Recovering Traceability Links between Artifacts of Software Variants in the Context of Software Product Line Engineering

Présentation extraite de la soutenance de thèse de

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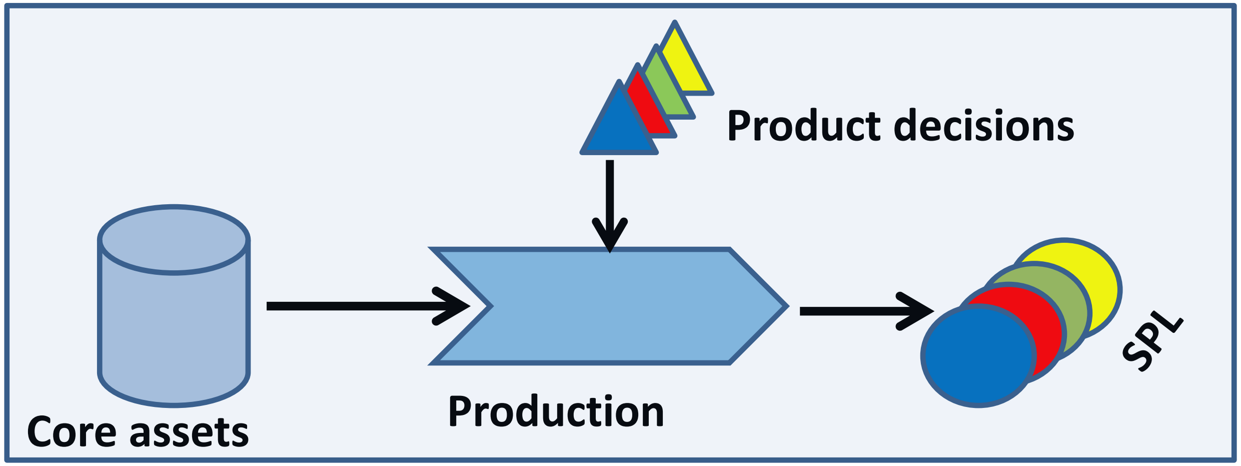
Software Product Line (SPL)

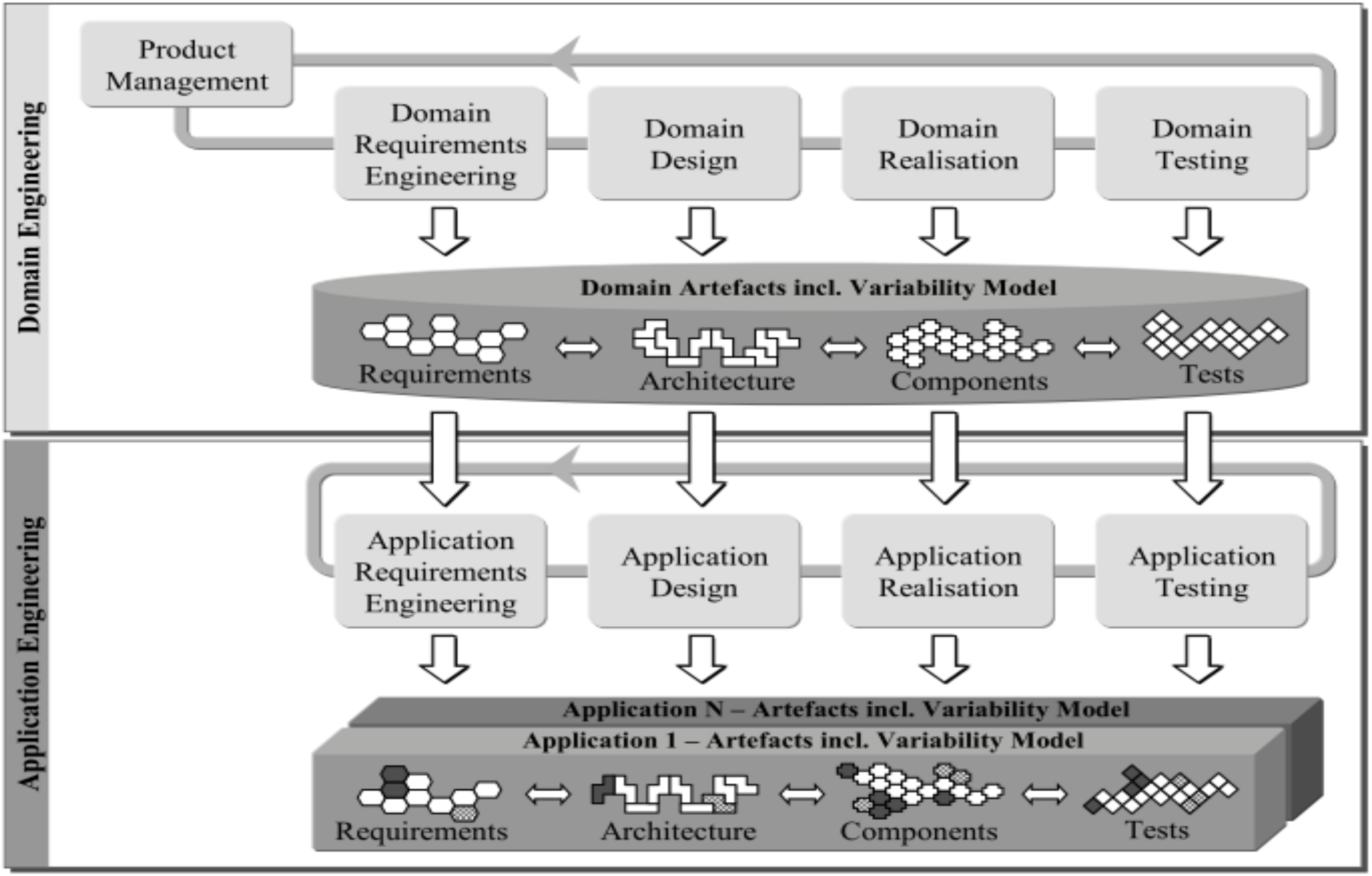
- **A family of software-intensive systems sharing a common, managed set of features developed from a common set of core assets in prescribed way**

- **A feature is a prominent or distinctive user-visible aspect, quality or characteristic of a software system** *[Kang et al. 1990]*



Basics SPL concepts *[Charles Kruger 2006]*

Software Product Line Engineering Framework

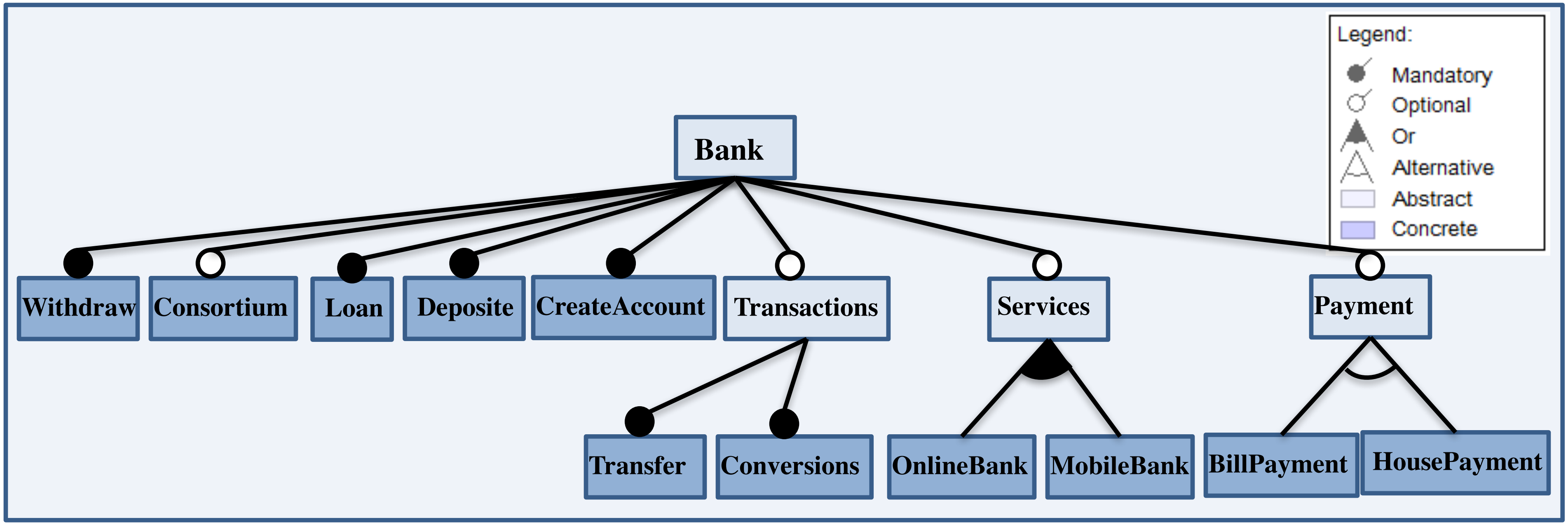


SPLE framework ***[Phol 2010]***

Variability Management: Feature Model (FM)

