Software Variability Management

From Clown-and-Own to Software Product Lines

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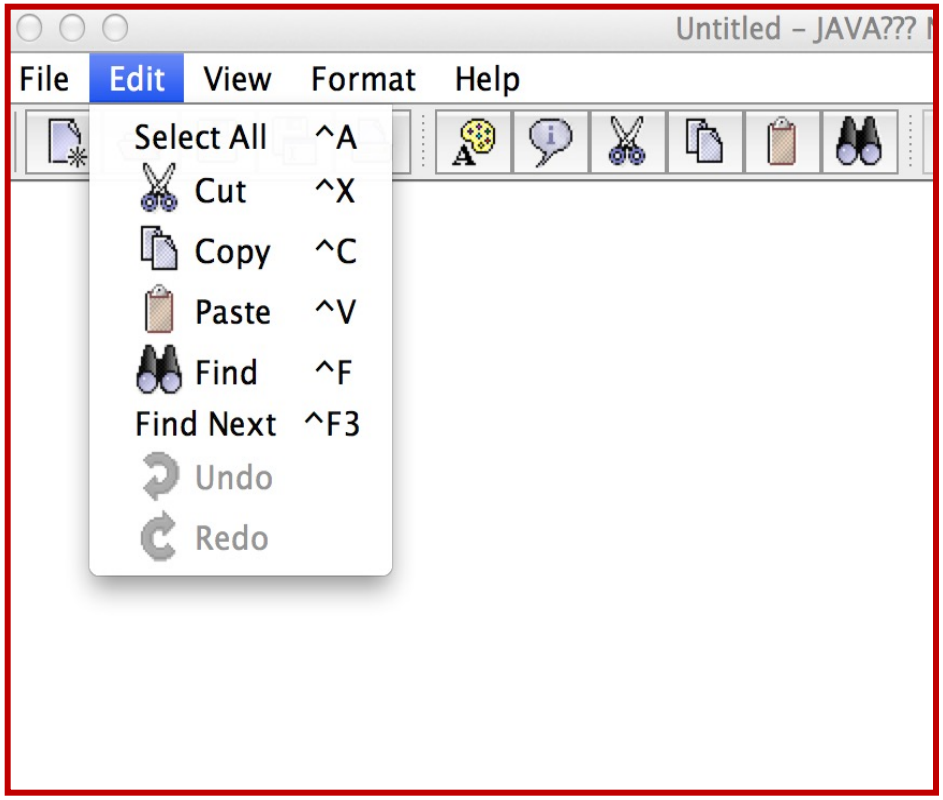
..Create a collection of **product variants** in the **same domain**..

Software Variability…

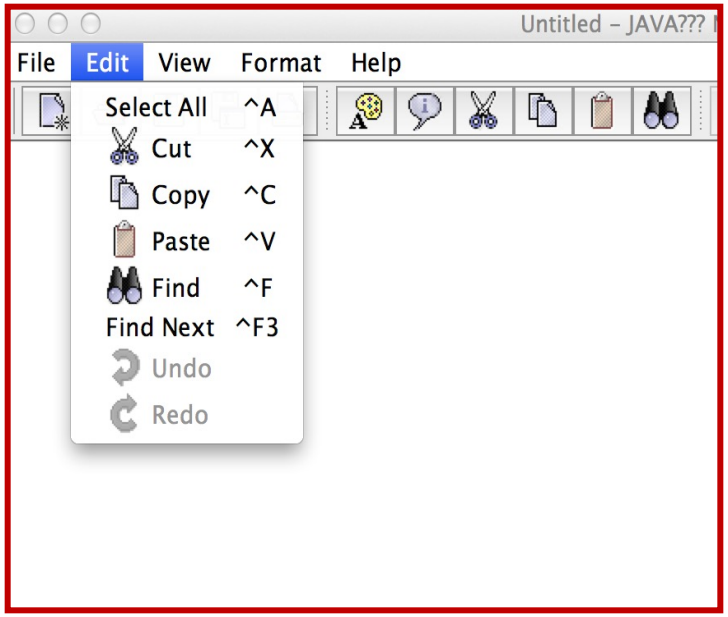
Motivations

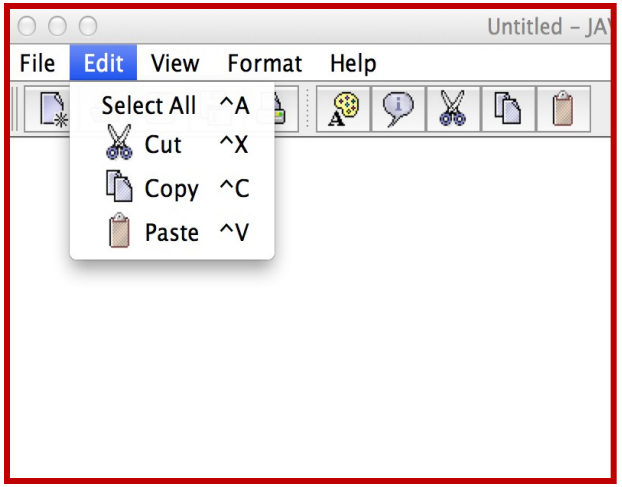
- We have the implementation in Java of a simple Notepad application

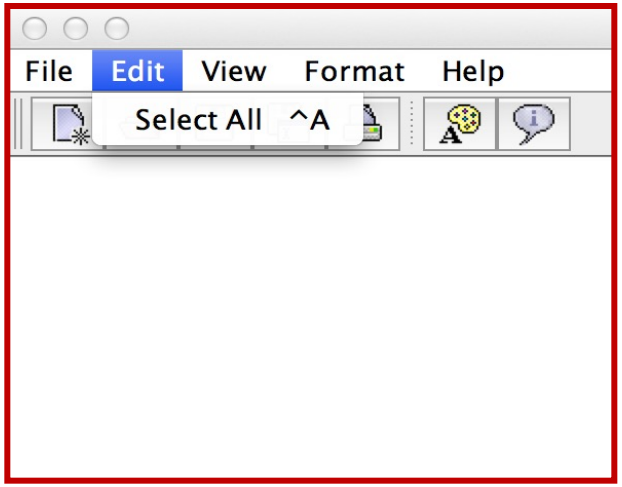


Motivations

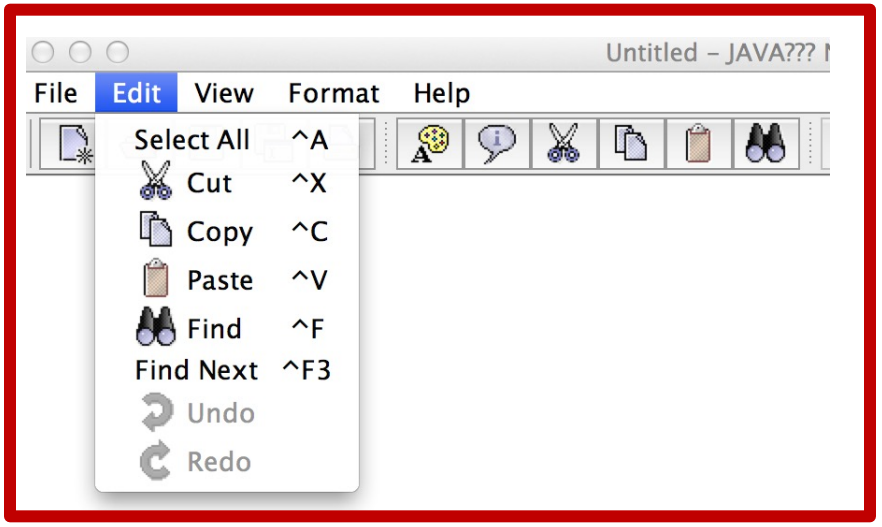
- How can we implement 2 additional variants for the same application?

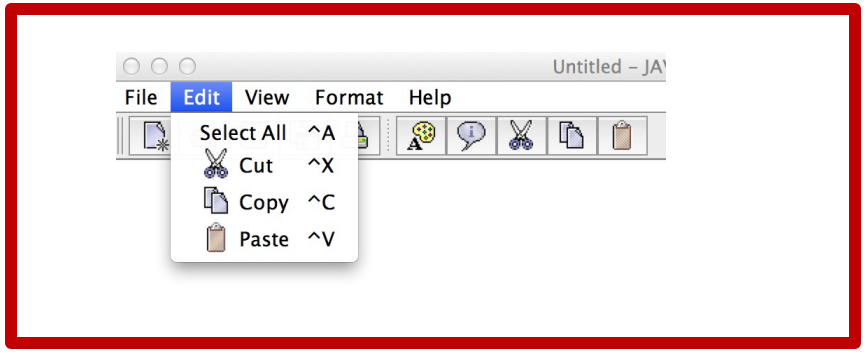


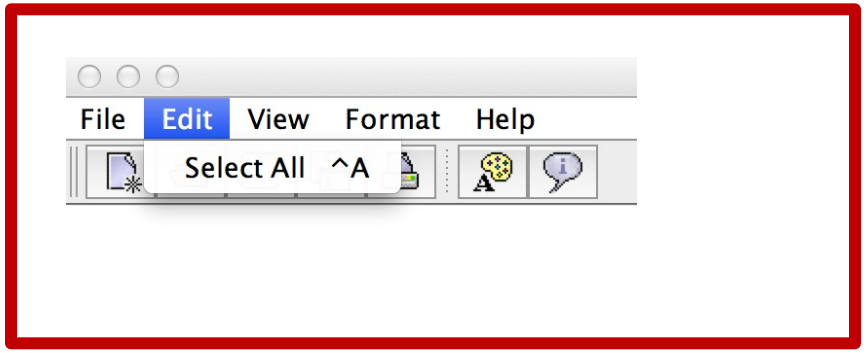




Classical Software



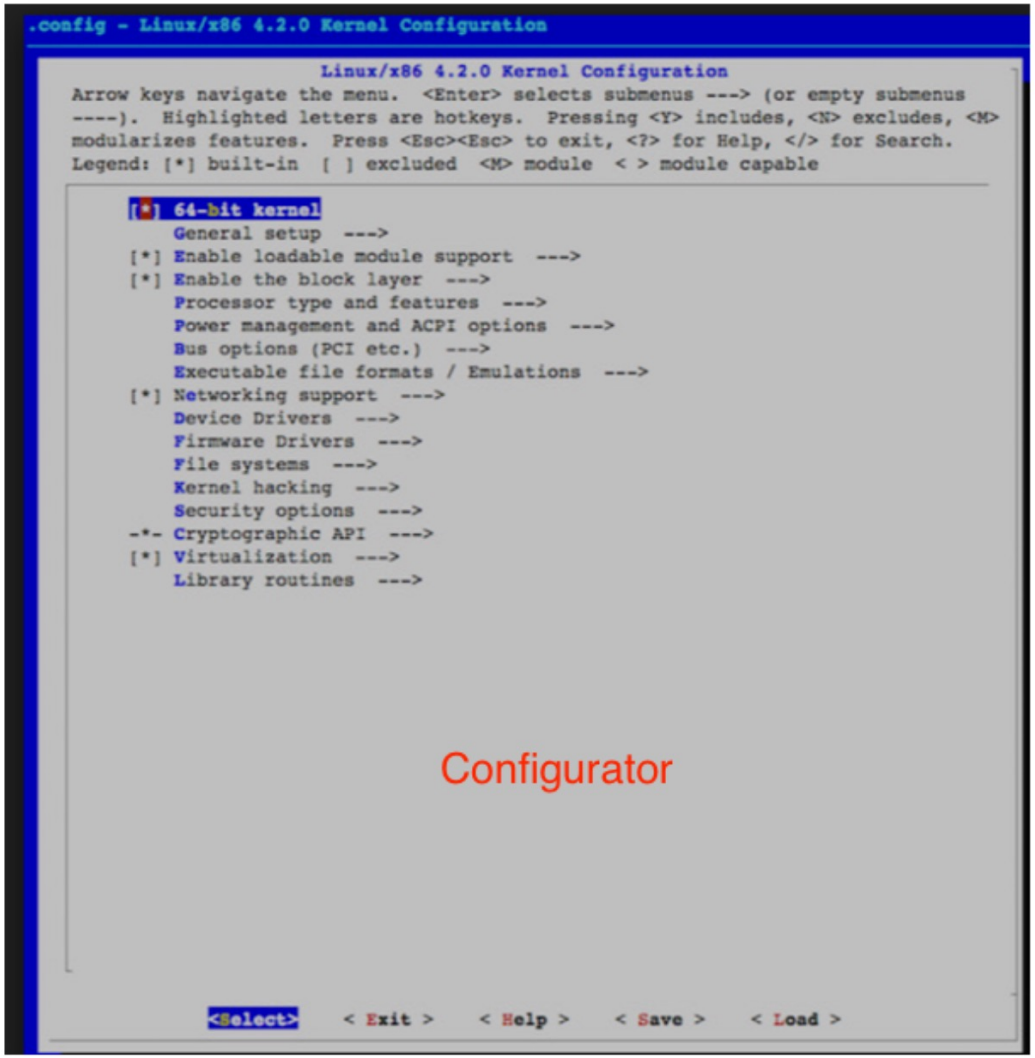




Linux

KConfig file

```
[...]

config PRINTK
	default y
	bool "Enable support for printk" if EXPERT
	select IRQ_WORK
	help
	  This option enables normal printk support. Removing it
	  eliminates most of the message strings from the kernel image
	  and makes the kernel more or less silent. As this makes it
	  very difficult to diagnose system problems, saying N here is
	  strongly discouraged.

config PRINTK_NMI
	def_bool y
	depends on PRINTK
	depends on HAVE_NMI

config BUG
	bool "BUG() support" if EXPERT
	default y
	help
	  Disabling this option eliminates support for BUG and WARN, reducing
	  the size of your kernel image and potentially quietly ignoring
	  numerous fatal conditions. You should only consider disabling this
	  option for embedded systems with no facilities for reporting errors.
	  Just say Y.

config ELF_CORE
	depends on COREDUMP
	default y
	bool "Enable ELF core dumps" if EXPERT
	help
	  Enable support for generating core dumps. Disabling saves about 4k.

[...]

config AIO
	bool "Enable AIO support" if EXPERT
	default y
	help
	  This option enables POSIX asynchronous I/O which may by used
	  by some high performance threaded applications. Disabling
	  this option saves about 7k.

[...]
```



