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Model-driven Compiler Construction

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Meta-Introduction, Meta-Languages
DSL, Compilers, Modelling
Examples
Meta-models vs. Grammars
Summary

Meta-Introduction A

- *Say* your name
- *Go* to the right side
- *Explain* the sequence-rule
- *Explain* the skip-rule
- *Go* to the left side
- *Explain* the meaning of life
- *Select* one participant
- *Pass* the word to the selected person, *Switch* to the next slide and *Sit down* on your seat

Meta-Introduction B

- *Say* your name
- *Go* to the right side
- *Draw* a circle on the blackboard
- *Explain* the term ”Meta”
- *Explain*
- *Go* to the left side
- *Extrapolate* positively
- *Select* one participant
- *Pass* the word to the selected person, *Switch* to the next slide and *Sit down* on your seat

Meta-Introduction C

- *Say* your name
- *Read* the following text aloud
  - The term “meta” means *transcending* or *above.*
  - In our context, “meta” can be replaced by the following phrases:
    - is a description of
    - is a model of
    - is an abstraction of
- *Select* Prof. Andreas Prinz
- *Pass* the word to the selected person, *Switch* to the next slide and *Sit down* on your seat

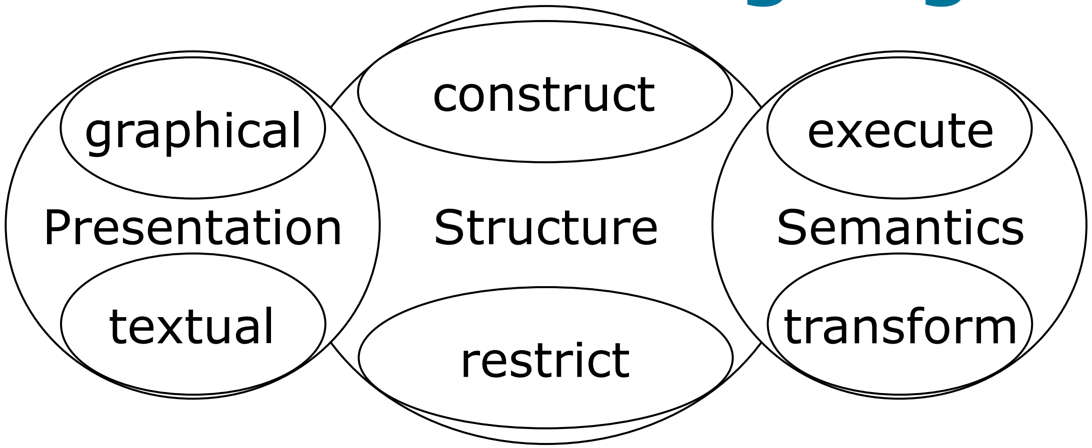
Meta-lecture

- description of a lecture
- if it is
  - formal (formulated in a formal language)
  - complete (on some level of abstraction)
  - executable (has semantics)
- then we can execute it (on a computer)

