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Comparative Study of Code Query Technologies

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Software Improvement Group
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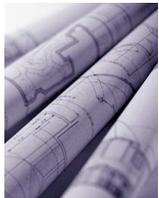
Company

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- Spin-off from CWI in 2000, self-owned, independent
- Management consultancy grounded in source code analysis
- Innovative, strong academic background, award-winning, profitable

Services

- Software Risk Assessments (snapshot) and Software Monitoring (continuous)
- Toolset enables to analyze source code in an automated manner
- Experienced staff transforms analysis data into recommendations
- We analyze over 50 systems annually
- Focus on technical quality, primarily maintainability / evolvability



DocGen

- Automated generation of technical documentation



Assessments

- In-depth investigation of software quality and risks



Monitoring

- Continuous measurement and decision support



Certification

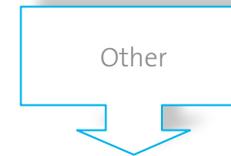
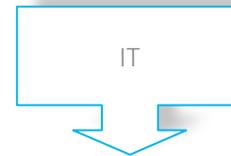
- Five levels of technical quality

Who is using our services?



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Raad voor Rechtsbijstand



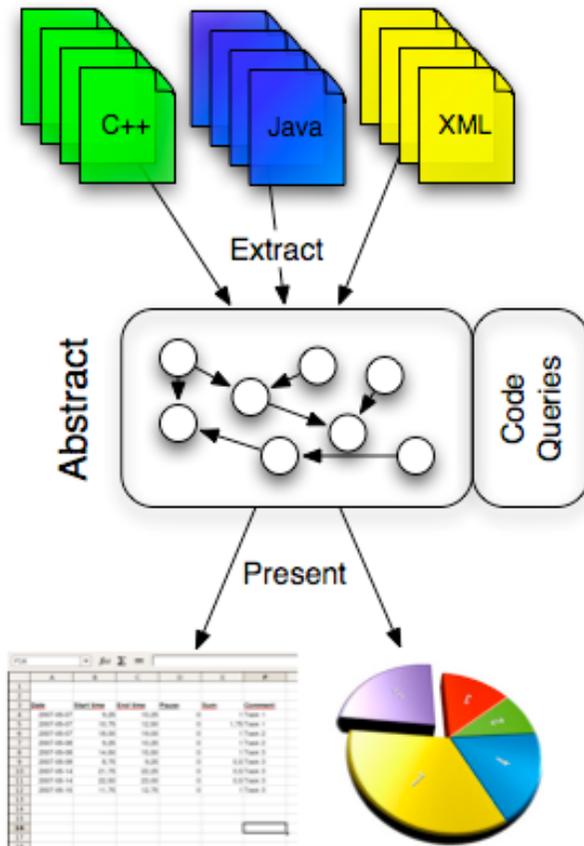
Zorg en Zekerheid



Background



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- **Extract**

- Facts and relations and represent them an intermediary structure

- **Abstract/Enrich**

- Add new facts and relations

- **Present**

- Visualize or extract information

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• Current implementation of SIG tooling

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- Extract: graph to store facts for several languages
- Abstract/enrich: implemented using Java visitors
- Present: through tables and charts

• Problems

- Implementation verbose and imperative
- Reuse among analyses difficult
- Error prone

