7th Educators' Symposium @ MODELS 2011:
Software Modeling in Education

Model Correctness Patterns as an Educational Instrument

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Model Quality

- Models are the backbone of MDA approach
- Model quality effects
  - the development process
  - the final result
- Producing high quality models is a difficult task
- A model quality can be achieved
  - ***automatically***
    - verification and transformation methods
  - ***educationally***
    - educated modelers who are aware of quality problems

Design patterns

- A design pattern
  - Is an **expert advice** to a **common problem**, in a **context** (Gamma and others 1995)
- Fulfill an educational role:
  - awareness to design patterns yields better solutions
- Essential part in many CS curricula

Contribution

- A catalog of ***correctness*** and ***quality*** patterns in class diagrams
  - characterizes correctness and quality problems
  - analyzes the causes
  - suggests possible solution

- Educational role:
  - increase the awareness to interactions that create incorrect or low quality models
  - educate to good modelers

Class Diagram Modeling Problems

- Inconsistency
- Finite satisfiability

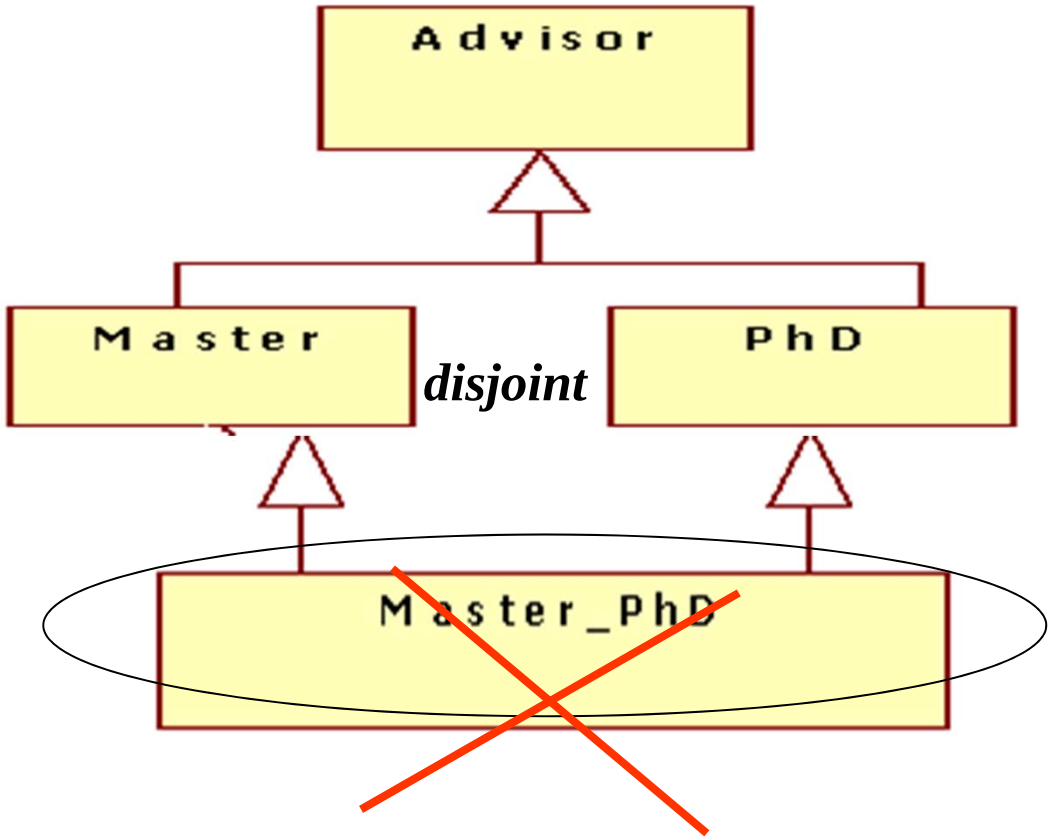
} Correctness

- Redundancy
- Incomplete design

} Quality

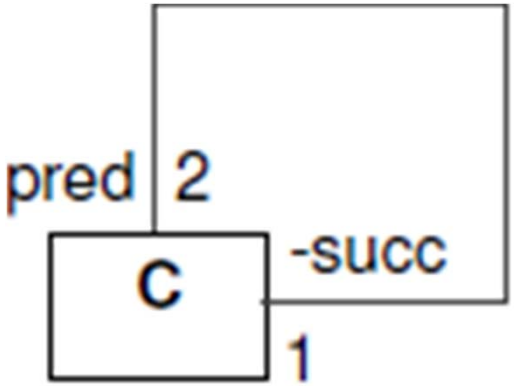
Modeling Problems – Inconsistency

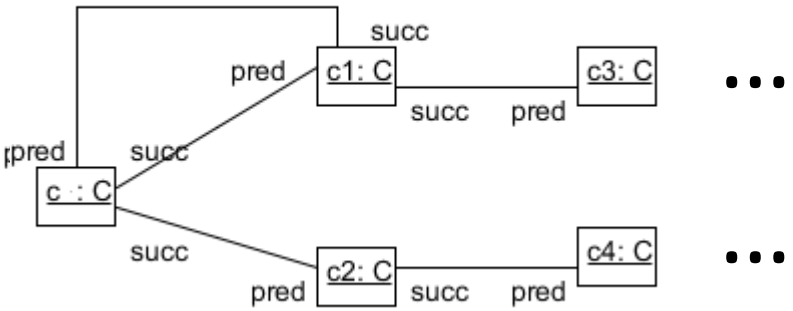
- Emptiness – *Contradictory generalization set constraints*

