A Model Transformation Semantics and Analysis Methodology for SecureUML

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joint work with

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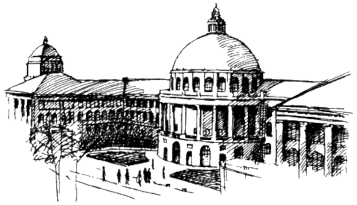

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Outline

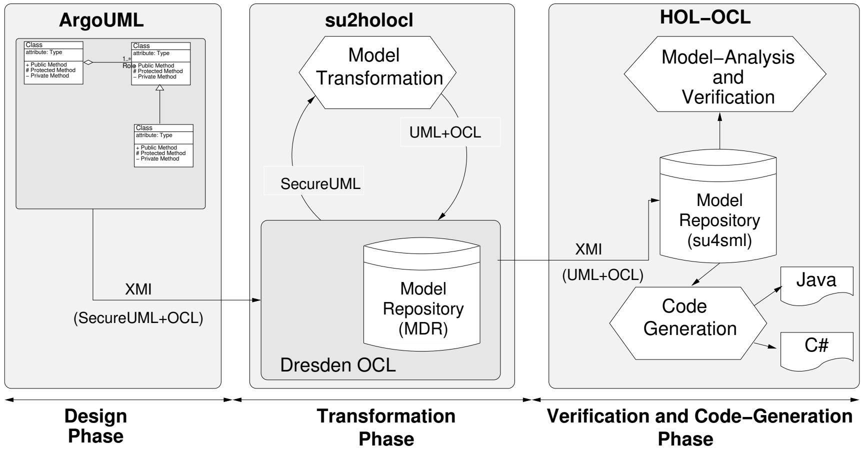
Introduction and Background
  Motivation
  SecureUML

Transformation
  The Authorization Environment
  Design Model Transformation
  Security Model Transformation

Consistency Analysis
  Relative Consistency
  Proof Obligations
  Modularity Results

Conclusion

Our Vision



Modeling Access Control with SecureUML

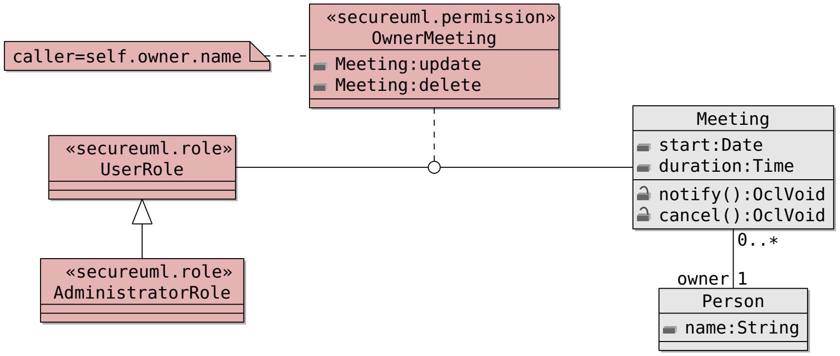
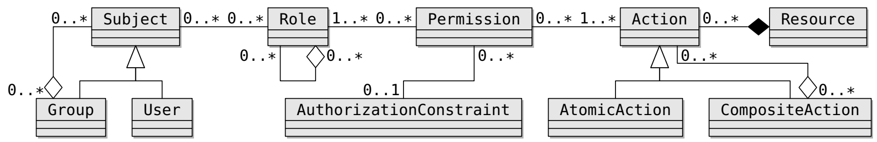