- Variability represented in FM as
  - Optional features
  - Feature groups
    - Exclusive alternative (XOR)
    - Inclusive alternative (OR)
    - Inclusive (AND)

- Feature groups are variation points (VPs)



An example of feature model

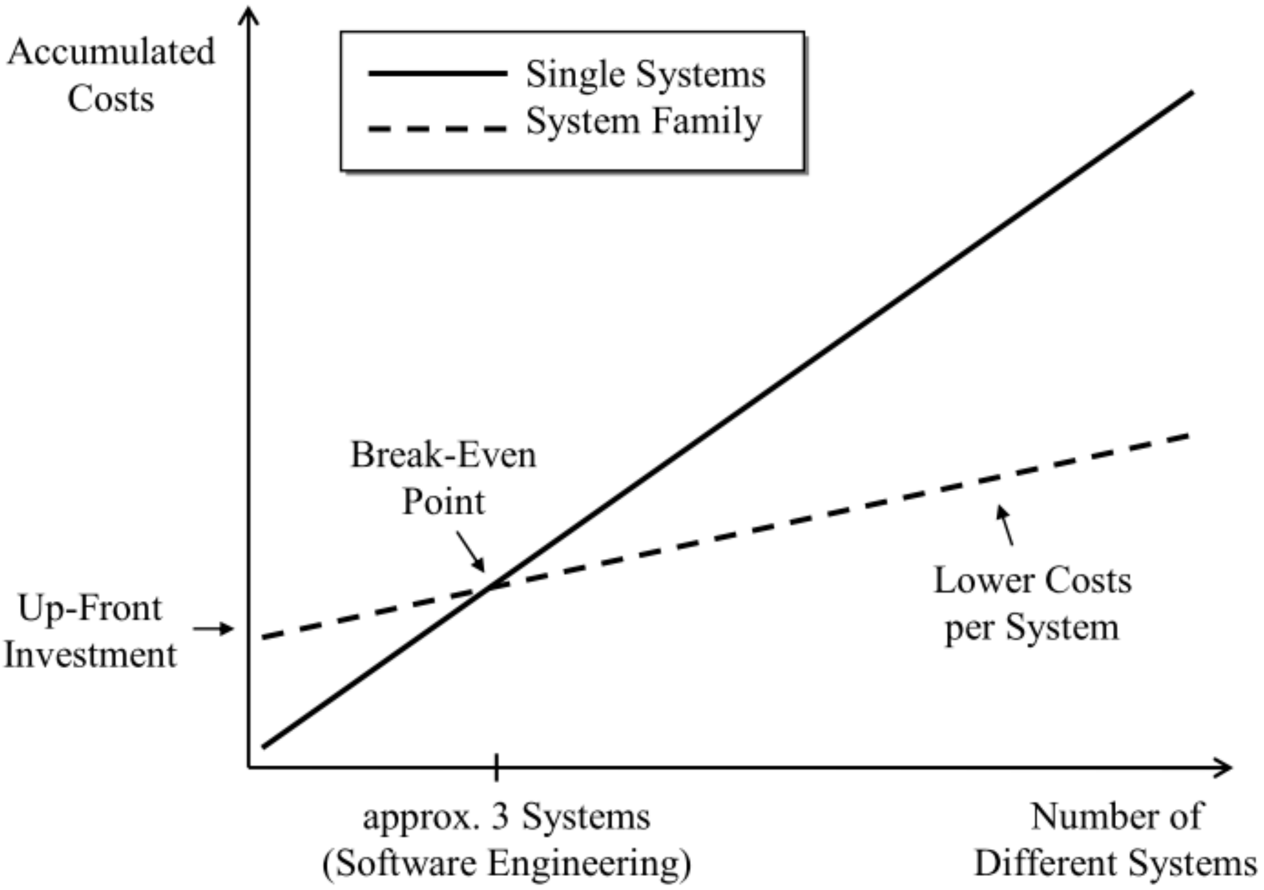
Software Product Variants

- ❑ **Software product variants**
  - ✓ **A collection of similar software products**
  - ✓ **Developed by ad-hoc reuse techniques**
  - ✓ **Share some features and differ in others**

- ❑ **Drawbacks of ad-hoc Development**
  - ✓ **Reusing features (resp. their implementations) is time-consuming**
  - ✓ **Changes made to code of common features must be repeated**
  - ✓ **Evolving product variants lack prescribed planning**

General Goal: Supporting Re-engineering SPL from Product Variants [1/2]

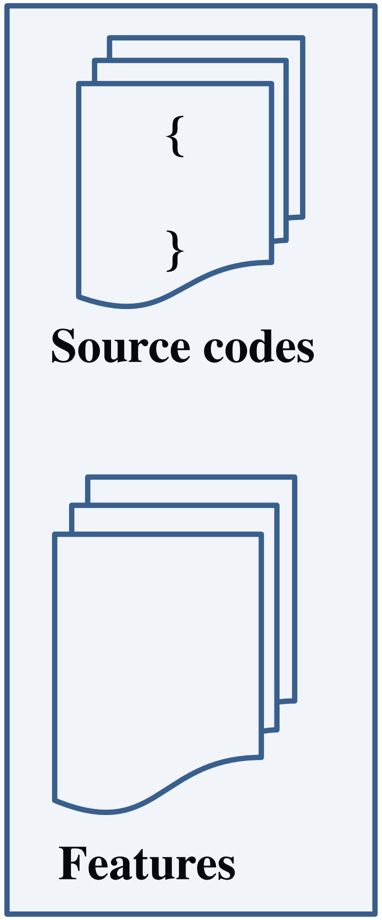
❑ Product variants versus SPL



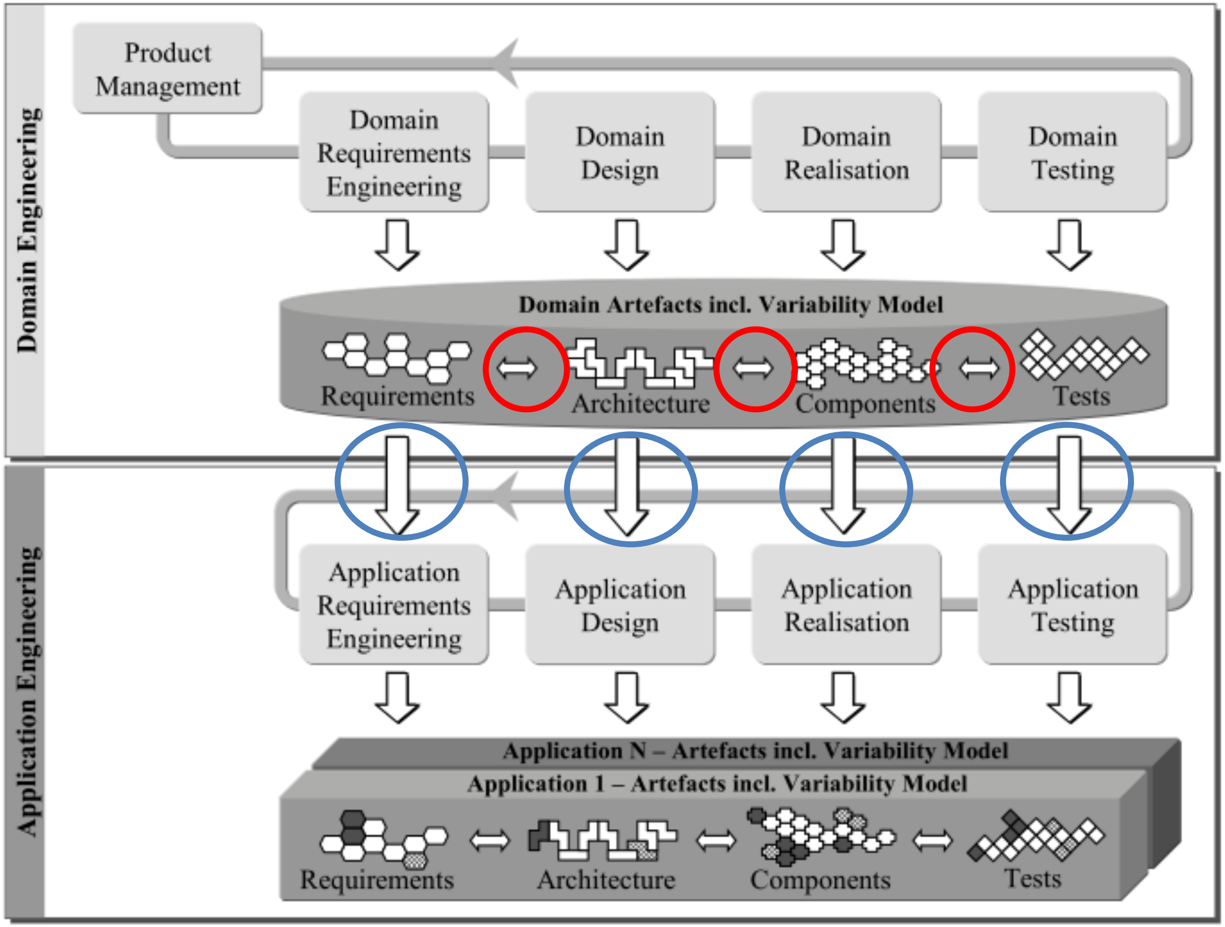
Accumulated costs for SPL development and traditional development [Phol 2010]