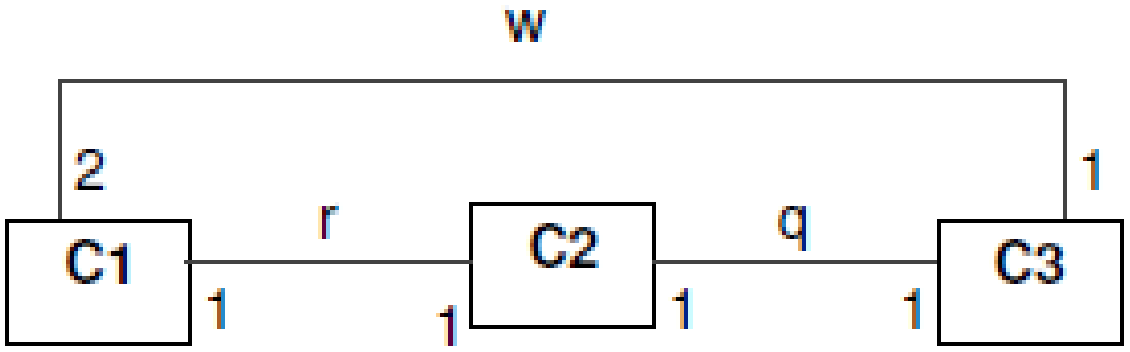


Modeling problem: Finite satisfiability

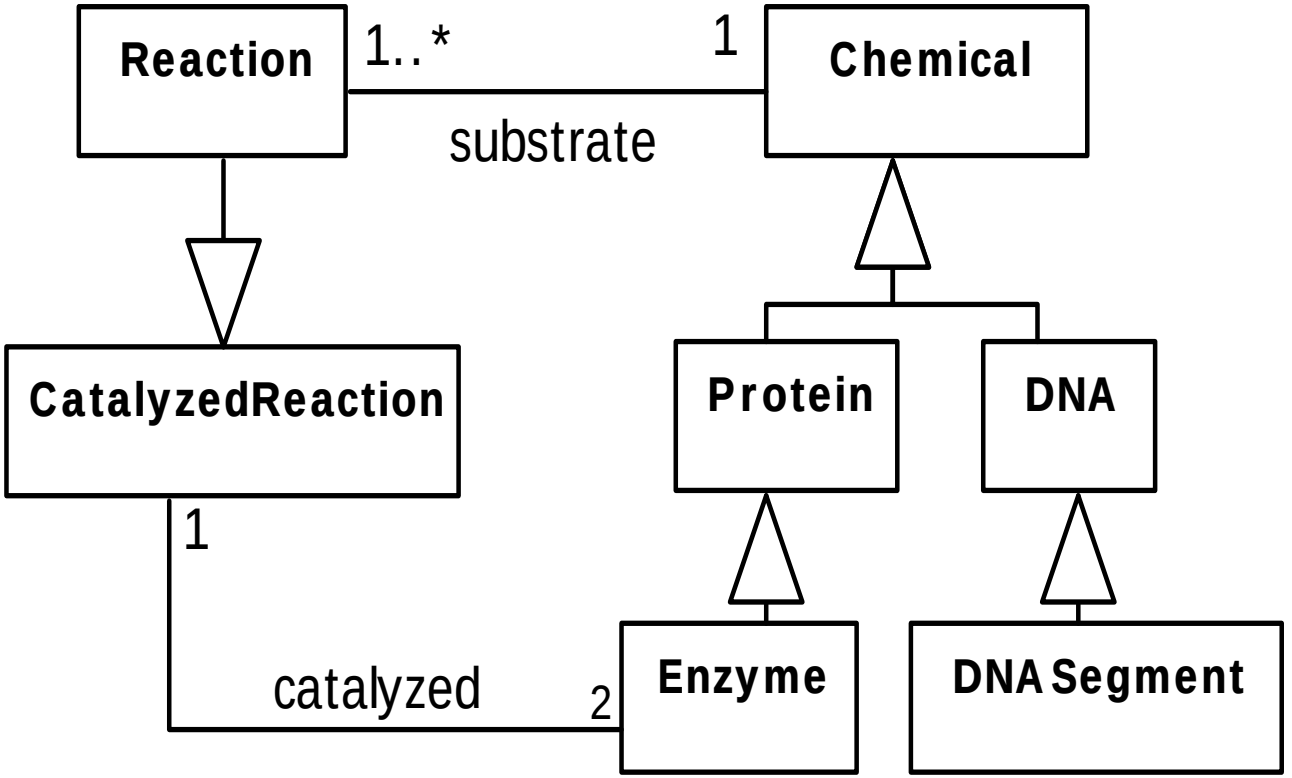
$|C^I| = 2|C^I|, for\ every\ legal\ instance\ I$







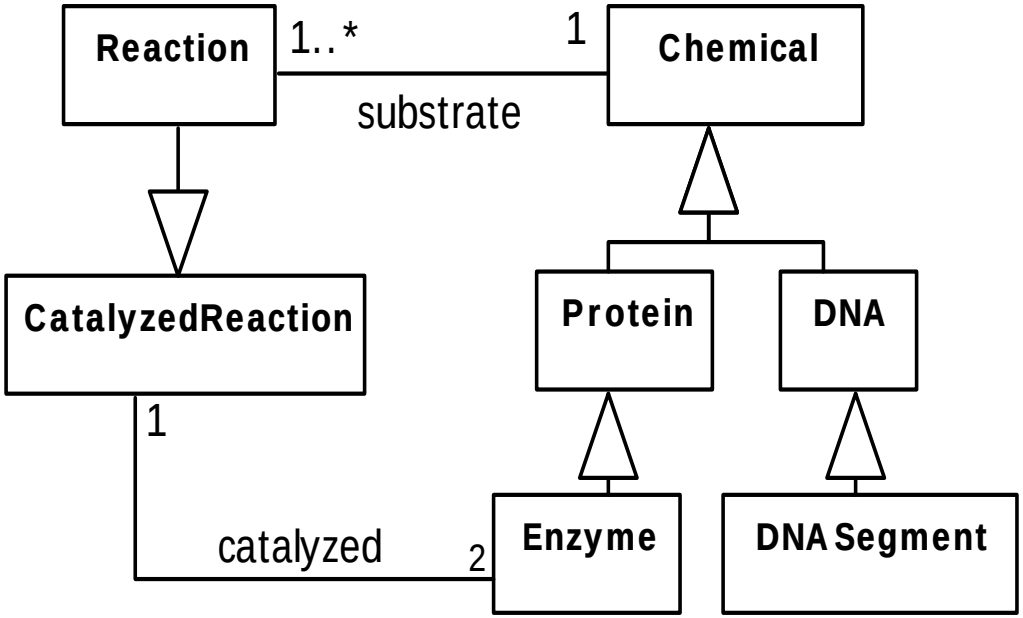
Modeling problem: Finite satisfiability

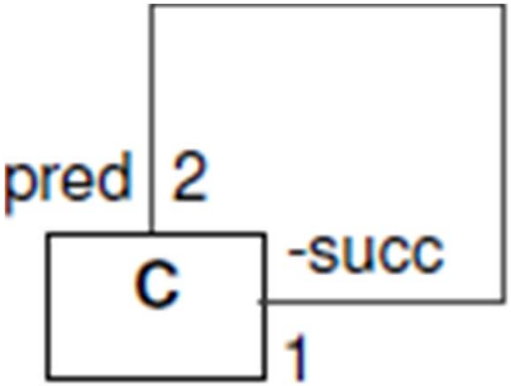


[Enzyme] ≤ [Protein] ≤ [Protein] ≤ [Chemical] ≤ [Chemical] ≤ [Reaction] ≤ [Reaction] < [Enzyme]

