UNIVERSITY OF AGDER

Meta-models and Grammars

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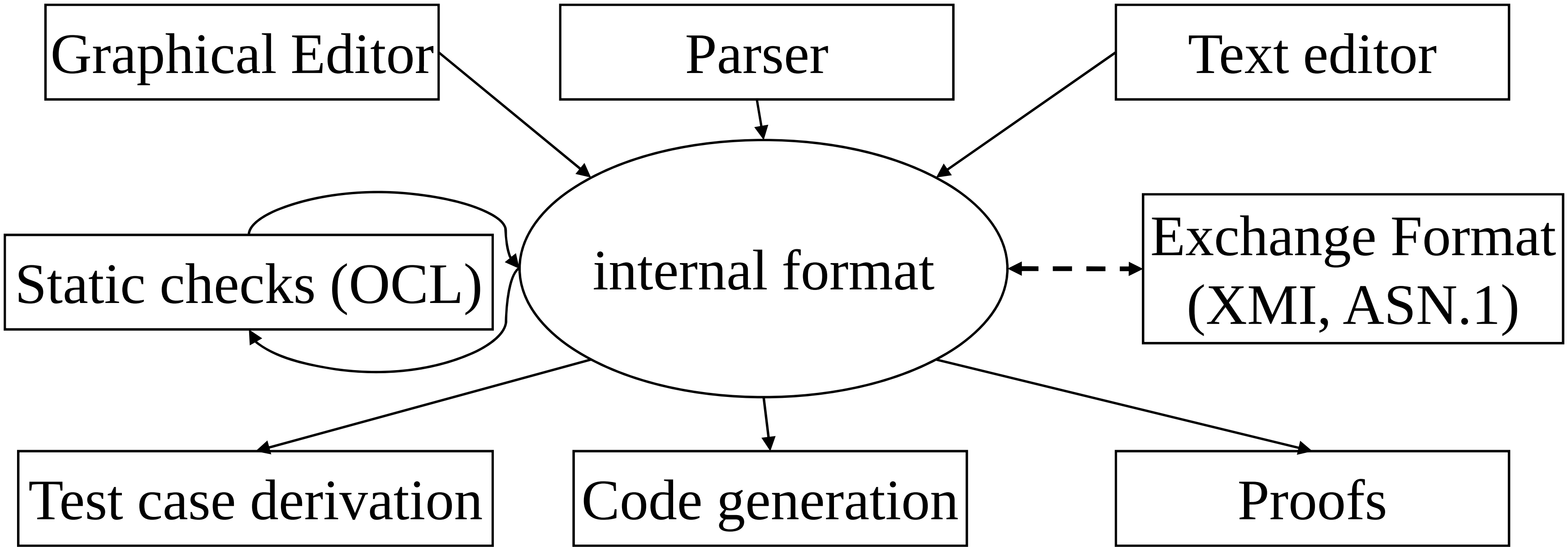
Introduction, Compilers
Modelling & Meta-modelling
Examples
Meta-models vs. Grammars
Summary

Challenges for Compilers

- graphical languages / combined languages
- fast production of compilers:
  - domain specific languages
  - small languages
- platform dependent code generation
- combination of tools
- language design!