General Goal: Supporting Re-engineering SPL from Product Variants[2/2]

- **Traceability is the ability to relate software artifacts developed during the life cycle to describe the system from different perspectives and at different levels of abstraction**



Product variants



SPLE framework *[Phol 2010]*

Problem1: Finding Traceability Links between Features and their Implementing Source Code Elements [1/2]

Implementation of *BillPayment* Feature

```
public class PayPartially
{
private Date PaymentDate;

PayPartially()
{
……
}

private void monthlyPayment (String month)
{
......
}

private void electricityBill (int BillID)
{
......
}

private void telephoneBill (int BillID)
{
......
}
}
```

```
public class PaymentMethod
{
private String price;
 PaymentMethod ()
{
......
}
 private void billInfo (int billNo)
 {
.......
 }
 private void printPaymentReport (int billNo)
 {
 ......
 }
 private void Postpaidbilling ( )
 {
 …..
 }
 private void PrepaiBilling ( )
 {
 …..
 }
 }
```

```
public class BillAccount
{
private int accountType;
private double taxBill;
BillAccount ()
{
……
}

public void payment ( )
{
……
}

public void pricingPllicy ( )
{
…..
}

public double taxesComputing (  )
{
return taxBill;
}
}
```

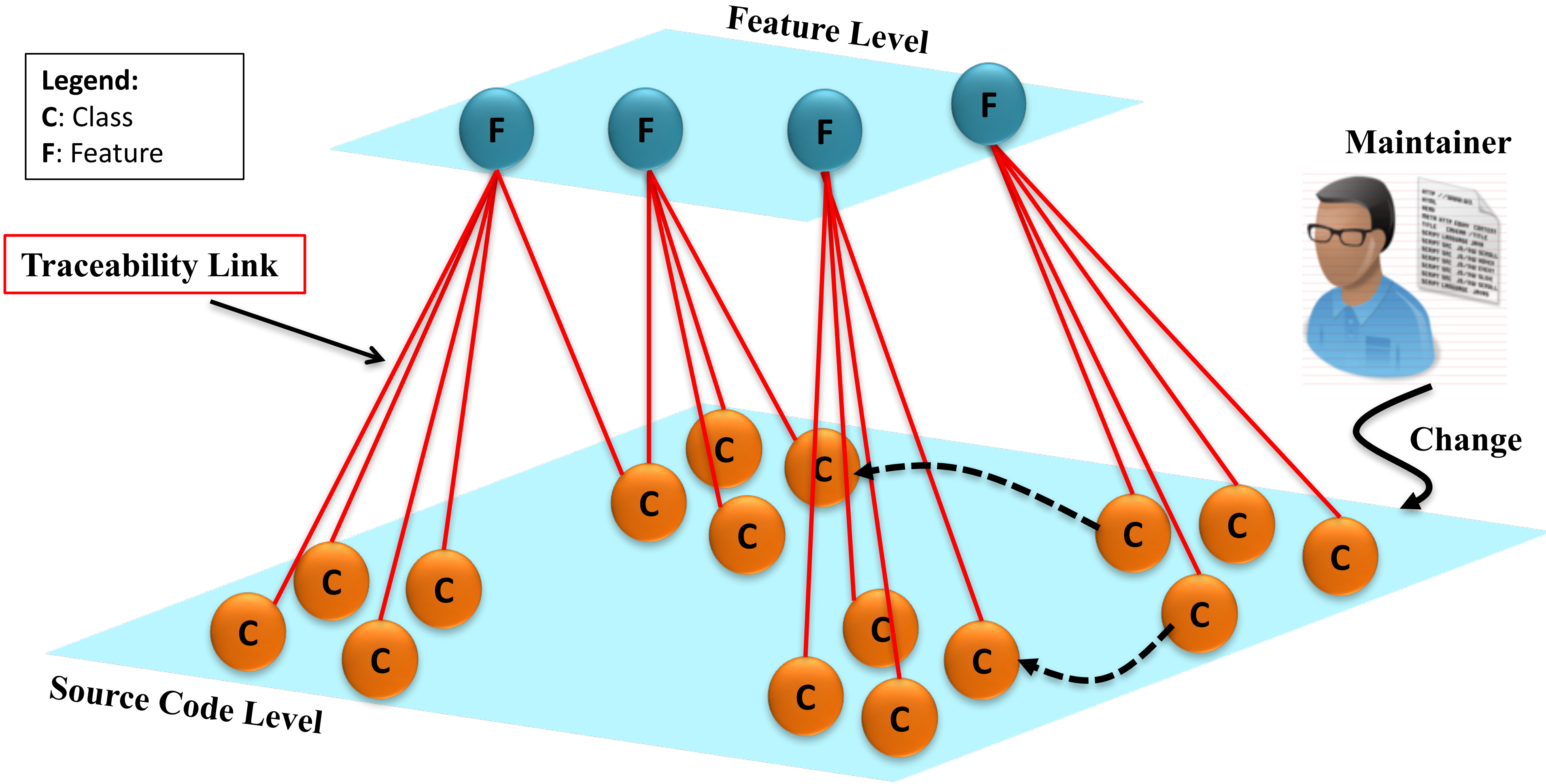
Problem1: Finding Traceability Links between Features and their Implementing Source Code Elements [2/2]

1. **Traceability links between features and their implementing source code elements for:**

   - Understanding source code of product variants
   - Reusing right features (resp. their implementations)
   - Facilitating and Automating new product derivation from SPL's core assets

