The **U**nified **M**odeling **L**anguage

Opportunities and Challenges for Formal Methods

Stuart Kent

University of Kent @ Canterbury, UK
www.cs.ukc.ac.uk

Outline

- An update on UML
- Language definition
- Tools
- A precise OO meta-modeling facility - MMF

Outline

- **An update on UML**
  - **A little history**
  - **UML and other OMG standards**
  - **The OMG revision process**
  - **UML related RFP's**
  - **UML profile RFP's**
  - **UML 2.0**
- Challenges & opportunities - Language definition
- Challenges & opportunities - Tools
- A precise OO meta-modeling facility - MMF

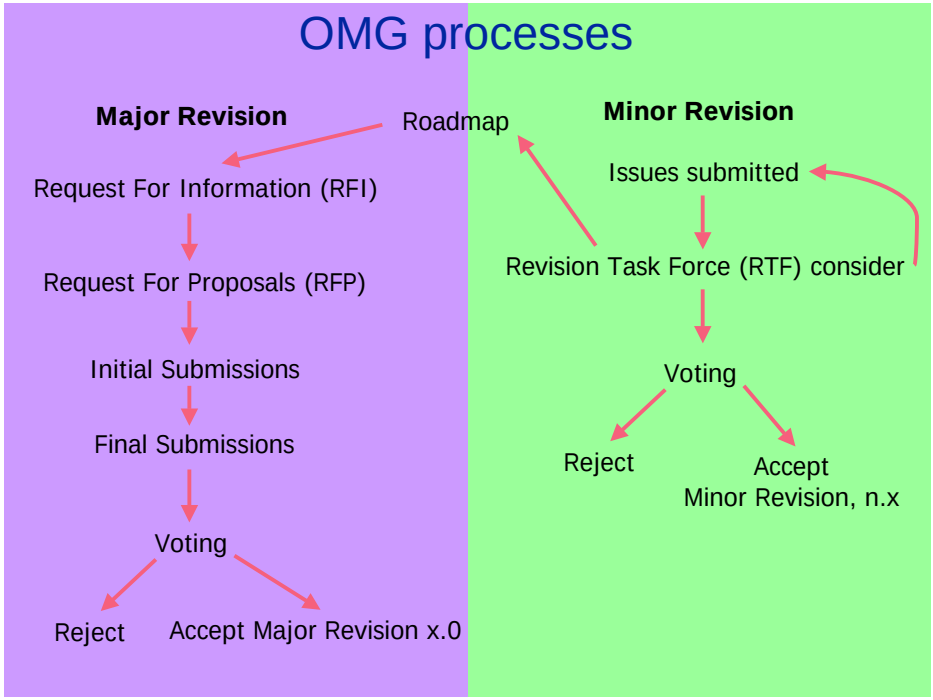
A little history

- UML began with Rational and the 3 amigos
- OMG put out a request for proposals for a standard object modeling language
- A number of consortiums put in initial submissions
- Initial submissions were combined into the eventual final submission, under one consortium
  - exception: the OPEN group
- UML was accepted by and **passed over to** the OMG
- Revision of UML is now in the hands of the OMG
- Possibility of ISO standardisation

UML & other OMG standards

- MOF
  - Language for describing other languages
  - Meta-models in MOF used to generate IDL and XMI
- CORBA (IDL)
  - Generate IDL from meta-model in MOF
  - IDL represents set of interfaces to a repository supporting that meta-model
  - UML could be one such meta-model
  - Generate IDL from (certain) UML models
- XMI (XML interchange)
  - Dictates how UML and MOF models are interchanged in XML
  - Based on MOF technology

OMG processes



UML related RFP's

www.omg.org/techprocess/meetings/schedule/

- Action Semantics
- Various Profiles
- UML 2.0
  - 4 RFP's
  - RFP's just issued; awaiting initial submissions

Action Semantics

- Goal is to sort out
  - abstract syntax
  - semantics

  For an **action language** for UML
- Initial submission received
- Adopts a meta-modeling approach
- Semantics expressed as a mapping from abstract syntax to possible executions