Meta-language

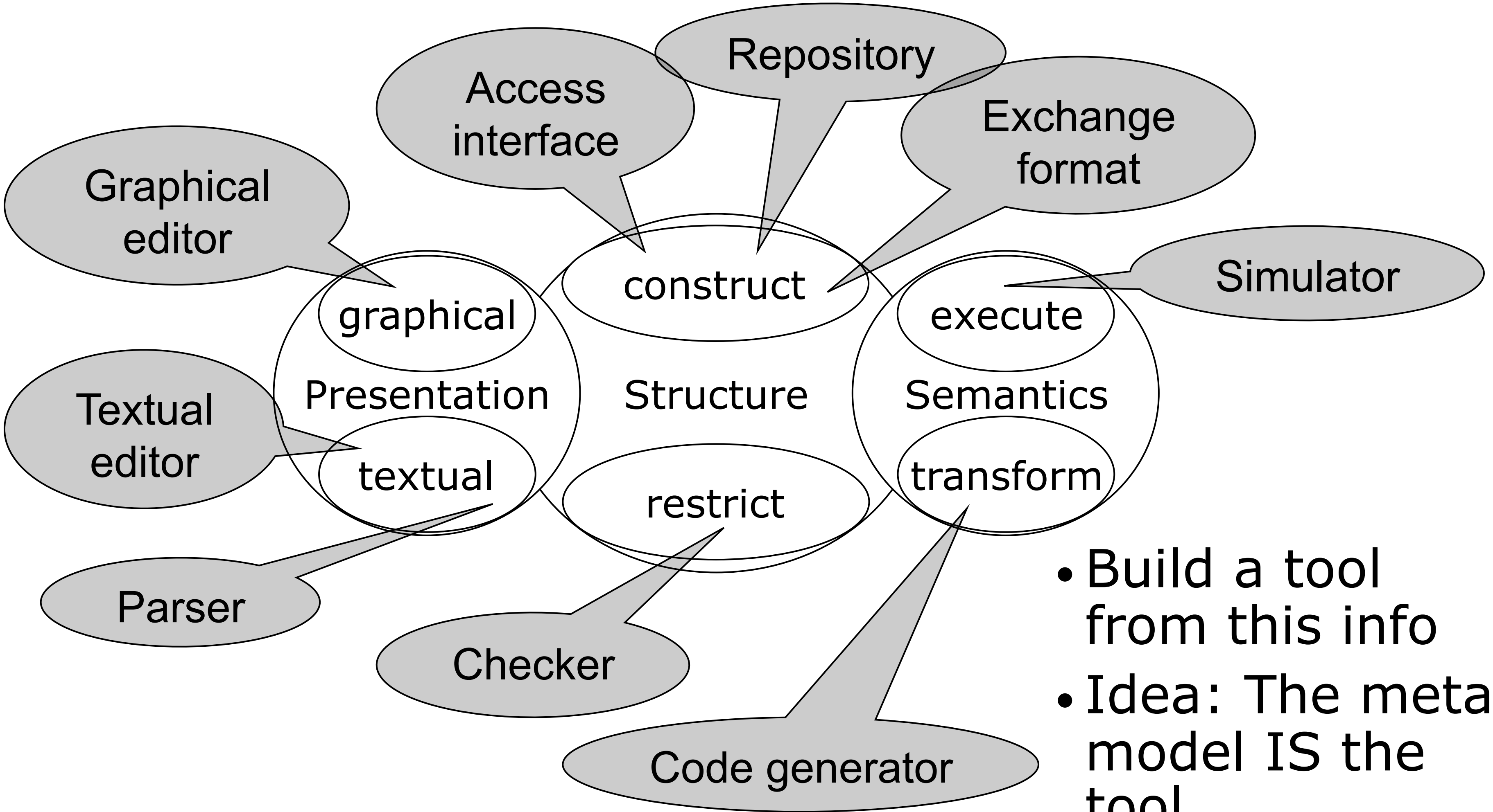
- description of a language
- if it is
  - formal (formulated in a formal language)
  - complete (on some level of abstraction)
  - executable (has semantics)
- then we can execute it (on a computer)

What describes a language?