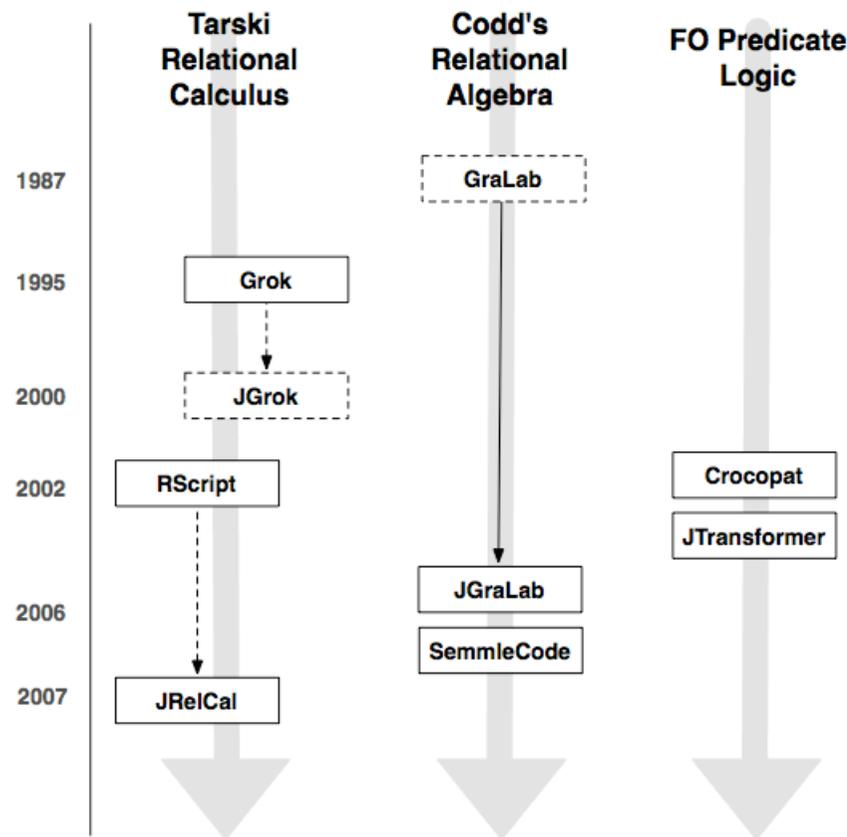
• Use of code query technologies to improve SIG developer's productivity

- Replace current imperative implementation by a more declarative one

Code Query Technologies - Timeline



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• Grok, JGrok

- Ric Holt, Canada
- Implemented in Turing

• Rscript

- Paul Klint, Netherlands
- Implemented in ASF+SDF

• JRelCal

- Tijs van der Storm, Netherlands
- Implemented in Java

• GraLab, JGraLab

- Jürgen Ebert, Germany
- Implemented in Java

• SemmleCode

- Oege de Moor, UK
- Implemented in Java

• CrocoPat

- Dirk Beyer, Germany
- Implemented in C

• JTransformer

- Günter Kiesel, Germany
- Implemented in Java

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Comparison



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- **Code query example**

- Experience the language and tool

- **Language criteria**

- Overview of the language features

- **Tool criteria**

- Overview of the tool features

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Language criteria



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- **Style/Paradigm**

- Compare implementation conciseness

- **Types**

- Support for Integers, Chars, Strings, ...

- **Parametrization**

- Behavior depends on a parameter value

- **Polymorphism**

- Abstract over the entities types

- **Modularity**

- Reuse of queries to construct other queries

- **Libraries**

- Support for libraries of queries

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• Output formats

- Text, preformatted text, tables, charts, others?

• Interactive interface

- Command line interface (CLI), Graphical user interface (GUI), Eclipse plug-in

• API support

- Invocations of the functionality from a host program

• Interchange format

- To store facts from the extraction and results of abstraction

• Extraction support

- None, Java, C/C++, XML, others?

• Licensing

- Free, Open-source, Proprietary

• Interactive use

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- The tool is used directly by the software analyst (exploratory)
- The user specifies and executes the queries, and extracts results

• Tool integration

- The tool is used by a programmer as a component to build other tools
- Reimplementation of existing functionality

Criteria vs. Scenarios



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Criteria vs. Scenarios		Interactive use	Tool integration
Language	Style/Paradigm	Important	Important
	Types	Important	Relevant
	Parametrization	Important	Relevant
	Polymorphism	Important	Relevant
	Modularity	Important	Relevant
	Libraries	Important	Relevant
Tool	Output formats	Important	Important
	Interactive use	Important	Not important
	API support	Not important	Important
	Interchange format	Important	Important
	Extraction support	Important	Relevant
	Licensing	Relevant	Important