Configurator

- Sotware systems

Comme in many **variants**

Printer Firmware

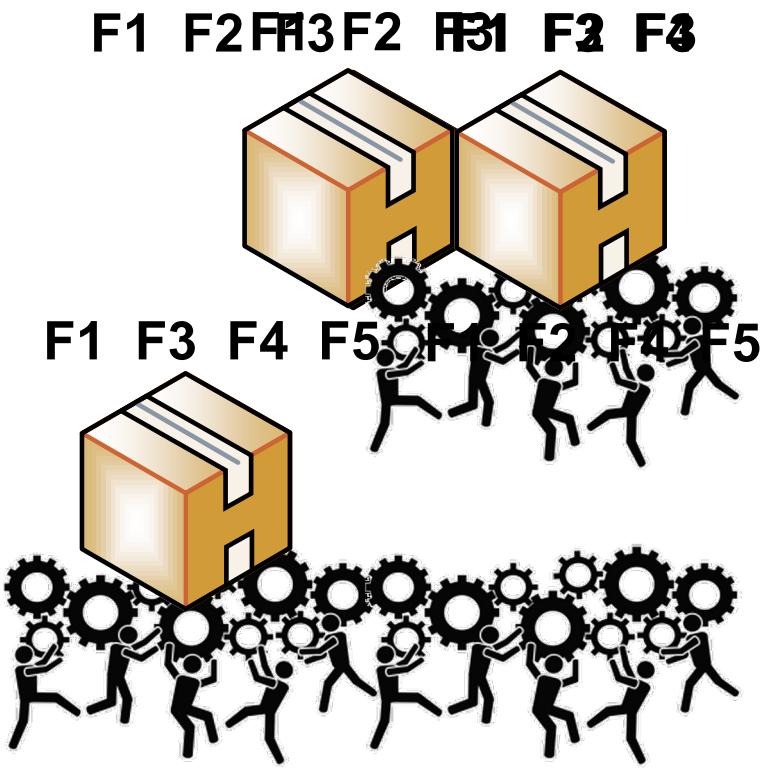
Ad hoc solution

- Copy and past the initial variant and manually delete the unwanted functionalities (copy/cut/finder/undo)

Clone-and-own:

Opportunistic reuse

Clone-and-own



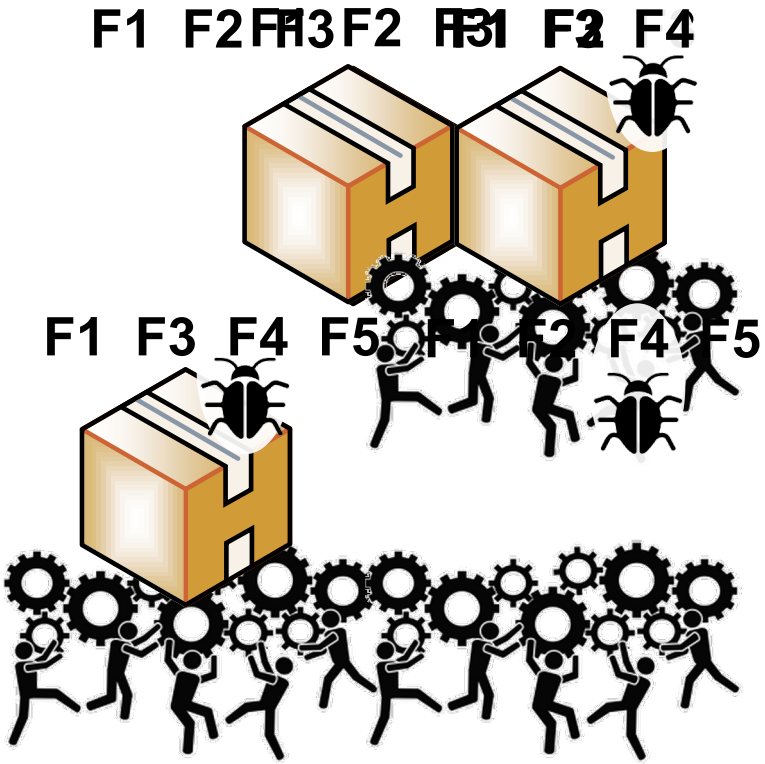
50% of industrial companies use clone-and-own to create variants.

Berger *et al.* A Survey of Variability Modeling in Industrial Practice, VaMoS ’13

Clone-and-own

- **Advantages** ?
  - Easy/quick solution to create variants!
- **Problems ?**

Clone-and-own



~~Clone-and-own:~~

~~Opportunistic reuse~~

Systematic Reuse: “**Software Product Lines:**

Systematic reuse

LIVE DEMO

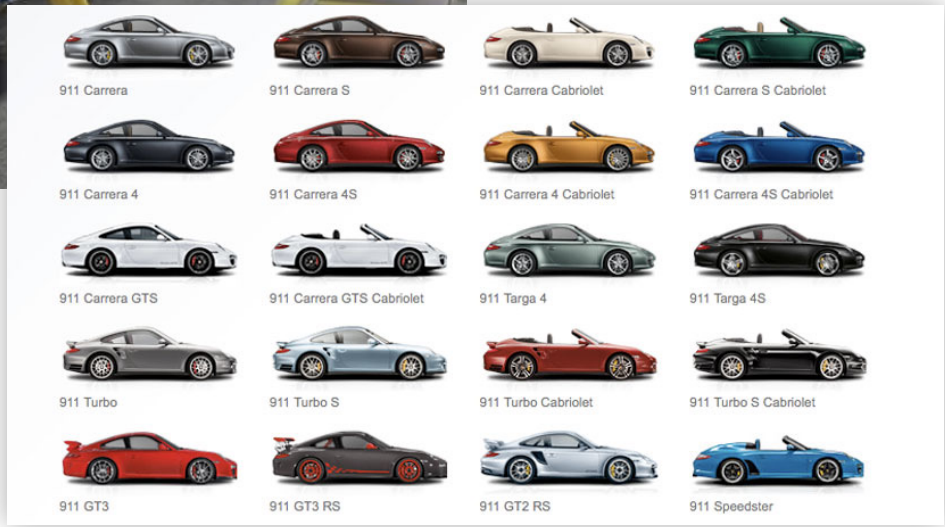
Content

- **Software Product Lines (SPL)**
  - Concepts & existing approaches to implement SPL
  - The Robocode case study

LIVE DEMOS

Product Lines in Industry

Variants



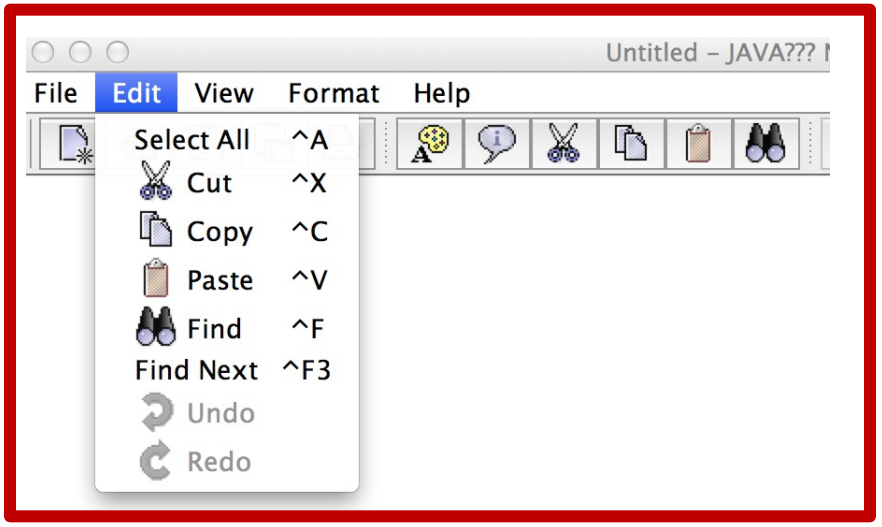
Why can't build our application as we build our car ?

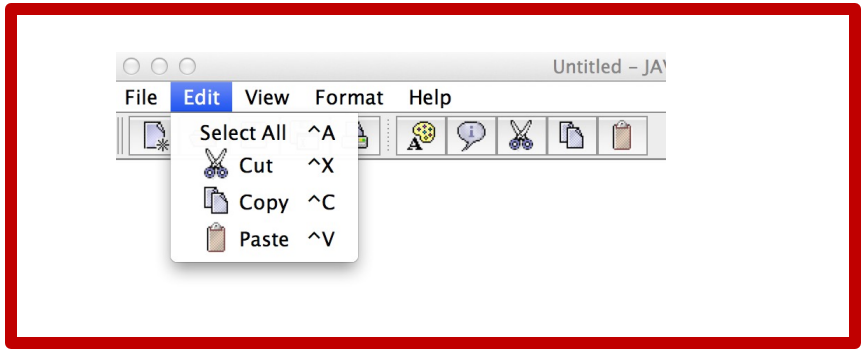
- Sotware systems

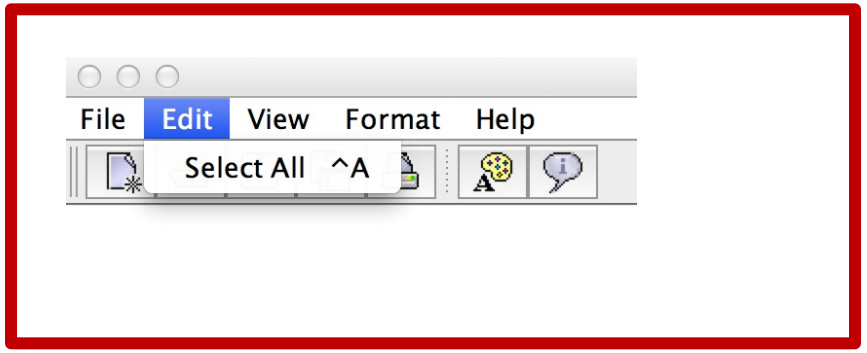
Comme in many **variants**

Printer Firmware

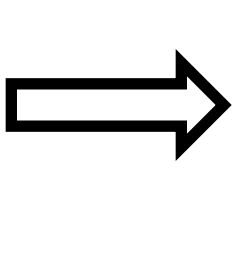
Classical Software

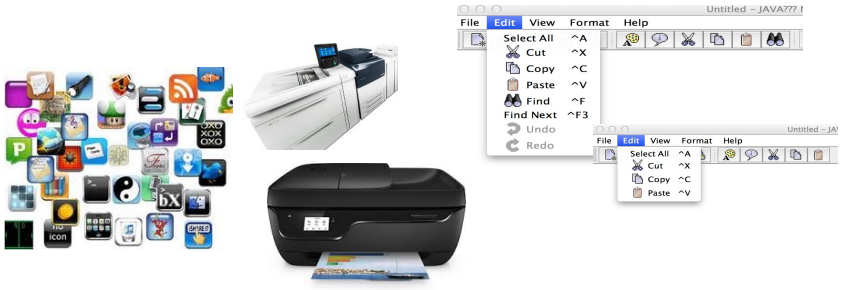






Mobile applications





Software Variability

“the ability of a system to be efficiently extended, changed, customized or configured for use in a particular context”

Mikael Svahnberg, Jilles van Gurp, and Jan Bosch (2005)