Problem 2 : Feature-Level Change Impact Analysis

- Change management from SPL manager point of view



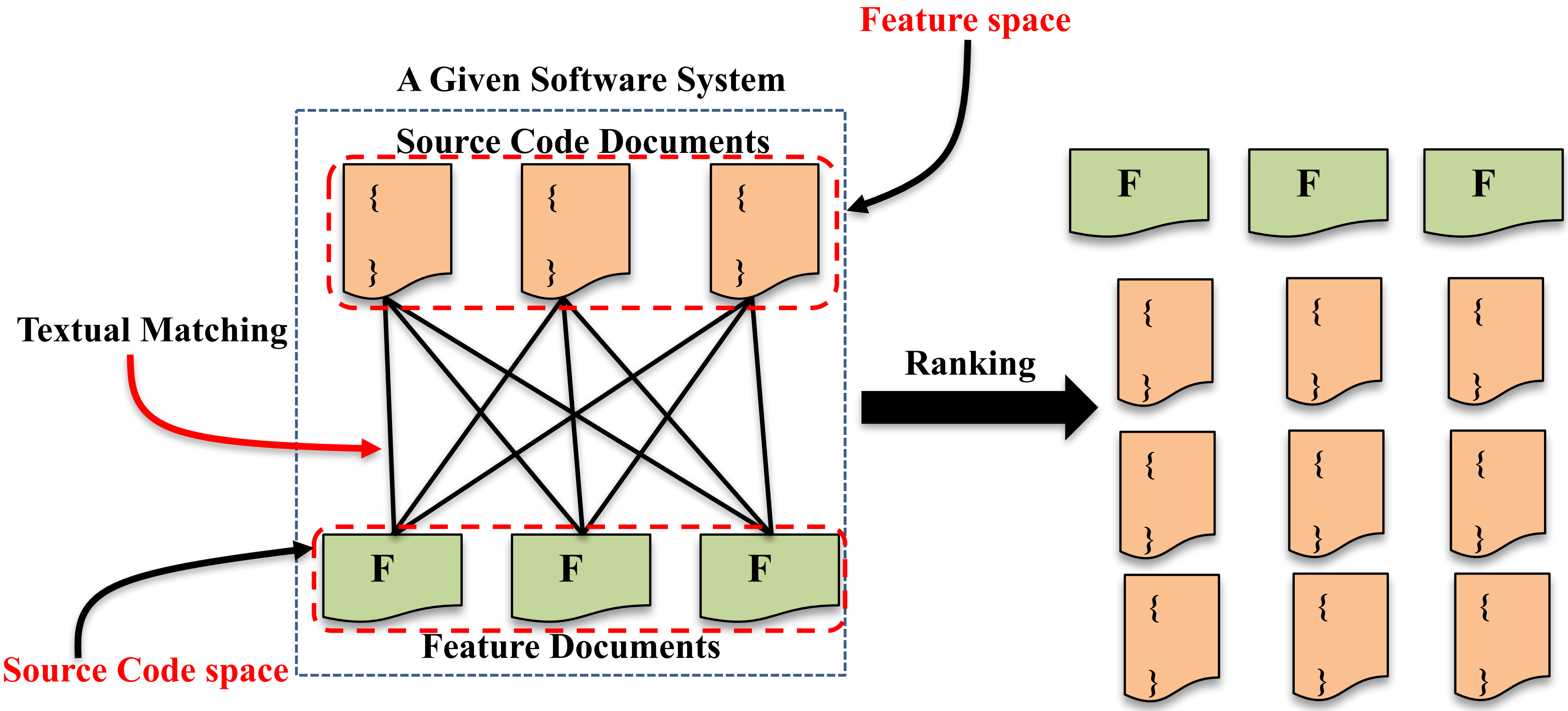
Outline

Feature Location in a Collection of Product Variants with Information Retrieval

Feature Location based on Information Retrieval (IR)

- ❑ Textual matching between feature descriptions and source code information

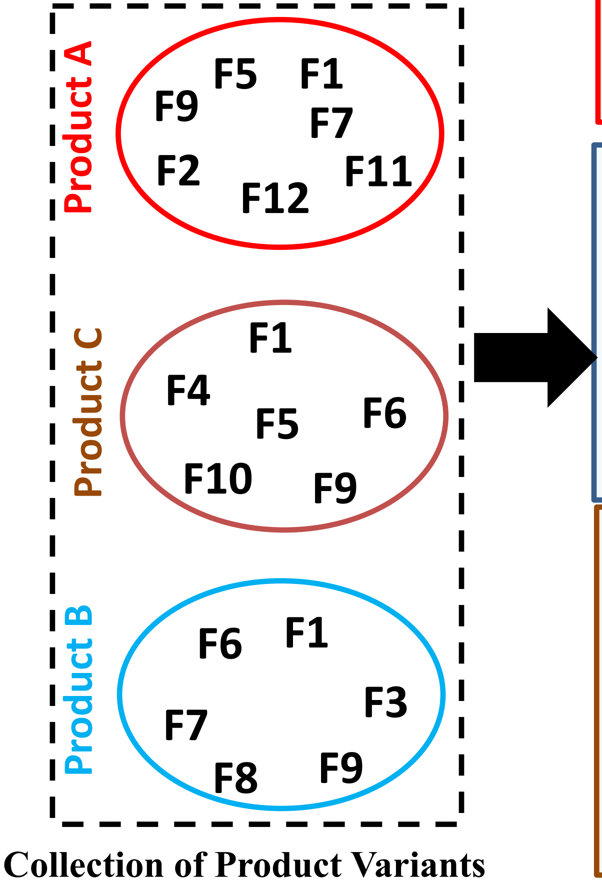
- ❑ Using a threshold mechanism for selection code documents



Conventional Application of IR for Feature Location in a Collection Product Variants

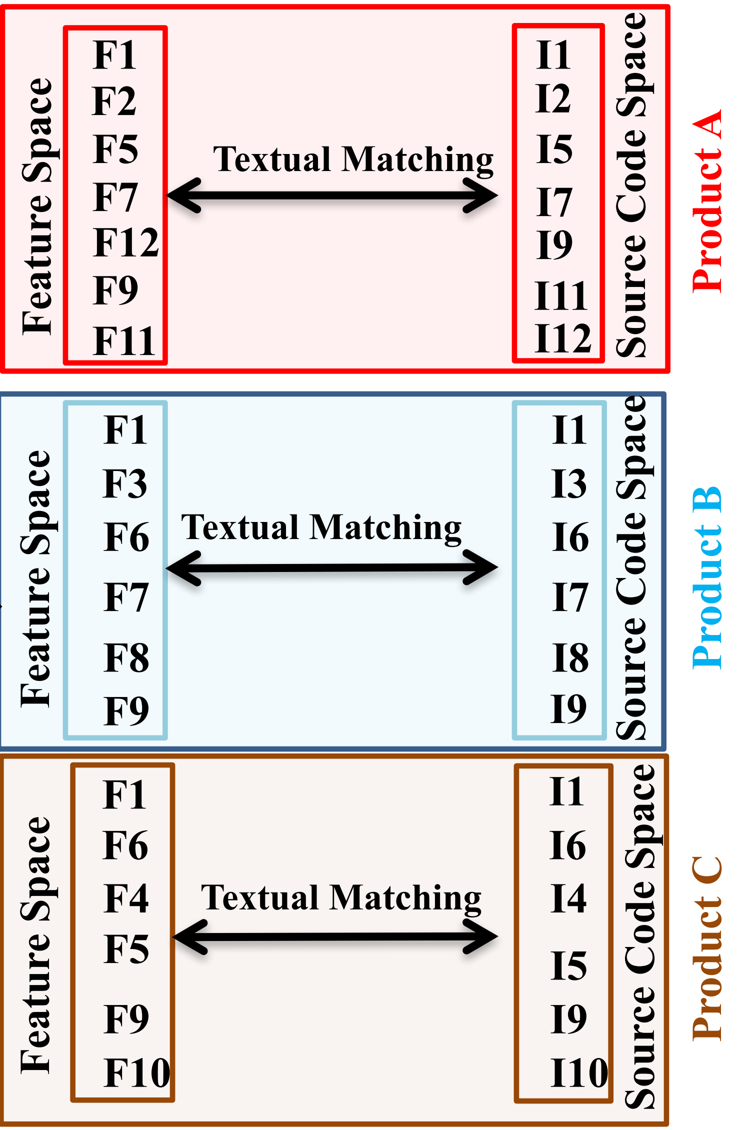
- *[Peng et al., 2013]*
- *[Ali et al., 2011]*
- *[Poshyvanyk et Marcus, 2007]*
- *[Lucia et al., 2008]*
- *[Marcus et al., 2004]*
- *[Antoniol et al., 2002]*

