CHROME: A Model-Driven Component-Based Rule Engine

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PhD Thesis, CIn-UFPE
February 2009

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1. Context of thesis: the ORCAS project
   - State-of-the art in automated reasoning and reused-oriented software engineering
   - Extending both in synergy: the ORCAS project
   - Goals of the thesis within project
2. Base technologies:
   - Model-Driven Architecture (MDA) languages and methods
   - Constraint Handling Rules with Disjunctions ($CHR^{\vee}$)
3. CHROME: Model-driven component assembly for an easy to extend, scalable, adaptive $CHR^{\vee}$ engine
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Thesis Context: ORCAS Project Motivation

- Limitations of Automated Reasoning (AR) technology:
  - Few reuse of AR services
  - Lack of modern Software Engineering
  - Poor Integration with mainstream Software
- Limitations of Software Engineering technology:
  - Lack of tools for MDE and CBD
  - Lack of conceptually complex examples (AR, Compilers)
  - Potencial AR use overlooked (e.g.model checking)

Thesis context: Orcas Goals

Orcas: A framework of AR components

Model-driven Engineered

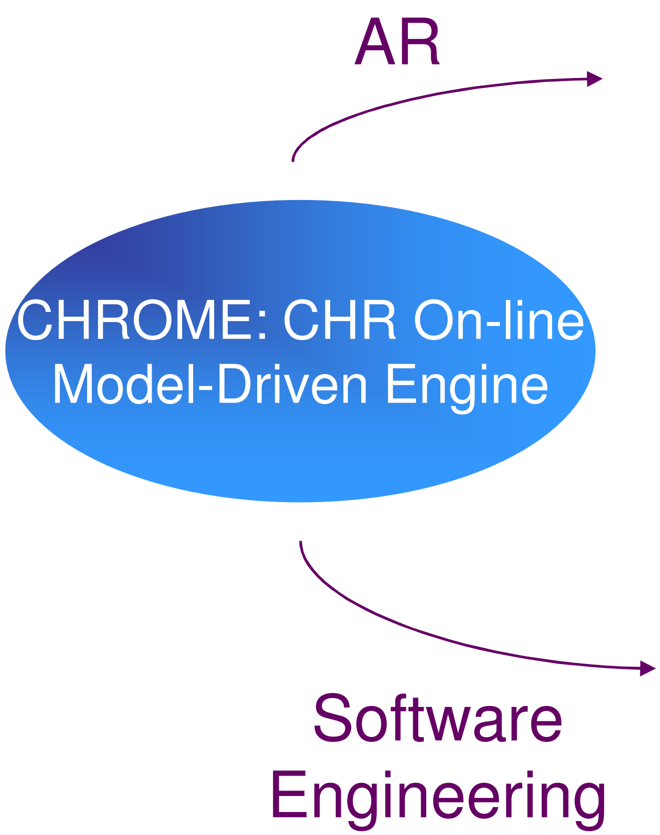
Based on $CHR^{\vee}$

AR services

- Constraint solving over any domain
- Classical First-Order Logic (CFOL) satisfiability and entailment
- Description Logic (DL) subsumption
- Abduction
- Agent belief update and action planning
- Truth-maintenance, default reasoning and inheritance

cf. Früwirth, Abdennadher, Fages, Martinez, Rodrigues, Christiansen, Thielscher, Martin, Yin, Wolf, Silva, Robin

Goals of the Thesis



- Most reused component and basis for ORCAS
- Deployable on a mainstream platform (Java)
- With built-in conflict-directed backjumping for efficient search
- With built-in truth-maintenance for adaptive, anytime, online reasoning
- With CHR$^{\vee}$ base to Java code compiler designed as a pipeline of model-tranformations.

- Demonstrate the synergy between:

Software components, MDE and
Model transformation

- Demonstrate the applicability to engineer:

CHROME Engine

Compilers between languages from different paradigms
Artificial intelligence software
(Large, non-toy model-transformations, 4358 lines of ATL)

Contents

Base Technologies: MDE Languages and Methodologies

- Unified Modeling Language 2.1 (UML):
  - OMG main MDE standard to specify Platform Independent Models (PIMs) and Platform-Specific Models (PSM, using self-extension profile mechanism)
  - Integrates concepts from imperative, Object-Oriented (OO), concurrent, distributed and component-based paradigms
  - Covers structural, behavioral, functional and deployment aspects of a software