[Enzyme] < [Enzyme]

Problem abstraction by example

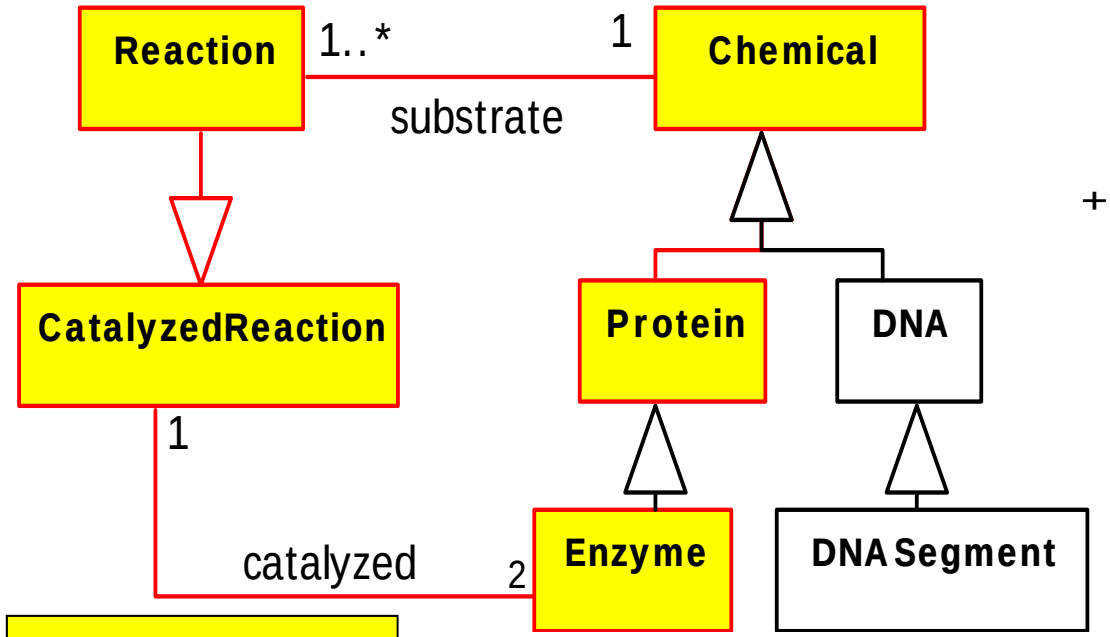




- Classes
- Associations

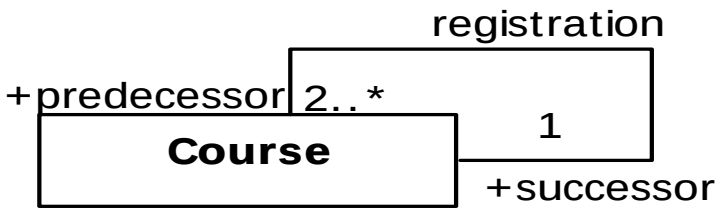
- Classes
- Associations
- Class Hierarchies

Problems Abstraction by example



- Classes
- Associations
- Class Hierarchies

Cycle Structure



- Classes
- Associations

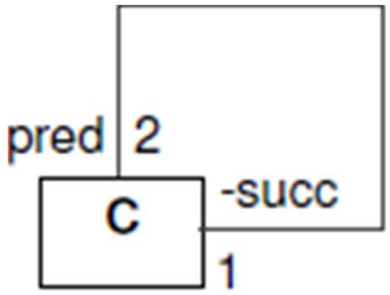
Cycle Structure

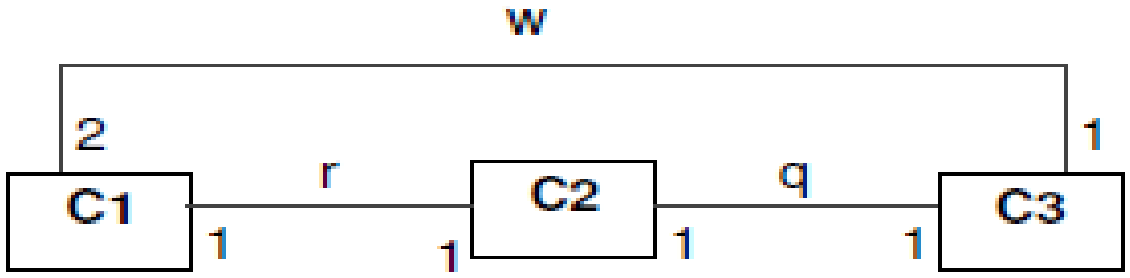
Correctness Patterns

- It turns out that correctness problems are varied and can occur for many reasons
  - problematic constraint interactions
    - understanding these interactions is a difficult task

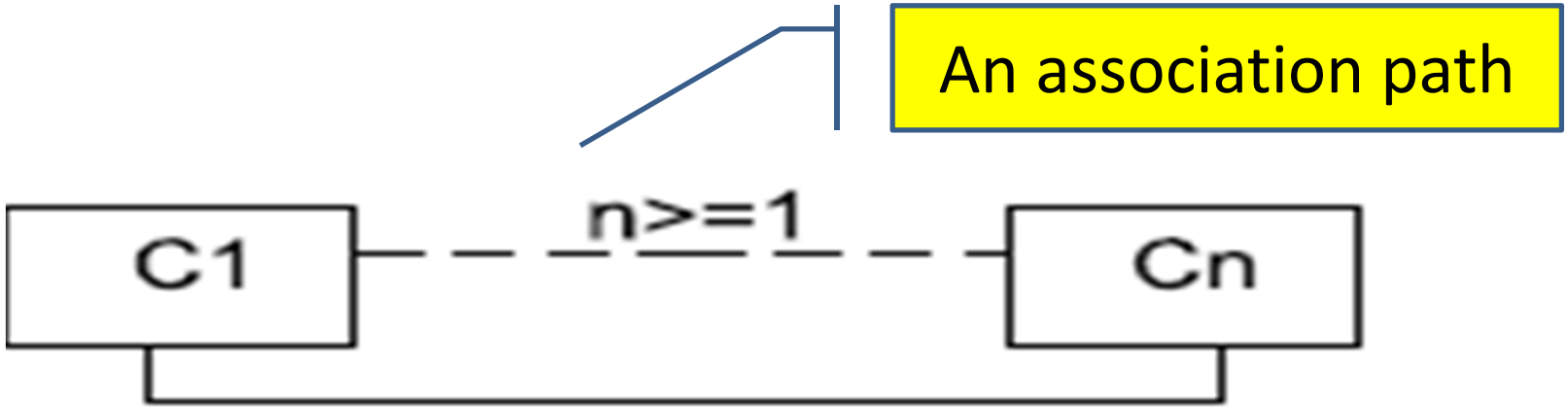
- Awareness to interactions improves the overall design quality