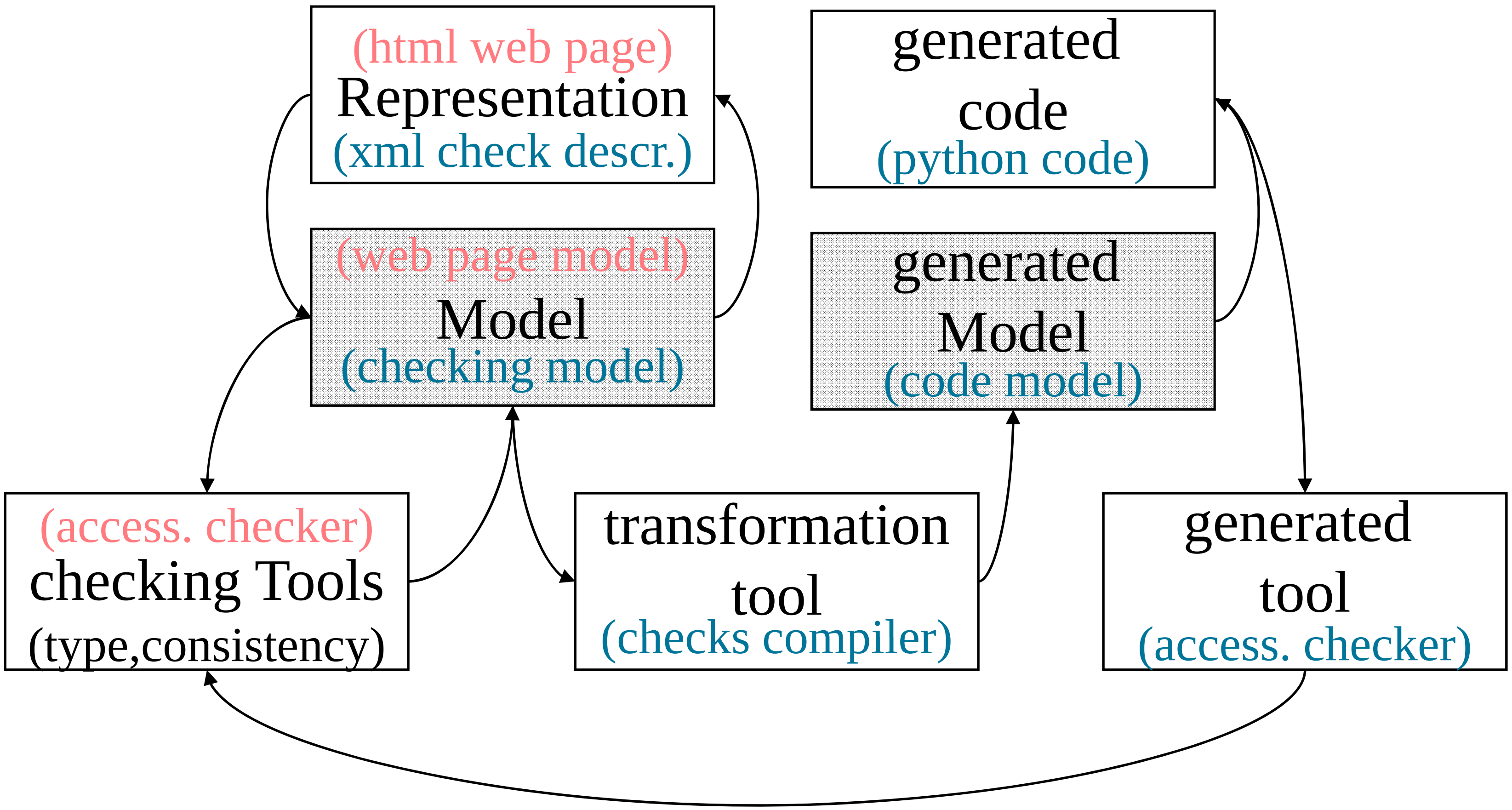
- but also: less focus on optimization because of high-level output languages

Solution 1: abstract syntax



- Solved: many input/output formats
- Graphical / Domain specific languages, many transformations
- internal format based on: abstract syntax, meta-model, MOF-structure

Importance of abstract syntax



Problem speed / many languages

- Why do we need many languages?
  - Higher abstraction levels – use of models
- A model is an abstraction of a (part of a) system.
  - one model describes several systems, one system can have several models
  - simplified view of a system with respect to criteria
  - needs a representation, e.g. using a language
- Models on different abstraction levels: Modelling language, Programming Language, Assembler, Machine code, Bits, Electricity, Atoms, ...