Software Product Li

Variant
~~version~~

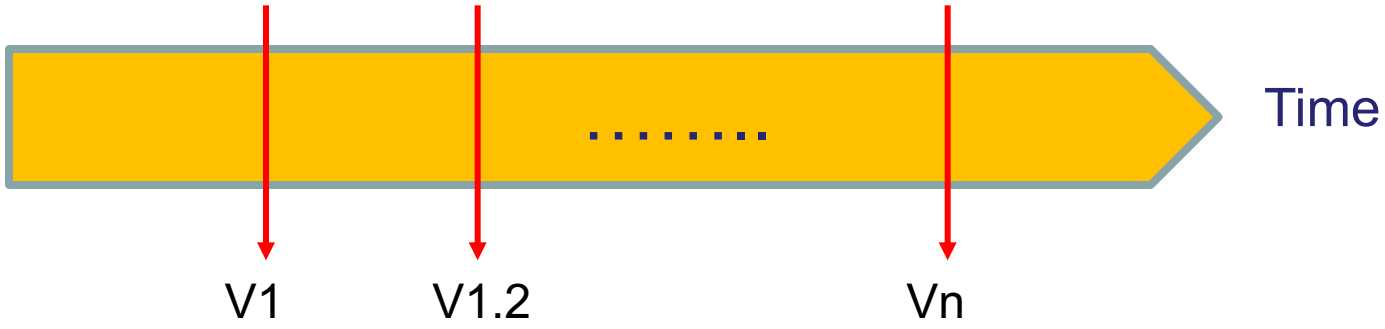
A collection (family) of Software **variants**:

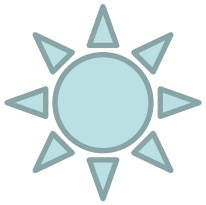
➔ The **same domain**
➔ Share a set of **commonalties** but also contain **variability**

- **Time to market**
- **Increase reuse**

Version vs. Variant

- **Version** :
  - Variability in **time**



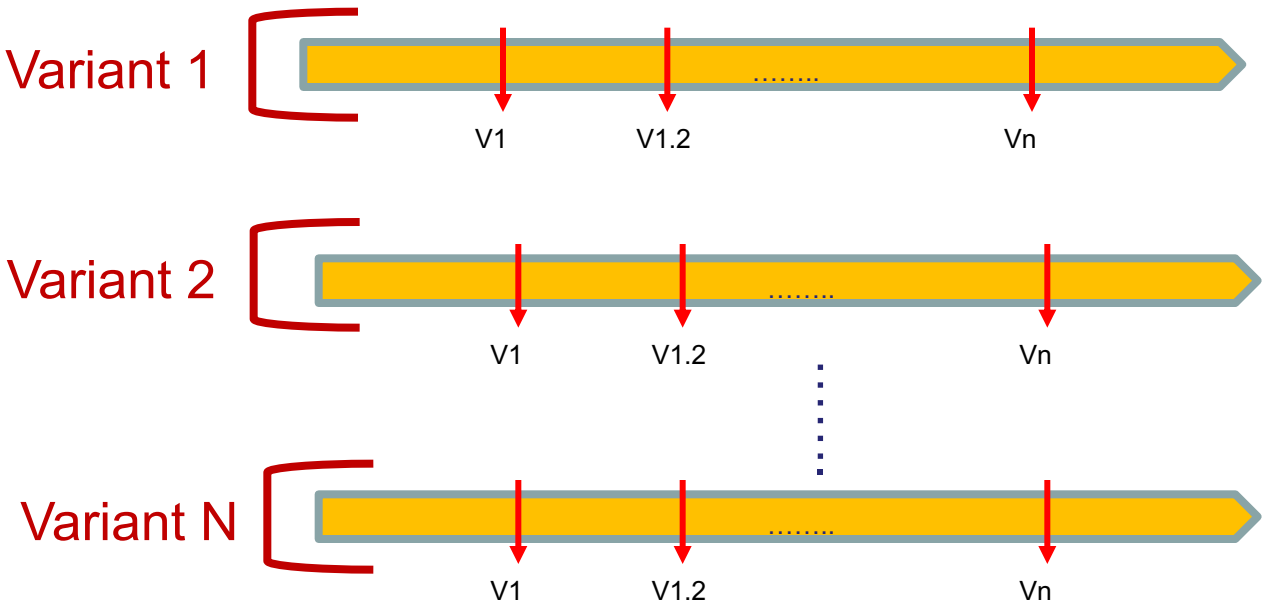


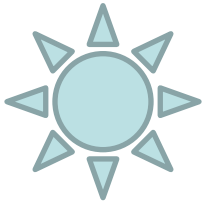
The **same software** that evolves in time

➔ Version Control Systems (git, svn..)

Variante vs. Version

- **Variant** :
  - Variability in **space**

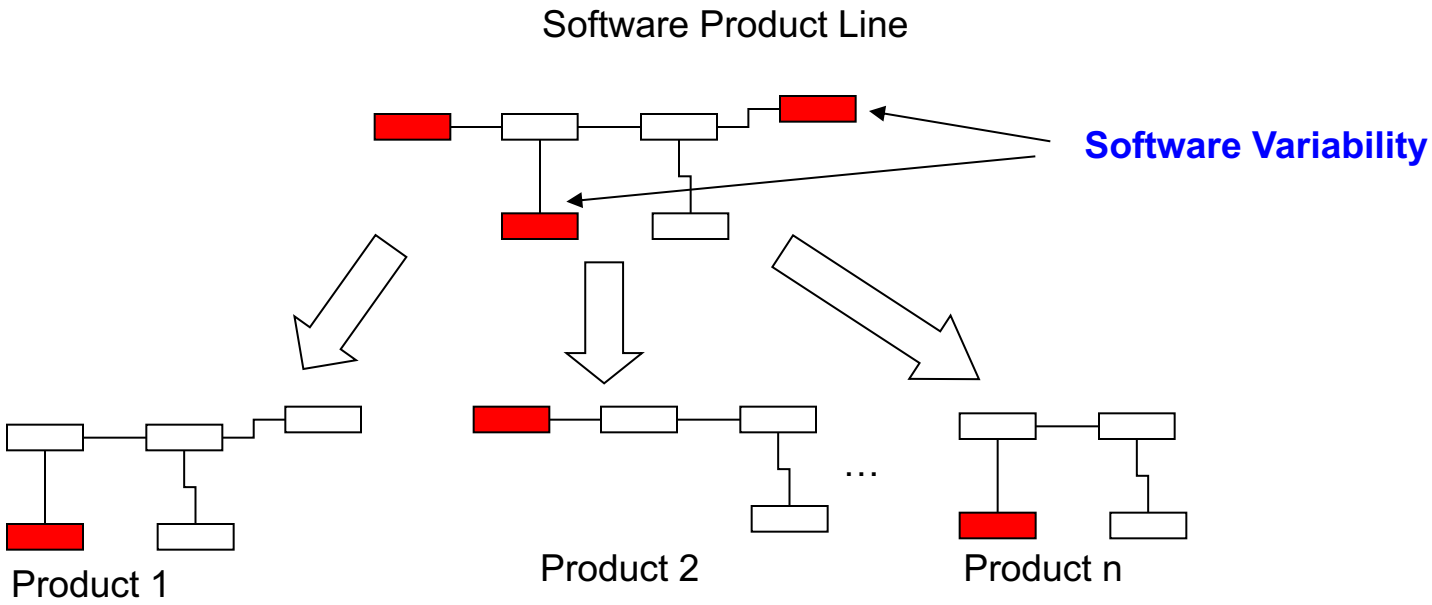




At the same time**, many variants exist**

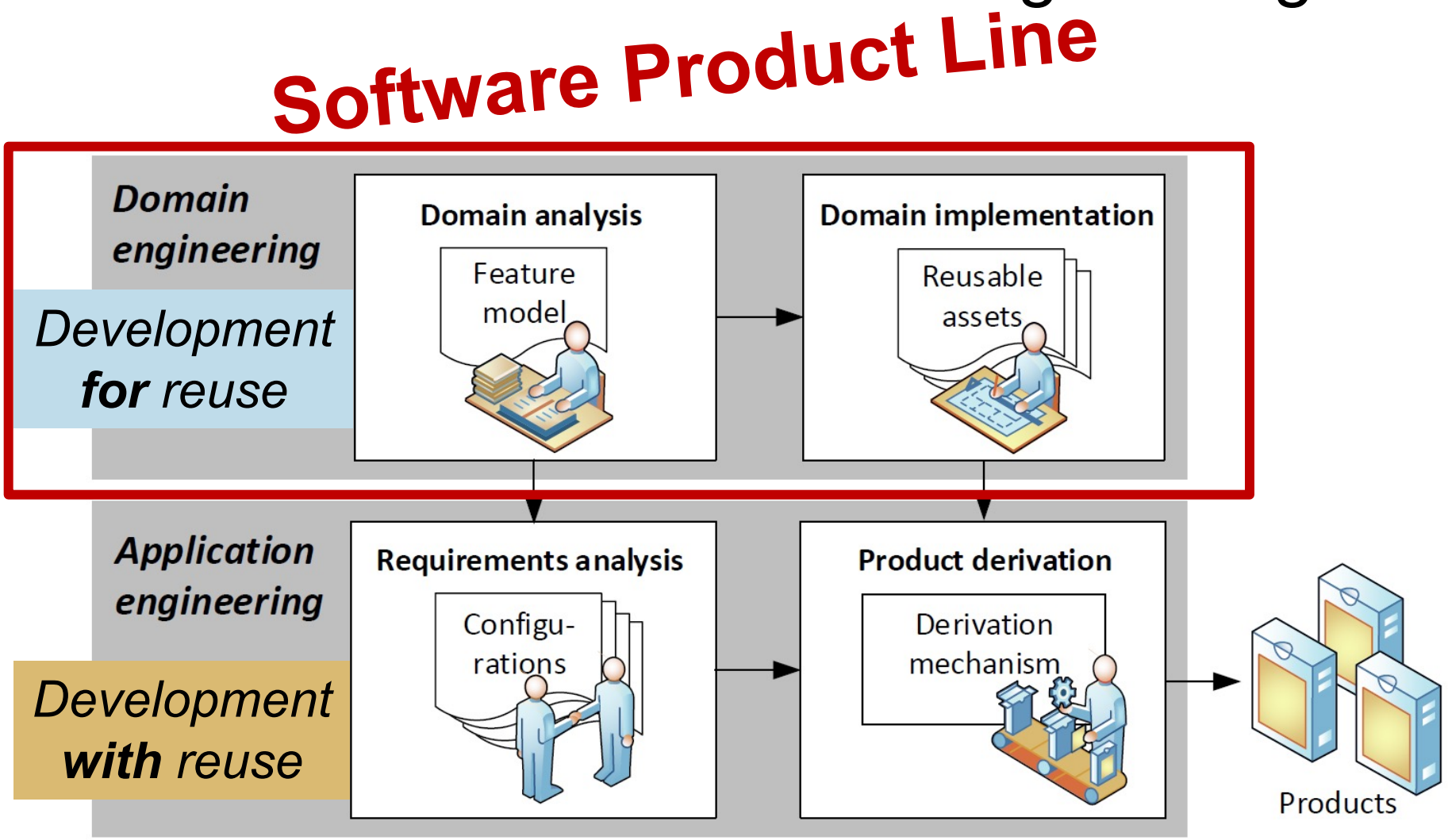
➔ Software Product Lines

Software Product Line

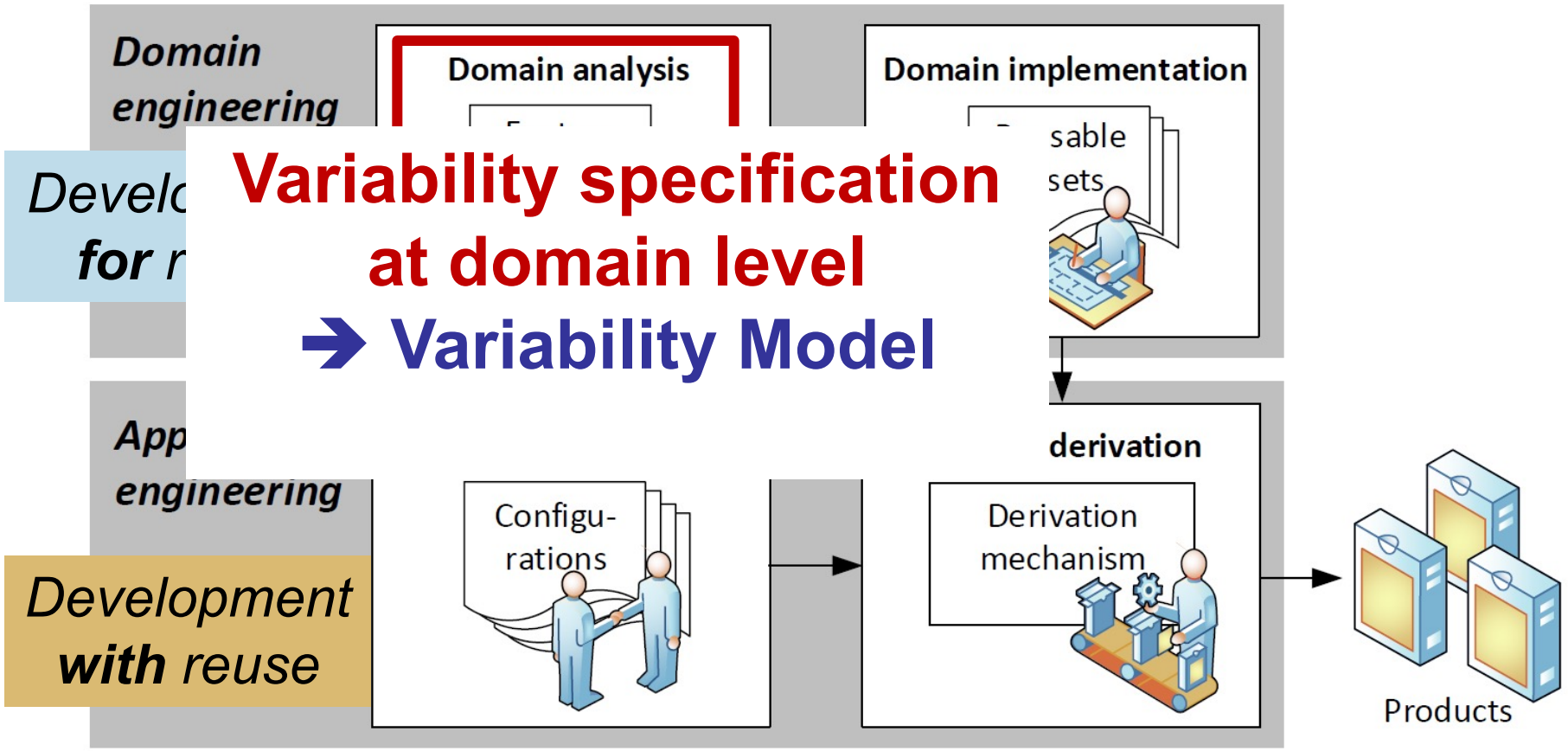


- ✓ **Dimension 1 : Variability Management.**
- ✓ **Dimension 2 : Product Derivation.**