The Pure Multiplicity Cycle

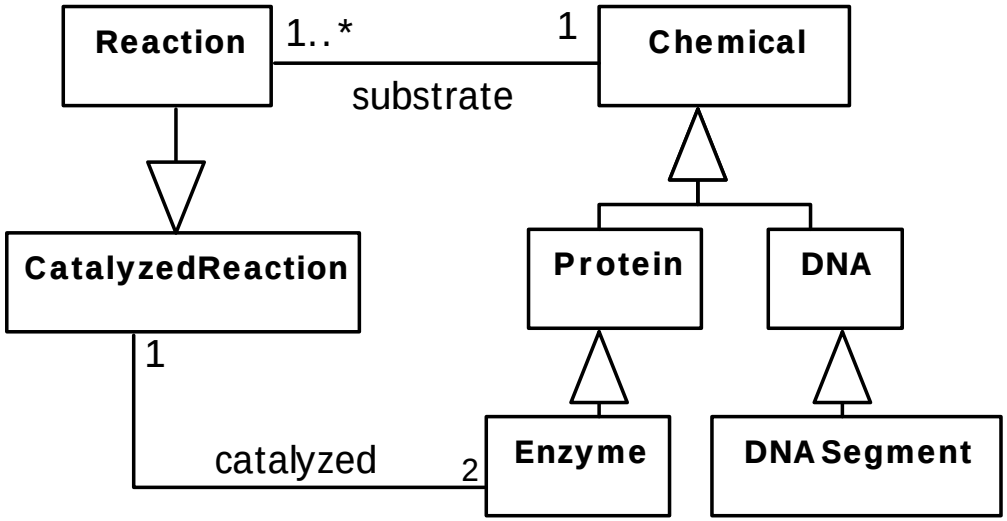


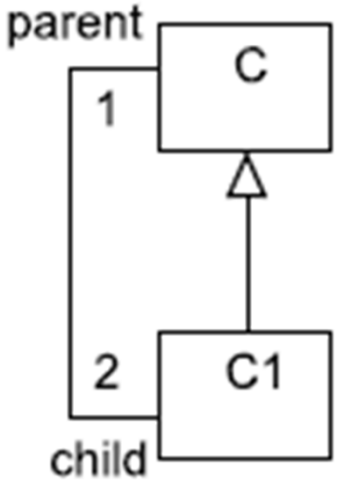


Pattern Description: A cycle of associations with multiplicity constraints might introduce a finite satisfiability problem