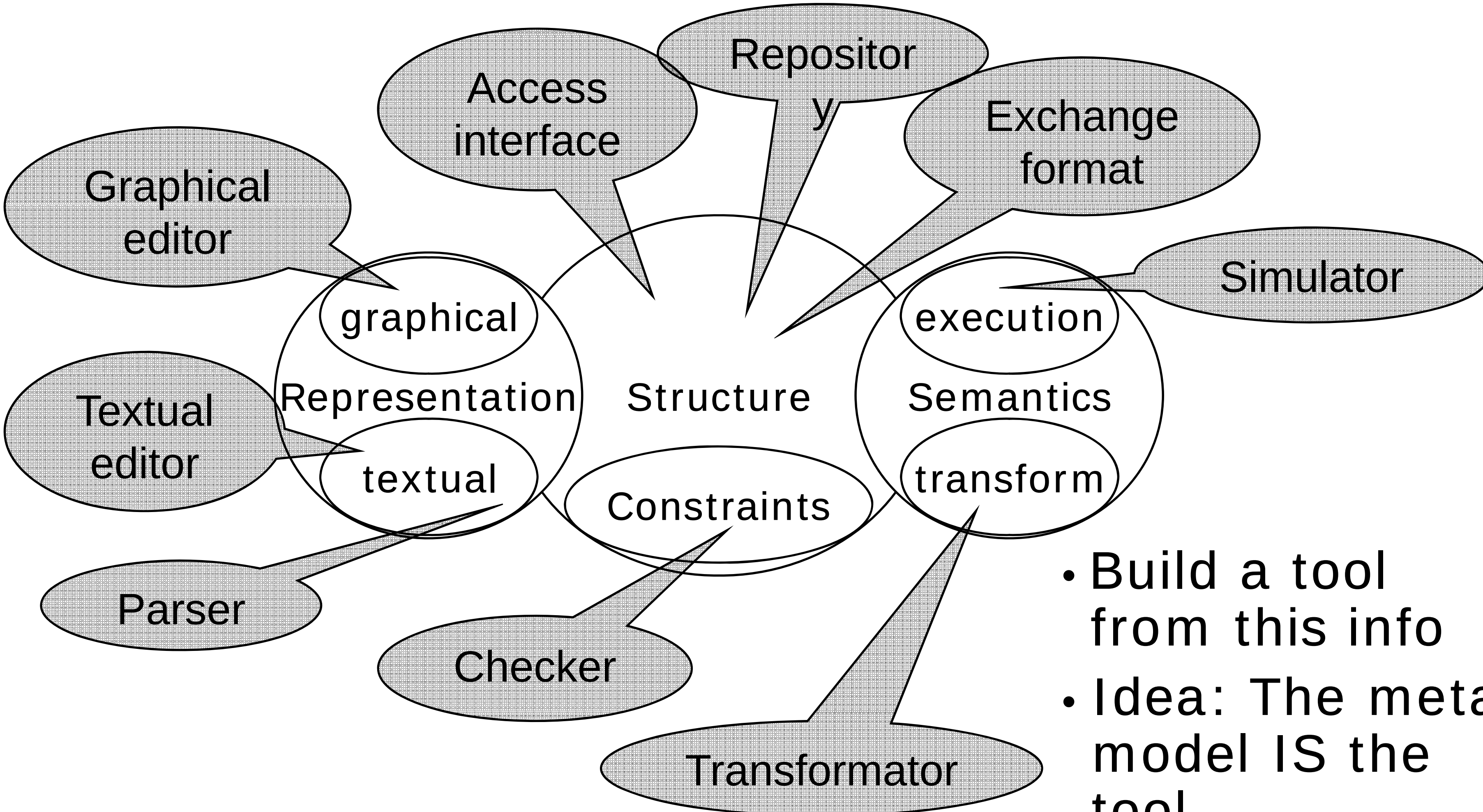
Solution: Language Description

- Do not write compilers, but describe languages
- Meta-model = high-level description of a language
  - narrow view: concepts of the language
  - wider view: all important aspects of the language, i.e. concepts, presentation, static and dynamic semantics
- Meta-models (language descriptions) are also languages and have aspects.

