UCL

Conceptual Code Mining

(work in progress)

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Software evolution and aspect-oriented programming

- Three important research goals

1. automatically identify crosscutting concerns
   - based on pattern matching, clone detection, logic reasoning, formal concept analysis, ...
2. refactor/restructure object-oriented programs into aspect-oriented ones
3. deal with evolution of aspect-oriented programs
   - aspect refactoring
   - co-evolution of base program and aspects

Overview

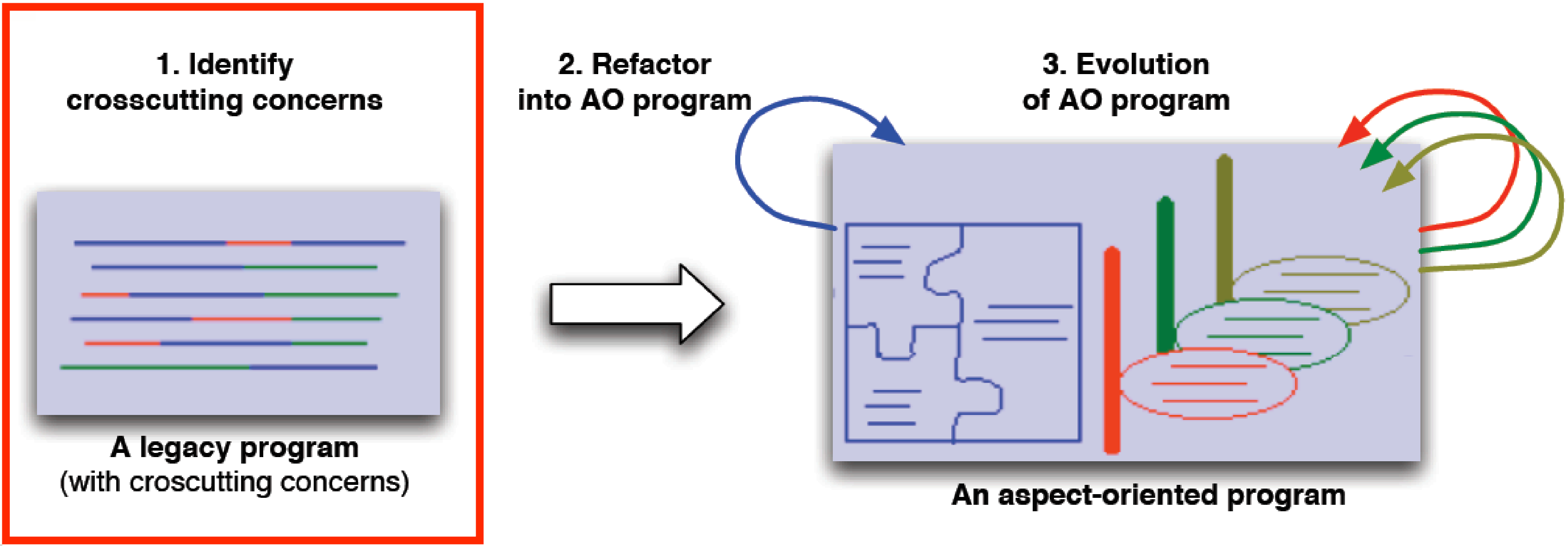
- Relation to "Software evolution and AOP"
- A crash course in formal concept analysis
- Mining for croscutting concerns with FCA
- Overall approach
- The substring experiment in detail
- The parsetree experiment
- Conclusion

Research idea :

Mining for croscutting concerns

using *Formal Concept Analysis*

Software Evolution and Aspect-Oriented Programming



1. Identify crosscutting concerns

A legacy program
(with croscutting concerns)

2. Refactor into AO program

3. Evolution of AO program

An aspect-oriented program

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Formal Concept Analysis (*FCA*)

- Starts from
  - a set of elements
  - a set of properties of those elements
- Determines concepts
  - Maximal groups of elements and properties
  - Group:
    - Every element of the concept has those properties
    - Every property of the concept holds for those elements
  - Maximal
    - No other element (outside the concept) has those same properties
    - No other property (outside the concept) is shared by all elements

