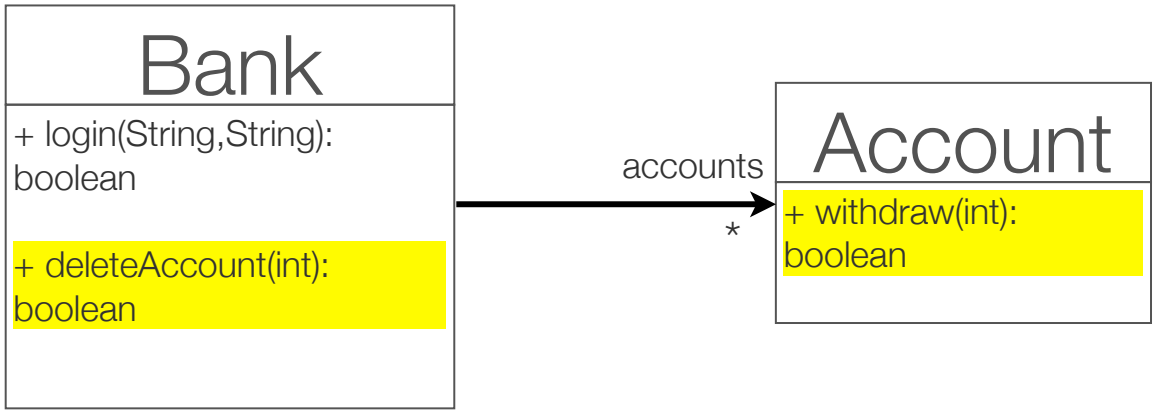


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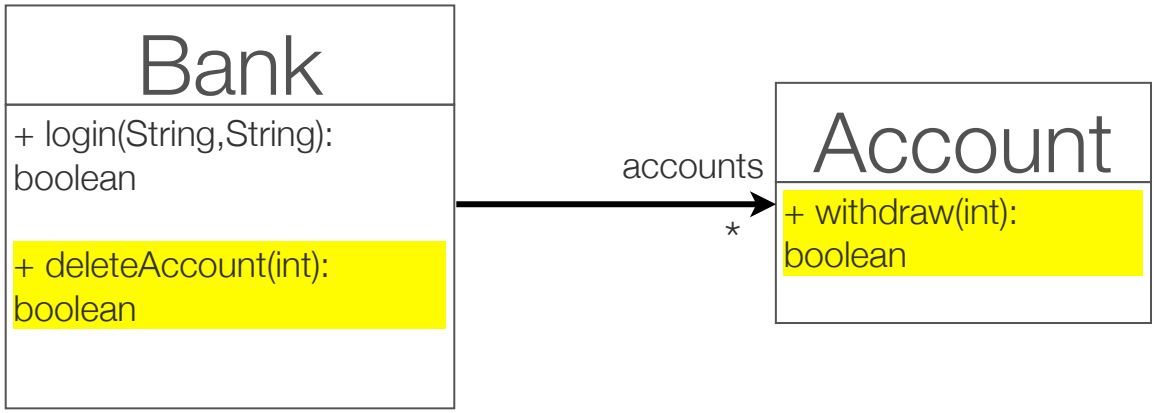
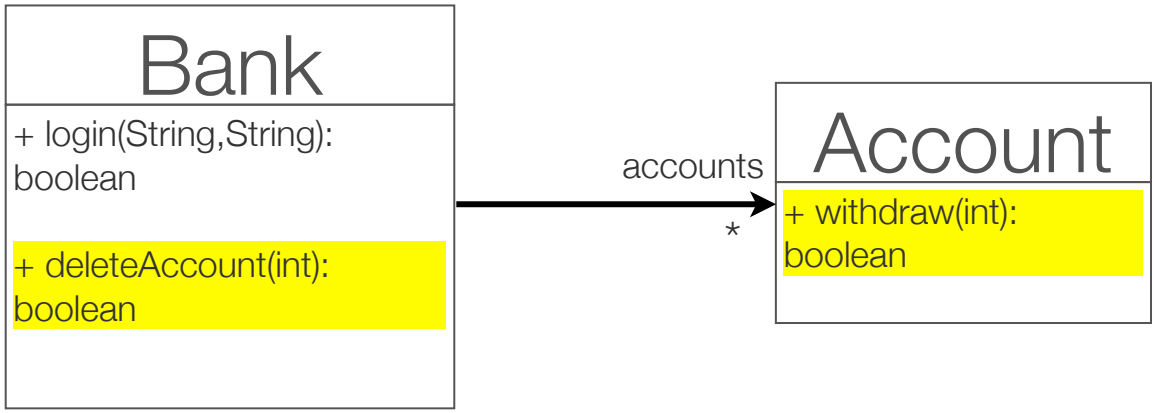
AdviceTracer: example – 5




```
public void testAccessControlDelete() {
    bank.login(nonAuthorizedUser,password);
    addTracedAdvice("AccessControl");
    setAdviceTracerOn();
    // System Test
    setAdviceTracerOff();
    assertAdviceExecutionEquals(4);
}
```