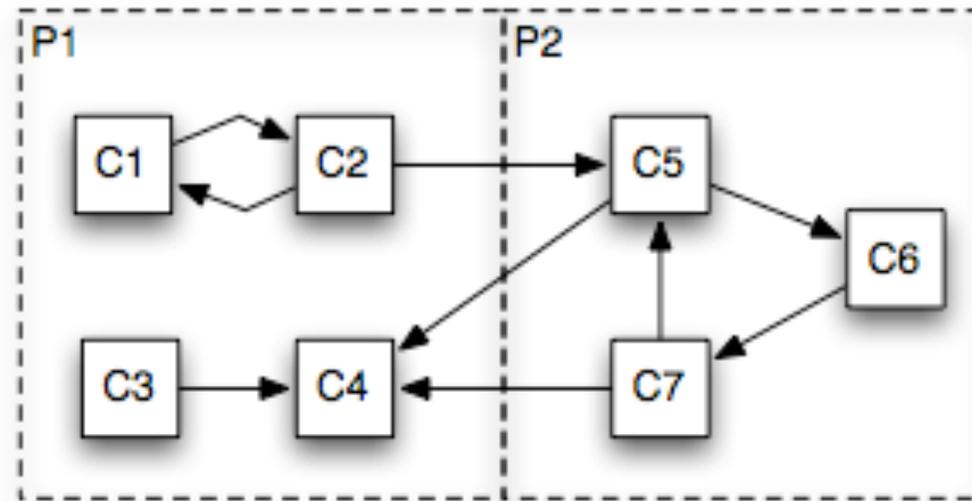
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Package instability



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Afferent Coupling

C_a = # of classes outside the package that depend upon classes within the package

$C_a = \{ (P1, C5), (P1, C7), (P2, C2) \}$

Efferent Coupling

C_e = # of classes inside the package that depend upon classes outside the package

$C_e = \{ (P1, C2), (P2, C5), (P2, C7) \}$

Package Instability $I = C_e / (C_a + C_e)$

$I = \{ (P1, 1 / (2 + 1)), (P2, 2 / (1 + 2)) \} = \{ (P1, 0.33), (P2, 0.67) \}$

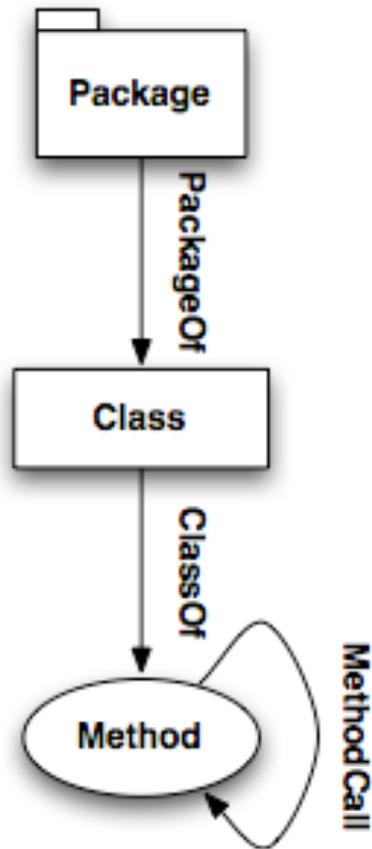
Input Relations



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Relations

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PackageOf : Package x Class

ClassOf : Class x Method

MethodCall : Method x Method

Implementation guidelines



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Defined relations

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ClassDepInterPackg : Class x Class