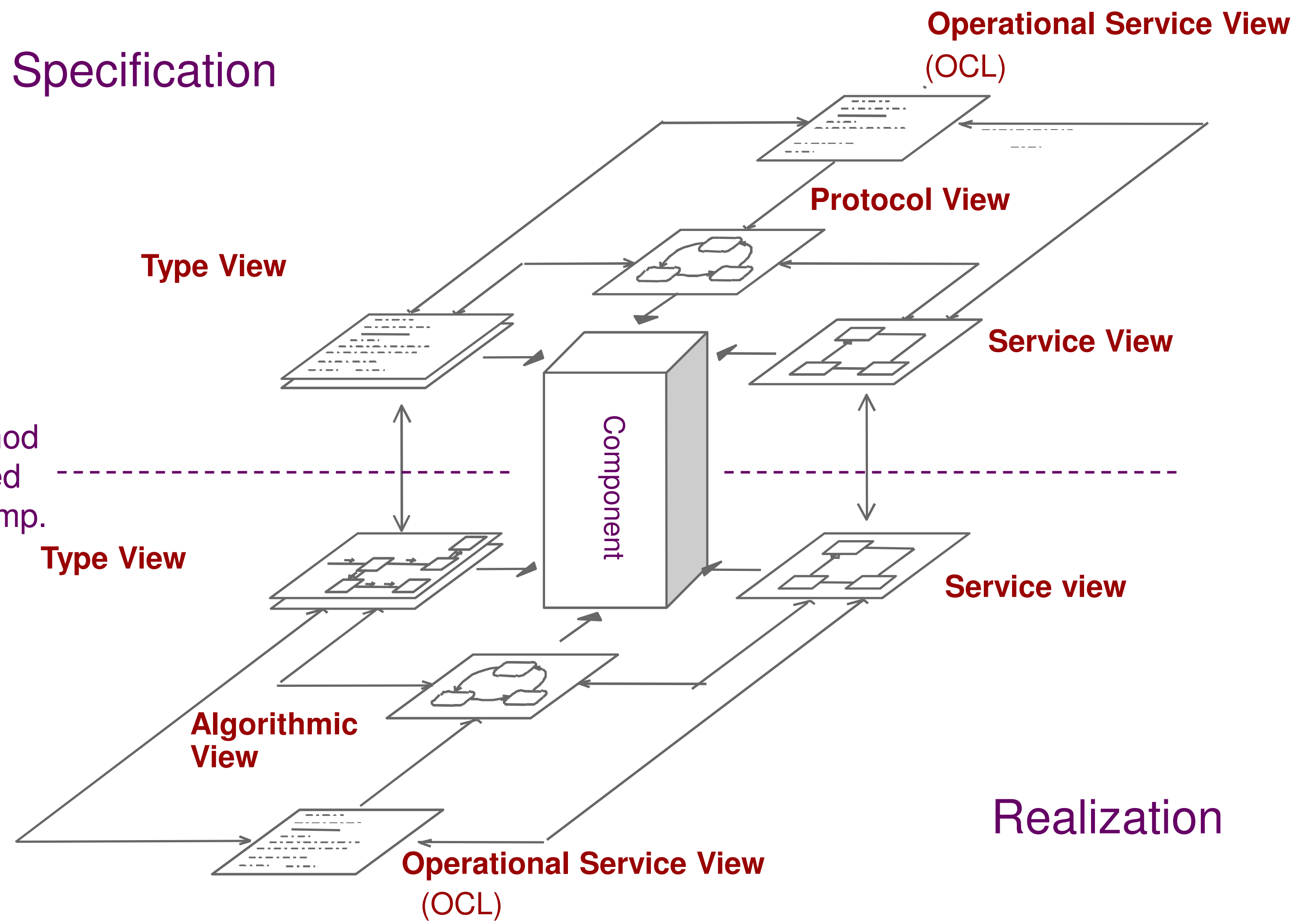
- Object Constraint Language 2.0 (OCL):
  - Textual part of UML2 to specify arbitrary first-order logic constraints among UML2 model elements
  - Allows modeling "executable" PIMs, *i.e.,* refined enough to be fully automatically translated into running code by MT
  - Functional OO syntax concise and intuitive for mainstream developers

Base Technologies:
MDE Languages and Methodologies

- Atlas Transformation Language (ATL, Bezevin, INRIA-Rennes)
  - Hybrid rule-based and imperative MT language
  - Pattern-matching model element rewrite rules with embedded procedures
  - Input and output models conform to a meta-model in Ecore (a MOF2 variant)
  - Core is an OCL2 execution engine for input model element pattern matching and output model element construction (≈ 80% of an ATL program is OCL)
  - Eclipse project, largest user community, *de facto* standard

Base Technologies:
KobrA2 (Atkinson, Robin, Stoll, U. Mannheim-UFPE)

MDECBD Method
UML/OCL based
16 views of Comp.



☛**CHROME is its first large application case study for Kobra2**

Base technologies: $CHR^{\vee}$ rule base concrete syntax and logical semantics

- Constraint simpagation rules :
  - Rule syntax: K\ R <=> G | B., with:
    - K keep heads, and R remove heads, both conjunctions of so called User-Defined Constraints (UDC)
    - G guards, conjunction of so called Built-In Constraints (BIC)
    - B bodies, disjunction of conjunction of either RDC or BIC
- Constraint store S (volatile $CHR^{\vee}$ KB) = $S_r \wedge S_b$
  with S_r conjunction of UDC and S_b conjunction of BIC
- Query Q: conjunction of constraints, either RDC or BIC
- $CHR^{\vee}$ propagation rule K ==> G | B,
  syntactic variant of simpagation rule K \ true <=> G | B.
- $CHR^{\vee}$ simplification rule R <=> G | B,
  syntactic variant of simpagation rule true \ R <=> G | B.