Figure: Access Control Policy for Class Meeting Using SecureUML

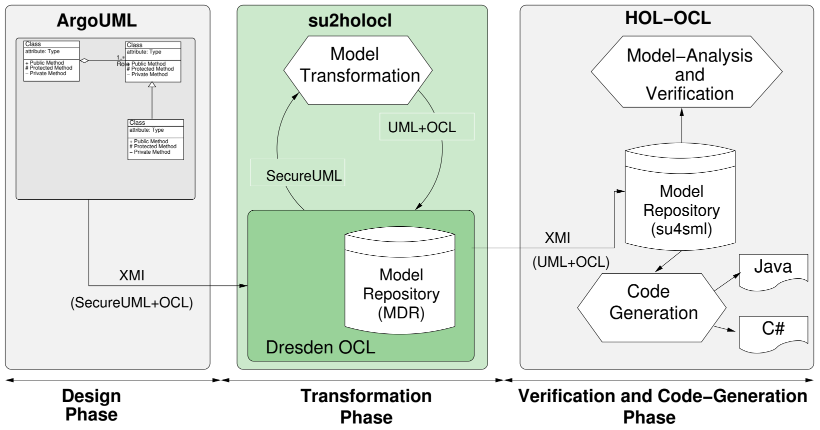
SecureUML



SecureUML

- is a UML-based notation,
- provides abstract Syntax given by MOF compliant metamodel,
- is pluggable into arbitrary design modeling languages,
- is supported by an ArgoUML plugin.

The Model Transformation



From SecureUML to UML/OCL

Substitute the SecureUML model by an explicit enforcement model using UML/OCL.

The transformation basically

1. initializes a concrete authorization environment,
2. transforms the design model,
3. transforms the security model.

The Authorization Environment

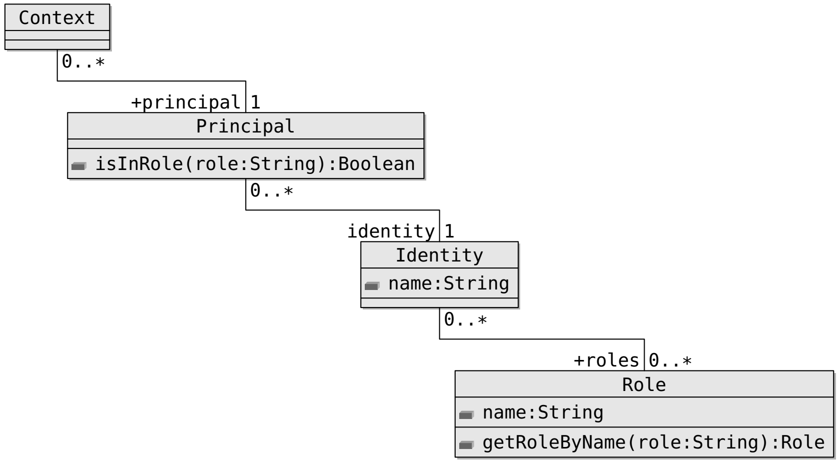


Figure: Basic Authorization Environment

Design Model Transformation

Generate *secured* operations for each class, attribute and operation in the design model.

- for each class `C` we add constructors and destructors,
- for each attribute of class `C` we add getter and setter operations, and
- for each operation `op` of class `C` we add a secured wrapper:

`context` C::op_sec(...):...
  `pre`: pre_{op}
  `post`: $\overline{\mathrm{post}}_{op} = \mathrm{post}_{op}$[f() ↦ f_sec(), att ↦ getAtt()]

Security Model Transformation

- The role hierarchy is transformed into invariants for the `Role` and `Identity` classes,
- Security constraints are transformed as follows:

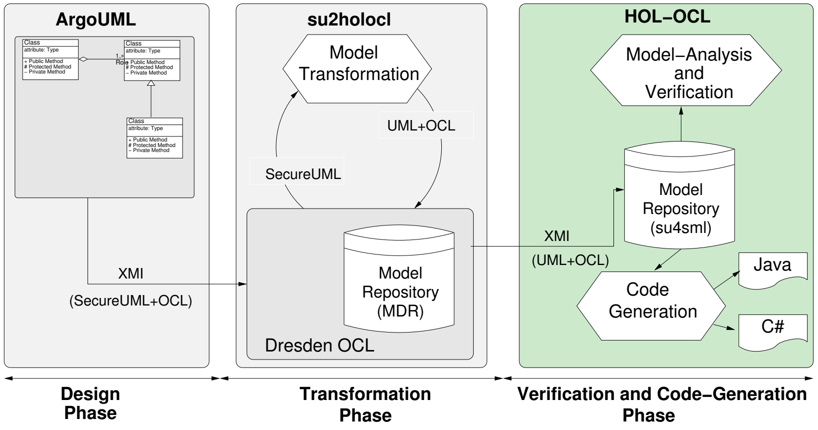
$\mathrm{inv}_C \mapsto \mathrm{inv}_C$

$\mathrm{pre}_{op} \mapsto \mathrm{pre}_{op}$

$\mathrm{post}_{op} \mapsto$ `let auth =` auth_{op}`in`
  `if auth`
  `then` $\overline{\mathrm{post}}_{op}$
  `else result.oclIsUndefined()`
     `and Set{}->modifiedOnly()`
  `endif`

where auth_{op} represents the authorization requirements.

Consistency Analysis



Relative Consistency

- An invariant is invariant-consistent, if a satisfying state exists:

$$\exists \sigma.\ \sigma \vDash inv$$

- A model is global consistent, if the conjunction of all invariants is invariant-consistent:

$$\exists \sigma.\ \sigma \vDash inv_1 \texttt{ and } inv_2 \cdots \texttt{ and } inv_n$$

- An operation is implementable if for each satisfying pre-state there exists a satisfying post-state:

$$\forall\ \sigma_{\mathrm{pre}} \in \Sigma, self, i_1, \ldots, i_n.\ \sigma_{\mathrm{pre}} \vDash \mathrm{pre}_{op} \longrightarrow$$
$$\exists\ \sigma_{\mathrm{post}} \in \Sigma, result.\ (\sigma_{\mathrm{pre}}, \sigma_{\mathrm{post}}) \vDash \mathrm{post}_{op}$$

Proof Obligations

- We require:
  - if a security violation occurs, the system state is preserved
  - if access is granted, the model transformation preserves the functional behavior

  Which results for each operation in a *security proof obligation*:

$$\text{spo}_{op} := \text{auth}_{op}\ \texttt{implies}\ \text{post}_{op} \triangleq \overline{\text{post}}_{op}$$

- A class system is called security consistent if all spo_{op} hold.

Modularity Results

Our method allows for a modular specifications and reasoning for secure systems.

Theorem (Implementability)

An operation `op_sec` *of the secured system model is implementable provided that the corresponding operation of the design model is implementable and* spo_{op} *holds.*

Theorem (Consistency)

A secured system model is consistent provided that the design model is consistent, the class system is security consistent, and the security model is consistent.

Conclusion

We presented

- a modelling approach including access control,
- a toolchain supporting our approach,
- a method for consistency analysis of access control specifications.

Future work includes,

- automatic generation of proof obligations,
- analyzing case studies,
- better proof support for access control specifications.

Appendix

HOL-OCL

HOL-OCL

- provides formal, machine-checked semantics for OCL 2.0,
- servers as a basis for examining extensions of OCL,
- is an interactive theorem prover for OCL (and UML class models),
- publicly available: `http://www.brucker.ch/projects/hol-ocl/`.

Demo available!

Design Model Transformation: Classes

- for each class `C`

```
context C::new():C
  post: result.oclIsNew() and result->modifiedOnly()
context C::delete():OclVoid
  post: self.oclIsUndefined() and self@pre->modifiedOnly()
```

Design Model Transformation: Attributes

- for each Attribute `att` of class `C`

```
context C::getAtt():T
  post: result=self.att
context C::setAtt(arg:T):OclVoid
  post: self.att=arg and self.att->modifiedOnly()
```

Design Model Transformation: Operations

- for each Operation op of class `C`

```
context C::op_sec(...):...
  pre: $\mathrm{pre}_{op}$
  post: $\overline{\mathrm{post}_{op}} = \mathrm{post}_{op}$[f() ↦ f_sec(), att ↦ getAtt()]
```

Security Model Transformation: Role Hierarchy

- The total set of roles in the system is specified by enumerating them:

```
context Role
inv: Role.allInstances().name=Bag{<List of Role Names>}
```

The inheritance relation between roles is then specified by an OCL invariant constraint on the `Identity` class:

```
context Identity
inv: self.roles.name->includes('<Role1>')
     implies self.roles.name->includes('<Role2>')
```