Aspects of Compilers/Languages

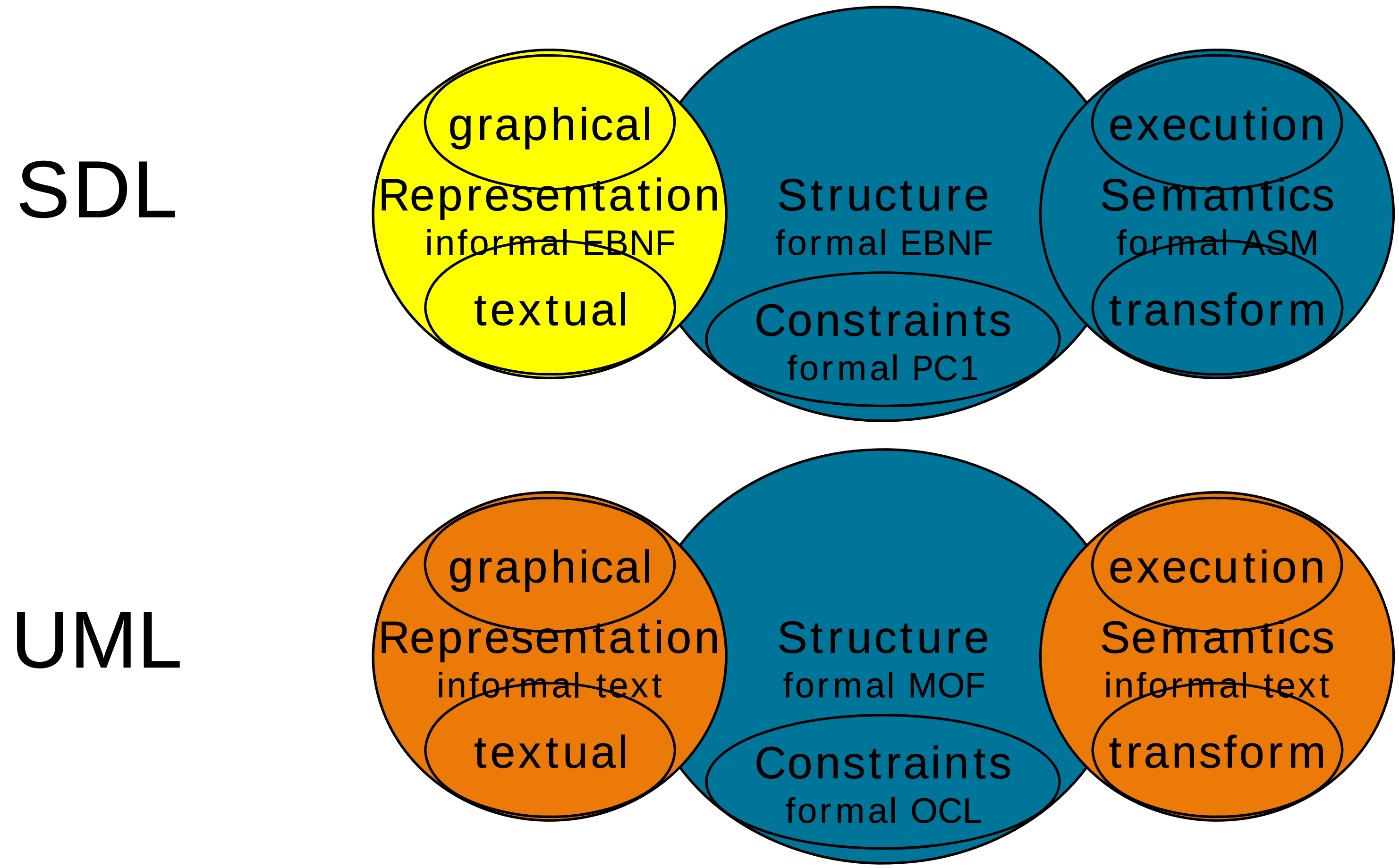
- Language structure: What are the concepts? How are they related?
- Static semantics: additional conditions, what is allowed?
- Representation: How are programs written? -> graphical vs. textual
- Dynamic semantics: What do the programs mean? How to generate code for them?