Software Product Line Engineering

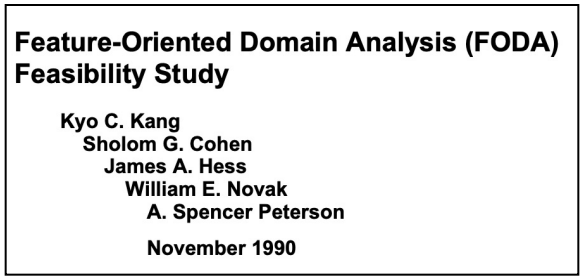


Phase1: Domain Analysis



Variability Model

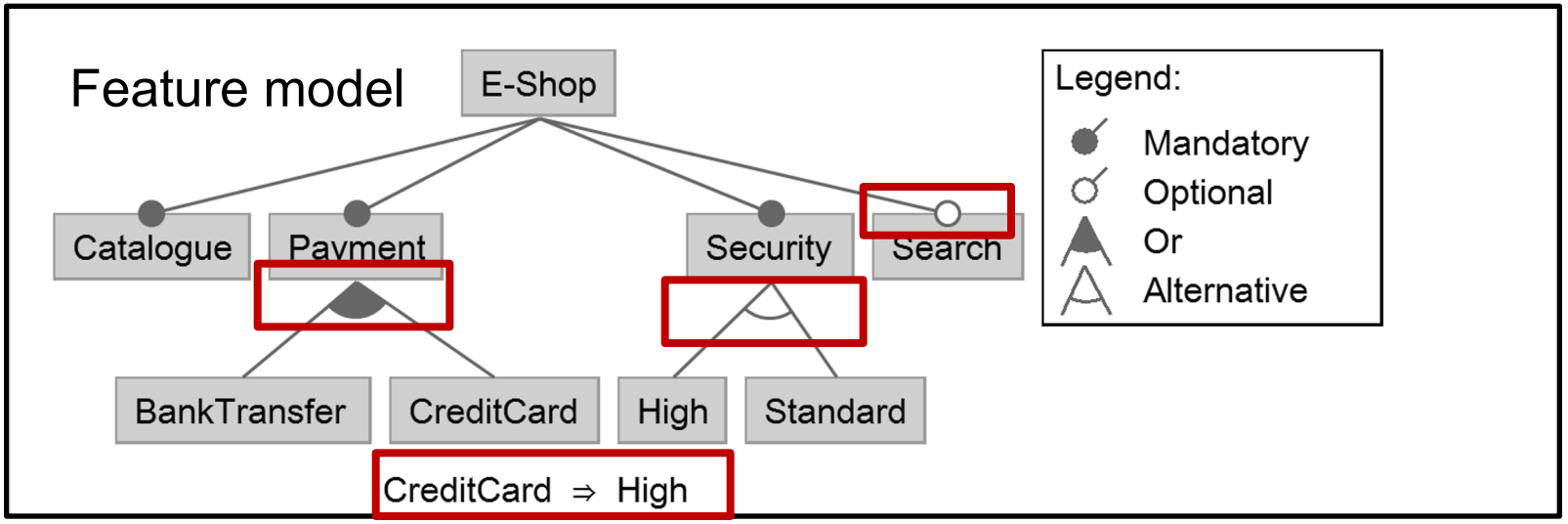
- **Explicit specification of variability**
- **Feature Model: *de facto* standard!**



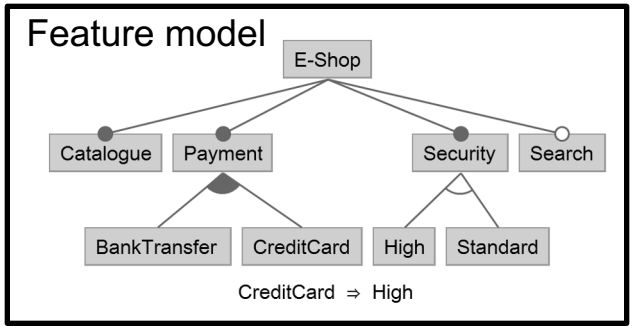
- **Research**
  - 5000++ citations!
  - Central for many research work
  - Tools & Languages: GUIDSL/FeatureIDE, SPLOT, FaMa, etc.)
- **Industry**
  - Tools (Gears, pure::variants),

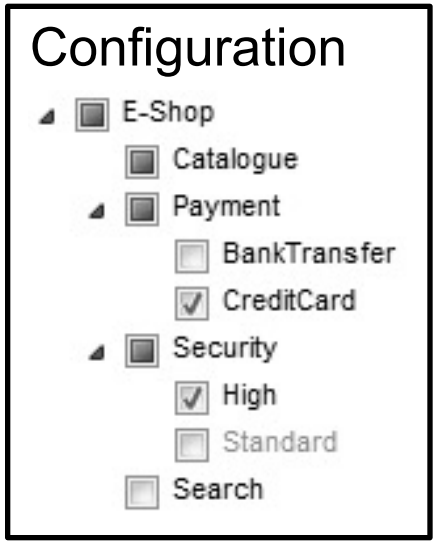
Feature Model

- The concept of **« feature »**
- **Hierarchy**: rooted tree
- Notations for **variability**
  - Optional, alternative, Or, constraints..



Feature Model & Configurations

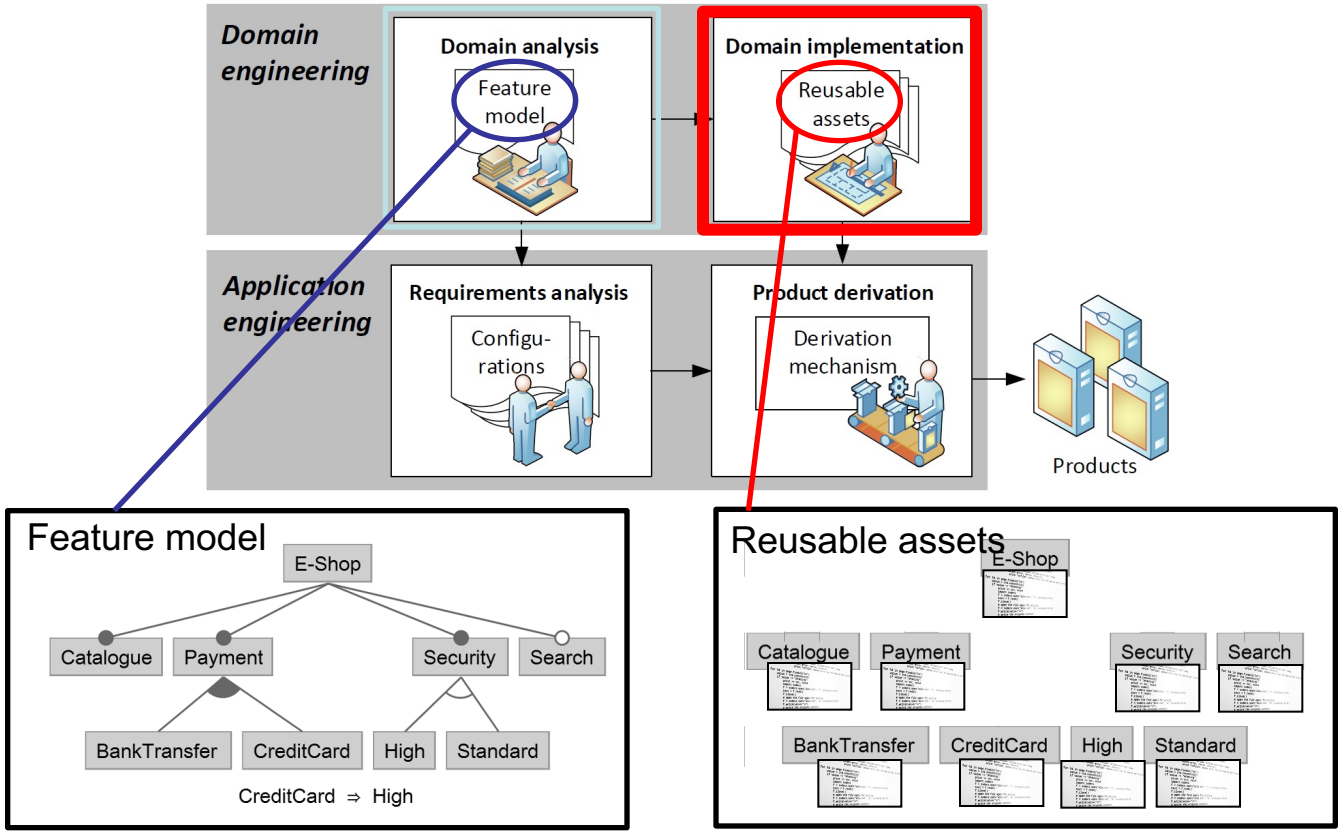




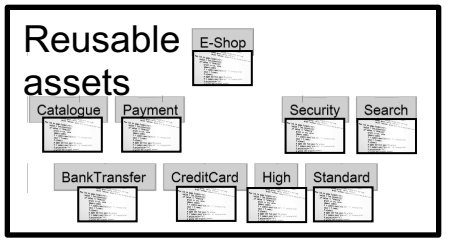
configuration =
set of features selected

Research Direction: **Automated Analysis and Reasoning on Feature models**

Software Product Line Engineering

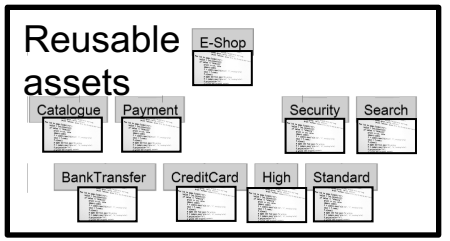


Domain Implementation



- **Objective**: Implement the reusable assets.
  - **Asset**: a **software artefact** needed to implement the product variants of the family.
    - *requirements*, *models, source code files, tests..*
  - **Reusable**: The assets that can be **reused** to implement the different variants:
    - ➔ Includes mechanisms to Implement the **software variability**
    - ➔ Links to the features.

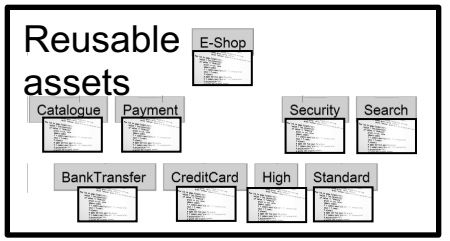
Domain Implementation



- How the reusable assets can be implemented?

Research Direction: **Software Product Lines Implementation**

Domain Implementation



- How the reusable assets can be implemented?

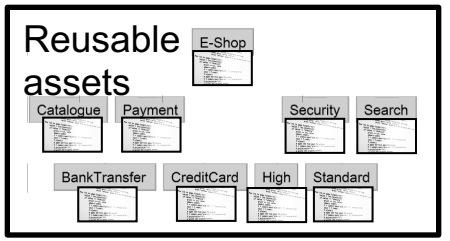
Research Direction: **Software Product Lines Implementation**

State of the art: two families of approaches:

➔ **Annotative** approaches

➔ **Compositional** approaches

Annotative approaches



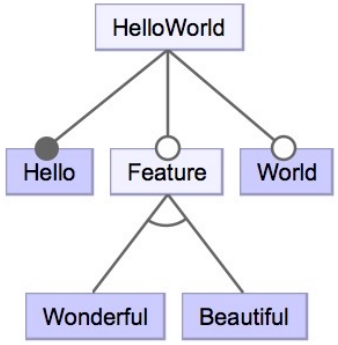
- **Asset Implementation:**
  - A **maximal** product (150% product).
  - **Annotations** to specify the fragments related to each feature.