Example : Elements and Properties

	object-oriented	functional	logic	static typing	dynamic typing
C++	X	-	-	X	-
Java	X	-	-	X	-
Smalltalk	X	-	-	-	X
Scheme	-	X	-	-	X
Prolog	-	-	X	-	X

Example : Concepts

	object-oriented	functional	logic	static typing	dynamic typing
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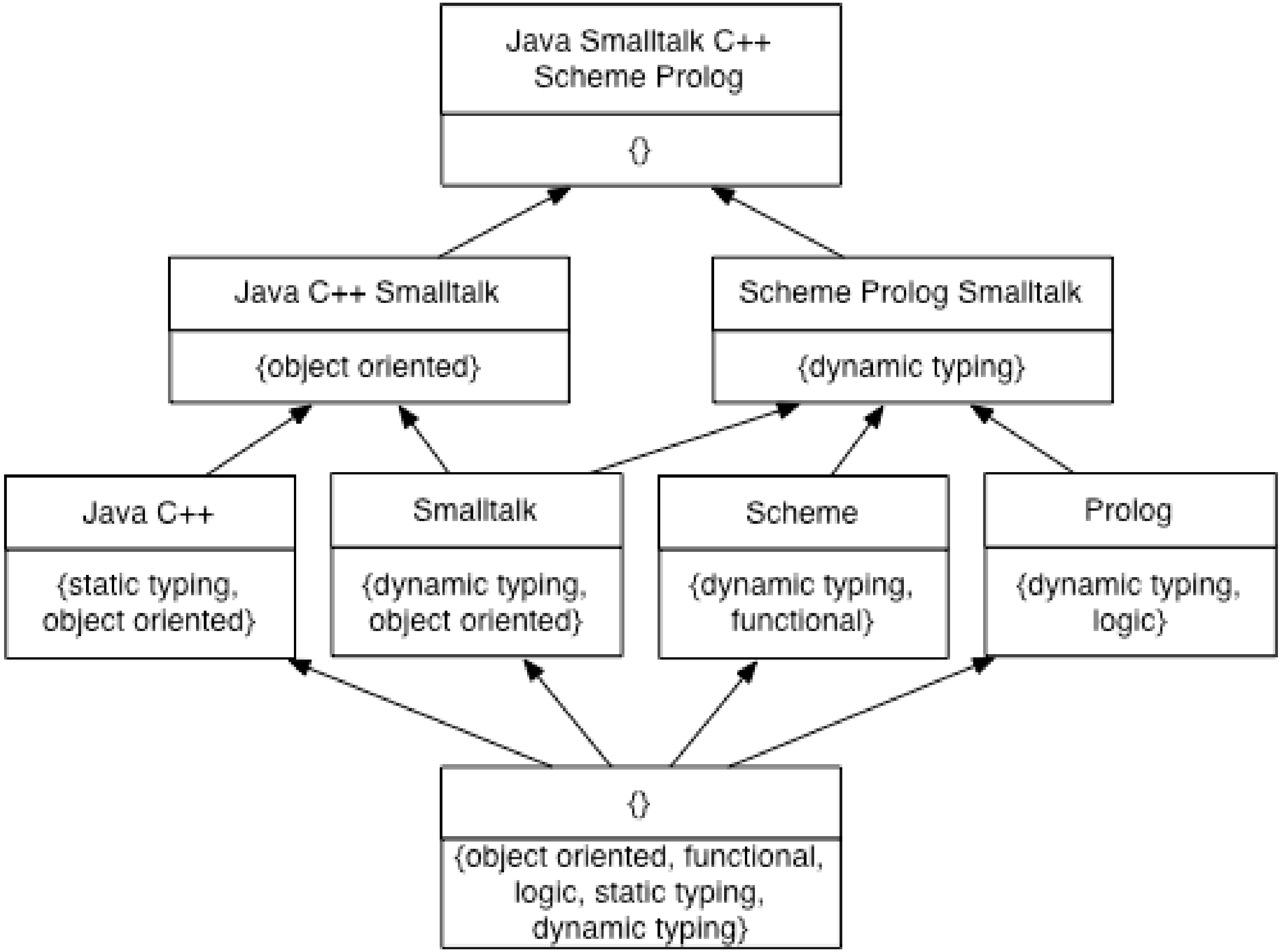
Concept Lattice