AdviceTracer: example – 5

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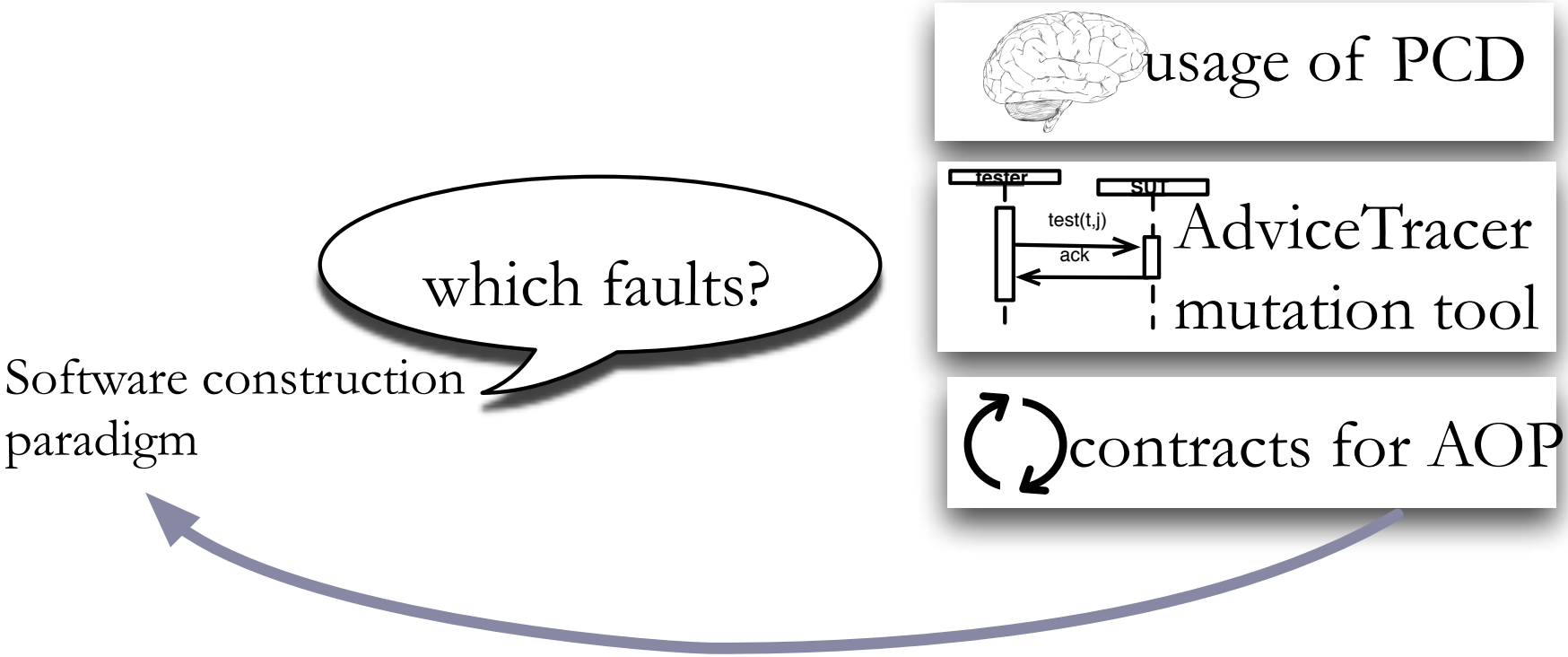
- R. Delamare, B. Baudry, S. Ghosh, Y. Le Traon. «An approach for testing pointcut descriptors in AspectJ». Journal of Software Testing, Verification and Reliability, 2011.