UML Profile RFP's

- EDOC – Enterprise Distributed Object Computing
  - Working on merging 2 initial submissions
  - Component architecture, viewpoints & whole lifecycle
  - Closely tied to EAI (intersecting teams)
- Textual language for EDOC profile
  - Awaiting initial submissions
- CORBA profile
  - Use UML to write IDL (in a nutshell)
  - Revised submission received
- Scheduling profile
  - Real-time profile for UML (in a nutshell)
  - Awaiting initial submissions
- Event Based Architecture in Enterprise Application Integration (EAI) profile
  - Working a single joint revised submission
  - Closely tied to EDOC

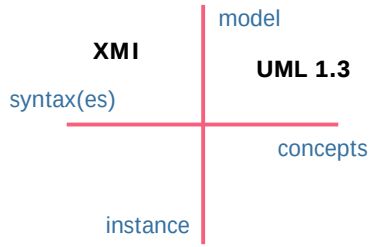
UML 2.0

- 4 RFP's
  - **Infrastructure**
  - Superstructure
  - Object Constraint Language (OCL)
  - Diagram interchange (planned)
- UML 2.0 Working Group

  www.celigent.com/omg/adptf/wgs/uml2wg.htm

Infrastructure

- Alignment with MOF
- Family of languages
  - Notation mix
  - Profiles
  - Language Evolution
  - Patterns
- Comprehensive definition + separation of concerns



- The precise UML group & IBM have done a feasibility study on this. Discussed later. Also see www.puml.org

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  - **Challenges**
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Language definition - challenges

- UML is a family of languages
  - Profiles
  - Continual evolution – product lines?
- Accessibility of the definition and tools used to produce it
  - Who are the stakeholders?
- Backwards compatibility with the existing definition
  - What does this mean, exactly?
  - Who are the stakeholders?
- Separation of concerns (syntax, semantics etc.)
  - Visual languages?

Language definition - opportunities

- Formal language definition is at the heart of FM
- Two approaches (at least):

Translate UML to a FM

- E.g. UML to PVS or Object Z

\+ Makes use of abstractions from semantic domain already captured by FM

– Definition can be **colored** by FM

– May not address
  - Family issues
  - Accessibility of definition
  - Backwards compatibility
  - Visual language issues

Adapt FM techniques to UML

- Address challenges directly, borrowing from FM as appropriate
  - Borrow from FM separation of concerns
    - Concrete/abstract syntax
    - Model-theoretic/axiomatic semantics
  - Learn from graph grammar work in defining diagrammatic syntax
- Example is pUML feasibility study

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Tools - challenges

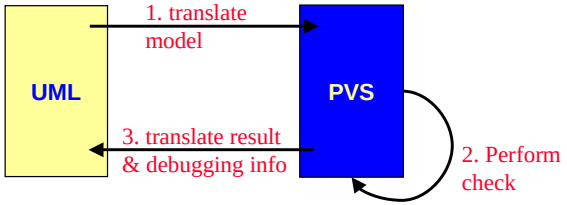
- Tools that allow a model to be exercised and reasoned with
  - Testing models – instance generation and instance checking
  - Reasoning
  - Feedback is given through the modeling language
- Specialized (visual) language editors
  - VL = diagrams + editor
  - 3D?
- Support for language families
  - Federated architecture
  - Automatic generation of tools from definitions

Tools - opportunities

- FM delivers techniques for exercising models:
  - Automated reasoning
  - Model checking
  - Animation (in presence of partial models)
- 2 approaches to utilizing these techniques:

Translate UML to a FM

- Can make use of existing tools
- Feedback is the challenge, e.g.