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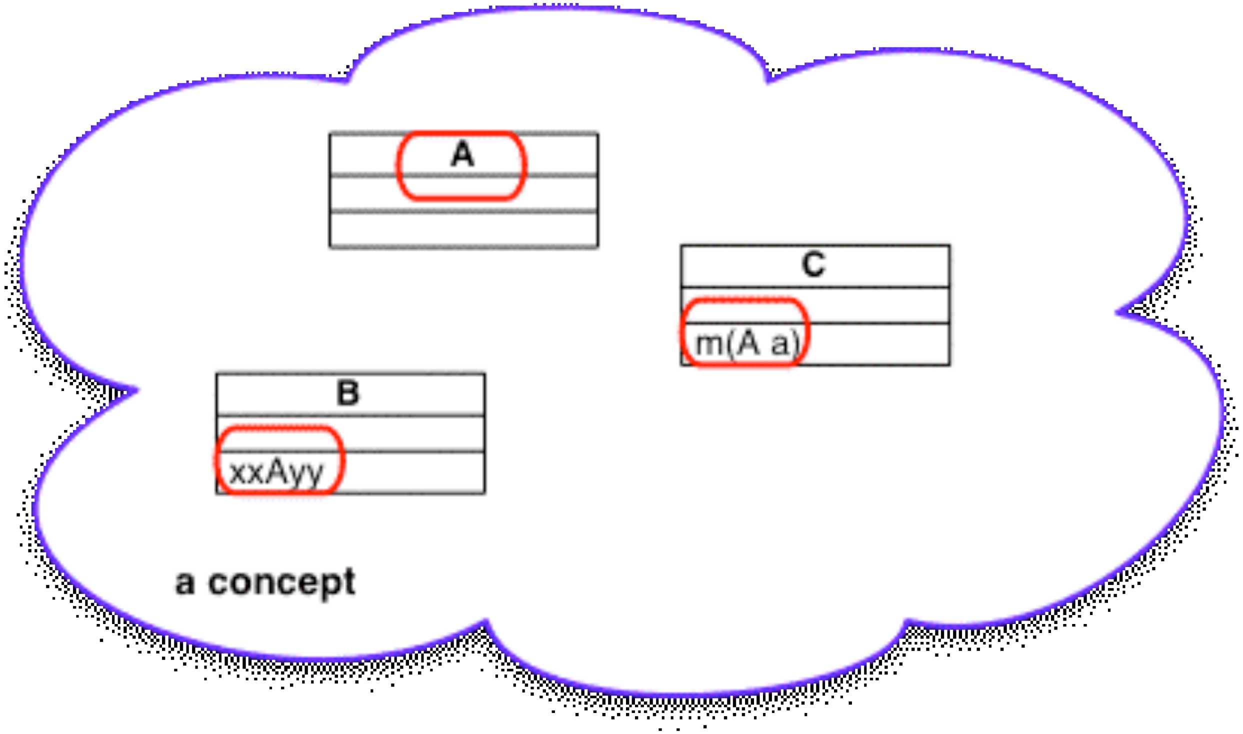
Mining for crosscutting concerns with formal concept analysis

- First Step
  - Use substrings of class, method & parameter names to group related source code elements
  - Relies on coding conventions
  - Assumes that elements corresponding to a same concern will have a *similar name*
- Next step
  - Use generic parse trees to group source code that implements similar behaviour
  - Looks for recurring patterns in the source code
  - Similar to clone detection, but more advanced
  - Assumes that elements corresponding to a same concern will have *similar code*