Aspects of a language & tools

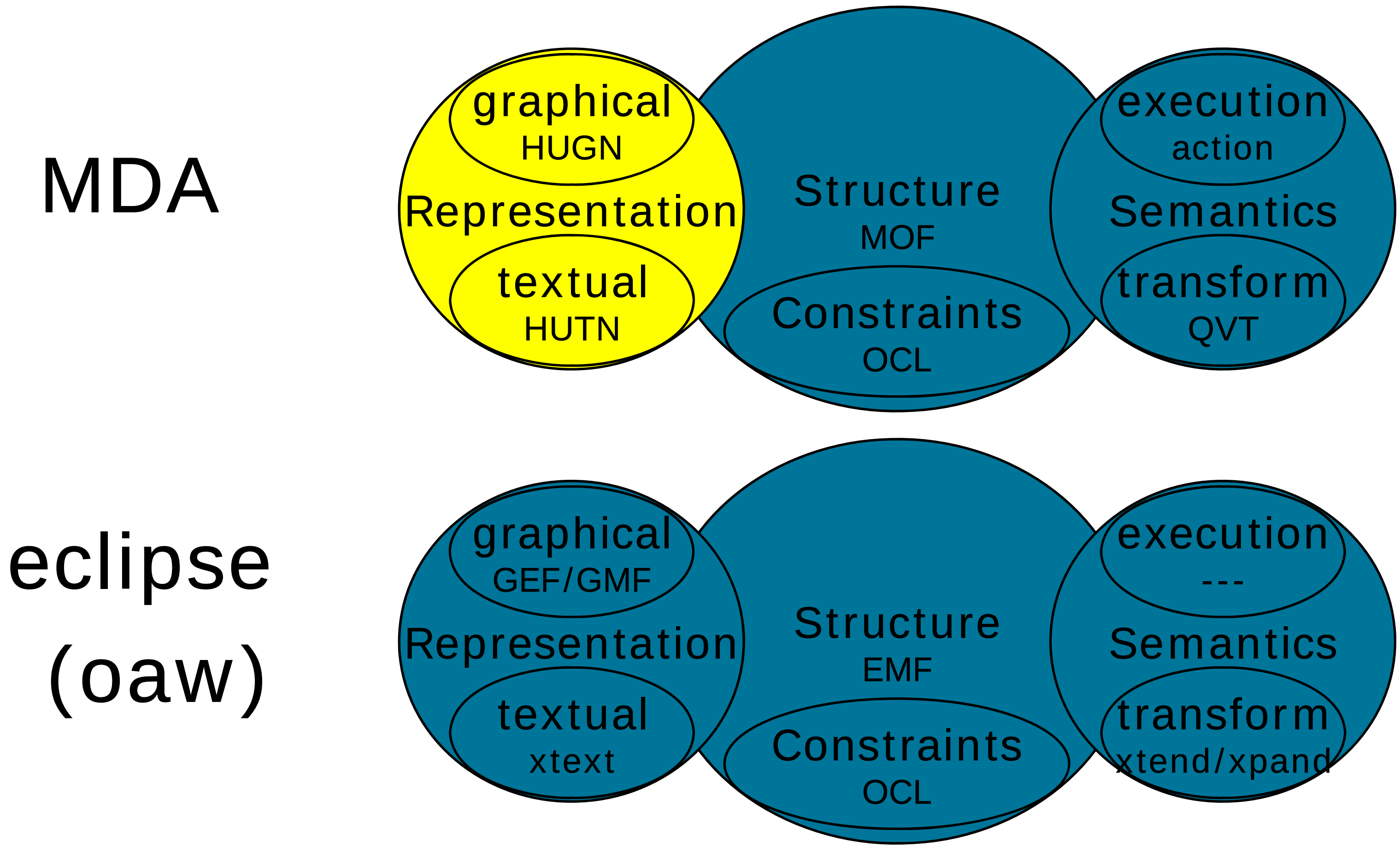


- Build a tool from this info
- Idea: The meta-model IS the tool.