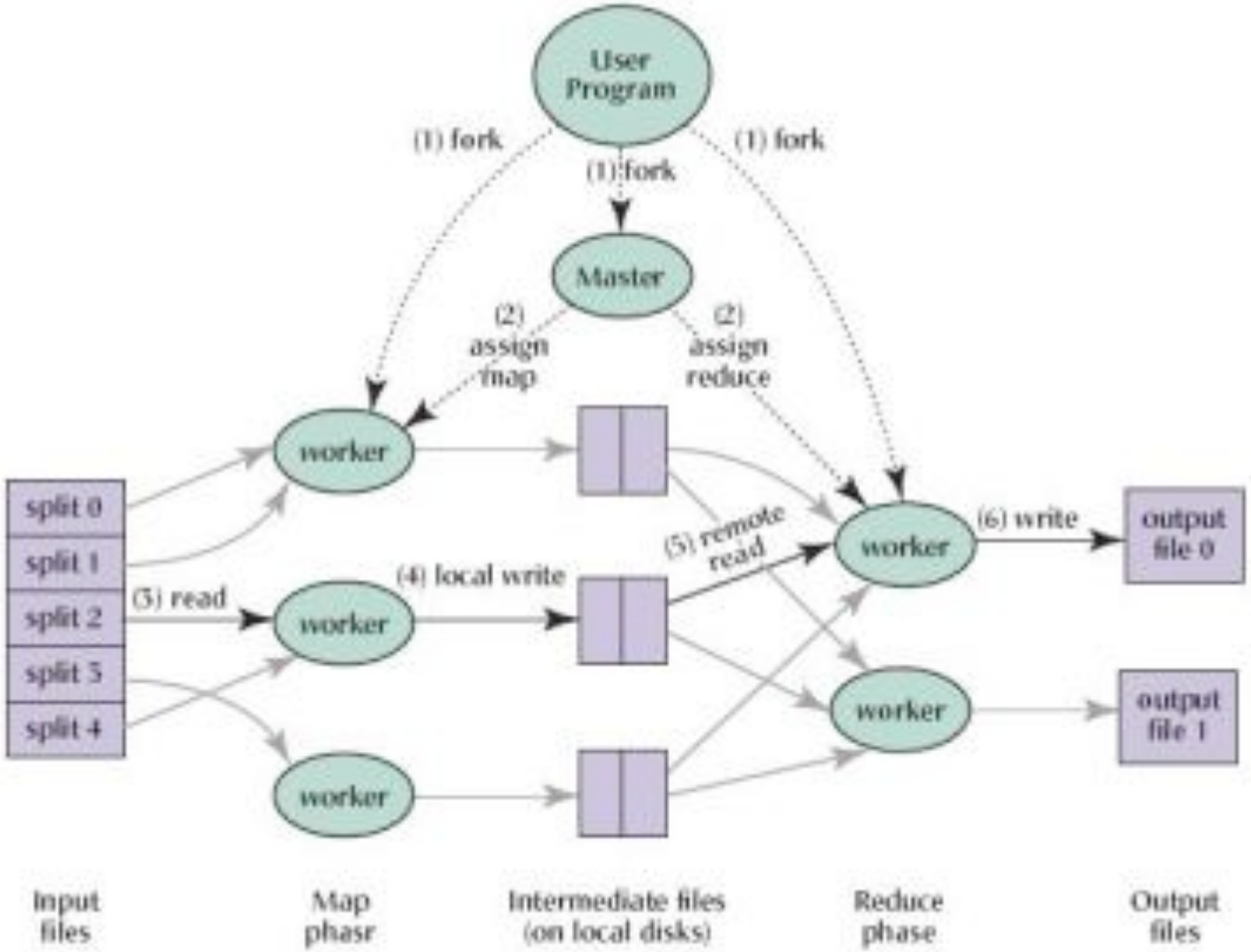
QLTF for AOP


usage of PCD
tester
SUT
test(t,j)
ack
AdviceTracer
mutation tool
contracts for AOP
which faults?
Software construction
paradigm

Cloud computing

- Build order of magnitude bigger systems with order of magnitude less efforts
  - http://boom.cs.berkeley.edu/
- Distribution, communication and synchronization are hidden
  - establish trust in these mechanisms
- Design applications as atoms and bits
  - reason on pieces of programs
  - understand the interactions between these pieces and the cloud framework

MapReduce


User Program
(1) fork
(1) fork
(1) fork
Master
(2) assign map
(2) assign reduce
worker
worker
worker
worker
worker
split 0
split 1
split 2
split 3
split 4
(3) read
(4) local write
(5) remote read
(6) write
output file 0
output file 1
Input files
Map phase
Intermediate files (on local disks)
Reduce phase
Output files

Word count

```
/**
 * Counts the words in each line.
 * For each line of input, break the line into words and emit them as
 * (<b>word</b>, <b>1</b>).
 */
public static class MapClass extends MapReduceBase
  implements Mapper<LongWritable, Text, Text, IntWritable> {

  private final static IntWritable one = new IntWritable(1);
  private Text word = new Text();

  public void map(LongWritable key, Text value,
                  OutputCollector<Text, IntWritable> output,
                  Reporter reporter) throws IOException {
    String line = value.toString();
    StringTokenizer itr = new StringTokenizer(line);
    while (itr.hasMoreTokens()) {
      word.set(itr.nextToken());
      output.collect(word, one);
    }
  }
}