Annot. approaches: State of the art

- ***Conditional compilation (preprocessors)*:**
  - Implement a maximal **C source code**
  - Add annotations using **compilation directives** (#ifdef)

(150% source code)

```
#include <stdio.h>
#include <stdlib.h>

int main(void) {
    printf("Hello");
#ifdef Beautiful
    printf(" beautiful");
#endif
#ifdef Wonderful
    printf(" wonderful");
#endif
#ifdef World
    printf(" world");
#endif
    return 0;
}
```



Feature ⇒ World

Annot. approaches: State of the art

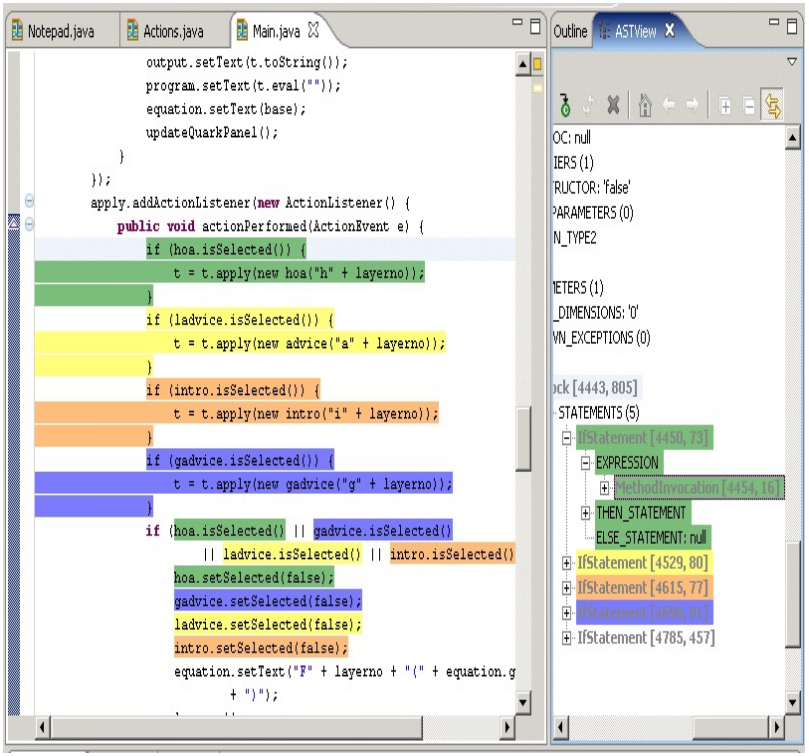
- Preprocessors for Java (integrated in the FeatureIDE tool)
  - **Munge** preprocessor: developed by the developers of Java's Swing library (main author:Thomas Ball)

```
public class HelloWorld {

    public static void main(String[] args){
        System.out.print("Hello");
        /*if[Beautiful]*/
        System.out.print(" beautiful");
        /*end[Beautiful]*/
        /*if[Wonderful]*/
        System.out.print(" wonderful");
        /*end[Wonderful]*/
        /*if[World]*/
        System.out.print(" world");
        /*end[World]*/
    }

}
```

(c) Source: FeatureIDE examples

Annot. approaches: State of the art

- **Colored IDE (CIDE)** [Kästner et al. ICSE]

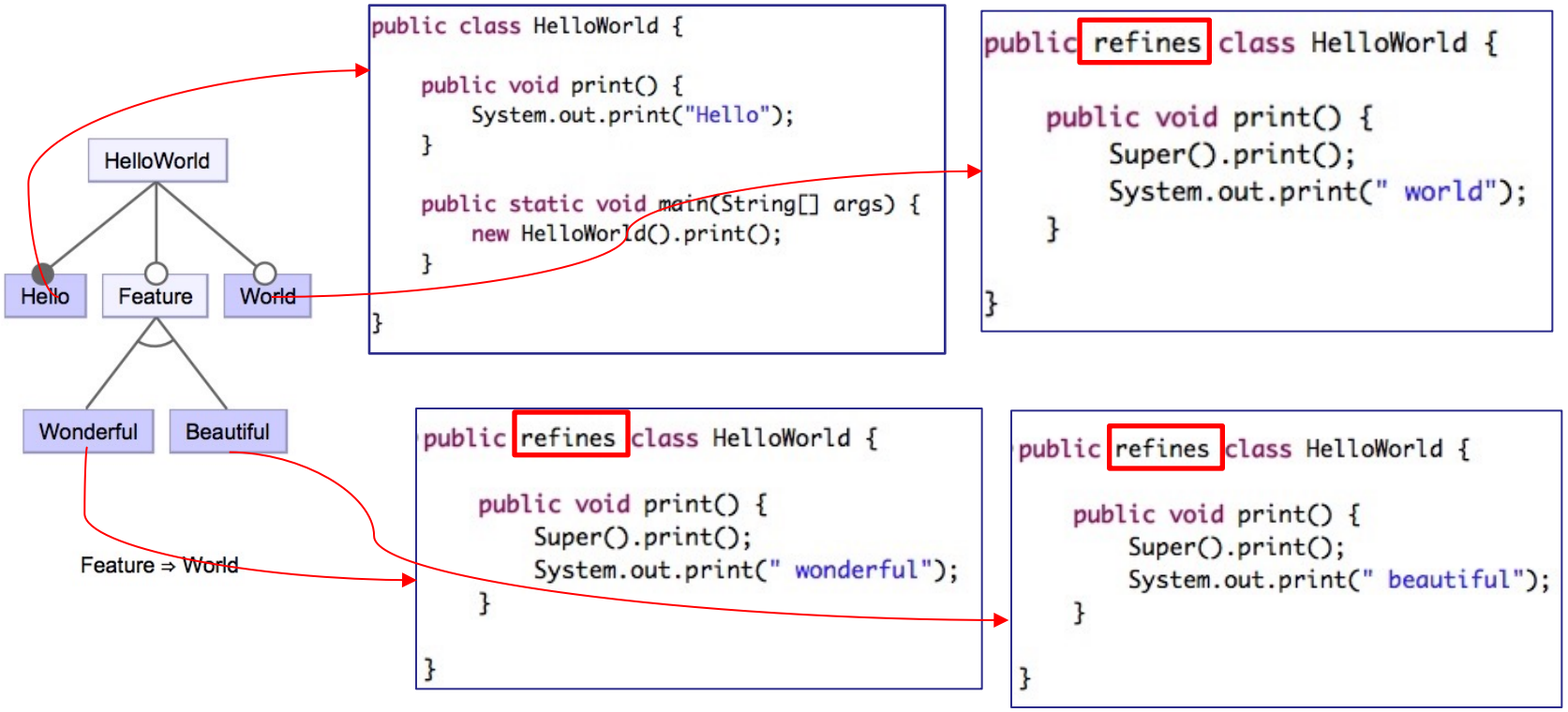


Compositional approaches

- Called also Feature-Oriented Programming/ Modeling approaches.
- **Asset Implementation**
  - the features of the product line are implemented as a set of ***separated fragments (modules)***

Comp. approaches: State of the art

- **AHEAD** framework (Batory et al., 04, IEEE TSE).
  - Based on code refinement

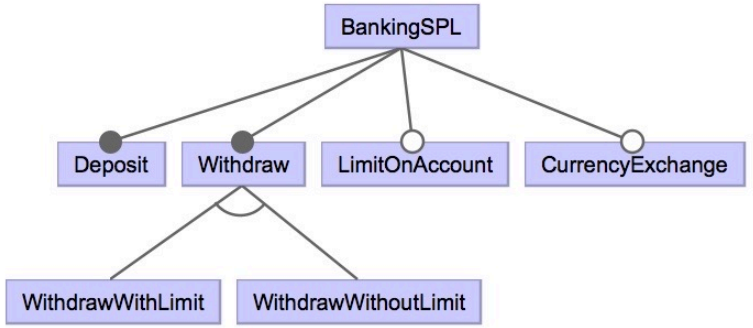


Comp. approaches: State of the art

- **FeatureHouse**, (Apel et al. TSE 10)
  - Based on code refinement
    - A **« base »** code that is a common to all variants.
    - Each feature wil **« refine »** the base code
      - Extend the base code
      - Adding new implementations.
  - A generic compositional approach that supports many languages.

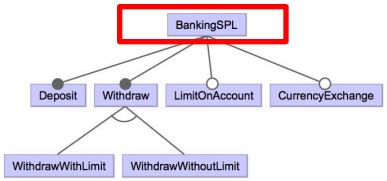
Example: The Banking System SPL

- Simple applications in the banking domain that implement the classical banking functionalities:
  - Deposit money
  - Withdraw
  - Currency conversion.
- **Variability** :
  - Limit on account is optional.
  - The conversion operation is are optional.



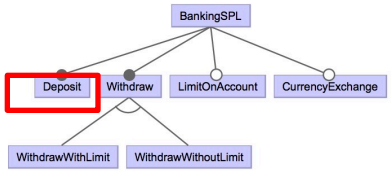
WithdrawWithLimit ⇔ LimitOnAccount

Feature : BankingSPL



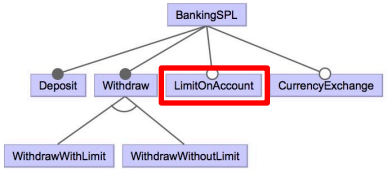
WithdrawWithLimit ⇔ LimitOnAccount

Feature : Deposit



WithdrawWithLimit ⇔ LimitOnAccount

Feature : LimitOnAccount



WithdrawWithLimit ⇔ LimitOnAccount

refine

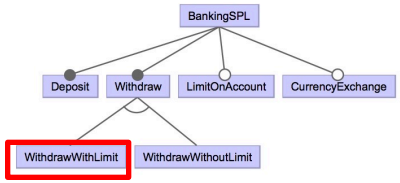
```
public class Account {

    public  String ID;

    private double balance;

    public Account(String id, double initial) {

        this.ID=id;
        this.balance=initial;
    }

    public double getBalance() {

        return this.balance;
    }

    public void display() {
        System.out.println("Account: "+ID+ " Balance ="+balance);
    }

}
```

"Base" code

```
public class Account {

    public void deposit(double amount) {

        balance+=amount;

    }


}
```

```
public class Account {


    final static int DAILY_LIMIT = -1000;


     public void display() {

            original();
            System.out.println("LIMIT ="+DAILY_LIMIT);
        }

}
```

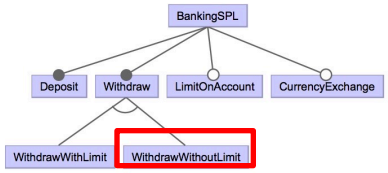
Feature : LimitOnAccount



WithdrawWithLimit ⇔ LimitOnAccount

```java
public class Account {

    public boolean withdraw(double amount) {

        if (balance>=amount+DAILY_LIMIT ) {
            balance-=amount;
            return true;
        }
        return false;
    }
}
```