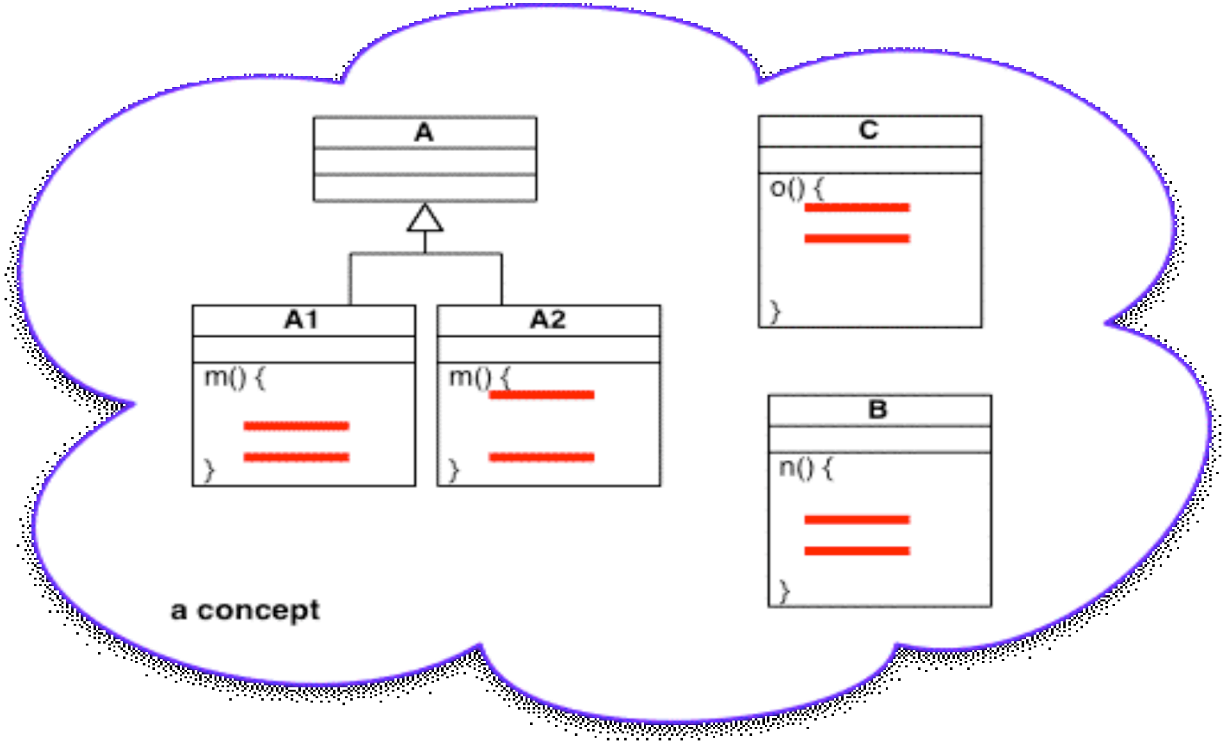
Substring Concepts

- Elements : classes, methods, parameters
- Properties : substrings of classes, methods, …