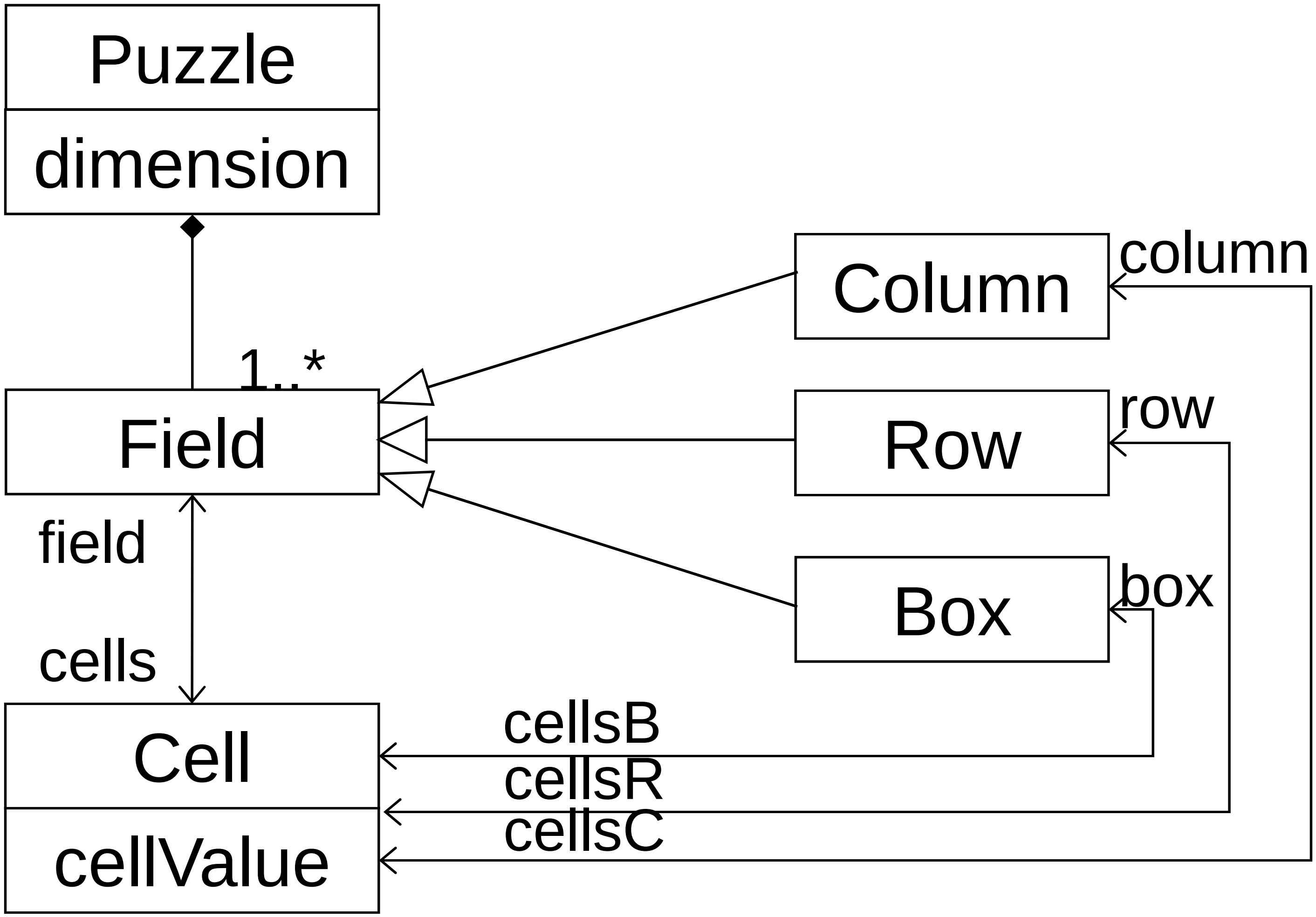
Aspects for SDL and UML



Language support in MDA and Eclipse



Simple sample structure (EMF)



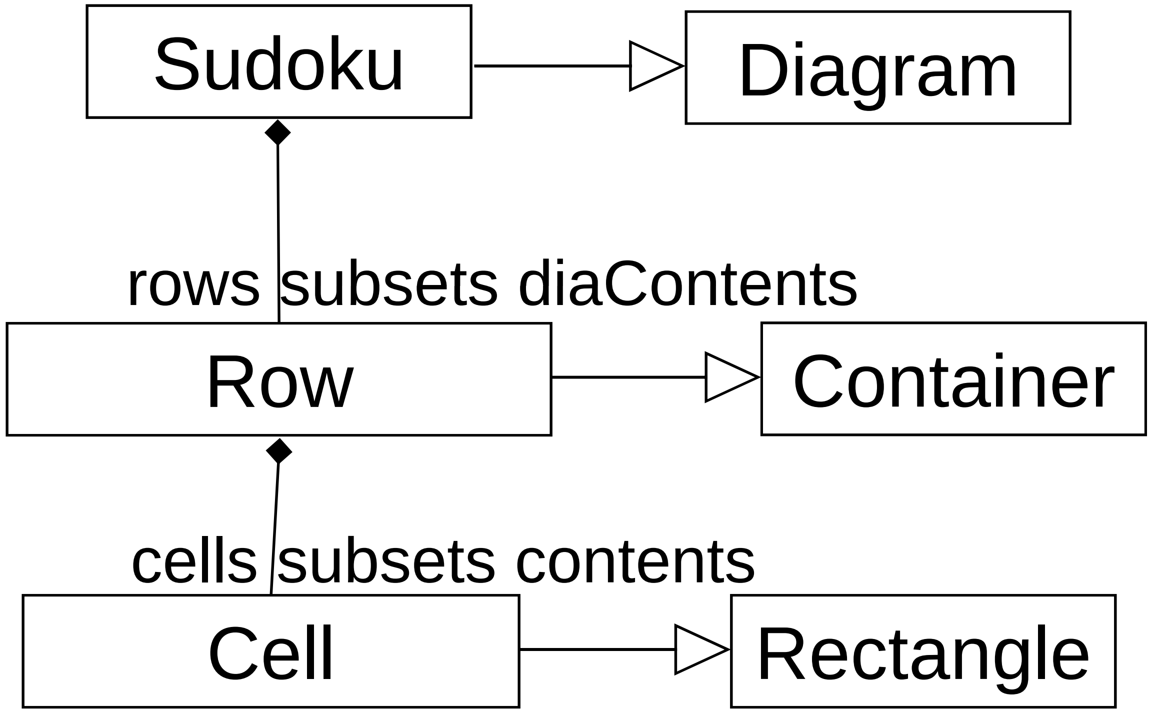
Simple sample constraints (OCL)

```
context Field inv uniqueICellValues:
self.cells->forAll(c1,c2 : Cell | c1<>c2 implies
        c1.iCellValue <> c2.iCellValue)

context Cell inv rowFromCell:
self.row -> size()=1

context Puzzle inv numberOfBoxes:
self.Elements->select(f : Field |  f.oclIsTypeOf(Box))
-> size()=9
```