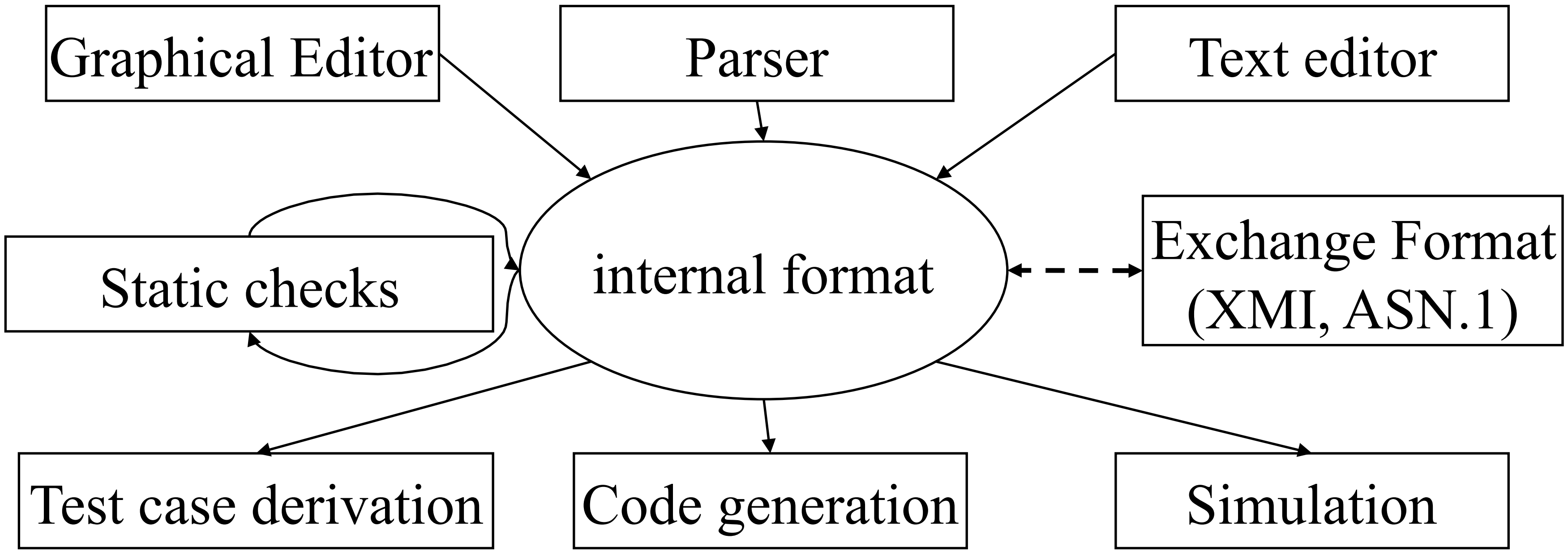
- Language structure
  - construct: concepts and their relations
  - restrict: conditions, constraints
- Presentation
  - textual: text that presents that structure
  - graphical: graphics for the structure
- Semantics (Meaning)
  - transform: translate to another language
  - execute: run the statements

Aspects of a language & tools



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

Language tools: compilers



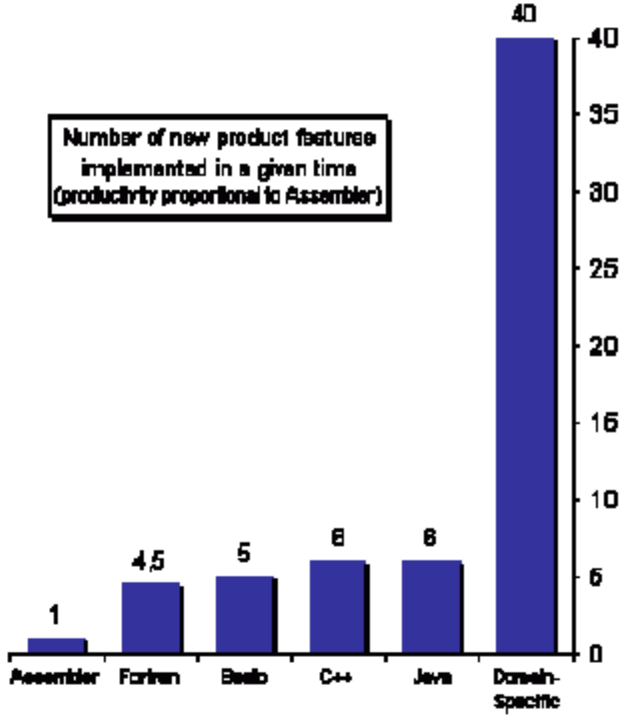
- Solved: many input/output formats
- Graphical / Domain specific languages, many transformations
- platform dependent code generation
- combination of tools
- internal format based on: abstract syntax, meta-model, MOF-structure

Why to describe Languages?