Tools - Opportunities

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Translate UML to a FM

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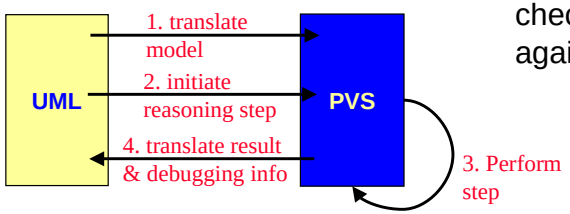
Adapt FM techniques to UML

- Diagrammatic reasoning
- A tool specifically for checking UML instances against UML models



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- **A precise OO meta-modeling facility - MMF**

Goals of MMF

To provide a **rearchitected definition** of UML which:

- is **precise** to the degree that
  - conformance can be checked systematically, without argument and, preferably automatically
  - self-consistency of the definition can be established.
- is **comprehensive**, covering syntax, both concrete and abstract, and semantics. On the other hand, redundant and overlapping concepts should be kept to a minimum.
- accepts that UML is a **family** of languages, providing mechanisms which
  - allow profiles and language extensions to be defined in a controlled and managed way
  - make the relationships of profiles and extensions to existing language fragments explicit and unambiguous.
- is **accessible** to tool builders and those involved in the standardization of the language.

Results

Intellectual Property

- A Meta-Modeling Facility (MMF)
- Fragments of a rearchitected definition of UML

Concrete Artefacts

- A report describing the facility and UML fragments
- A tool supporting the facility
- available from www.puml.org

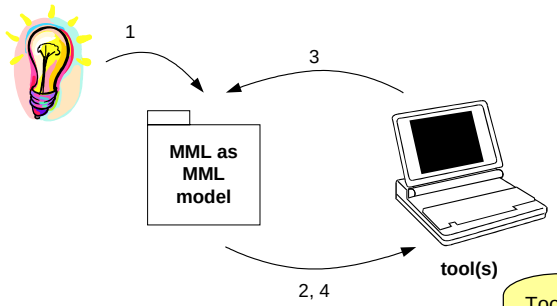
Conclusion

- Rearchitecting UML using pOOMM approach is entirely feasible

Meta-Modeling Facility (MMF)

- MMF = MM Language (MML) + MM Tool (MMT)
- MML
  - is used to define the UML family
  - is a member of the UML family
  - has facilities for componentizing language definitions, maintaining a separation between
    - → Language aspect (model–instance, syntax–concepts)
    - → Subject area (static core, constraints, model managament, etc.)
- MMT supports
  - checking
  - reflection
  - constraint execution

Precision – a confidence trick

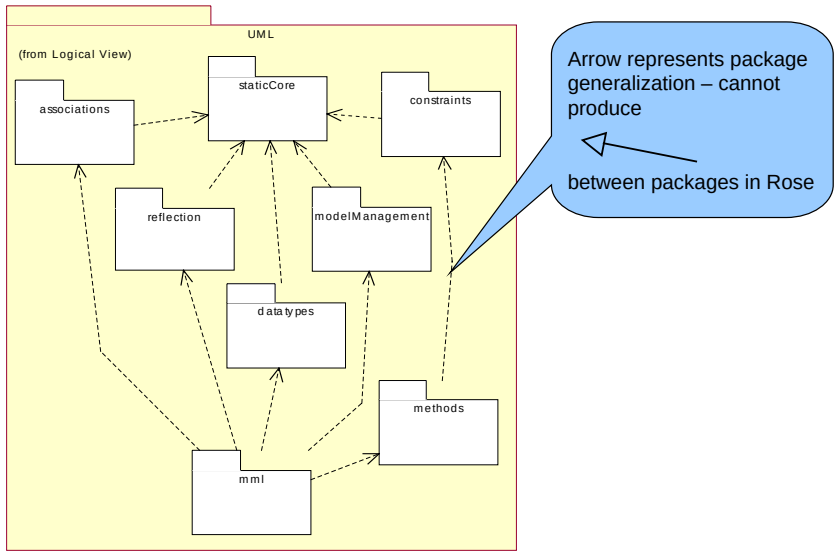


Tool is based on a small, object-based virtual machine. Can define a formal semantics for this machine.