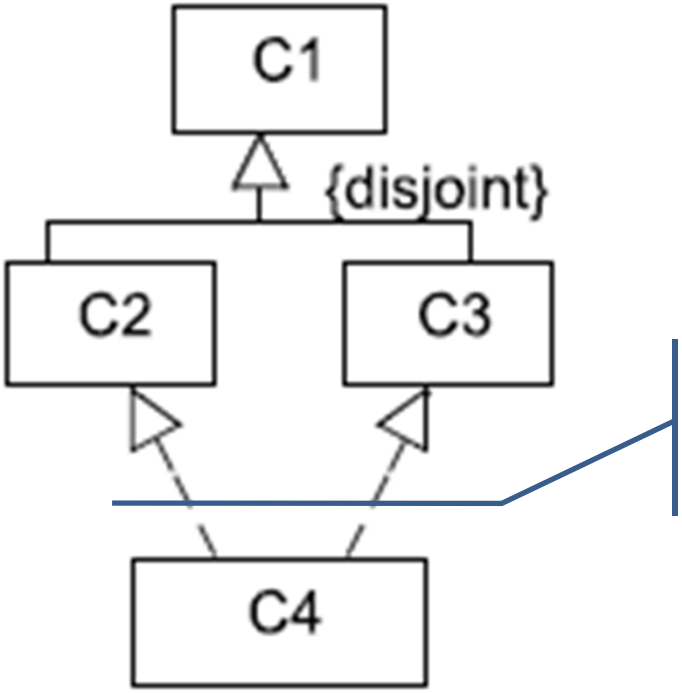
The Multiplicity Hierarchy Cycle

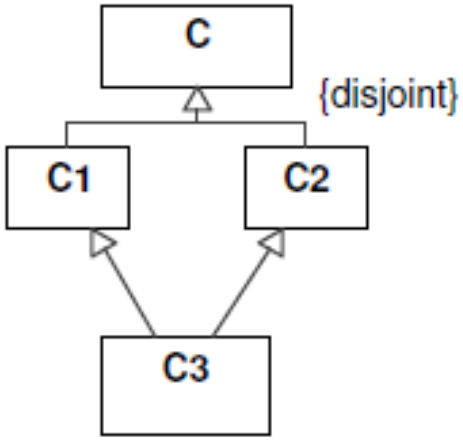


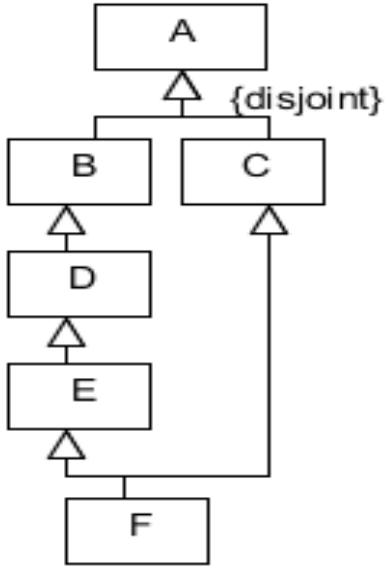


An association-hierarchy path

The Diamond pattern





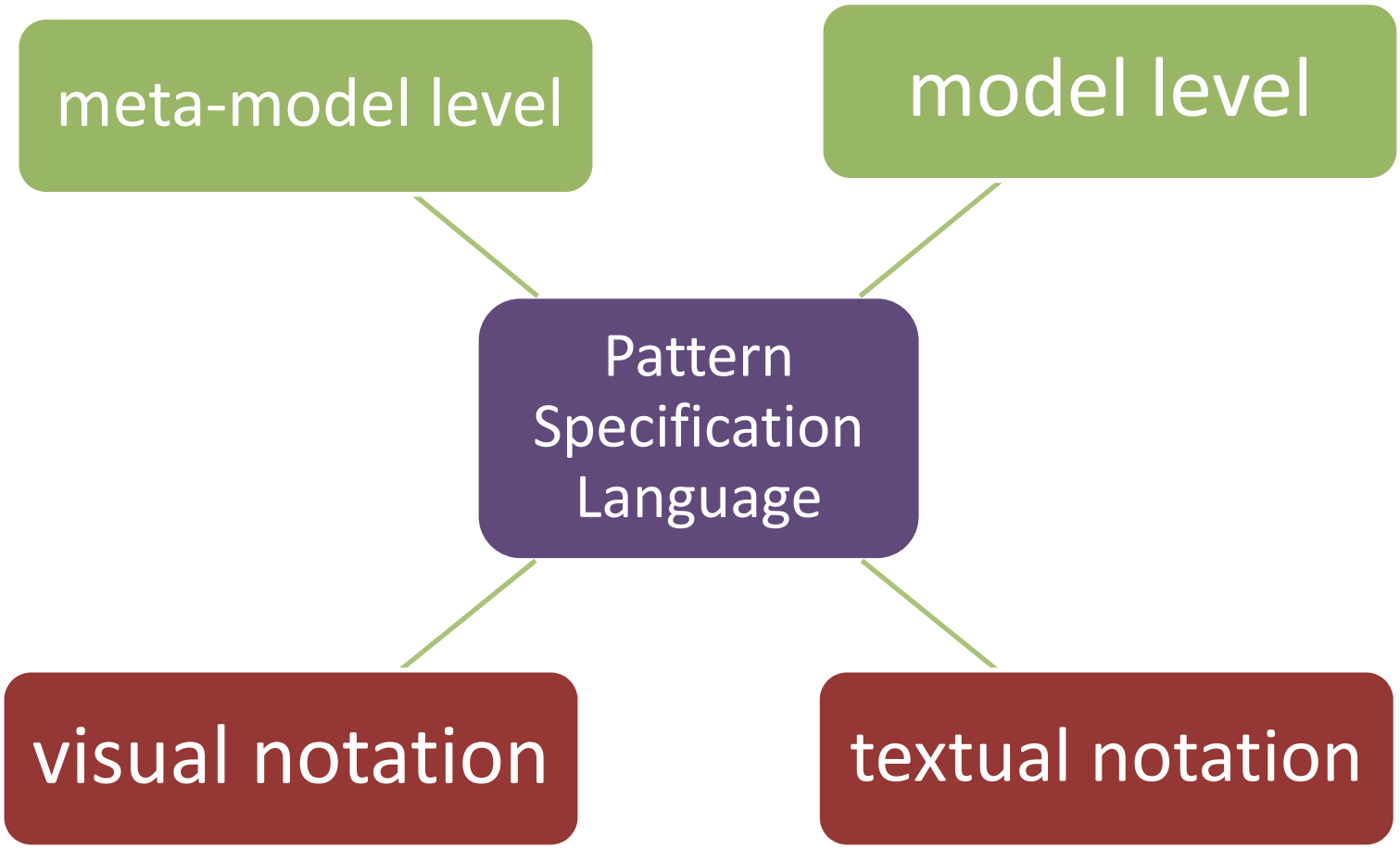


A path of class hierarchy constraints

Conceptual Concepts

- Constructs for specification of unbounded relationship structures like
  - a cycle of associations
  - a cycle of class hierarchy constraints
  - interleaved association and hierarchy paths
- A language specification is essential