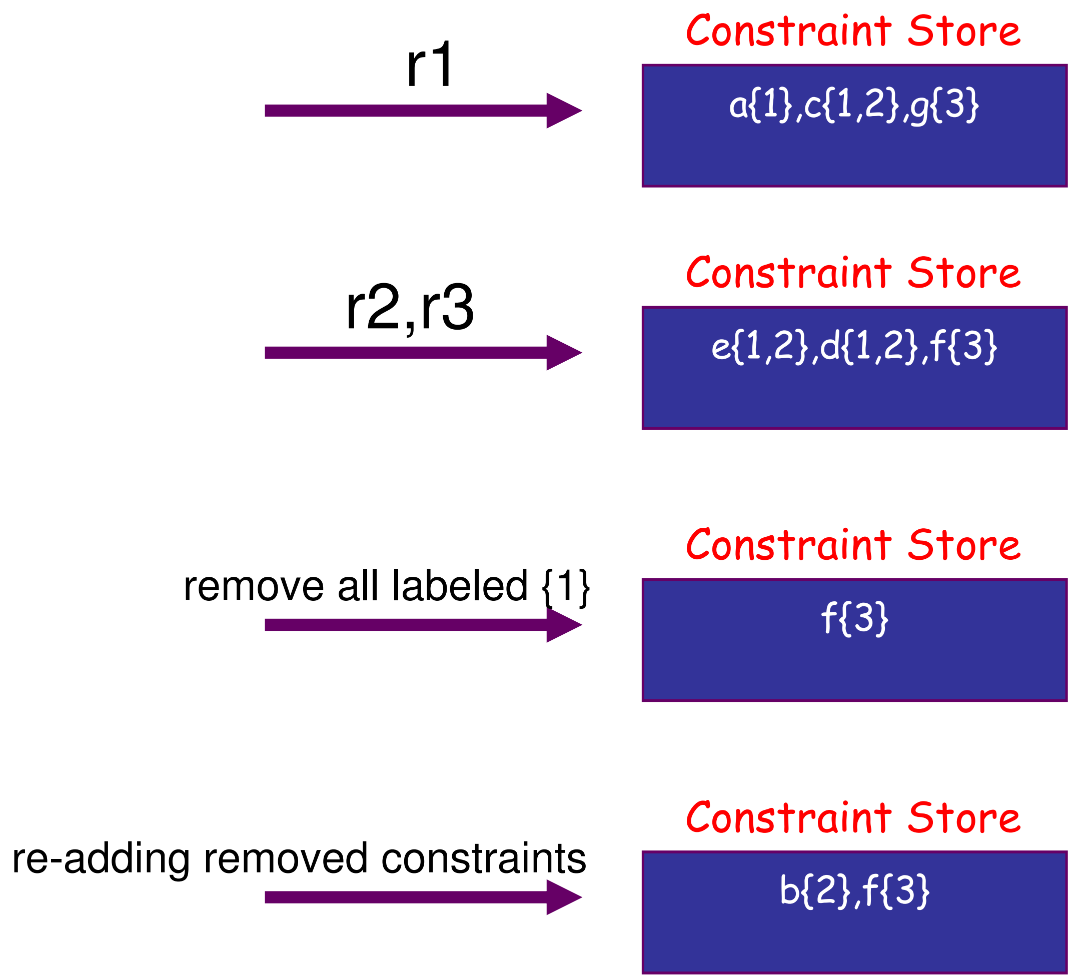
CHR$^{\vee}$ by Example: Justification and solution adaptation