Legend:
I: Implementation
F: Feature



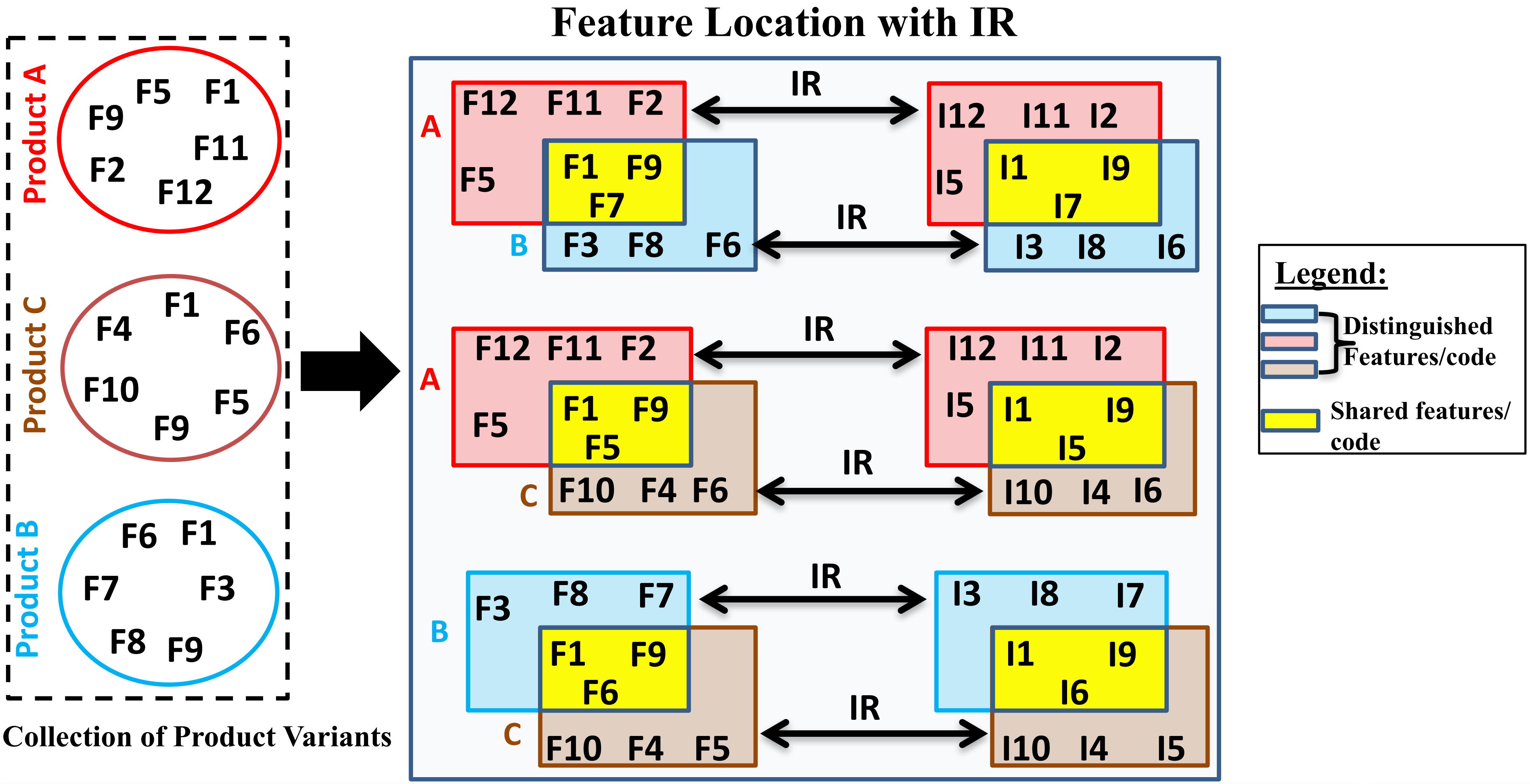
Collection of Product Variants

Feature Location with IR



Variability Analysis for Reducing IR Search Spaces

- ❑ **Exploiting only variability and ignore commonality across product variants pair-wisely** *[Rubin and chechik 2012]*



The Proposed Approach

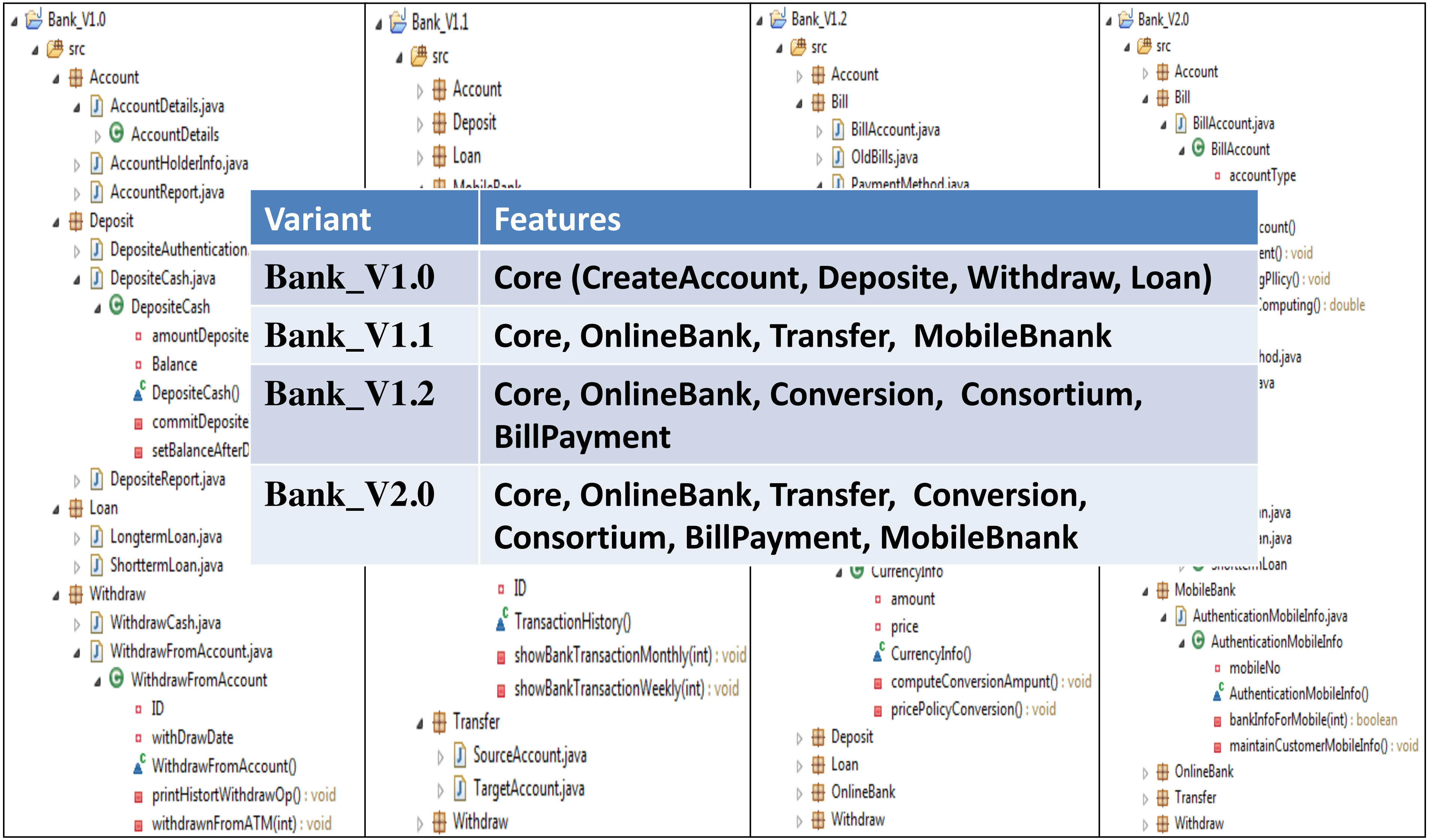
❑ Two strategies to improve the effectiveness of IR-based feature location

1. Reduction the IR search spaces into minimal disjoint sets

2. Reduction the abstraction gap between feature and source code

Illustrative Example

❑ **Four product variants of a software bank system**



```
Bank_V1.0
  src
    Account
      AccountDetails.java
        AccountDetails
      AccountHolderInfo.java
      AccountReport.java
    Deposit
      DepositeAuthentication
      DepositeCash.java
        DepositeCash
          amountDeposite
          Balance
          DepositeCash()
          commitDeposite
          setBalanceAfterD
      DepositeReport.java
    Loan
      LongtermLoan.java
      ShorttermLoan.java
    Withdraw
      WithdrawCash.java
      WithdrawFromAccount.java
        WithdrawFromAccount
          ID
          withDrawDate
          WithdrawFromAccount()
          printHistortWithdrawOp() : void
          withdrawnFromATM(int) : void
```

```
Bank_V1.1
  src
    Account
    Deposit
    Loan
    MobileBank
          ID
          TransactionHistory()
          showBankTransactionMonthly(int) : void
          showBankTransactionWeekly(int) : void
    Transfer
      SourceAccount.java
      TargetAccount.java
    Withdraw
```

```
Bank_V1.2
  src
    Account
    Bill
      BillAccount.java
      OldBills.java
      PaymentMethod.java
        CurrencyInfo
          amount
          price
          CurrencyInfo()
          computeConversionAmpunt() : void
          pricePolicyConversion() : void
    Deposit
    Loan
    OnlineBank
    Withdraw
```

```
Bank_V2.0
  src
    Account
    Bill
      BillAccount.java
        BillAccount
          accountType
          count()
          ent() : void
          gPllicy() : void
          omputing() : double
      hod.java
      ava
      n.java
      n.java
        ShorttermLoan
    MobileBank
      AuthenticationMobileInfo.java
        AuthenticationMobileInfo
          mobileNo
          AuthenticationMobileInfo()
          bankInfoForMobile(int) : boolean
          maintainCustomerMobileInfo() : void
    OnlineBank
    Transfer
    Withdraw
```

Variant	Features
Bank_V1.0	**Core (CreateAccount, Deposite, Withdraw, Loan)**
Bank_V1.1	**Core, OnlineBank, Transfer, MobileBnank**
Bank_V1.2	**Core, OnlineBank, Conversion, Consortium, BillPayment**
Bank_V2.0	**Core, OnlineBank, Transfer, Conversion, Consortium, BillPayment, MobileBnank**

Strategy 1: Reducing IR Spaces [1/2]

1. **Determining common and variable partitions at the feature and source code levels**