Pattern Specification Language

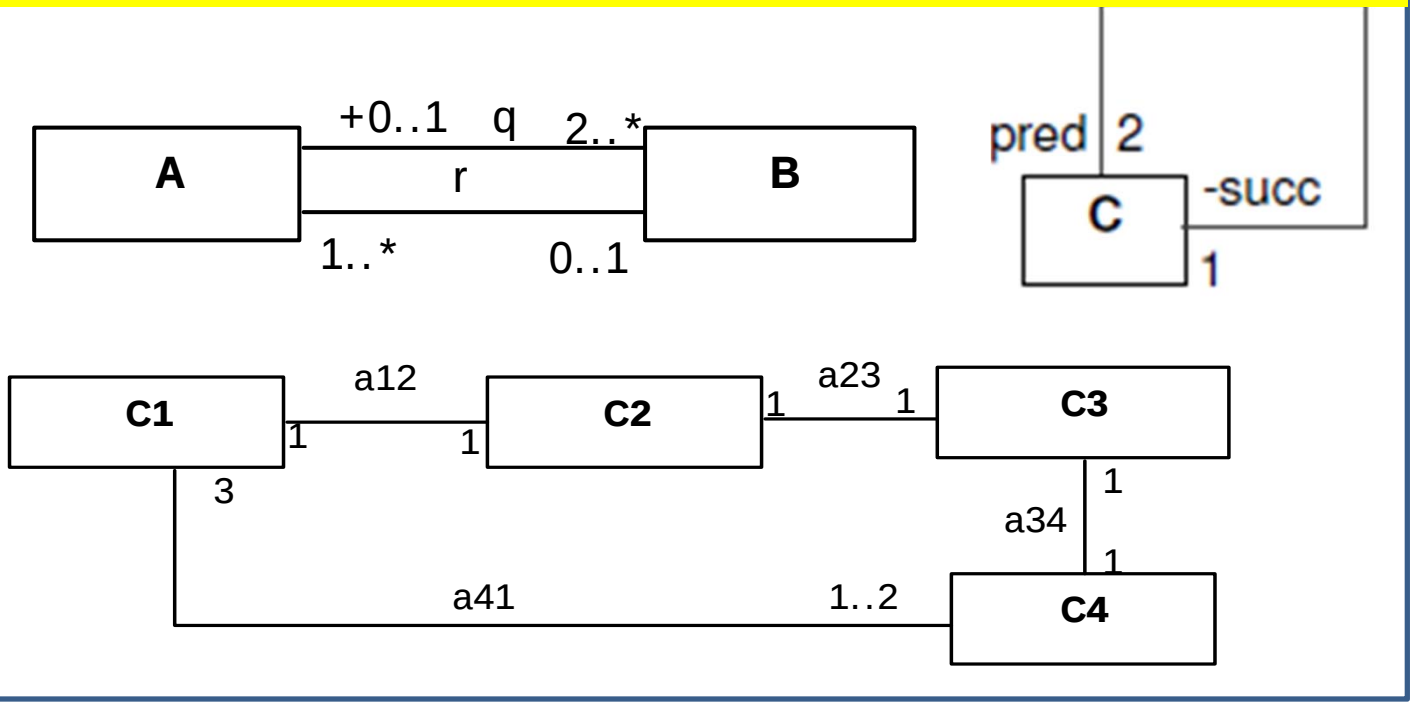


Visual vs. textuals

- Visual notations (Moody 2009)
  - human oriented representations
  - facilitate human communication, comprehension and problem solving
- Textual notations
  - barely usable by UML practitioners (Ballis and others 2008)

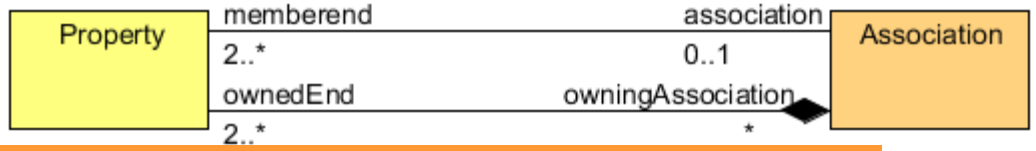
Model Level

Do not capture the intentioned ***problem domain***: *finite satisfiability* problems due to a cycle of associations with multiplicity constraints



Meta-model level specification

- Specification of problem domains in the term of Meta-Model terminology




```
context Association inv AcyclicAssocCycle:
 not(self.allConnectedAssociations()->includes(self))
```

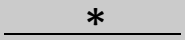
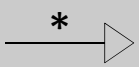
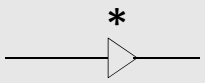
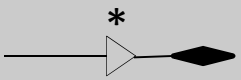
- Inappropriate for educational purposes
  - demand expert knowledge

Pattern Specification

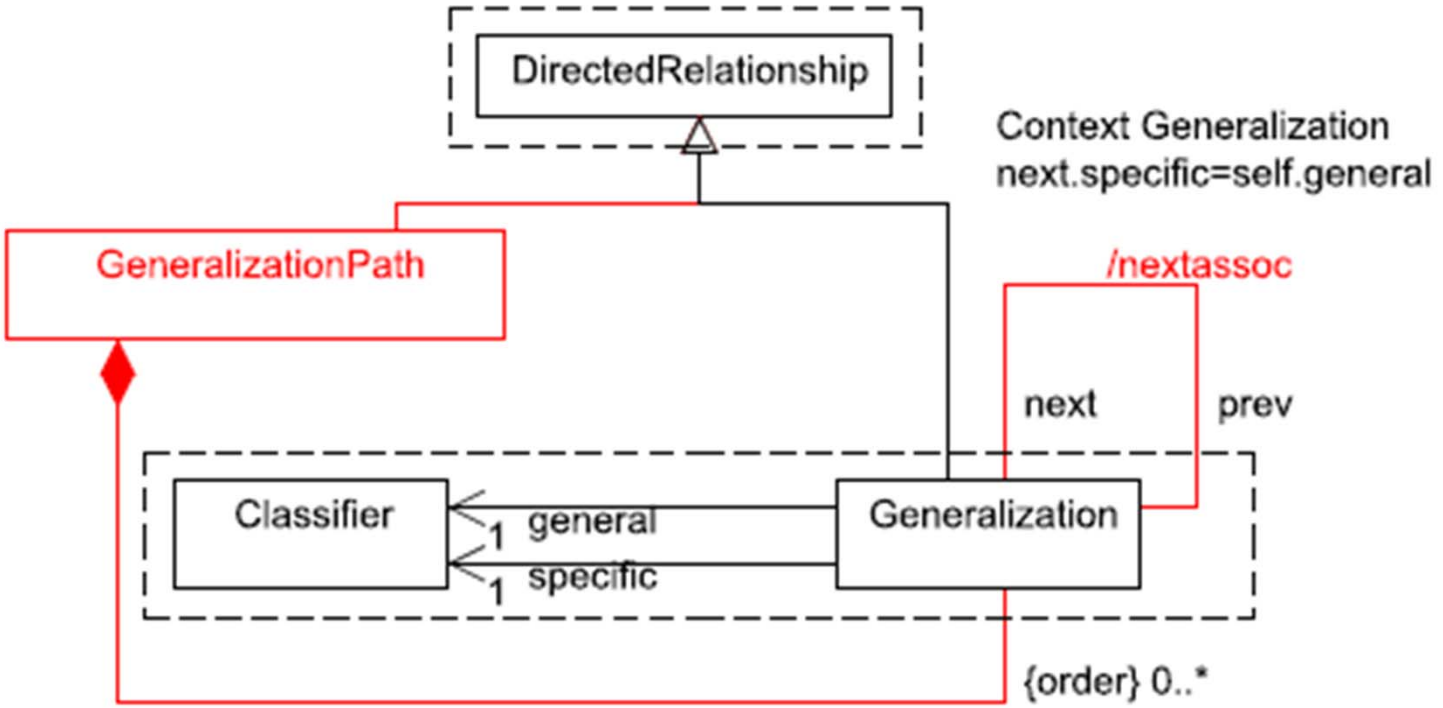
- Patterns should be visual with notations
  - that captures **meta-model level abstractions**