r1@ a \ b <==> c
r2@ a,c <==> e,d
r3@ g <==> f

query: a{1}, b{2}, g{3}

remove: a{1}

remove: a{1}



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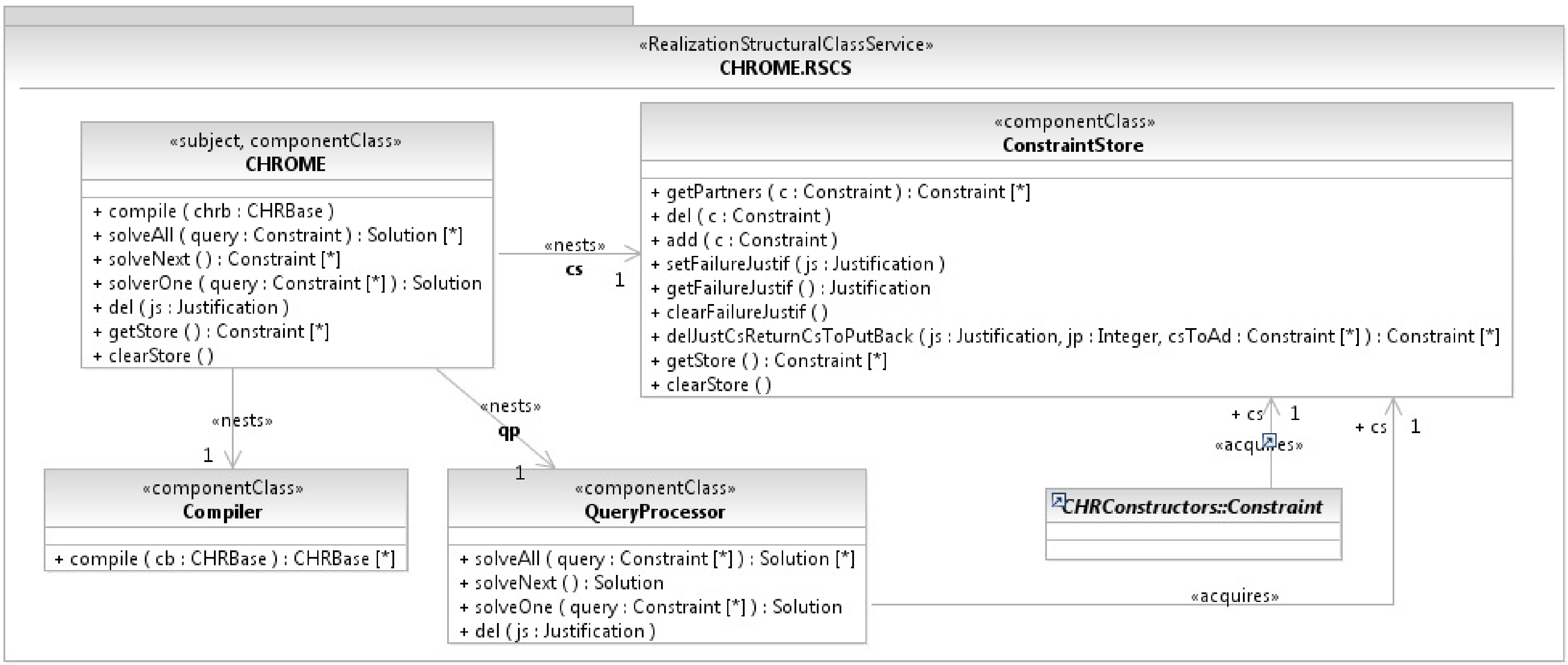
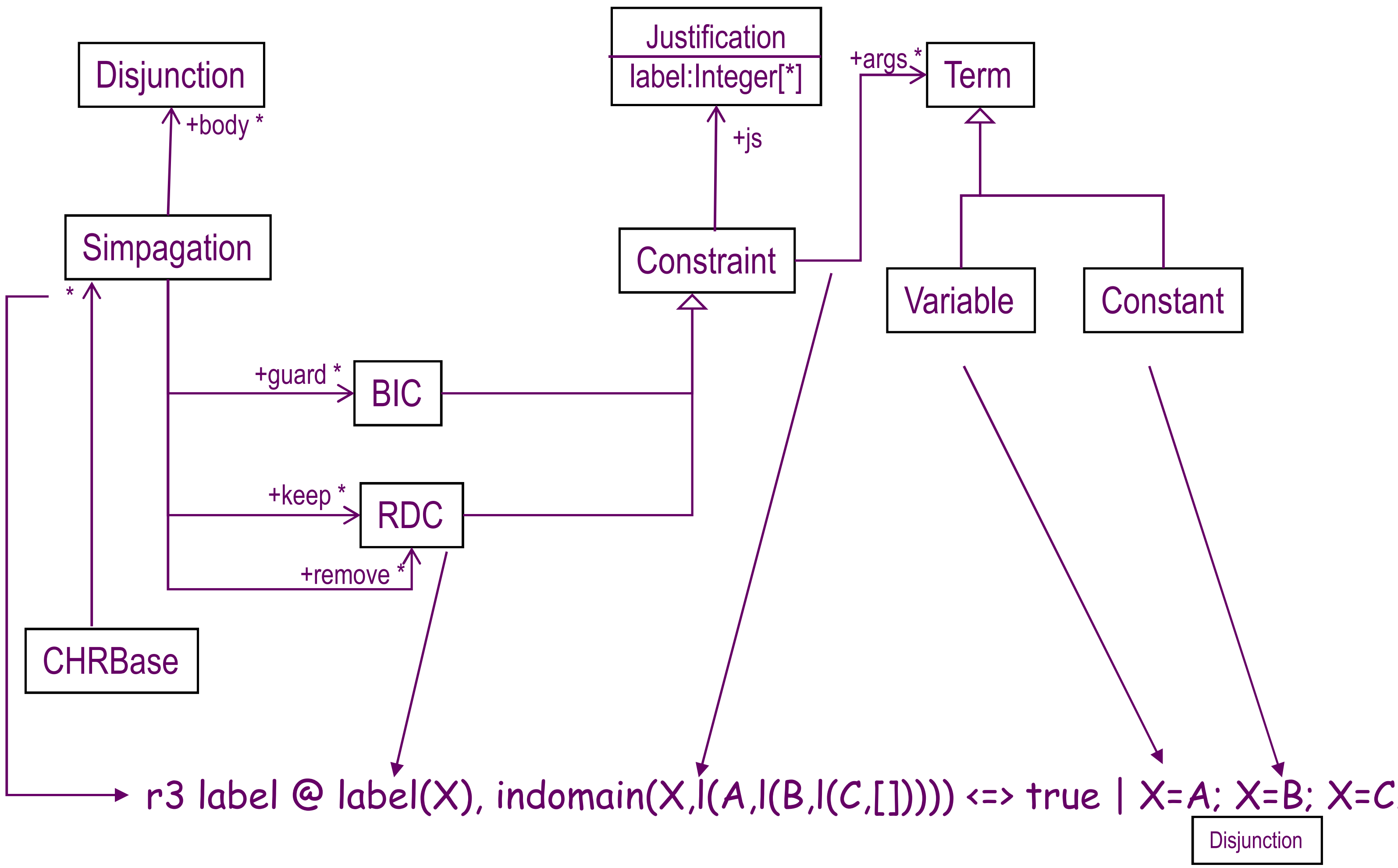
CHROME: Top-Level Assembly