   – Textual similarity computing

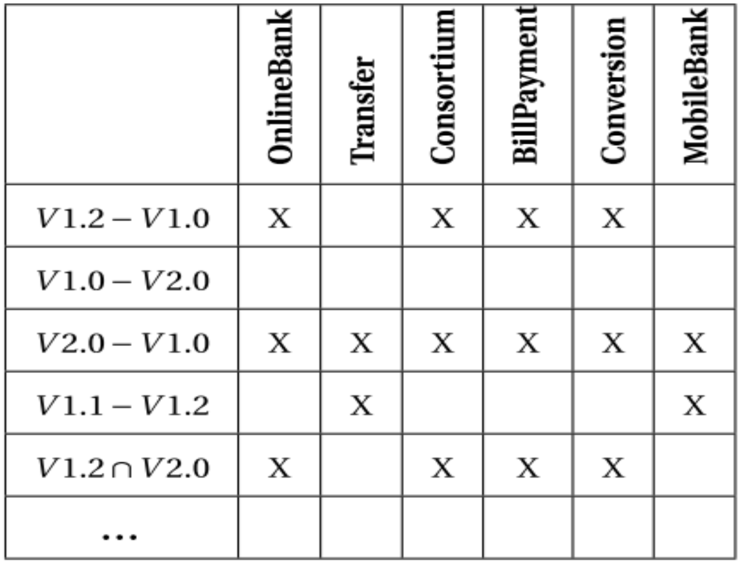
Variant	Features
Bank_V1.0	Core (CreateAccount, Deposite, Withdraw, Loan)
Bank_V1.1	Core, OnlineBank, Transfer, MobileBnank
Bank_V1.2	Core, OnlineBank, Conversion, Consortium, BillPayment
Bank_V2.0	Core, OnlineBank, Transfer, Conversion, Consortium, BillPayment, MobileBnank

Common Partition → Core (CreateAccount, Deposit, Withdraw, Loan)

Variable Partition → OnlineBank, Transfer, MobileBank, Conversation, Consortium, BillPayment

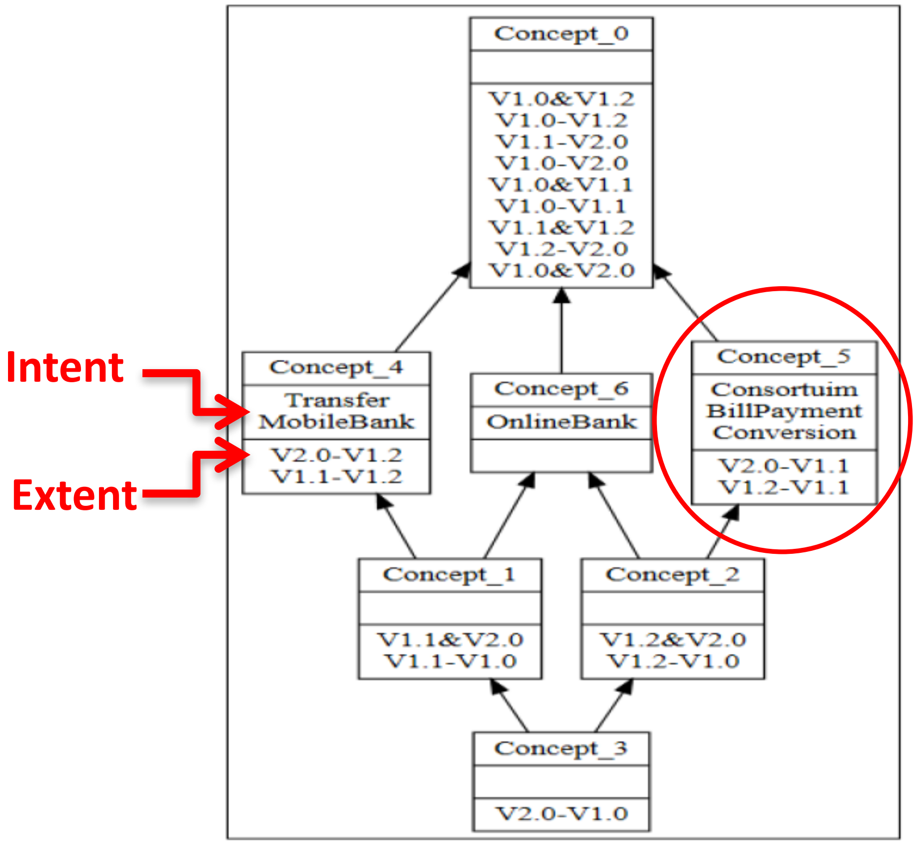
Strategy 1: Reducing IR Spaces [2/2]

2. **Fragmentation of the variable partition at feature and source code levels into minimal disjoint sets**



	OnlineBank	Transfer	Consortium	BillPayment	Conversion	MobileBank
$V1.2 - V1.0$	X		X	X	X	
$V1.0 - V2.0$						
$V2.0 - V1.0$	X	X	X	X	X	X
$V1.1 - V1.2$		X				X
$V1.2 \cap V2.0$	X		X	X	X	
...						

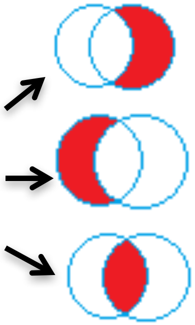
Formal Context



Concept Lattice

Variants-differences

- Bank_V1.2 – Bank_V2.0
- Bank_V2.0 – Bank_V1.2
- Bank_V2.0 ∩ Bank_V1.2



Strategy 2: Reducing Abstraction Gap between Feature and Source Code Levels [1/2]

❑ **What is a code-topic?**

- **It is a cluster of similar classes that have common terms and they also depend on each other.**

❑ **Why code-topic is introduced?**

- **Mainly to get more textual information descripting features implemented by code-topic classes**

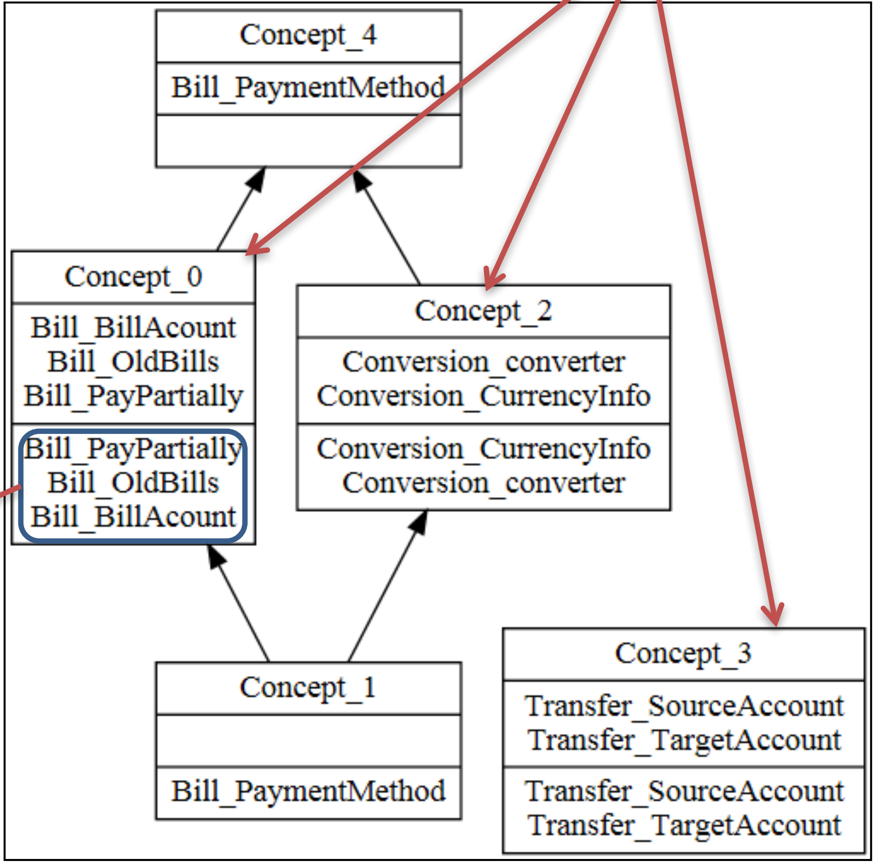
Strategy 2: Reducing Abstraction Gap between Feature and Source Code Levels [2/2]

- **An example for identifying code-topic using FCA**

	Bill_BillAcount	Conversion_converter	Bill_OldBills	Transfer_TargetAccount	Bill_PayPartially	Conversion_CurrencyInfo	Bill_PaymentMethod	Transfer_SourceAccount	…
Bill_BillAcount	X		X		X		X		
Conversion_converter		X				X	X		
Bill_OldBills	X		X		X		X		
Transfer_TargetAccount				X				X	
Bill_PayPartially	X		X		X		X		
Conversion_CurrencyInfo		X				X	X		
Bill_PaymentMethod	X	X	X		X	X	X		
Transfer_SourceAccount				X				X	
…									