AffCoupling : Package x Class

EffCoupling : Package x Class

AfferentCoupling : Package x N

EfferentCoupling : Package x N

PackageInstability : Package x N

Lifting implementation example



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Input relations

PackageOf : Package x Class

ClassOf : Class x Method

MethodCall : Method x Method

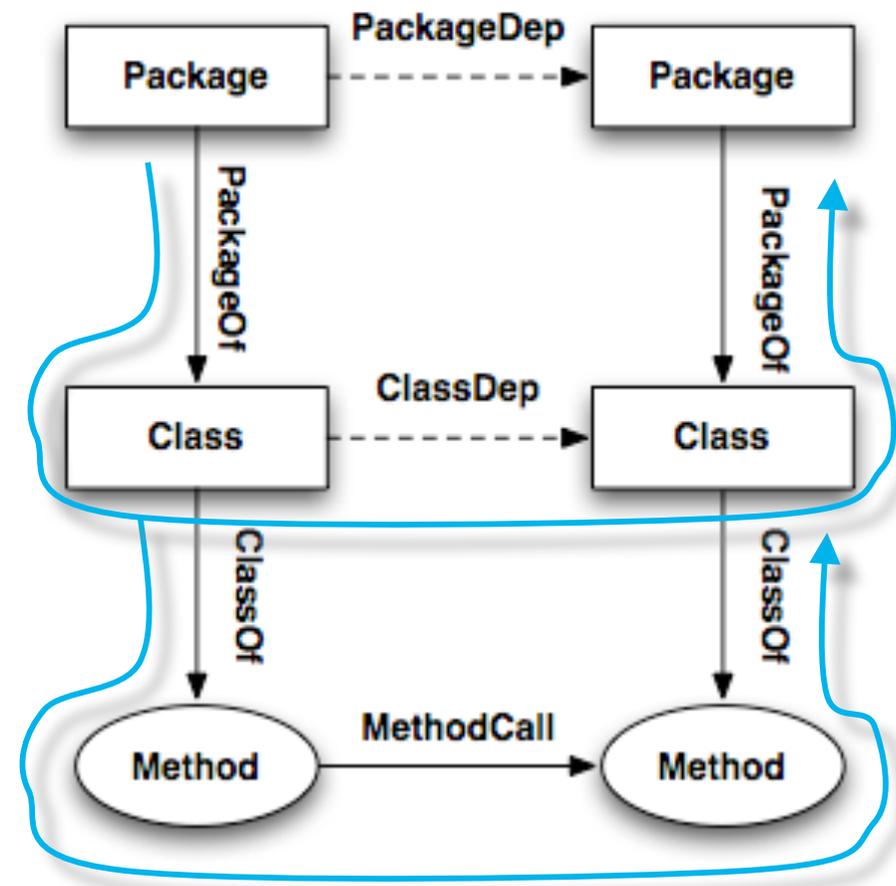
Compute lifting

ClassDep : Class x Class

= ClassOf o MethodCall o inv (ClassOf)

PackageDep : Package x Package

= PackageOf o ClassDep o inv (PackageOf)



Grok



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$\text{PackageDep} := \text{PackageOf} \circ \text{ClassDep} \circ (\text{inv } \text{PackageOf})$

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$\text{PackgDepInterPackg} := \text{PackageDep} - (\text{id } \text{dom } \text{PackageOf})$

$\text{ClassFowardRel} := (\text{inv } \text{PackageOf}) \circ \text{PackgDepInterPackg} \circ \text{PackageOf}$

$\text{ClassDepInterPackg} := \text{ClassForwardRel} \wedge \text{ClassDep}$

$\text{AffCoupling} := \text{PackageOf} \circ (\text{inv } \text{ClassDepInterPackg})$

$\text{AfferentCoupling} := (\text{dom } \text{AffCoupling}) \text{ outdegree } (\text{AffCoupling})$

Rscript



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```
rel[str,str] PackageOf
rel[str,str] ClassOf
rel[str,str] MethodCall
```

```
rel[&T1, int] outdegree(rel[&T1,&T2] R)
= { <D, #R[D]> | <&T1 D, &T2 U> : R }
```

```
rel[str,str] ClassDepInterPackg
= { <C1,C2> | <str C1, str C2> : ClassDep
    , PackageOf[- ,C1] != PackageOf[- ,C2] }
```

```
rel[str,str] AffCoupling = PackageOf o inv(ClassDepInterPackg)
```

```
rel[str,int] AfferentCoupling = outdegree(AffCoupling)
```

```
rel [str,int] PackageInstability
= { <P1,  $(100*N1)/(N1+N2)$ > | <str P1, int N1> : EfferentCoupling
    , <str P2, int N2> : AfferentCoupling, P1 == P2 }
```

JRelCal



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```
Relation<String, String> packageDep  
  = packageOf.compose(classDep.compose(packageOf.inverse()));
```

```
Relation<String, String> packgDepInterPackg  
  = packageDep.difference(packageOf.domain().id());
```

```
Relation<String,String> classForwardRel  
  = (packageOf.inverse()).compose(packgDepInterPackg).compose(packageOf);
```

```
Relation<String,String> classDepInterPackg  
  = classForwardRel.intersection(classDep);
```

```
Relation<String,String> affCoupling  
  = packageOf.compose(classDepInterPackg.inverse());
```

```
Relation<String,Int> afferentCoupling = affCoupling.outdegree();
```

```
predicate classDepInterPackg( Class c1, Class c2) {
  c1.getPackage() != c2.getPackage() and classDep(c1,c2)
}
class MyPackage extends Package {
  MyPackage() { this.fromSource() }

  predicate affCoupling(Class c) {
    exists(Class c1 | this.contains(c1) and classDepInterPackg(c1, c))
  }
  int afferentCoupling() {
    result = count(Class c | this.affCoupling(c))
  }
  float packageInstability() {
    result = (1.0 * this.efferentCoupling()) /
      (this.afferentCoupling() + this.afferentCoupling())
  }
}
```

```
from p : V {JavaPackage}
reportMap p,
  from outerClass : V {JavaClass}
  with
    (not p --> {PackageOf} outerClass) and
    (p --> {PackageOf} <-- {ClassDep} outerClass)
  report outerClass end
end store as AffCoupling
```

```
using AffCoupling:
from p : V {JavaPackage}
reportMap p, count(get(AffCoupling,p)) end
store as AfferentCoupling
```

```
using AfferentCoupling, EfferentCoupling:
from p : V {JavaPackage}
reportMap p, get(EfferentCoupling,p) /
  ( get(EfferentCoupling,p) + get(AfferentCoupling,p))
end store as PackageInstability
```

```
ClassDepInterPackg(c1,c2)
:= EX( p1, PackageOf(p1, c1) & EX( p2, PackageOf(p2, c2) &
    !=(p1,p2) & ClassDep( c1, c2)));
```

```
AffCoupling(p,c)
:= EX( c1, PackageOf( p, c1) & ClassDepInterPackg( c, c1));
```

```
Package(x) := PackageOf(x,_);
```

```
FOR p IN Package(x) {
  ca := #(AffCoupling(p,c));
  PRINT "AfferentCoupling ", p, " ", ca, ENDL;

  ce := #(EffCoupling(p,c));
  PRINT "EfferentCoupling ", p, " ", ce, ENDL;

  i := ce / (ca + ce);
  PRINT "Instability ", p, " ", i, ENDL;
}
```