KobrA2 Realization Structural Class Service View



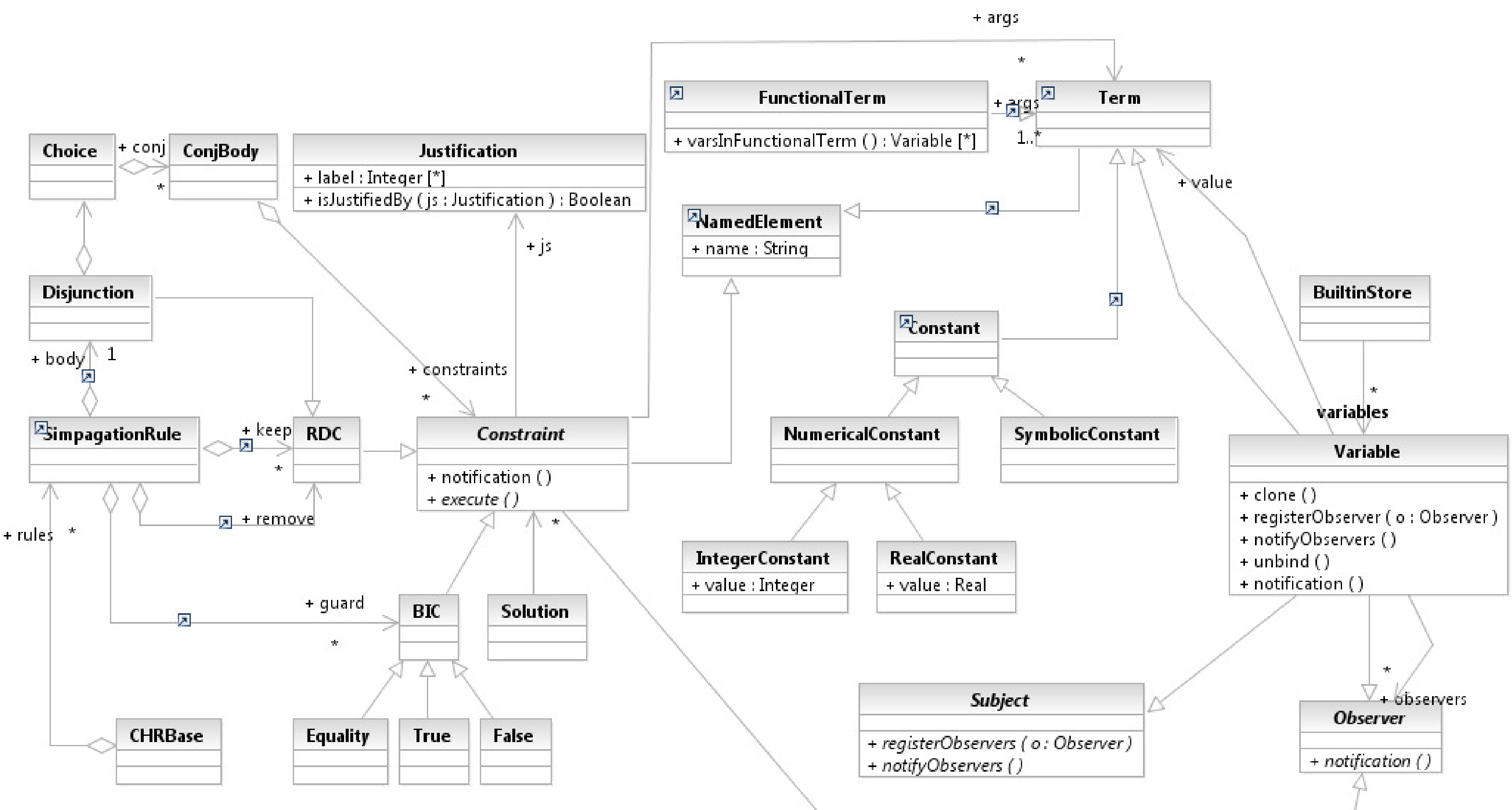
CHROME: OO Data Structures for CHR$^{\vee}$