Parse tree Concepts

- Elements : methods
- Properties : generic parse tree elements



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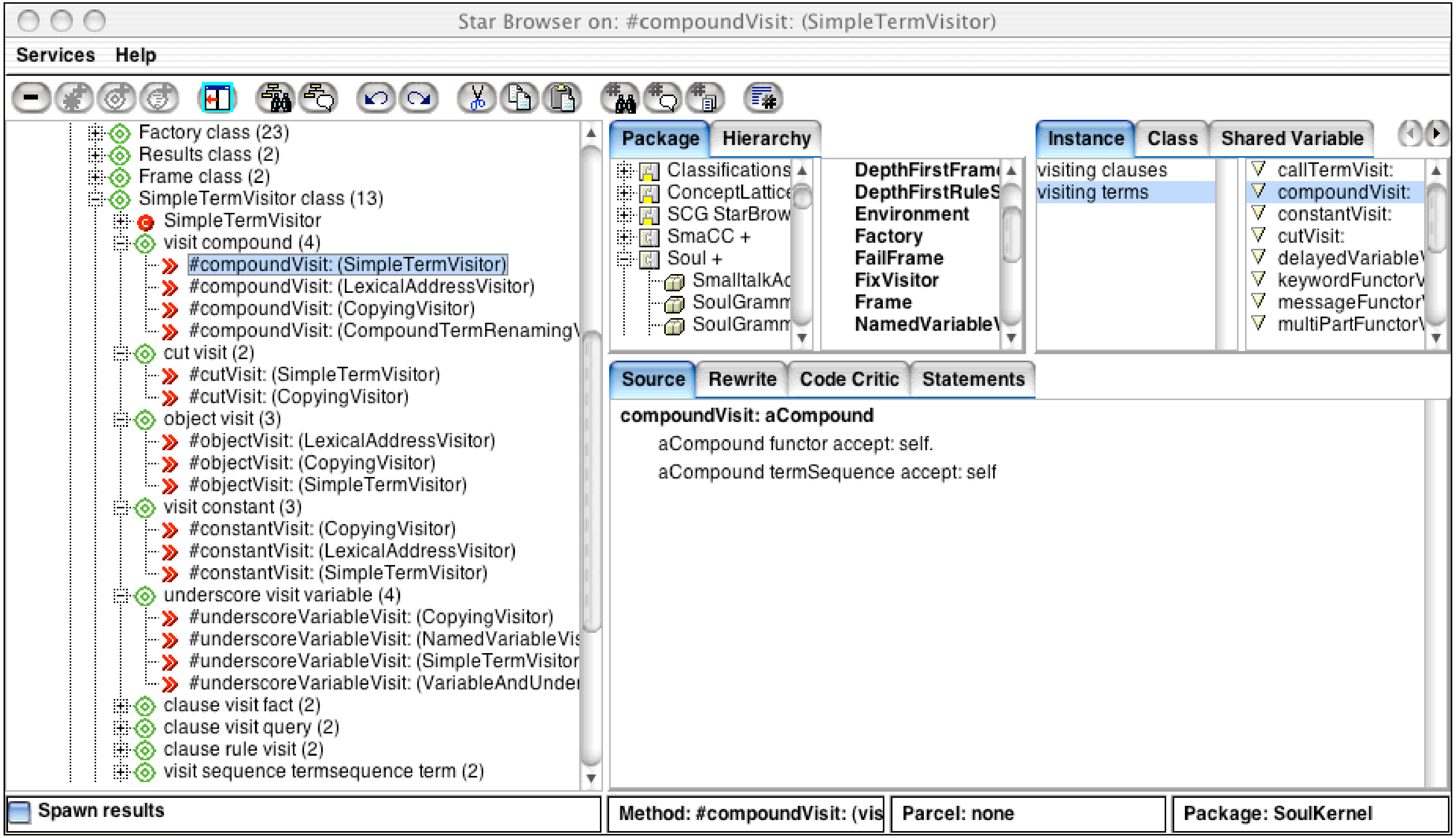
Overall approach

1. Generate elements & properties for FCA algorithm
   - ✓ Pre-filter irrelevant ones
2. Concept Analysis
   - ✓ Find relevant groupings of elements in source code
3. Filtering
   - ✓ Remove irrelevant concepts (false positives, noise, useless, …)
4. Classification
   - ✓ Classify results according to relevance for user
5. Analyse unclassified concepts
   - ✓ Manually analyse concepts that were not classified automatically
6. Completion of concepts
   - ✓ Some concepts are relevant
     but need to be completed to represent reality correctly

Our Conceptual Code Mining Tool



Star Browser on: #compoundVisit: (SimpleTermVisitor)

- Factory class (23)
- Results class (2)
- Frame class (2)
- SimpleTermVisitor class (13)
  - SimpleTermVisitor
  - visit compound (4)
    - #compoundVisit: (SimpleTermVisitor)
    - #compoundVisit: (LexicalAddressVisitor)
    - #compoundVisit: (CopyingVisitor)
    - #compoundVisit: (CompoundTermRenaming\
  - cut visit (2)
    - #cutVisit: (SimpleTermVisitor)
    - #cutVisit: (CopyingVisitor)
  - object visit (3)
    - #objectVisit: (LexicalAddressVisitor)
    - #objectVisit: (CopyingVisitor)
    - #objectVisit: (SimpleTermVisitor)
  - visit constant (3)
    - #constantVisit: (CopyingVisitor)
    - #constantVisit: (LexicalAddressVisitor)
    - #constantVisit: (SimpleTermVisitor)
  - underscore visit variable (4)
    - #underscoreVariableVisit: (CopyingVisitor)
    - #underscoreVariableVisit: (NamedVariableVis
    - #underscoreVariableVisit: (SimpleTermVisitor
    - #underscoreVariableVisit: (VariableAndUnder
  - clause visit fact (2)
  - clause visit query (2)
  - clause rule visit (2)
  - visit sequence termsequence term (2)