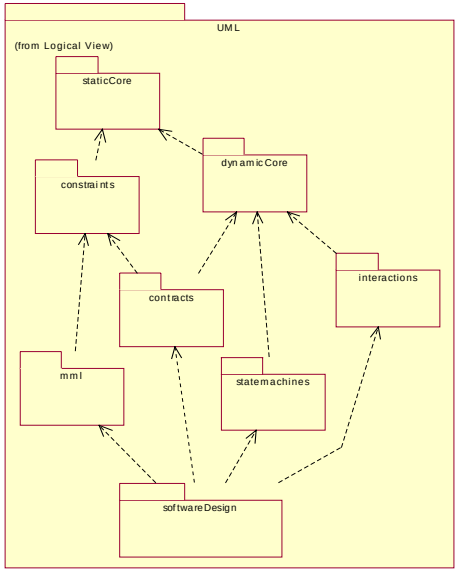
1. Construct a MML model of MML
   - based on intuitive semantics of MML
   - class/package diagrams + constraints
2. Implement tool based on that model; define MML in tool
3. Learn from tool to improve model
4. Implement changes in tool and definition in tool

- Confidence increases the more one cycles through 3, 4

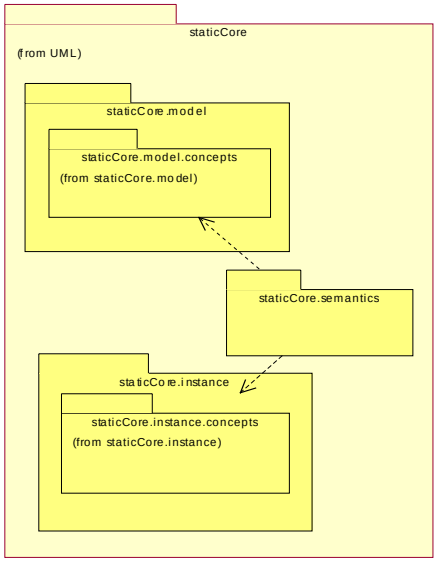
UML Architecture: subject areas



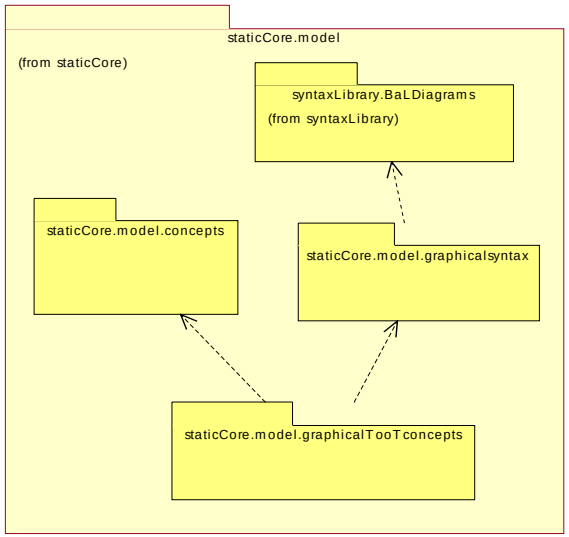
UML Architecture: subject areas



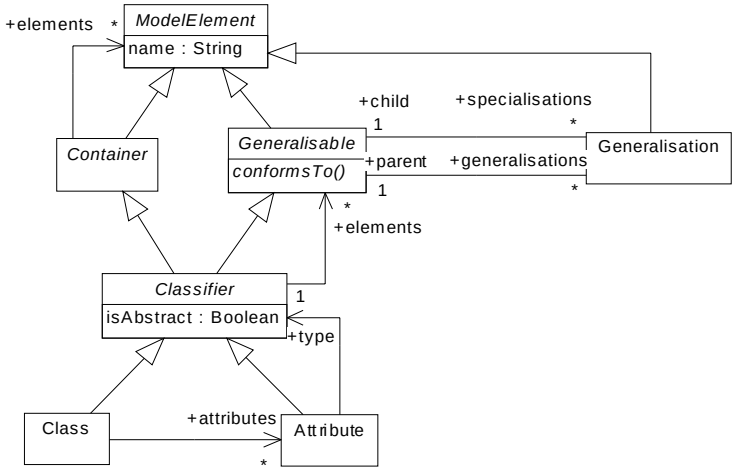
Semantics: model – instance



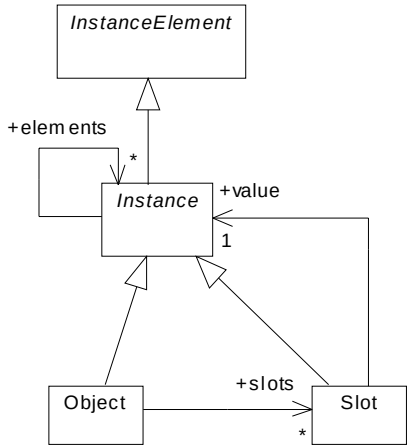
Syntax – concepts



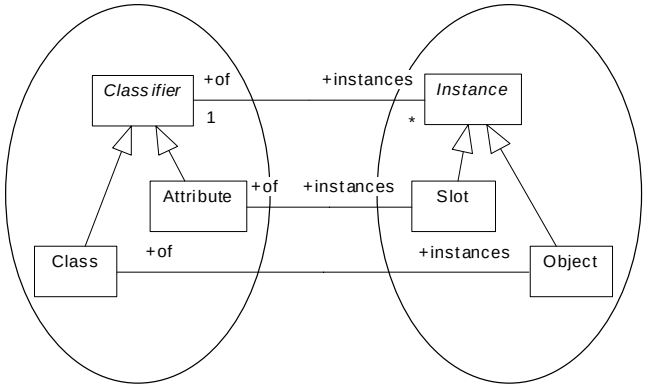
The staticCore.model.concepts package



The staticCore.instance.concepts package



The staticCore.semantics package



Concepts (abstract syntax) Semantic domain

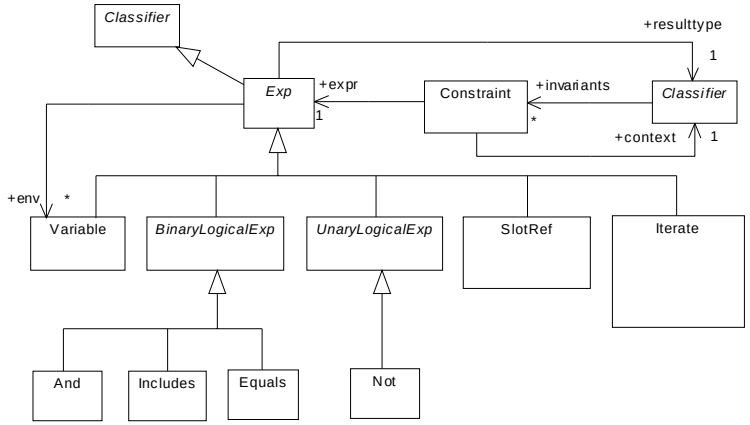
OCL constraints for semantic mappings

```
context uml.staticCore.semantics.Instance inv:
satisfies(c : Classifier) : Boolean
if self.of = c then
        of.allContents() -> forall(e1 |
                elements -> exists(e2 |
                e2.name = e1.name and
                e2.satisfies(e1)))
        else false
endif
```


A systematic method for extending MML

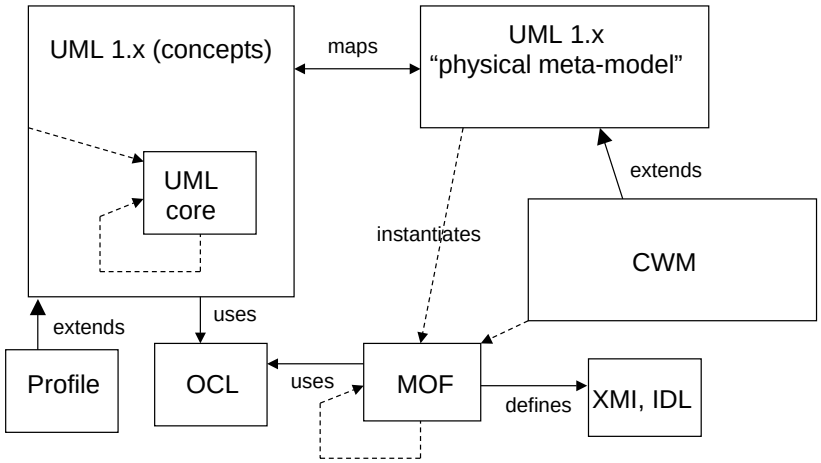
1. determine whether the model element is a subclass of Classifier, i.e. exhibits the properties of a generalisable container;
2. if so, subclass the model element from Classifier in the model.concepts package;
3. constrain the model element's contents to be those of the attribute 'elements';
4. in the instance.concepts package, identify or add a new instance subclass which is an instance of the classifier;
5. in the semantics package, link them by subclassing the 'of/instances' association;
6. for each element of the new model element repeat steps 4-5;
7. determine any dependencies between instances and their elements, and specify these using appropriate constraints.