CHROME types (draft)



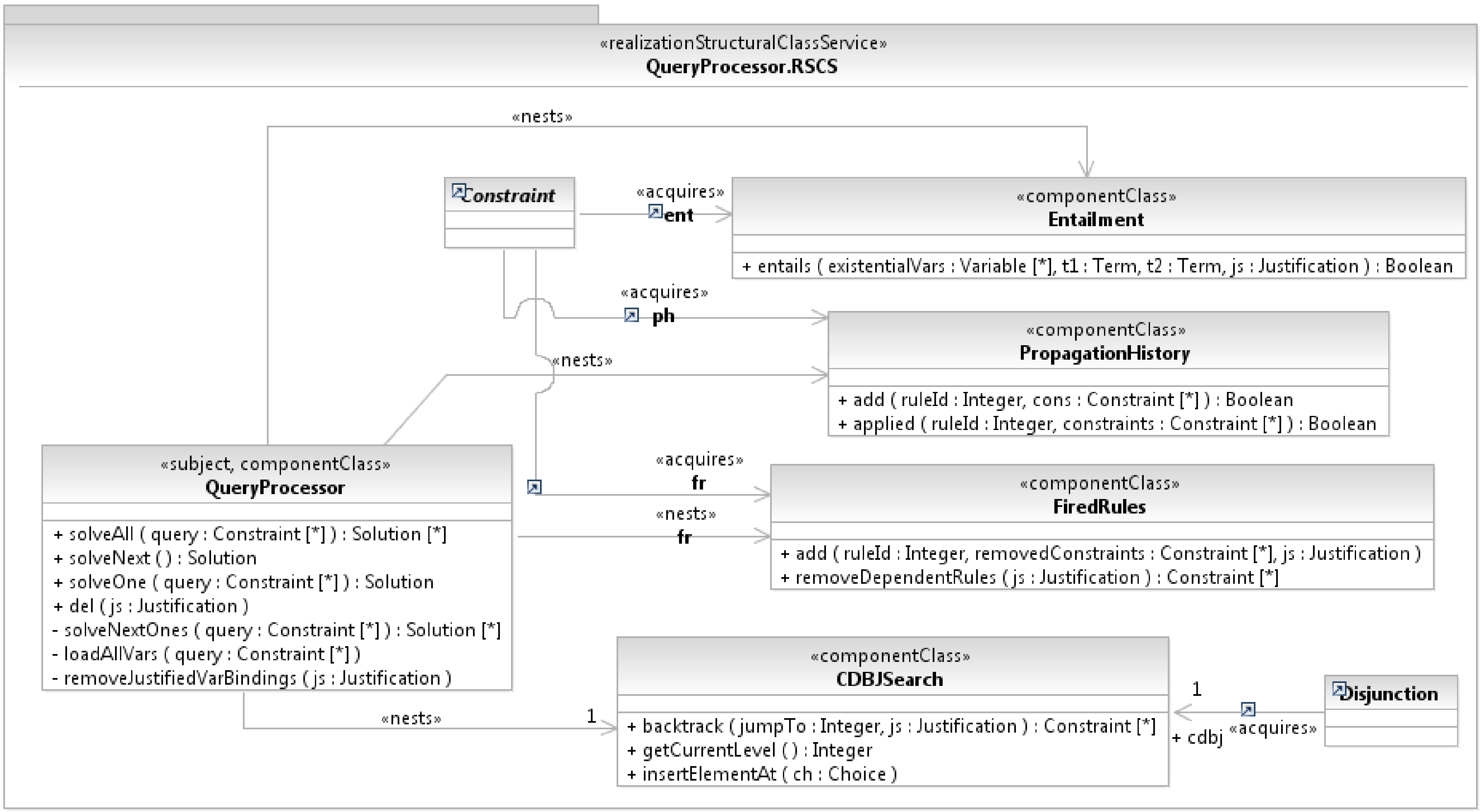
CHROME: OO Data Structures for CHR∨

KobrA2 Specification Structural Class Type View



CHROME: Query Processor Assembly

KobrA2 Realization Structural Class Service View



CHROME Run-Time PIM Assembly

- 8 KobrA2/UML2 Components
- 40 KobrA2/UML2 Classes
- 33 KobrA2 view packages
- 30 UML2 diagrams
- 187 lines of OCL2 expressions