Simple sample text syntax (TEF)

```
syntax toplevel PuzzleTpl, ecorepath “..." {
 element CellTpl for Cell{ single for iCellValue, with INTEGER; }
 element RowTpl for Row{
  "Row"; "(";
  sequence for cellsInRow, with @CellTpl, seperator ",", last false;
  ")";
 }
 element PuzzleTpl for Puzzle{
  "Puzzle"; "("; single for iDimension, with INTEGER; ")"; "=";
  sequence for Elements, with @FieldTpl, seperator ",", last false;
 }
 choice FieldTpl for Field{ @RowTpl }
}
```

Simple sample graphics



Simple sample transformation (QVT)

```
transformation theOne (source : sudoku, target: sudoku){
 top relation change1to16 {
  checkonly domain source sudoku:Cell { iCellValue = 1 };
  enforce domain target sudoku:Cell { iCellValue = 16 };
 }
 top relation change6to11 {
  checkonly domain source newstructure:Cell { iCellValue = 6 };
  enforce domain target newstructure:Cell { iCellValue = 11 };
 }
 top relation nochange { value: Integer;
  checkonly domain source newstructure:Cell { iCellValue = value };
  enforce domain target newstructure:Cell { iCellValue = value };
  when{ iCellValue <> 1 or iCellValue <> 6; }
} }
```

Simple sample execution

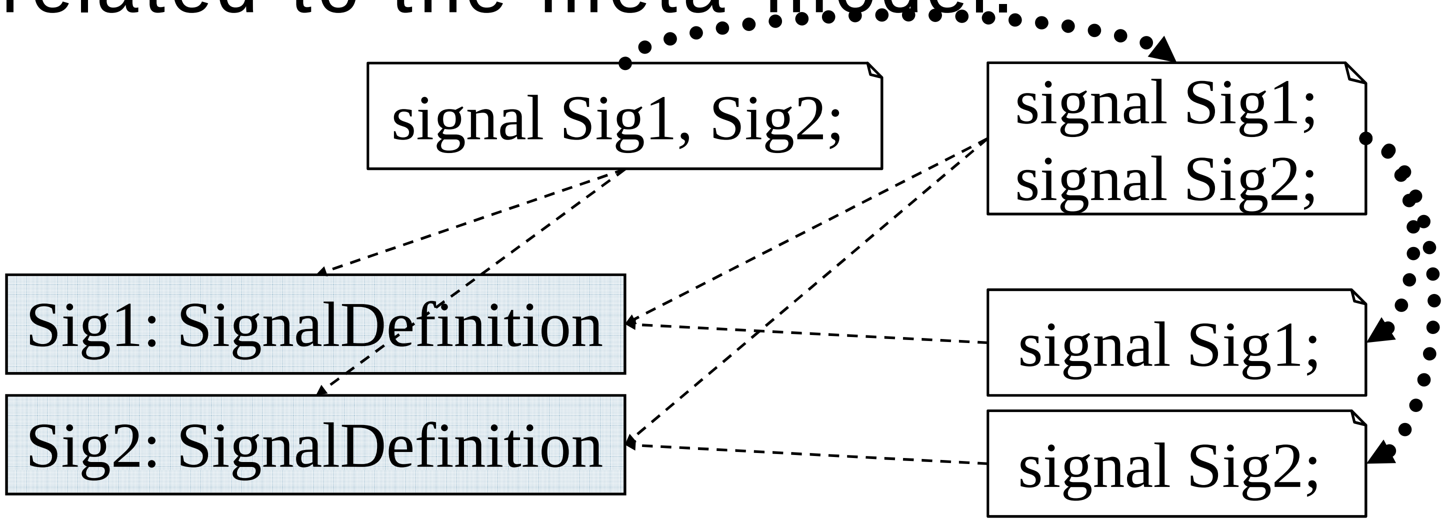
```
Run(s:Sudoku) =def
  forall f in self.field do RunF(f)
Runf(f:Field) =def
  choose c in self.cell with c.value=null
      and c.possible.size = 1
    choose v in c.possible do c.value:= v
  choose c in self.cell with c.value<>null
    forall cc in self.cell do
      delete c.value from cc.possible
```