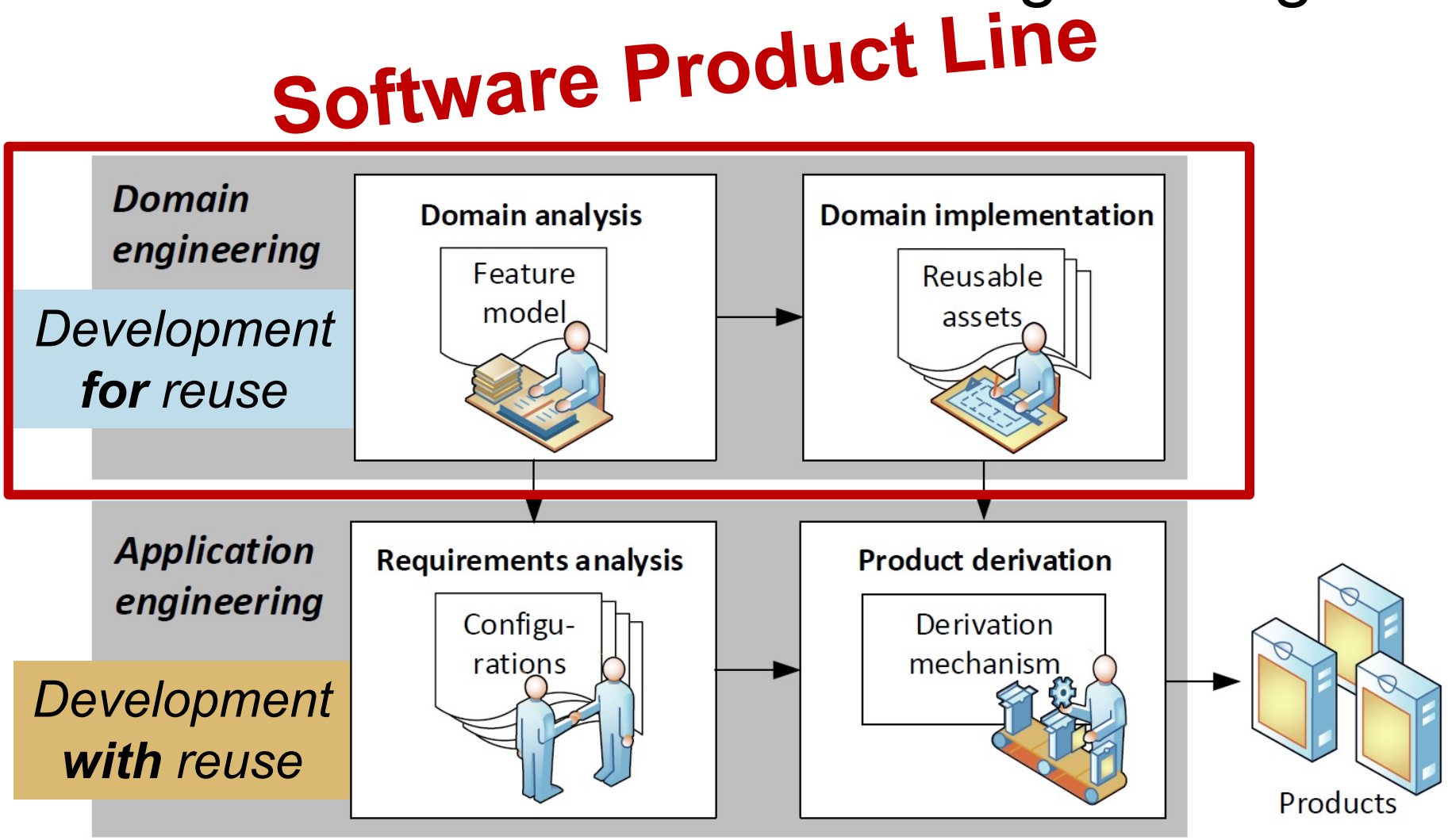
Feature : LimitOnAccount



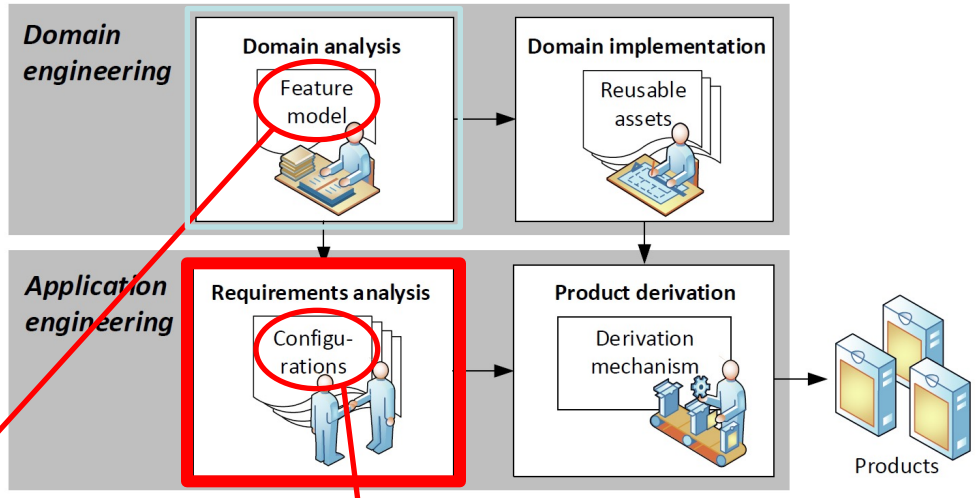
WithdrawWithLimit ⇔ LimitOnAccount

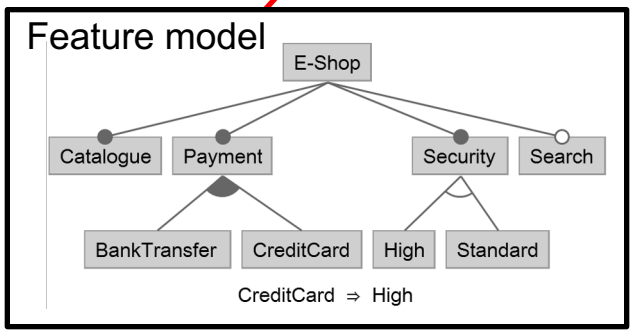
```java
public class Account {

    public boolean withdraw(double amount) {

        if (balance>=amount ) {
            balance-=amount;
            return true;
        }
        return false;
    }
}
```

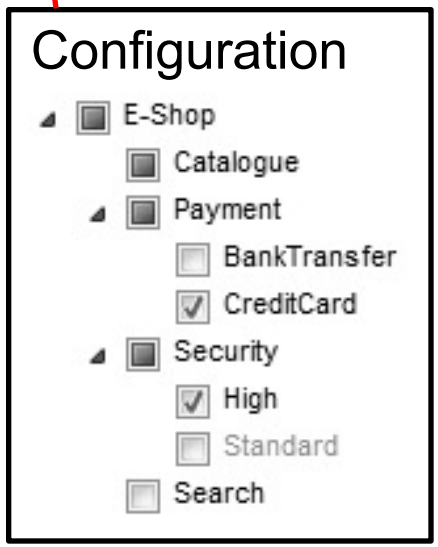
Software Product Line Engineering



Software Product Line Engineering



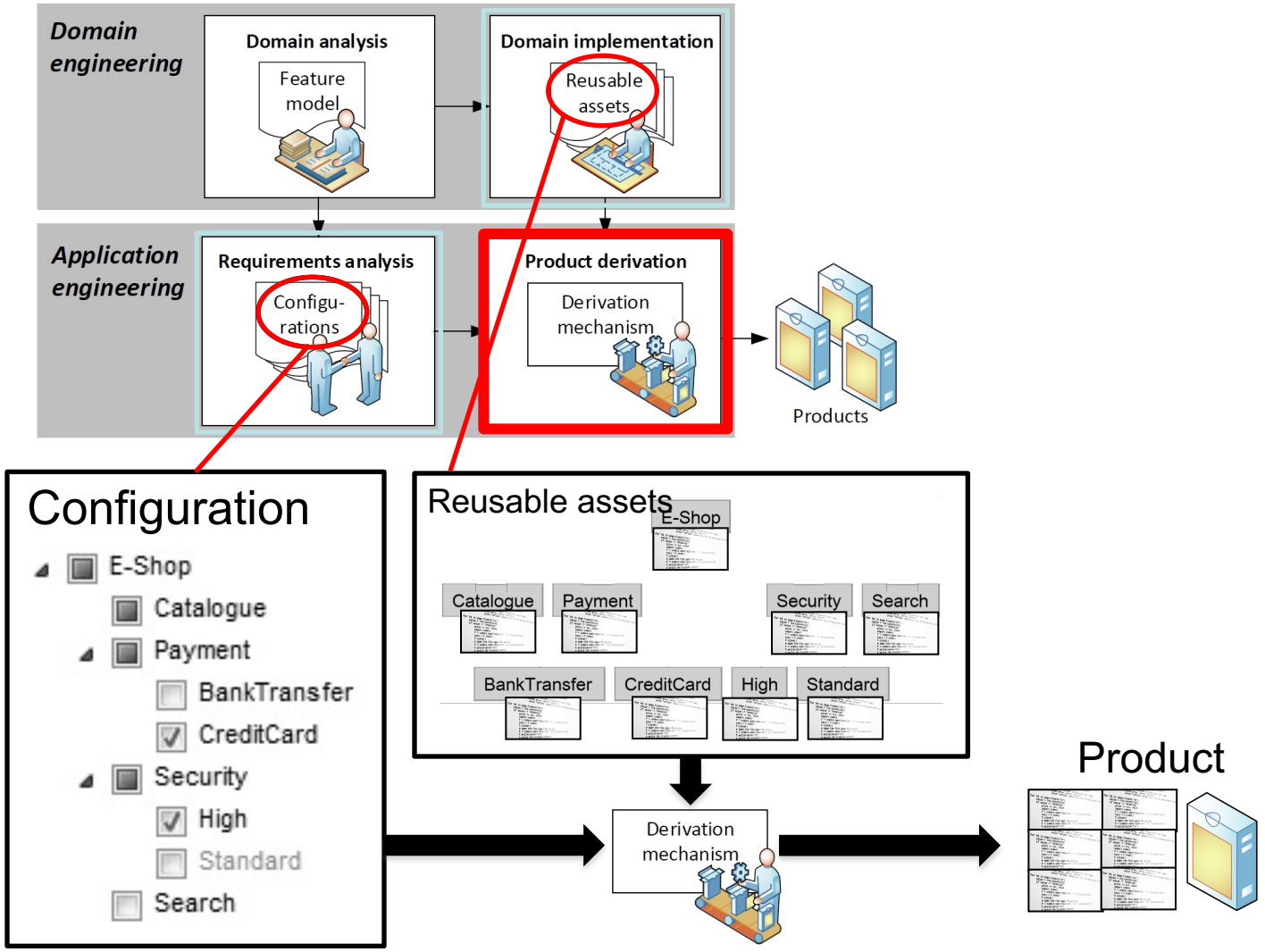




configuration =
set of features selected

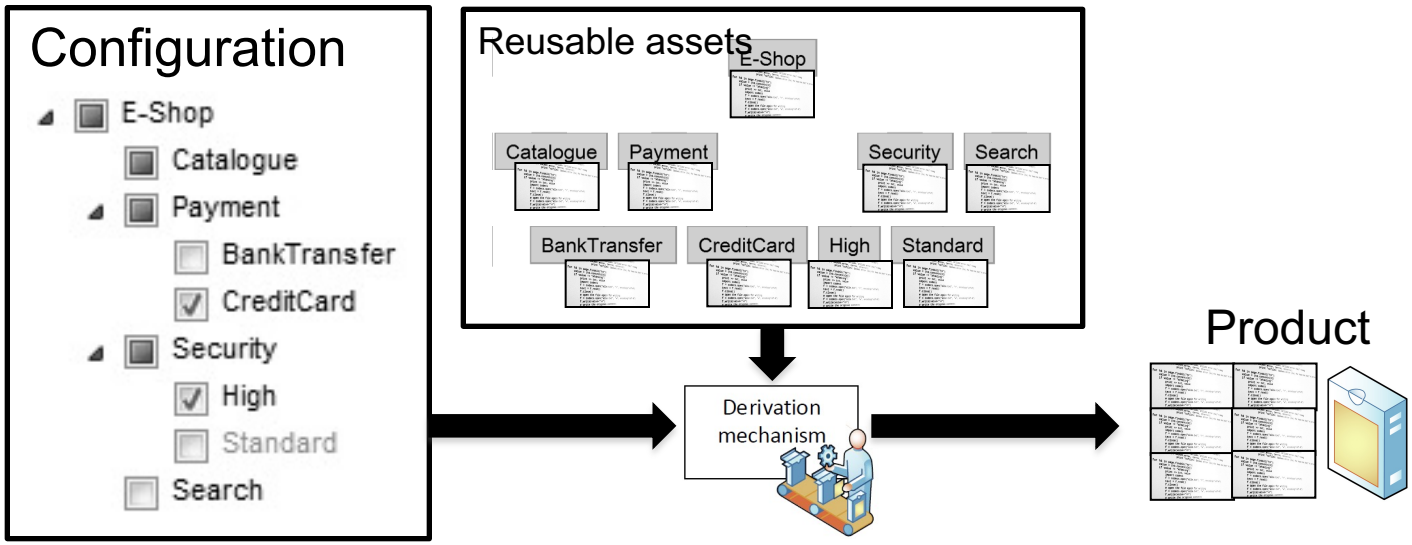
➔ **Only valid configurations**

Software Product Line Engineering



Product Derivation

- **Derive** (generate/synthesize) the product variants, members of the family.
- Generate the assets of the product variant that corresponding to a specific configuration.



Product Derivation

- How product derivation can be achieved ?

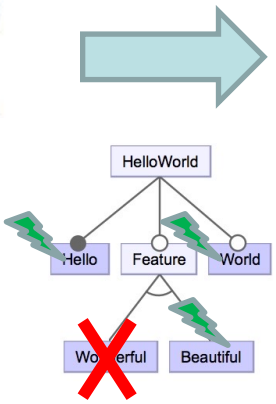
Research Direction: **Product Derivation**

  - Product Derivation depends on the used approach for reusable assets implementation.

Annot. Approaches: Product derivation

- **Product Derivation**
  - A specific product is derived by **removing** fragments related to the disabled features (program transformation).

```
public class HelloWorld {

    public static void main(String[] args){
        System.out.print("Hello");
        /*if[Beautiful]*/
        System.out.print(" beautiful");
        /*end[Beautiful]*/
        /*if[Wonderful]*/
        System.out.print(" wonderful");
        /*end[Wonderful]*/
        /*if[World]*/
        System.out.print(" world");
        /*end[World]*/
    }

}
```



Feature ⇒ World

```
public class HelloWorld {

    public static void main(String[] args){

        System.out.print("Hello");

        System.out.print(" wonderful");

        System.out.print(" world");

}
```

Comp. Approaches: Product derivation

- **Product derivation** is based on the composition of modules/fragments.
  - We need to implement a **composer** that composes the corresponding fragments for the selected features.