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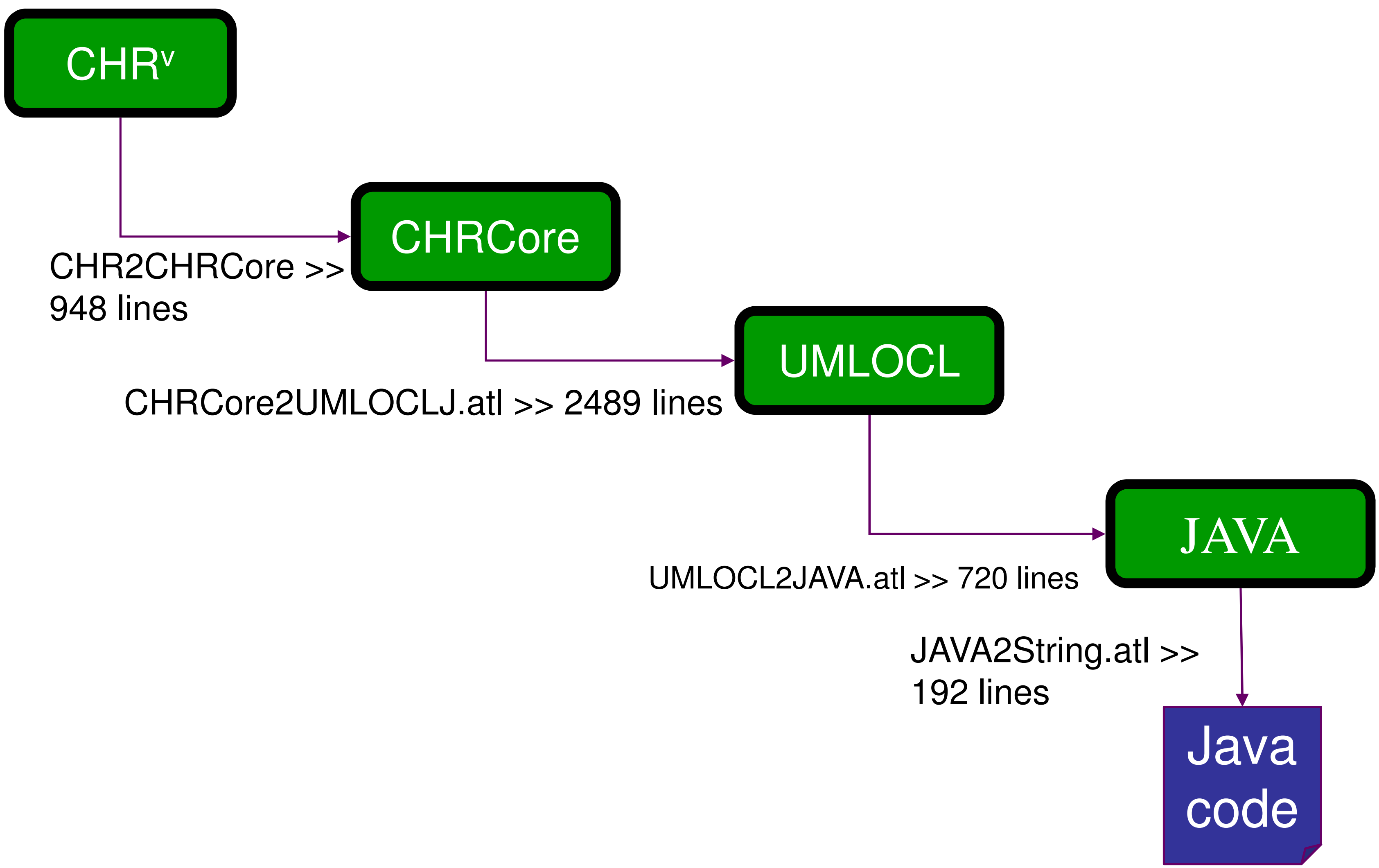
CHROME: Compiler Pipeline



CHROME Compiler Stage 1: from full CHR$^{\vee}$ to CHRCore

- Example input (textual):
  - k(1,X) \ d(X) <=> g | b.

- Example output (textual):
  - k \ d <=> g, k.at(1) = 1, k.at(2) =d.at(1) | b.