- graphical languages / combined languages
- domain specific languages
  - small languages
  - higher abstraction levels – use of models
  - fast production of compilers
- Needs good language design!
- Less focus on optimization because of high-level output languages

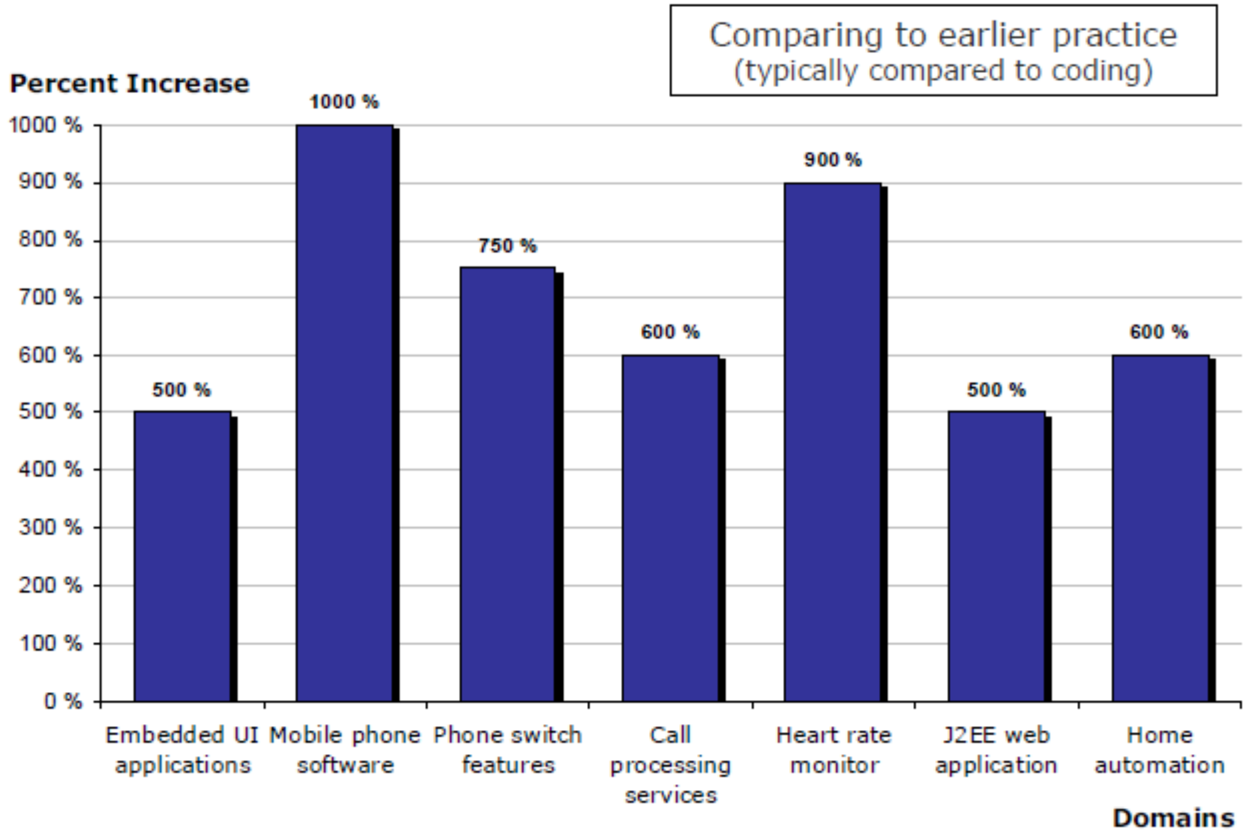
A rise in productivity is overdue

- "The entire history of software engineering is that of the rise in levels of abstraction"
- New general-purpose programming languages have not increased productivity
- Abstraction of development can be raised above current level…
- … without losing control or accepting substandard results



*Software Productivity Research & Capers Jones, 2002

Productivity increase from DSM



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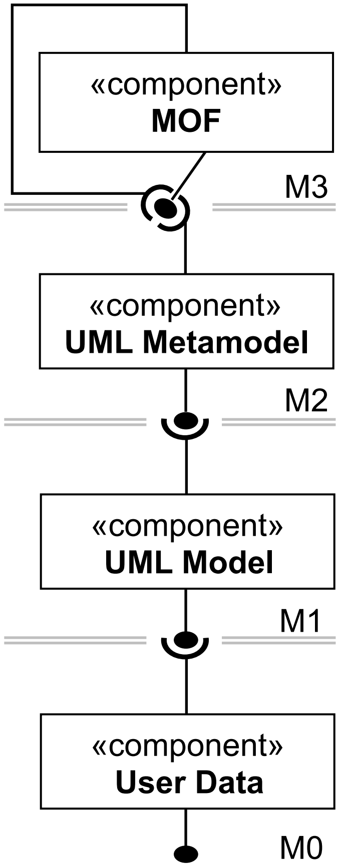
Models and systems

- 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, …
- 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
- Language descriptions use also DSLs and have aspects.