- Classifications
- ConceptLattice
- SCG StarBrow
- SmaCC +
- Soul +
  - SmalltalkAc
  - SoulGramm
  - SoulGramm

DepthFirstFram
DepthFirstRuleS
Environment
Factory
FailFrame
FixVisitor
Frame
NamedVariable\

visiting clauses
visiting terms

callTermVisit:
compoundVisit:
constantVisit:
cutVisit:
delayedVariable\
keywordFunctor\
messageFunctor\
multiPartFunctor\

```
compoundVisit: aCompound
    aCompound functor accept: self.
    aCompound termSequence accept: self
```

☐ Spawn results

Method: #compoundVisit: (vis

Parcel: none

Package: SoulKernel

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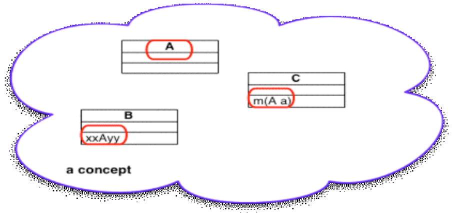
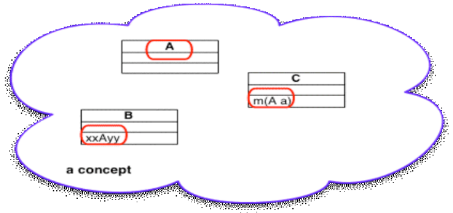
The substring experiment