MML includes a model of OCL



+ instance.concepts and semantics

Current architecture of UML / MOF



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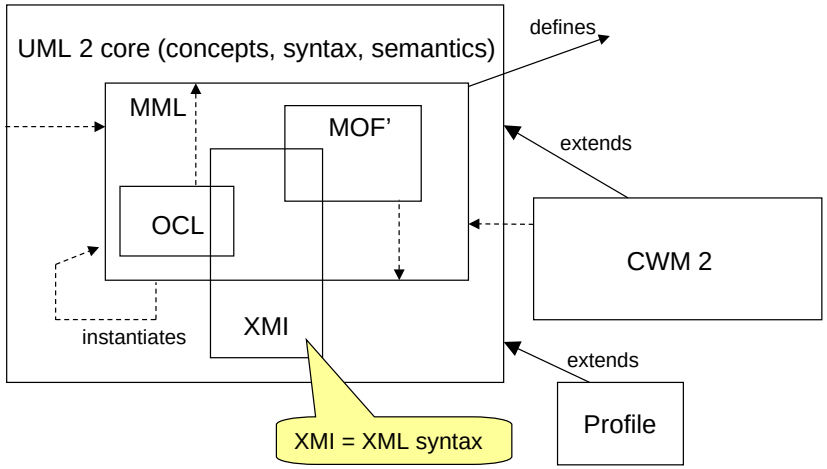
A possible new architecture for UML / MOF



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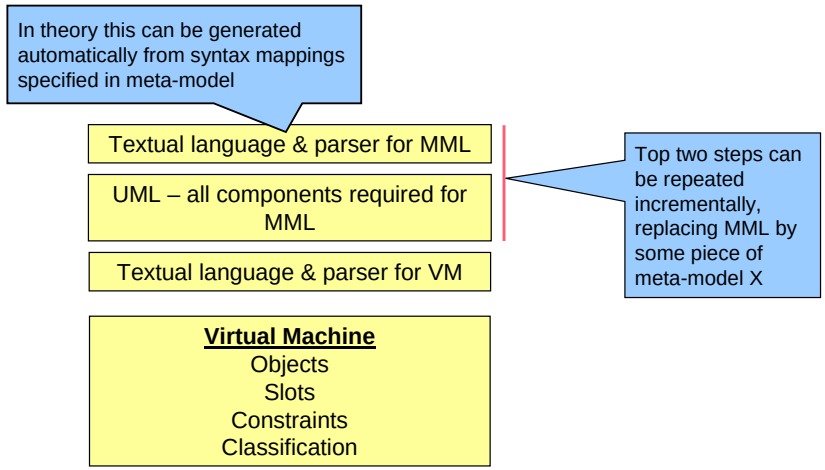
MMT architecture



Advantages of MMT

- Meta-models, models and instances can be checked for correctness against their definition
- Tool to support MML comes from executing MML meta-model in virtual machine
  - Changes are easy to implement
  - As well as ability to check a M-M against MML, the M-M can be executed providing direct tool support for the M-M (CASE tool generation)
- Because of comprehensive M-M, this should also support e.g. syntax mappings
- User only needs to deal with MML and languages defined in MML

Conclusions

- FM has a lot to offer UML, specifically:
  - Patterns and techniques for formal language definition
  - Semantically sophisticated tools
- There is an opportunity **now** to make UML into a formal language. Key challenges are:
  - To treat UML as a family of languages
  - To provide accessible definitions
  - To deal with visual syntax
  - To rework all the stuff for dynamic modeling
  - To deal with backwards compatibility issues
- Users could really do with tools that allow models to be exercised. Key challenge is:
  - To feedback results and debugging information through UML
- Reworking the UML infrastructure using a precise OO meta-modeling approach should (at least) provide a better platform for FM folks to work from