Formal Context

Square Concepts

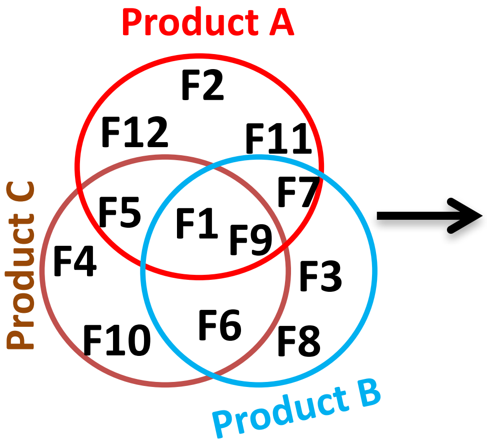


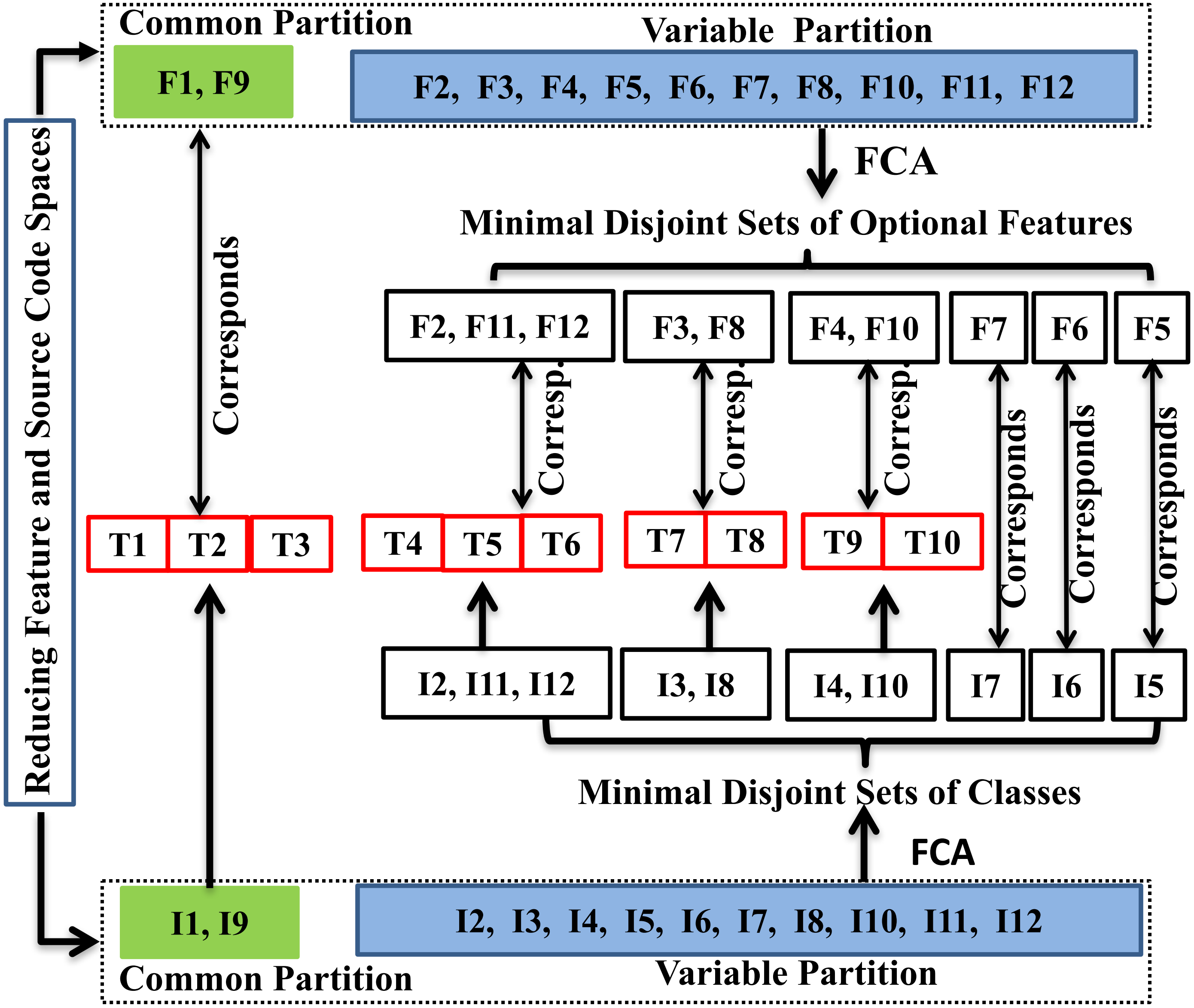
Candidate Code-Topic

Concept Lattice

Graphical Representation of Proposed Strategies

Legend:
I: Implementation Element
F: Feature
T: Code-Topic





Reducing Feature and Source Code Spaces

Common Partition: F1, F9

Variable Partition: F2, F3, F4, F5, F6, F7, F8, F10, F11, F12

FCA

Minimal Disjoint Sets of Optional Features: F2, F11, F12 | F3, F8 | F4, F10 | F7 | F6 | F5

Corresponds

T1 | T2 | T3

T4 | T5 | T6

T7 | T8

T9 | T10

Corresp.

Corresponds

I2, I11, I12 | I3, I8 | I4, I10 | I7 | I6 | I5

Minimal Disjoint Sets of Classes

FCA

Common Partition: I1, I9

Variable Partition: I2, I3, I4, I5, I6, I7, I8, I10, I11, I12

Locating Features by LSI

1. **Linking each feature to their corresponding code-topics using LSI**

   - **For each code-topic there is a document**
   - **For each a feature there is a document**

2. **Decomposing each code-topic to its classes**

Case Studies

❑ Case studies used

- Seven product variants of ***ArgoUML-SPL***
  - » Large-scale system
  - » Well-known case study in our context.
- Five product variants of ***MobileMedia***
  - » Small-scale system

Evaluation Measures

❑ The effectiveness of IR is commonly measured by:

- **Precision:** the percentage of retrieved traceability links that are relevant to the total number of retrieved links

- **Recall:** the percentage of retrieved traceability links that are relevant to the total number of relevant links

- **F-measure:** to find the best possible compromise between recall and precision

Experimental Results

- Comparing our approach (**FCT**) and conventional application of IR (**Conv**)

ArgoUML-SPL						
	Precision		Recall		F-measure	
K	FCT	Conv	FCT	Conv	FCT	Conv
0.01	51%	21%	99%	91%	68%	34%
0.02	52%	22%	86%	82%	65%	35%
0.03	52%	29%	85%	59%	65%	39%
0.04	52%	42%	87%	39%	65%	40%
0.05	63%	56%	73%	25%	63%	36%

Experimental Results [Cont.]

- Comparing our approach (**FCT**) and the most relevant work on the subject (**FL-PV**) *[Xue et al. 2012]*

ArgoUML-SPL						
	Precision		Recall		F-measure	
K	FCT	FL-PV	FCT	FL-PV	FCT	FL-PV
0.1	70%	34%	40%	29%	51%	31%
0.2	57%	07%	09%	04%	16%	05%
0.3	57%	02%	05%	01%	09%	02%
0.4	62%	01%	04%	00%	08%	01%
0.5	57%	00%	02%	00%	03%	00%

Outline

Feature-Level Change Impact Analysis

Step1: Determining the Impact Set of Classes

❑ Statically analyzing the source code of features

- Using abstract syntax tree (AST)