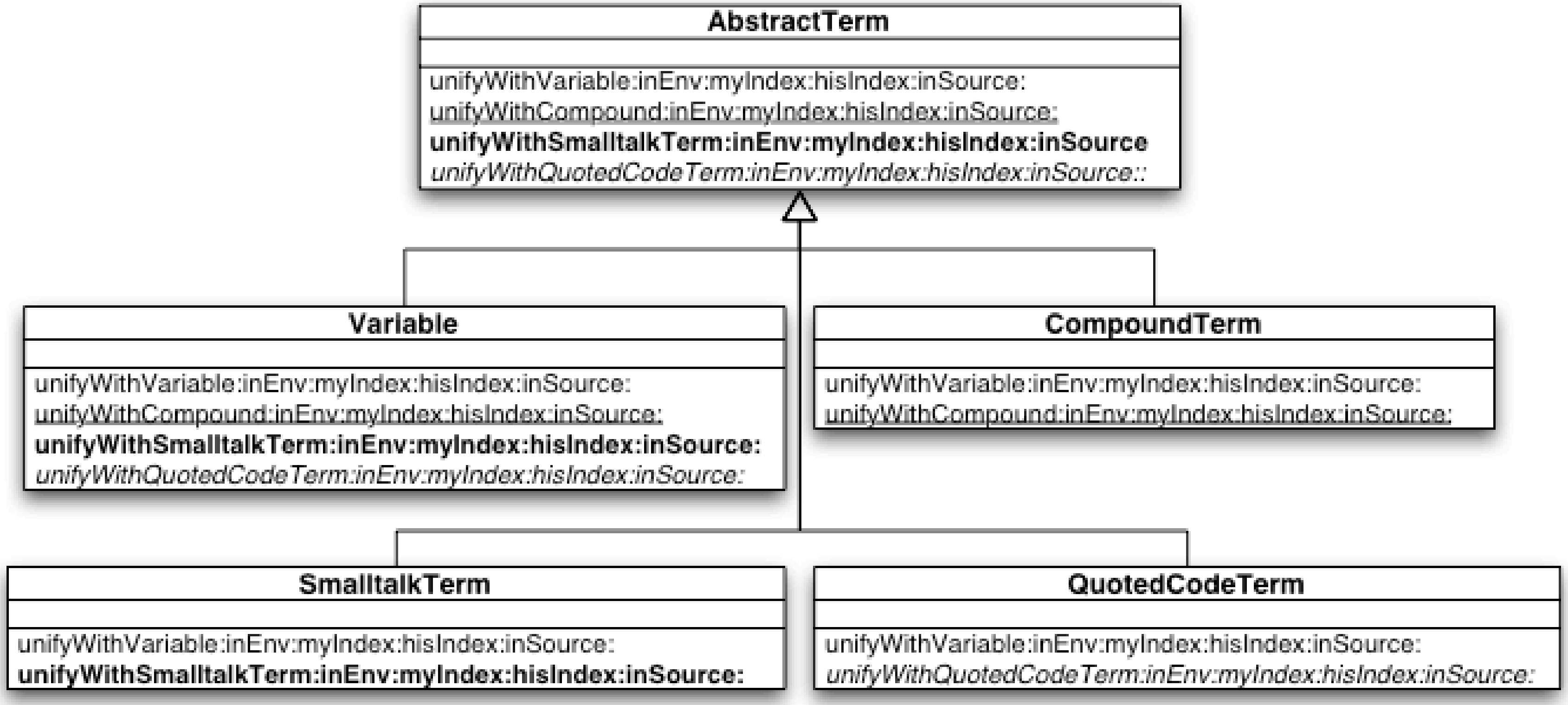
1. Generate elements & properties

- We want to group elements that share a substring
- Problem :
  - "Having a substring in common" is *binary*
  - FCA properties are *unary*
    - Does an element satisfy the property or not?
- Solution :
  - Every substring corresponds to an FCA property
    - Does an element have this substring in its name?
  - Generate relevant substrings
    - Based on where uppercases occur in an element's name
      - QuotedCodeConstant → { quoted, code, constant }
    - Filter substrings that produce too much noise

The substring experiment



2. Concept Analysis - a concept (1)



AbstractTerm

unifyWithVariable:inEnv:myIndex:hisIndex:inSource:
unifyWithCompound:inEnv:myIndex:hisIndex:inSource:
unifyWithSmalltalkTerm:inEnv:myIndex:hisIndex:inSource
unifyWithQuotedCodeTerm:inEnv:myIndex:hisIndex:inSource::

Variable

unifyWithVariable:inEnv:myIndex:hisIndex:inSource:
unifyWithCompound:inEnv:myIndex:hisIndex:inSource:
unifyWithSmalltalkTerm:inEnv:myIndex:hisIndex:inSource:
unifyWithQuotedCodeTerm:inEnv:myIndex:hisIndex:inSource:

CompoundTerm

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SmalltalkTerm

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unifyWithSmalltalkTerm:inEnv:myIndex:hisIndex:inSource:

QuotedCodeTerm

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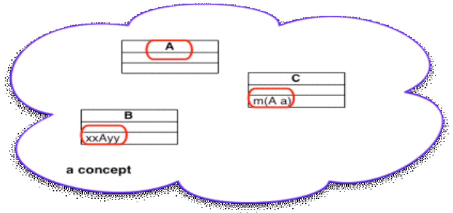
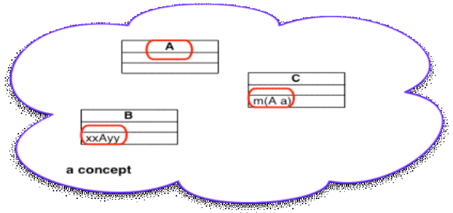
The substring experiment



2. Concept Analysis - a concept (2)

	unify	index	env	source	message	functor	variable	…
Object>>unifyWithObject: inEnv: myIndex: hisIndex: inSource:	X	X	X	X	-		-	…
Variable>>unifyWithMessageFunctor: inEnv: myIndex: hisIndex: inSource:	X	X	X	X	X	X	-	…
AbstractTerm>>unifyWith: inEnv: myIndex: hisIndex: inSource:	X	X	X	X	-	-	-	…
AbstractTerm>>unifyWithVariable: inEnv: myIndex: hisIndex: inSource:	X	X	X	X	-	X	X	…
…	X	X	X	X	…	…	…	…