✓ Simpler matching

✓ Sequence of Equalities

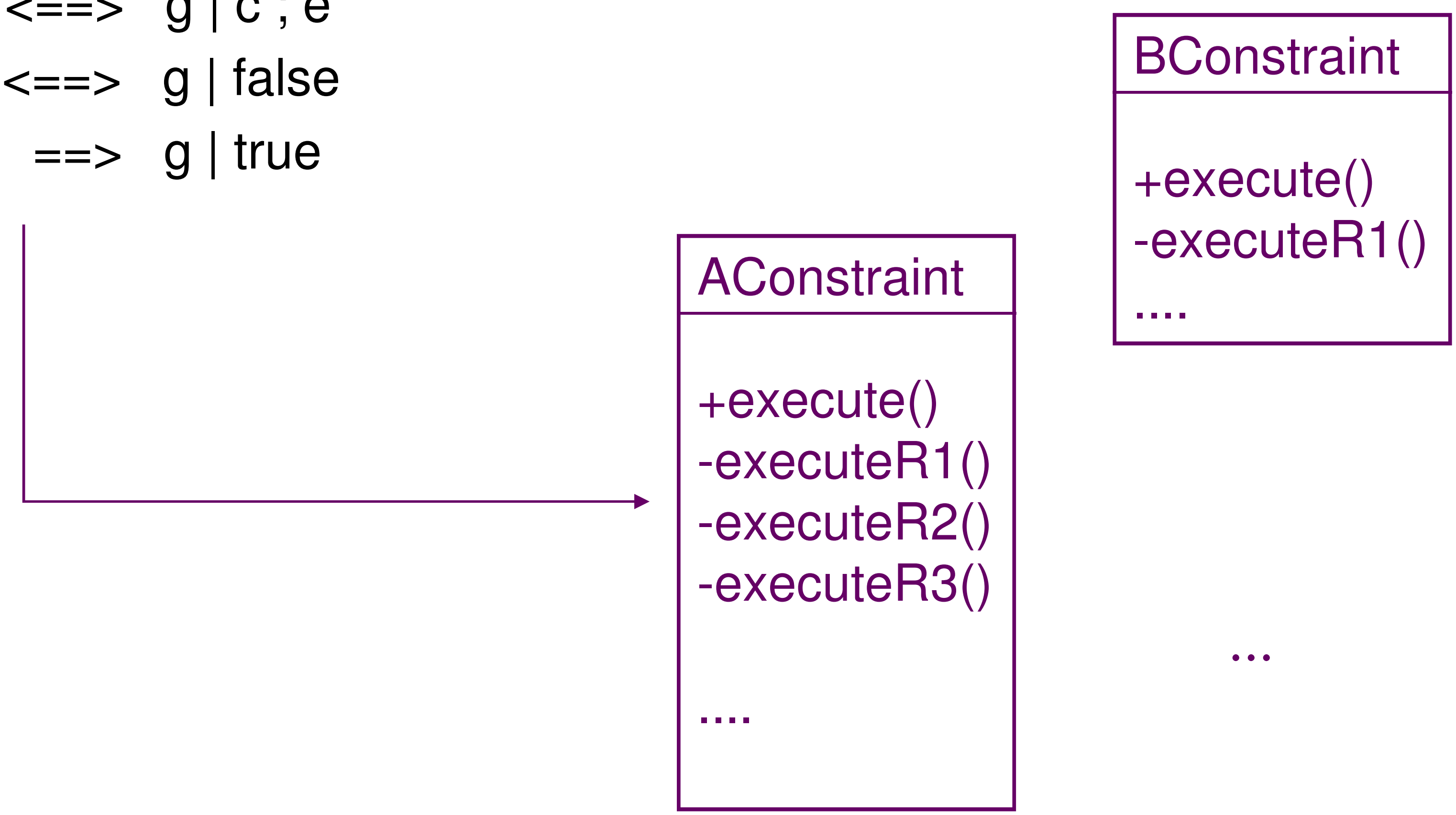
CHROME Compiler Stage 2: from CHRCore to UML2/OCL2

Basic idea: Every Constraint is converted into a UML Class

r1@ a \ b <==> g | c ; e

r2@ a,c <==> g | false

r3@ a,e ==> g | true



CHROME Compiler Stage 2: from core CHR to UML2/OCL2

AConstraint

+execute()
-executeR1()
-executeR2()
-executeR3()

-checkGuardR1()
-checkGuardR2()
-checcGuardR3()

-addR1Body()
-addR2Body()
-addR3Body()

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5. Testing and benchmarking
6. **Contributions**
7. Limitations and future work

Contributions

Contributions

- To CHR and CLP:
  - First justification-based adaptive CHR$^{\vee}$ engine (crucial for practical applications and tracing);
  - First CHR$^{\vee}$ engine with intelligent search (CDBJ);
  - First component-based CHR$^{\vee}$ engine (easy to extend);
  - First MDE CHR$^{\vee}$ engine (easy to port to other OO host platforms).
- To MDE:
  - CHROME: Largest case study to date to integrate MDE with MT and components for AR.
  - First MDE/MT compiler from source language to target language from different structural paradigm (4358 ATL lines).

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Limitations and future work

Limitations

- Only 3 built-in constraints: =, true, false
- No visual tracing IDE
- Still an order of magnitude slower than $CHR^{\vee}$ Prolog platforms on run benchmark
- Untested scalability for other AR tasks beyond finite domain solvers
- Compiler not component-based and verbose (ATL)

Future work

- Visual tracing IDE (MSc. Thesis of Rafael Oliveira 2010)
- Create variable size benchmark for variety of AR tasks
- Port to Python to test scalability of transparent distribution to Google's cloud
- Extend to run OO CHR bases (cf. MSc. of Marcos Silva 2009)

Thank you!

Any Questions?