Feature : **BankingSPL**

```
public class Account {

    public  String ID;

    private double balance;

    public Account(String id, double initial) {

        this.ID=id;
        this.balance=initial;
    }

    public double getBalance() {

        return this.balance;
    }

    public void display() {
        System.out.println("Account: "+ID+ " Balance ="+balance);
    }

}
```

Feature : **LimitOnAccount**

```
public class Account {


    final static int DAILY_LIMIT = -1000;


     public void display() {

            original();
            System.out.println("LIMIT ="+DAILY_LIMIT);
        }

}
```

Composition(**BankingSPL**, **LimitOnAccount**)?

```
public   class  Account {


    public  String ID;
    private double balance;
    final static int DAILY_LIMIT = -1000;

    public Account(String id, double initial) {
        this.ID=id;
        this.balance=initial;
    }

    public double getBalance() {

        return this.balance;
    }
     private void  display__wrappee__BankingSPL  () {
        System.out.println("Account: "+ID+ " Balance ="+balance);
    }
     public void display() {

            display__wrappee__BankingSPL();
            System.out.println("LIMIT ="+DAILY_LIMIT);
        }
    public boolean withdraw(double amount) {

        if (balance>=amount+DAILY_LIMIT ) {
            balance-=amount;
            return true;
        }
        return false;

    }

}
```

LIVE DEMO

Content

- **Software Product Lines (SPL)**
  - Concepts & existing approaches to implement SPL
  - The Robocode case study

LIVE DEMOS

A real-world case study: Robocode

- Based on a paper presented in SPLC18

Software Product Line Extraction from Variability-Rich Systems: The Robocode Case Study

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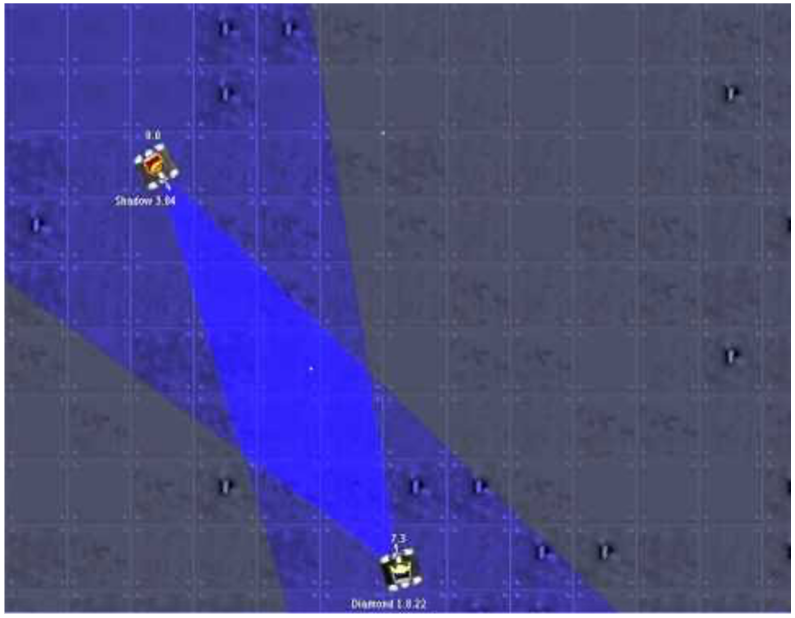
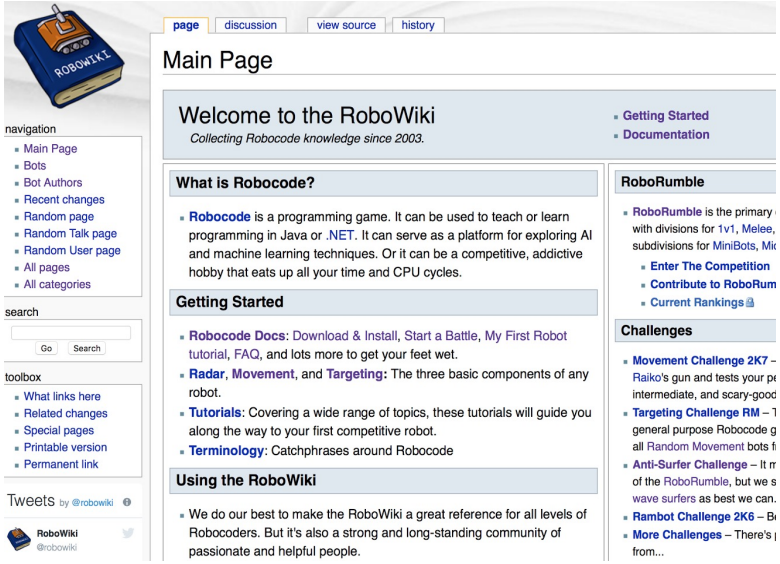
- Available at https://github.com/but4reuse/RobocodeSPL_teaching

Robocode: the case study

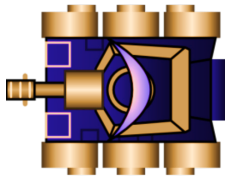
Robocode is a **programming game** where the goal is **to code** a **robot** to compete against other robots in a battle arena.





Robocode: the case study

- API to implement the behavior of the robots
- Each implementation is called **“Bot”**



```java
package sample;
import robocode.HitByBulletEvent;
import robocode.Robot;
import robocode.ScannedRobotEvent;


/**
 * MyFirstRobot - a sample robot by Mathew Nelson.
 * <p/>
 * Moves in a seesaw motion, and spins the gun around at each end.
 *
 * @author Mathew A. Nelson (original)
 */
public class MyFirstRobot extends Robot {

    /**
     * MyFirstRobot's run method - Seesaw
     */
    public void run() {

        while (true) {
            ahead(100); // Move ahead 100
            turnGunRight(360); // Spin gun around
            back(100); // Move back 100
            turnGunRight(360); // Spin gun around
        }
    }

    /**
     * Fire when we see a robot
     */
    public void onScannedRobot(ScannedRobotEvent e) {
        fire(1);
    }

    /**
     * We were hit!  Turn perpendicular to the bullet,
     * so our seesaw might avoid a future shot.
     */
    public void onHitByBullet(HitByBulletEvent e) {
        turnLeft(90 - e.getBearing());
    }
}
```

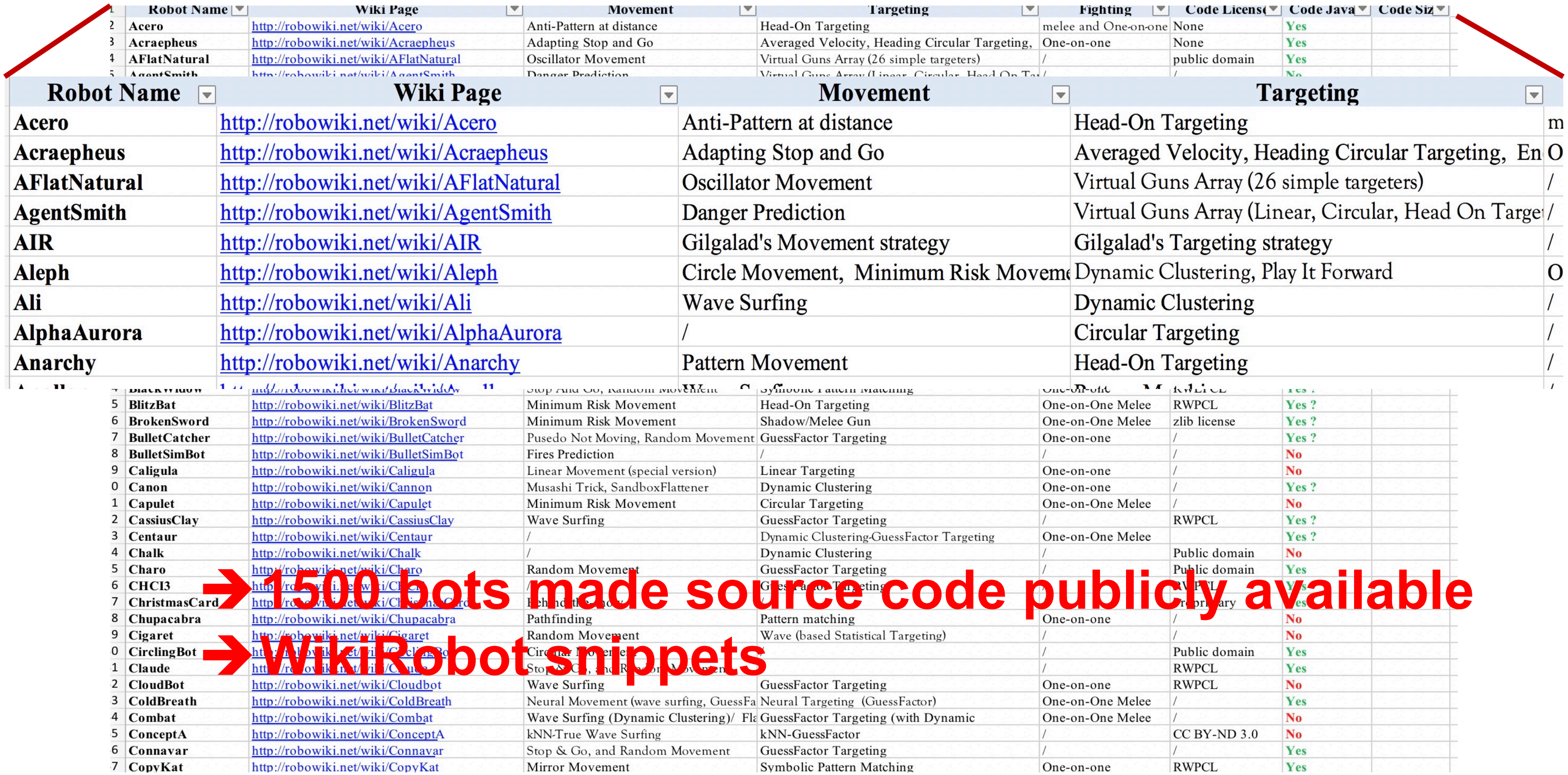
Robocode: A Variability-Rich System

5 components in each bot:

- **Targeting**
- **Movement**
- **Select Enemy**
- **Radar**
- **Gun & Energy Management**

➔ **Many variations for each component**

More than **3000** variants of bots are available from RobotWiki



Robot Name	Wiki Page	Movement	Targeting	Fighting	Code License	Code Java	Code Size
Acero	http://robowiki.net/wiki/Acero	Anti-Pattern at distance	Head-On Targeting	melee and One-on-one	None	Yes	
Acraepheus	http://robowiki.net/wiki/Acraepheus	Adapting Stop and Go	Averaged Velocity, Heading Circular Targeting,	One-on-one	None	Yes	
AFlatNatural	http://robowiki.net/wiki/AFlatNatural	Oscillator Movement	Virtual Guns Array (26 simple targeters)	/	public domain	Yes	

Robot Name	Wiki Page	Movement	Targeting
Acero	http://robowiki.net/wiki/Acero	Anti-Pattern at distance	Head-On Targeting
Acraepheus	http://robowiki.net/wiki/Acraepheus	Adapting Stop and Go	Averaged Velocity, Heading Circular Targeting, En
AFlatNatural	http://robowiki.net/wiki/AFlatNatural	Oscillator Movement	Virtual Guns Array (26 simple targeters)
AgentSmith	http://robowiki.net/wiki/AgentSmith	Danger Prediction	Virtual Guns Array (Linear, Circular, Head On Targe
AIR	http://robowiki.net/wiki/AIR	Gilgalad's Movement strategy	Gilgalad's Targeting strategy
Aleph	http://robowiki.net/wiki/Aleph	Circle Movement, Minimum Risk Moveme	Dynamic Clustering, Play It Forward
Ali	http://robowiki.net/wiki/Ali	Wave Surfing	Dynamic Clustering
AlphaAurora	http://robowiki.net/wiki/AlphaAurora	/	Circular Targeting
Anarchy	http://robowiki.net/wiki/Anarchy	Pattern Movement	Head-On Targeting