Problem area execution

	Syntax	Runtime
Meta-model	Cell	RTCell e.g. history, possibilities
Model	X:Cell	A: RTCell B: RTCell

Problem area “representation”

- There are usually several representations for the same meta-model instances.
- Tools and theory exist only for the case 1:1.
- A representation is a separate model that is related to the meta-model.



Meta-models versus grammars

- Advantages of grammars
  - Strong mathematical basis
  - Tree-based
  - Trees can be extended into general graphs
  - Several advanced tools available
  - Easily understandable
- Advantages of meta-models
  - Direct representation of graphs (graphics!)
  - Namespaces and relations between language elements (in particular for language transformations and combinations)
  - Object-oriented definition of oo languages
  - More problem-oriented
  - Reuse and inheritance
  - Tools allow direct handling of models (repositories)
  - Structuring possible (e.g. packages)

Grammars → meta-models

1. Every symbol is represented with a class.
2. A rule with a single symbol on the rhs is represented with an association between the class representing the lhs and the rhs.
3. A rule with a composition on the rhs is represented with an association for every sub-expression.
4. A rule with an alternative on the rhs is represented with a generalization for every sub-expression.
5. A sub-expression consisting of just one symbol is represented with the symbol's class.
6. A sub-expression being a composition or an alternative is represented with a new class with new name. The composition is then handled like a rule.

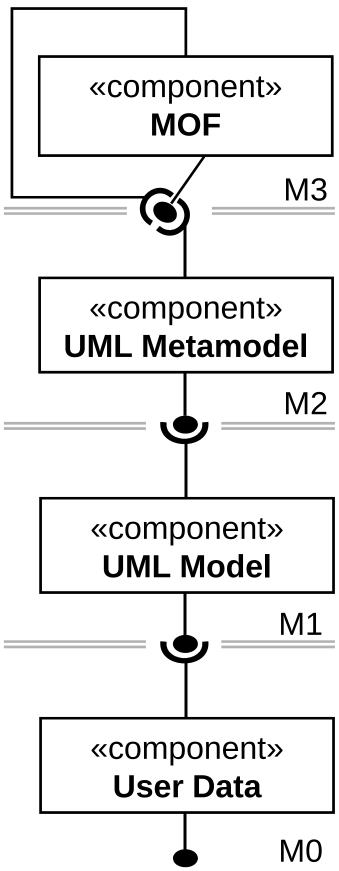
Using the transformation for SDL

- Joachim Fischer, Michael Piefel, Markus Scheidgen: A Metamodel for SDL-2000 in the Context of Metamodelling ULF in Proceedings of SAM2006
- Introduction of abstract concepts
  - General: namespace, namedElement, typedElement
  - Specific: parametrizedElement, bodiedElement
- Introduction of relations
  - Procedure name versus procedure definition
- Deletion of grammar artefacts
  - Referencing: identifier, qualifier
  - Names in general
  - Superfluous structuring

Conclusions / Summary

- Future language definitions based on meta-models.
  - definition of good meta-models is difficult
  - need also agreement (standard)
  - patterns for good models needed, maybe joint concepts
- Meta-models / Languages have several aspects: structure + constraints, syntax, semantics
- Formal language definitions allow tool generation
  - Direct access to the models
  - Easy exchange of representation or several of them
  - Combination of tools handling the language
  - Description of relations between languages
- This leads to model-driven compiler technology.

A meta-modelling architecture



OMG Level	Examples	Grammar example	OCL example
3 = meta meta model	MOF	EBNF	MOF
2 = meta model	UML MM	Java grammar	OCL language
1 = model	UML Model	a program	a formula
0 = instances	real objects	A run	a truth value

Instances on several levels