JTransformer



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```
classDepInterPackg(C1, C2) :-  
    packageOf(P1, C1), packageOf(P2,C2),  
    not(P1 = P2), classDep(C1,C2).
```

```
affCoupling(P, C) :-  
    packageOf(P, C1), classDepInterPackg(C, C1).
```

```
afferentCoupling(P,N) :-  
    setof(C, affCoupling(P, C), AffClasses),  
    length(AffClasses, N).
```

```
packageInstability(P, I) :-  
    efferentCoupling(P, Ec),  
    afferentCoupling(P, Ac),  
    I is Ec/(Ec + Ac).
```

Language comparison



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Criteria vs. tools		Grok	Rscript	JRelCal	SemmlCode	CrocoPat	JGraLab	JTransformer
Style/paradigm		Relational	Relational & comprehensions	API Relational	OO & SQL-like	FO-logic & imperative	SQL-like & Path expr.	FO-logic
Types	String	x	x	x	x	x	x	x
	Int	x	x	x	x	x	x	x
	Real	x	-	x	x	x	x	x
	Bool	-	x	x	x	x	x	x
	Other	-	Composite & location	Java	Class	-	Edge & Node	Logic terms
Parametrization		-	x	x	-	x	x	x
Polymorphism		-	x	x	x	-	x	x
Modules		x	x	x	x	x	-	x
Libraries		-	-	x	x	-	-	x

Tool comparison



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Criteria vs. tools	Grok	Rscript	JRelCal	SemmlCode	CrocoPat	JGraLab	JTransformer
Output formats	Text	Rstore	Sets & Relations	Text, Charts, maps, graphs	Text, RSF	Text, HTML	Text
Interactive interface	CLI	CLI, GUI	-	CLI, Eclipse	CLI	CLI	Eclipse
API support	-	-	x	x	x	x	x
Interchange format	RSF, TA	Rstore	RSF	-	RSF	TGraph	Prolog
Extraction support	C++	-	-	Java, XML	-	Java, C	Java
Licensing	-	BSD	LGPL	Proprietary	LGPL	GPL 2 Proprietary	EPL

Summary



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• Language criteria

- No significant differences found
- It is not possible to implement Package Instability in Grok

• Tool criteria

- Significant differences: interchange format, extraction, licensing
- Poor support for extraction

• Interactive use

- Only JRelCal is less suitable.

• Tool integration

- JRelCal, SemmleCode, CrocoPat, JGraLab, JTransformer
- Grok, Rscript only through interchange format

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Conclusion



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- **Compared seven code query technologies**

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- Package instability example
- Six language criteria
- Six tool criteria

- **Comparison not evaluation**

- **Presented findings**

- Allow an informed decision about which tool to choose

Future work & challenges



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• Future wok

- Add more tools / formalisms
- Performance comparison

• Challenges

- Adoption of each tool stronger points
- Better support for libraries, interchange format and extractors
- Availability of API
- Interfacing through IDE

• Research directions

- Analyze several versions of software
- Architecture checking

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Questions?



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