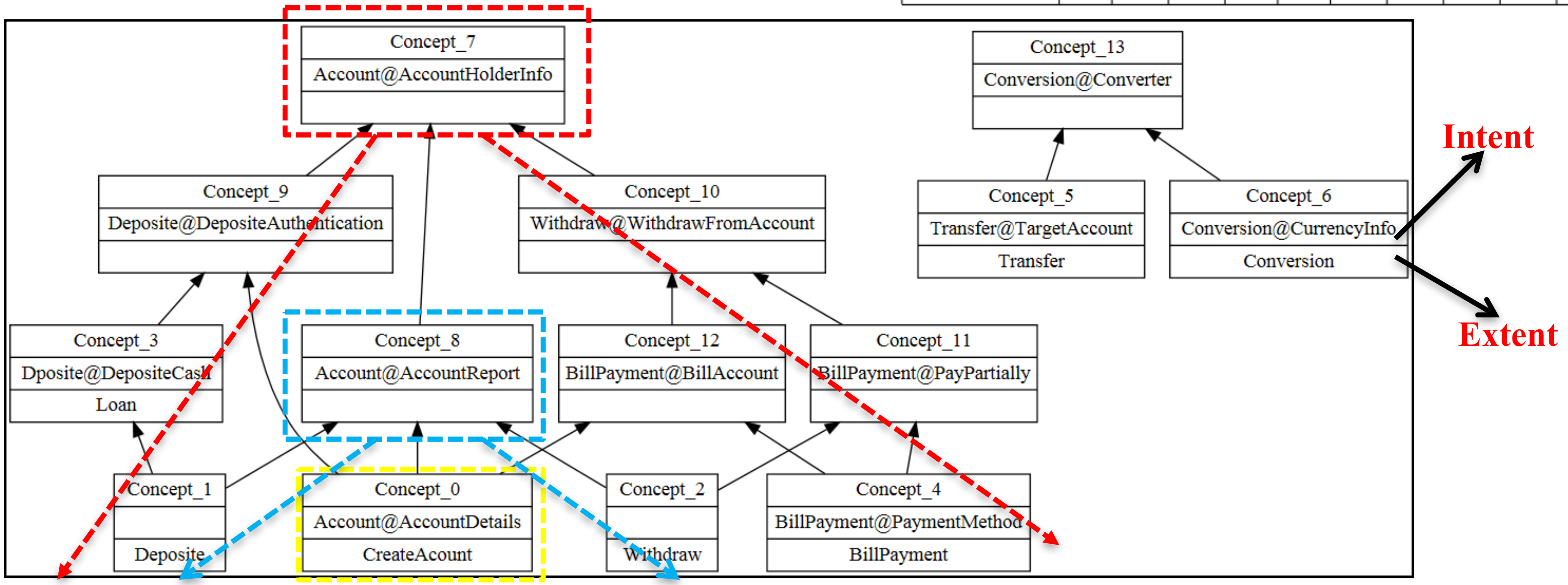
❑ Determining coupled classes based on

1. Inheritance relationship
2. Method call
3. Attribute access
4. Shared attribute access

Step2: Determining Coupled Features Using FCA

- **An example of determining coupled features using FCA**

	Account@AccountHolderInfo	Account@AccountReport	Deposite@DepositeAuthentication	Account@AccountDetails	Withdraw@WithdrawFromAccount	Dposite@DepositeCash	BillPayment@PayPartially	BillPayment@PaymentMethod	BillPayment@BillAccount	Conversion@Converter	Transfer@TargetAccount	Conversion@CurrencyInfo
CreateAcount	X	X	X	X	X				X			
Deposite	X	X	X			X						
Withdraw	X	X			X		X					
Loan	X		X			X						
BillPayment	X				X		X	X	X			
Transfer										X	X	
Conversion										X		X



Concept_7
Account@AccountHolderInfo

Concept_13
Conversion@Converter

Concept_9
Deposite@DepositeAuthentication

Concept_10
Withdraw@WithdrawFromAccount

Concept_5
Transfer@TargetAccount
Transfer

Concept_6
Conversion@CurrencyInfo
Conversion

Concept_3
Dposite@DepositeCash
Loan

Concept_8
Account@AccountReport

Concept_12
BillPayment@BillAccount

Concept_11
BillPayment@PayPartially

Concept_1
Deposite

Concept_0
Account@AccountDetails
CreateAcount

Concept_2
Withdraw

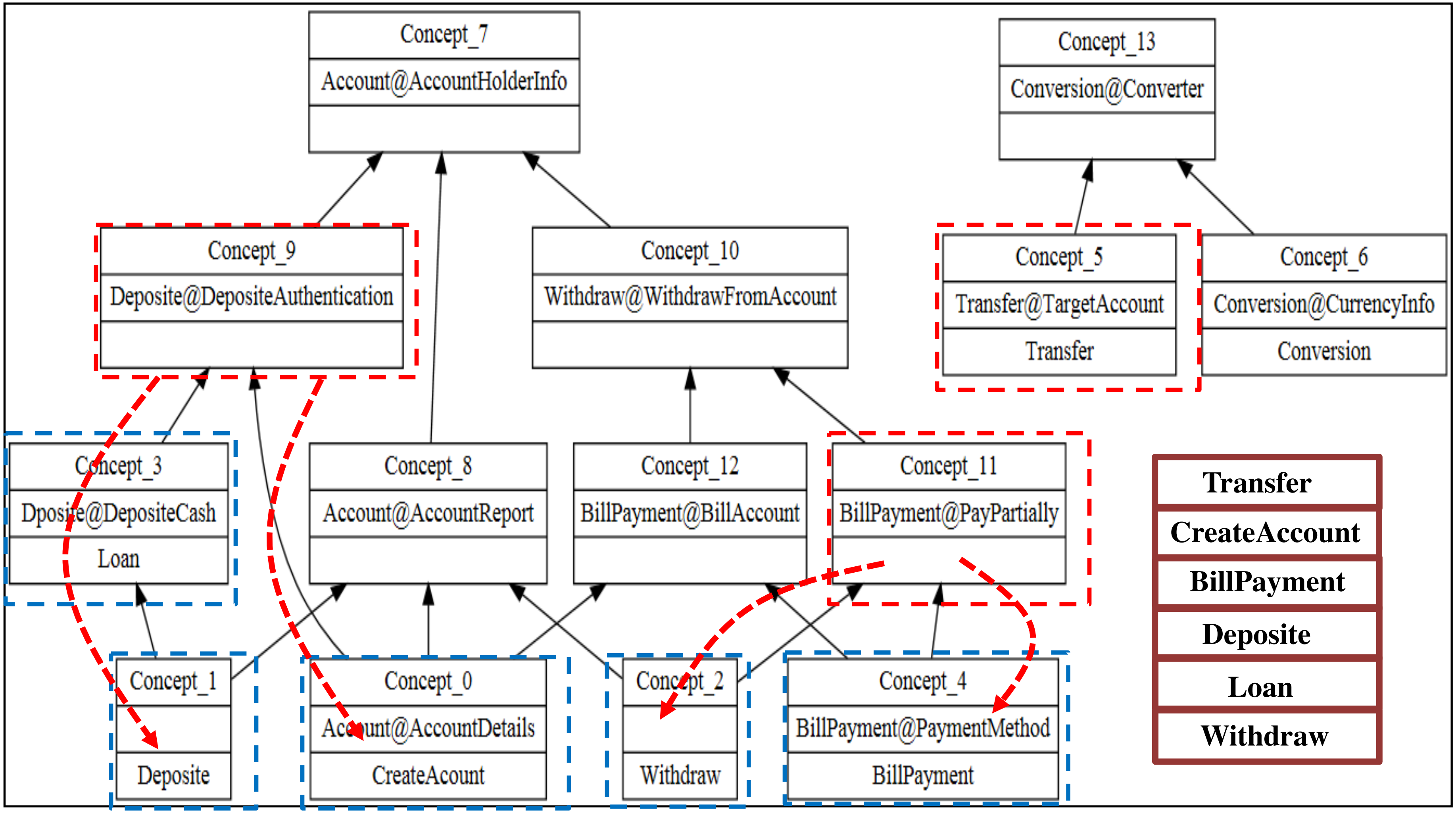
Concept_4
BillPayment@PaymentMethod
BillPayment

Intent

Extent

Step3: Querying concept lattice for determining a ranked list of affected features using impact set of classes

- Consider the impact set of classes consists of {***DeositeAuthentication, TargetAccount, PayPartially***}



Transfer
CreateAccount
BillPayment
Deposite
Loan
Withdraw

Ranking the Affected Features using Impact Degree Metric (IDM)

- We propose two metrics to support feature-level CIA:

1. **Impact Degree Metric (IDM)**
   - To measure the degree to which the implementation of a given feature can be affected.
2. **Changeability Assessment Metric (CAM)**
   - To measure the percentage of features that are affected by a given change.

Concept	Features	IDM	Rank	CAM
Concept_5	Transfer	50%	1	85%
Concept_2	Withdraw	50%	1	
Concept_4	BillPayment	40%	2	
Concept_0	CreateAccount	33%	3	
Concept_3	Loan	33%	3	
Concept_1	Deposite	25%	4	

Experimental Evaluation

❑ Case studies

Case Studies	# Features	# Classes
ArgoUML-SPL	**8**	**515**
MobileMedia	**5**	**28**
BerkeleyDB-SPL	**25**	**227**

Subject core assets and their respective information

– Evaluation measures

1. **Precision:** is the percentage of the estimated affected features that are actually impacted to all estimated affected features

2. **Recall:** is the percentage of the estimated affected features that are really impacted to all actually affected features

3. **F-measure:** to find the best possible compromise between recall and precision

Experimental Evaluation [Cont.]

- » **Precision: [60% - 100%]**
- » **Recall: [75% - 100%]**
- » **F-measure: [67% - 100%]**

- CSC : change set of classes

- EIS : Estimated impacted set of features

CSC	|CSC|	|EIS|	Precision	Recall	F-measure	CAM
MobileMedia						
CSC1	5	5	60%	75%	67%	100%
CSC2	5	6	83%	100%	90%	83%
CSC1	8	6	67%	100%	80%	100%
AgroUML-SPL						
CSC1	9	5	80%	100%	88%	62%
CSC2	8	4	75%	100%	86%	50%
CSC1	18	5	80%	100%	88%	62%
BerkeleyDB-SPL						
CSC1	6	25	92%	100%	96%	92%
CSC2	5	25	100%	100%	100%	100%