The substring experiment



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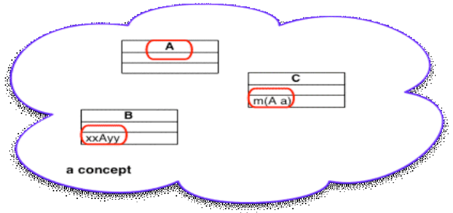
AbstractTerm>>unifyWith: inEnv: myIndex: hisIndex: inSource:	X	X	X	X	-	-	-	…
AbstractTerm>>unifyWithVariable: inEnv: myIndex: hisIndex: inSource:	X	X	X	X	-	X	X	…
…	X	X	X	X	…	…	…	…

The substring experiment

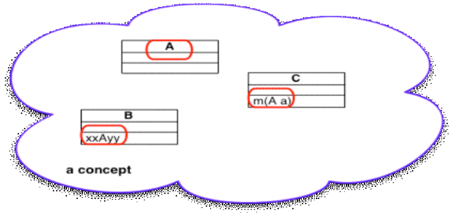


2. Concept Analysis - some numbers

Case study	#elements	#properties	#raw concepts	#combined concepts	time (sec)
Soul	1469	439	1197	593	29
StarBrowser	512	262	500	196	5
CodeCrawler	1370	478	1502	699	37
CA tool	750	238	656	347	7

- Remarks :
  - Without filtering
  - | properties | < | elements | is a good sign
  - Time to compute = a few seconds
  - Lots of noise and some false positives
    - Better filtering & classification needed

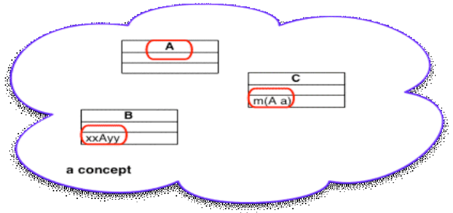
The substring experiment



3. Filtering

- Irrelevant substrings are already filtered
  - with little meaning : “do”, “with”, “for”, “from”, “the”, “ifTrue”, …
  - too small (< 3 chars)
  - ignore plurals, uppercase and colons
- More filtering needed
  - Drop top & bottom concept when empty
  - Drop concepts with only one element
  - Recombine substrings belonging together
  - Require some minimal coverage of element name by properties
  - Concepts higher in the lattice (more properties) may be more relevant
  - Avoid redundancy in discovered concepts
    - Make better use of the lattice structure (Now it is “flattened”)
- Ongoing work

The substring experiment



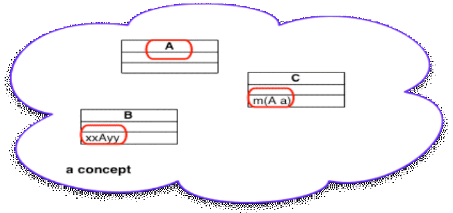
4. Classification

- In single class
  - Accessors
  - Chained messages
  - Delegating methods
  - Similar signatures
- Too few elements
- In same hierarchy
  - Polymorphic methods
  - Substring shared by method name & parameter name
  - Similar signatures
  - Similar class names

- Croscutting
  - Polymorphic methods
  - Substring shared by method name & parameter name
  - Similar signatures
  - Similar class names
- Substring shared by method name & class name
- Substring shared by class name & parameter name
- Unclassified

These seem most relevant when mining for concerns

The substring experiment



Discovered aspectual views (Soul)

- Programming idioms
  - Accessor methods (*accessors*)
  - Polymorphism (*hierarchy methods*)
- Design patterns (*hierarchy methods*)
  - Visitor, Abstract Factory, Observer
- Features
  - "Unification" (*hierarchy methods*)
  - Crosscutting class-related behaviour (*class name in keyword* & *class name in parameter*)
  - "Bindings", "Horn clauses", "resolution" (*unclassified*)
- Code duplication

  (*methods in single class* & *crosscutting methods*)

An aspectual view is a set of source code entities, such as classes, methods and parameters, that are structurally related and often crosscut the entire source code.

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Conclusion

- Current status
  - Substring experiment already performed, but needs refinement
    - Mainly more advanced filtering
  - Parse tree experiment seems promising complement / extension to already existing experiment
  - Enough to detect aspects?
- Future work
  - Work out parse tree experiment
  - Check it on a real aspect program : are the weaved aspects discovered by the approach?