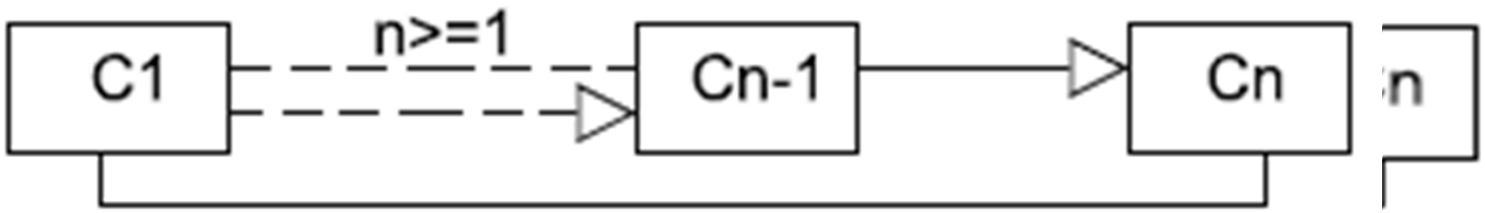
    Kim 2008, Ballis and others 2008
- Visual representations should include the
  - ***cognitive effectiveness property***
    - the ability to directly clarify associations between cognitive and visual concepts
      - Moody 2009, Figl and others 2010

Concrete syntax for relationship paths

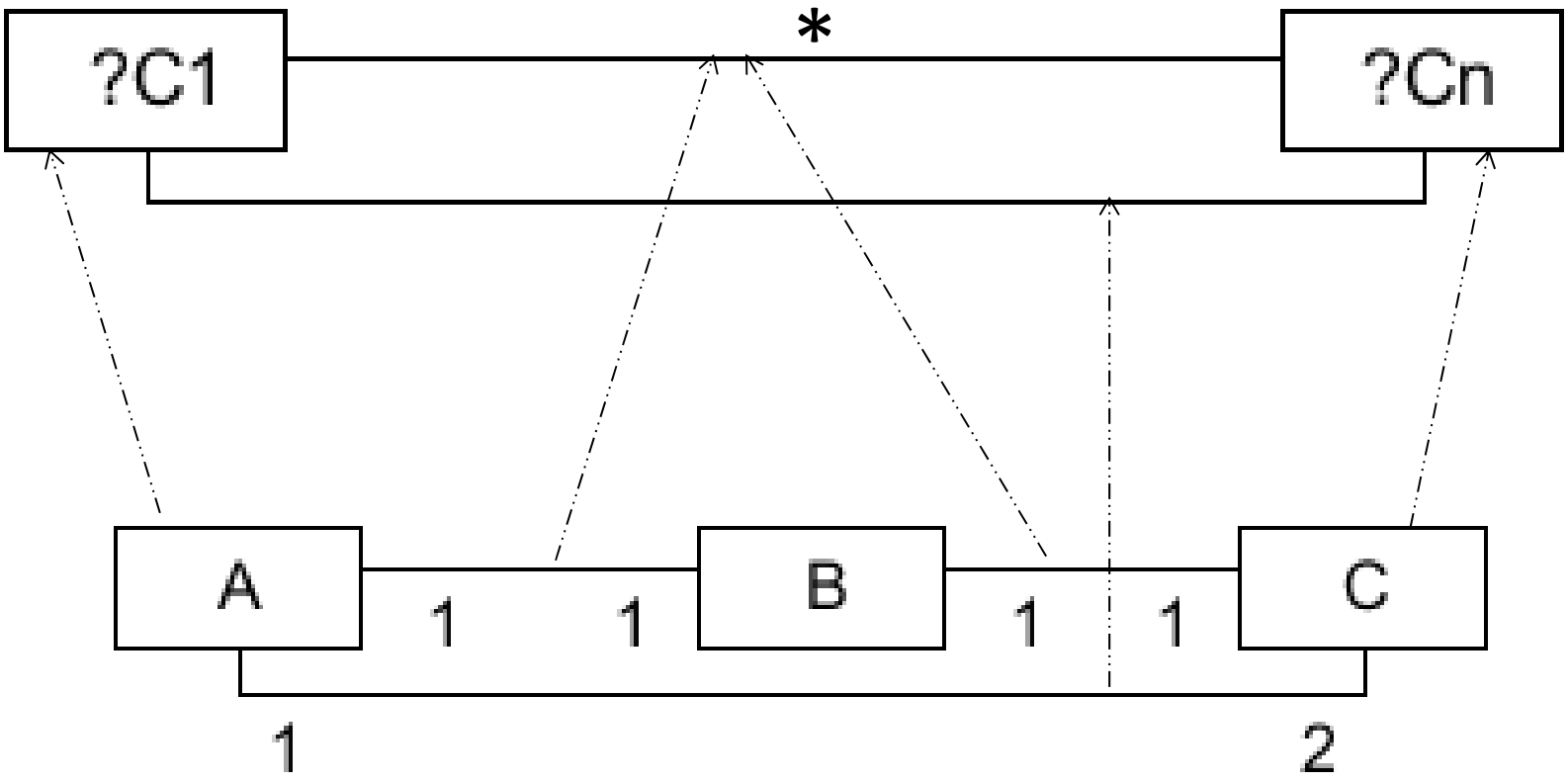
	A path of association with length ≥ 0
	A path of composition (aggregation) with length ≥ 0
	A path of generalization with length ≥ 0
	An interleaved path of associations and generalizations with length ≥ 0
	An interleaved path of compositions and generalizations with length ≥ 0