```

Word count

```
/**
 * A reducer class that just emits the sum of the input values.
 */
public static class Reduce extends MapReduceBase
  implements Reducer<Text, IntWritable, Text, IntWritable> {

  public void reduce(Text key, Iterator<IntWritable> values,
                     OutputCollector<Text, IntWritable> output,
                     Reporter reporter) throws IOException {
    int sum = 0;
    while (values.hasNext()) {
      sum += values.next().get();
    }
    output.collect(key, new IntWritable(sum));
  }
}
```

MapReduce application

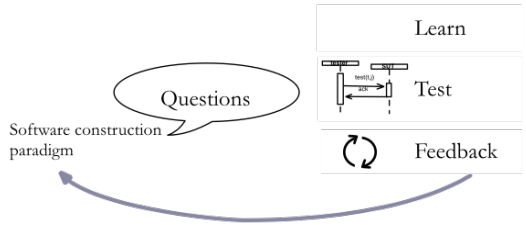
- Two independents parts
  - Mapper processes a bit of information; 1-to-1 input/output sources
  - Reducer processes n mapped bits of information in a global result; n-to-1 I/O sources
- + configuration, dispatch modules

- Map and reduce modules rely on
  - high level languages
    - low level arithmetic, control, etc. are hidden from the programmer
  - that have been heavily tested
    - i.e., we can trust the iterator Java library
  - framework that abstracts I/O and distribution operations
    - all errors are handled by the framework (e.g., Hadoop)

MapReduce faults

- Some faults in map and reduce
  - logic, arithmetic
- Most of them elsewhere
  - ‘cutting’ a function in map and reduce is a hard design task
  - understanding the MapReduce framework is hard

Conclusion



- New ways of building software
- require new ways of testing it
- Mutation analysis can play a central role
  - understanding faults in the methods and techniques
  - focusing testing on relevant defects
  - tailoring testing research questions