	Robot Name	Wiki Page	Movement	Targeting	Fighting	Code License	Code Java
5	BlitzBat	http://robowiki.net/wiki/BlitzBat	Minimum Risk Movement	Head-On Targeting	One-on-One Melee	RWPCL	Yes ?
6	BrokenSword	http://robowiki.net/wiki/BrokenSword	Minimum Risk Movement	Shadow/Melee Gun	One-on-One Melee	zlib license	Yes ?
7	BulletCatcher	http://robowiki.net/wiki/BulletCatcher	Pusedo Not Moving, Random Movement	GuessFactor Targeting	One-on-one	/	Yes ?
8	BulletSimBot	http://robowiki.net/wiki/BulletSimBot	Fires Prediction	/	/	/	No
9	Caligula	http://robowiki.net/wiki/Caligula	Linear Movement (special version)	Linear Targeting	One-on-one	/	No
0	Canon	http://robowiki.net/wiki/Cannon	Musashi Trick, SandboxFlattener	Dynamic Clustering	One-on-one	/	Yes ?
1	Capulet	http://robowiki.net/wiki/Capulet	Minimum Risk Movement	Circular Targeting	One-on-One Melee	/	No
2	CassiusClay	http://robowiki.net/wiki/CassiusClay	Wave Surfing	GuessFactor Targeting	/	RWPCL	Yes ?
3	Centaur	http://robowiki.net/wiki/Centaur	/	Dynamic Clustering-GuessFactor Targeting	One-on-One Melee		Yes ?
4	Chalk	http://robowiki.net/wiki/Chalk	/	Dynamic Clustering	/	Public domain	No
5	Charo	http://robowiki.net/wiki/Charo	Random Movement	GuessFactor Targeting	/	Public domain	Yes
6	CHCI3	[illegible]	/	[illegible]	/	[illegible]	[illegible]
7	ChristmasCard	[illegible]	[illegible]	/	/	Proprietary	[illegible]
8	Chupacabra	http://robowiki.net/wiki/Chupacabra	Pathfinding	Pattern matching	One-on-one	/	No
9	Cigaret	http://robowiki.net/wiki/Cigaret	Random Movement	Wave (based Statistical Targeting)	/	/	No
0	CirclingBot	[illegible]	[illegible]	/	/	Public domain	Yes
1	Claude	[illegible]	[illegible]		/	RWPCL	Yes
2	CloudBot	http://robowiki.net/wiki/Cloudbot	Wave Surfing	GuessFactor Targeting	One-on-one	RWPCL	No
3	ColdBreath	http://robowiki.net/wiki/ColdBreath	Neural Movement (wave surfing, GuessFa	Neural Targeting (GuessFactor)	One-on-One Melee	/	Yes
4	Combat	http://robowiki.net/wiki/Combat	Wave Surfing (Dynamic Clustering)/ Fla	GuessFactor Targeting (with Dynamic	One-on-One Melee	/	No
5	ConceptA	http://robowiki.net/wiki/ConceptA	kNN-True Wave Surfing	kNN-GuessFactor	/	CC BY-ND 3.0	No
6	Connavar	http://robowiki.net/wiki/Connavar	Stop & Go, and Random Movement	GuessFactor Targeting	/	/	Yes
7	CopyKat	http://robowiki.net/wiki/CopyKat	Mirror Movement	Symbolic Pattern Matching	One-on-one	RWPCL	Yes

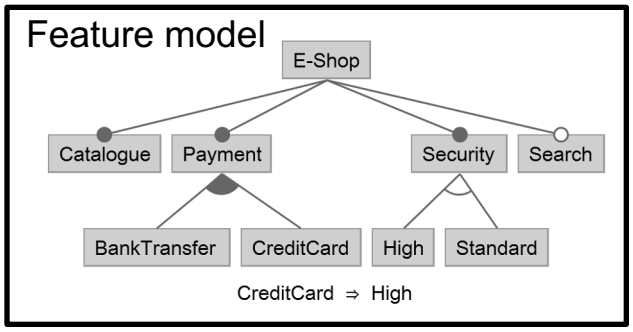
➔ **1500 bots made source code publicly available**

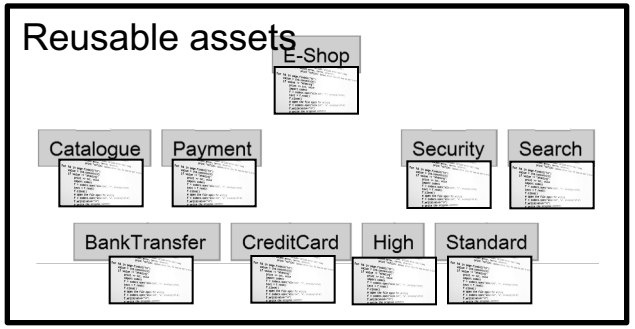
➔ **WikiRobot snippets**

➔ **All follow the same architecture**

Robocode SPL Implementation

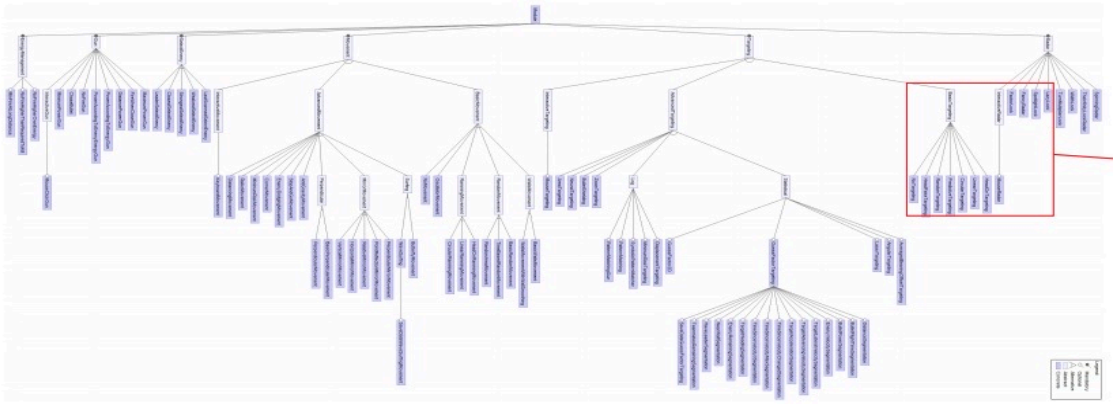
- **Inputs**:
  - Source code of bots
  - RoboWiki Snippet
  - Documentation
- **Output**: Robocode SPL

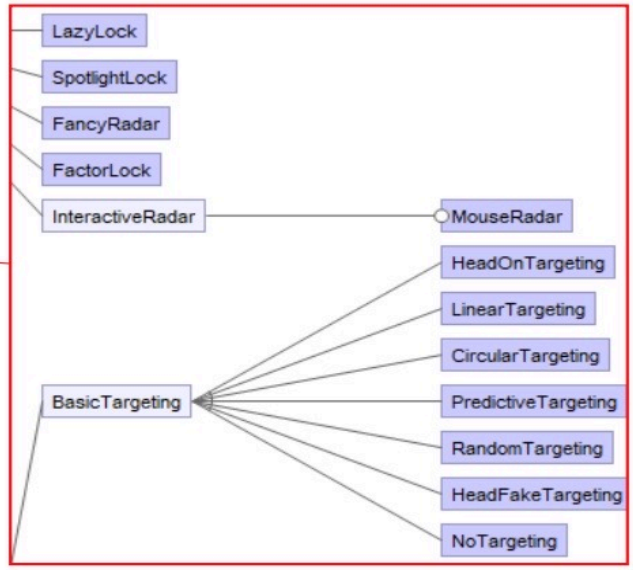




Domain Analysis

- **Objective**: Identify features and construct the feature model

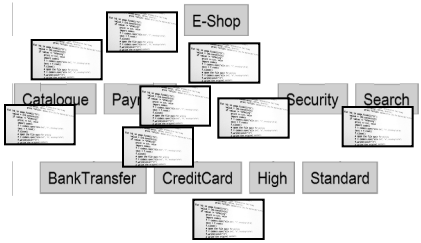




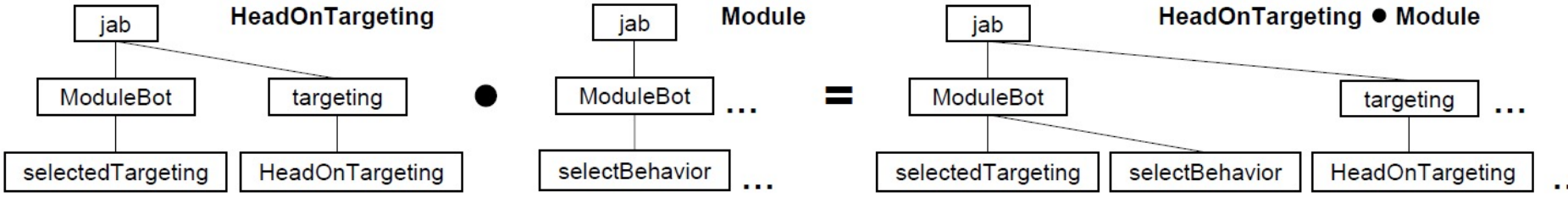
115 features:

- **7** mandatory features.
- **22** abstract features
- **93** are behavioral features

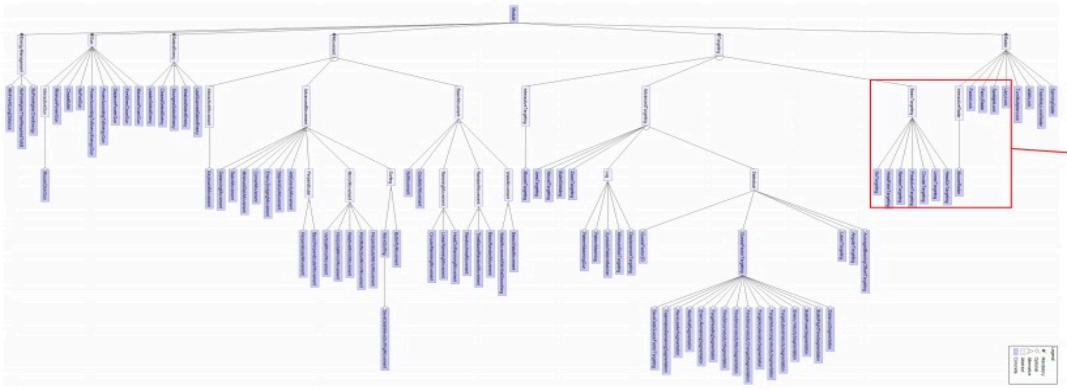
Domain Implementation

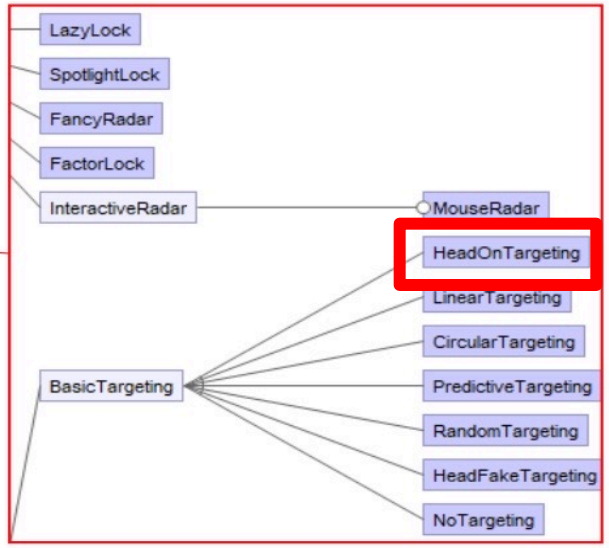


- **Objective**: Implement the reusable assets.
  - ➔ The use of the FeatureHouse framework [FH,13]
    - ➔A compositional approach at the source code level



[FH,99] Apel et al., Language-Independent and Automated Software Composition: The FeatureHouse Experience. IEEE Trans. Software Eng. 39(1): 63-79 (2013)






```java
package jab.targeting;

public class HeadOnTargeting extends Targeting {

  public HeadOnTargeting(Module bot) {
    super(bot);
  }

  public void target() {
    if (bot.enemy != null) {
      double absoluteBearing = bot.getHeadingRadians() +
     bot.enemy.bearingRadians;      bot.
     setTurnGunRightRadians(robocode.util.Utils.
     normalRelativeAngle(absoluteBearing - bot.
     getGunHeadingRadians()));
    }
  }
}
```

```java
package jab;

public class ModuleBot extends Module {
  Targeting selectedTargeting = new HeadOnTargeting(this)
    ;
}
```

“Base” refinement

```java
package jab;

public class ModuleBot extends Module {
  ...
  Targeting selectedTargeting = new HeadOnTargeting(this)
    ;
  ...
  protected void selectBehavior() {
    radar = selectedRadar;
    movement = selectedMovement;
    targeting = selectedTargeting;
    selectEnemy = selectedSelectEnemy;
    gun = selectedGun;
  }
    ...
}
```

Robocode SPL

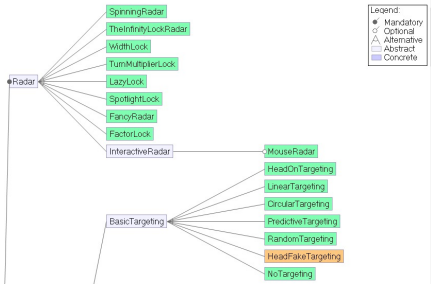
Domain Analysis

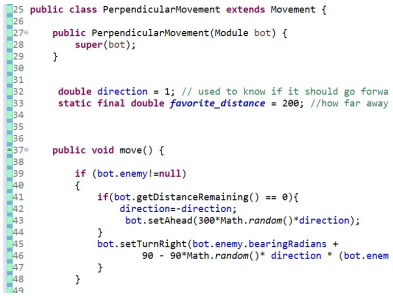
Domain Implementation

FeatureHouse

Configuration & Product Derivation

Bots





```
public class PerpendicularMovement extends Movement {

    public PerpendicularMovement(Module bot) {
        super(bot);
    }


     double direction = 1; // used to know if it should go forwa
     static final double favorite_distance = 200; //how far away


    public void move() {

        if (bot.enemy!=null)
        {
            if(bot.getDistanceRemaining() == 0){
                direction=-direction;
                 bot.setAhead(300*Math.random()*direction);
            }
            bot.setTurnRight(bot.enemy.bearingRadians +
                    90 - 90*Math.random()* direction * (bot.enem
            }
        }
```