Example: The Meta-Model enhancement for generalization paths



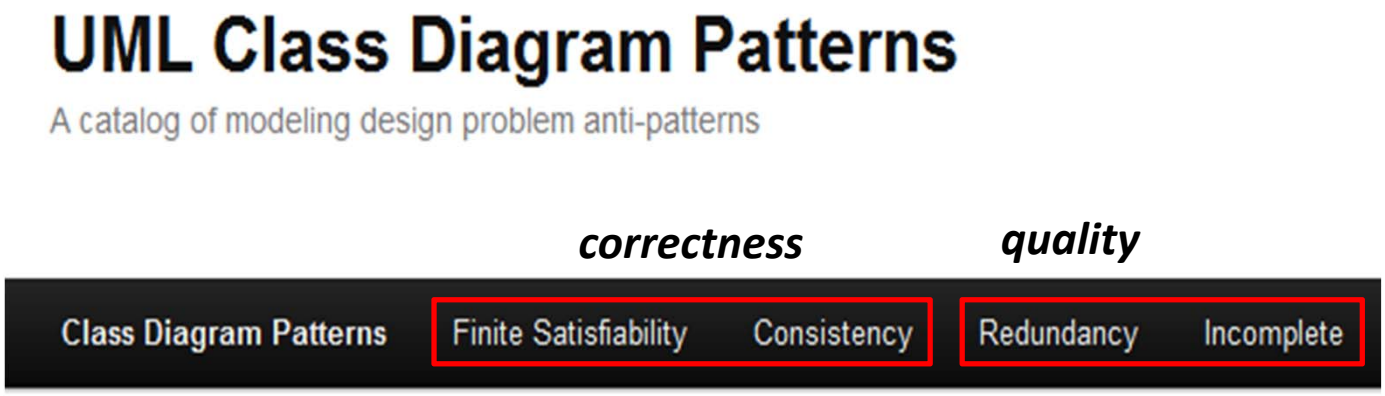


Instantiation of the Pure-Multiplicity-Cycle pattern



The Correctness- Pattern Catalog

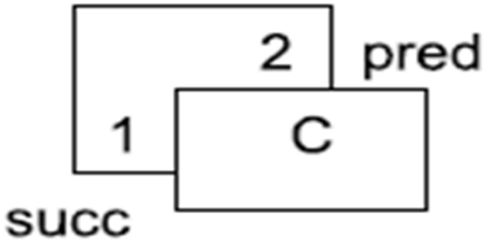
- The catalog includes ***correctness*** and ***quality*** patterns



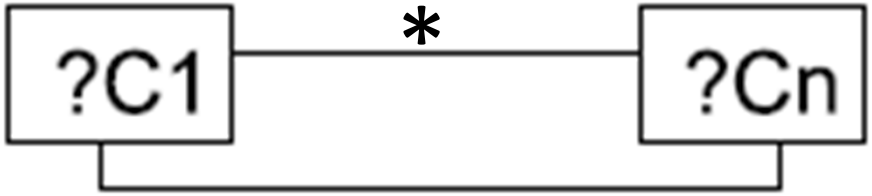
- The catalog currently includes a total of 43 patterns:
  - 15 patterns for finite satisfiability problems, 11 patterns for consistency problems and 17 patterns for quality problems.

The Correctness-Pattern Catalog by example 1

- ***Pattern name***: Pure Multiplicity Cycle (PMC).
- ***Problem***: A cycle of associations with multiplicity constraints might introduce a finite satisfiability problem.
- ***Concrete Example***:



- ***Pattern Identification Structure:***



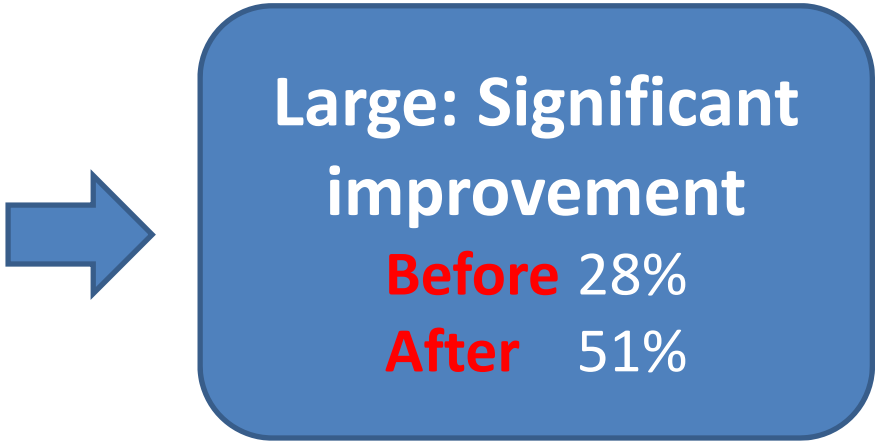
Experiments

Experiment 1

- **Education type**: Concrete examples
- **Experiment**: Real models
- **Checking Mode**: Class Assignment

Experiment 2

- **Education type**: Concrete examples
- **Experiment**: Synthetic models
  - Distinguish small from large
- **Checking Mode**: Class Assignment

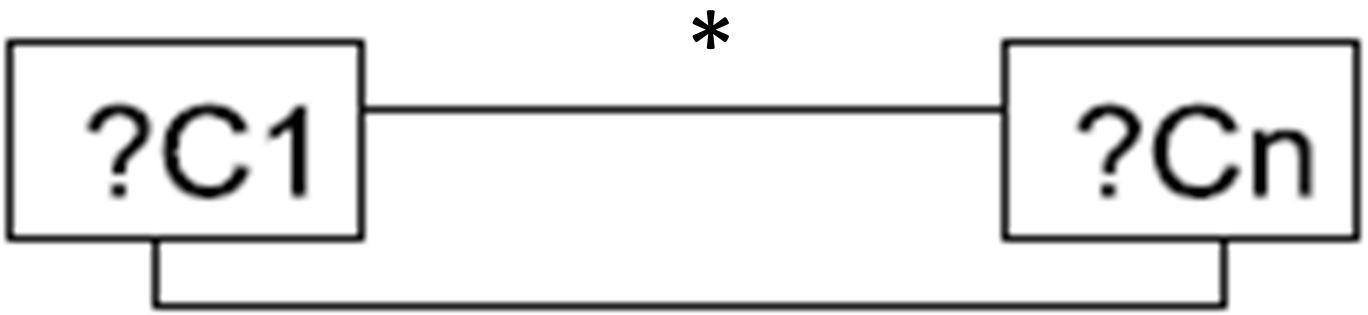


Experiment 3

- **Education type**: Patterns
- **Experiment**: Synthetic models
- **Checking Mode**: Class Assignment

Main consequences

- Correctness patterns effectiveness increase in the case:
  - presented in the abstract form
    - Concrete examples approach decrease the effectiveness
  - models are complex



Conclusion

- Correctness patterns provide guidelines for identifying erroneous models
  - Using patterns is an effective educational tool for developing high modeling skills (Bolloju and others 2009, Tanriover and Bilgen 2011)
    - positive examples enhance syntactic quality
    - negative examples enhance semantic quality

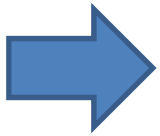
Future work

- Continue developing the catalog
- Including the catalog as a class material in our object modeling courses.
- Link cause identification of the ***FiniteSatUSE*** tool with the catalog of correctness patterns to produce
  - human understandable explanations
  - repair devices

Thank You

Experiment 4

- **Education type**: Concrete examples
- **Experiment**: Synthetic models
- **Checking Mode**: Exam



Large: Significant improvement
Precision 86%
Recall 66 %