A meta-modelling architecture

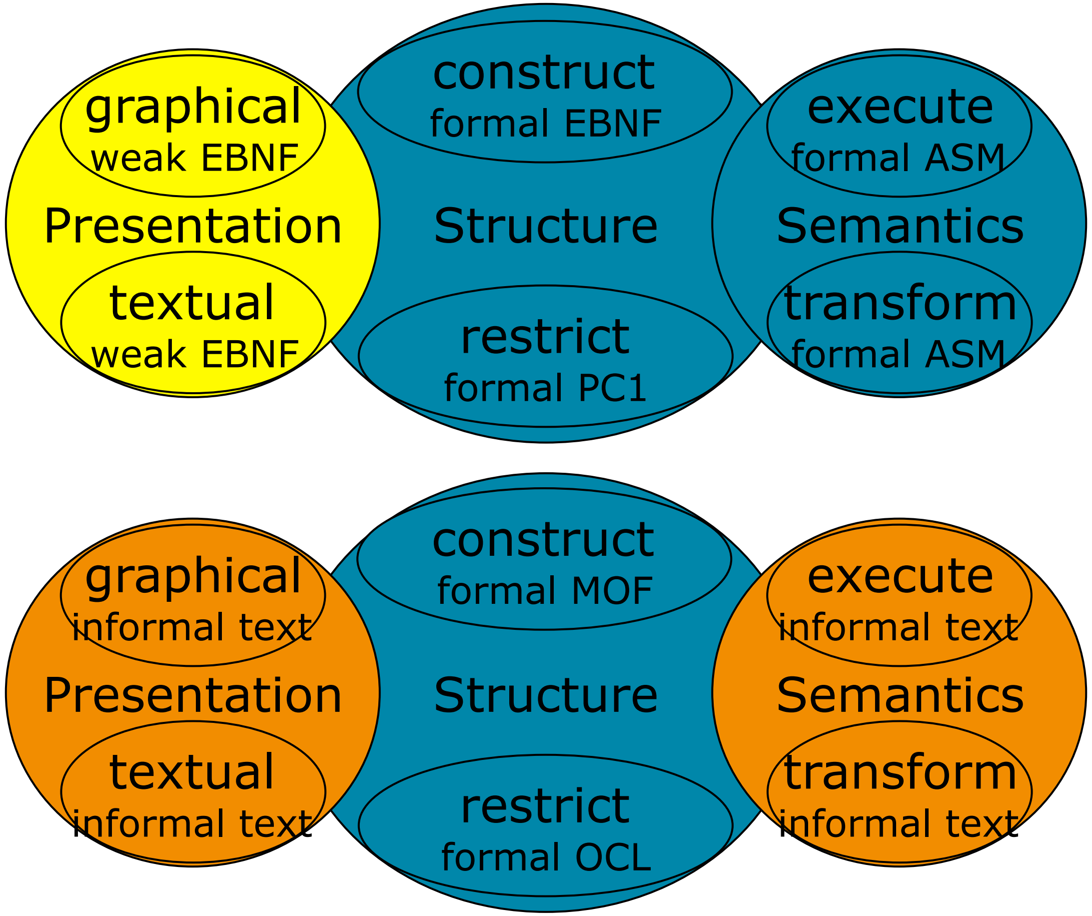


OMG Level	Examples	Grammar example	OCL example
3 = meta meta model	MOF	EBNF	MOF
2 = meta model	UML MM	Java grammar	OCL language
1 = model	UML Model	a program	a formula
0 = instances	real objects	A run	a truth value

Language Aspects for SDL and UML

SDL

UML



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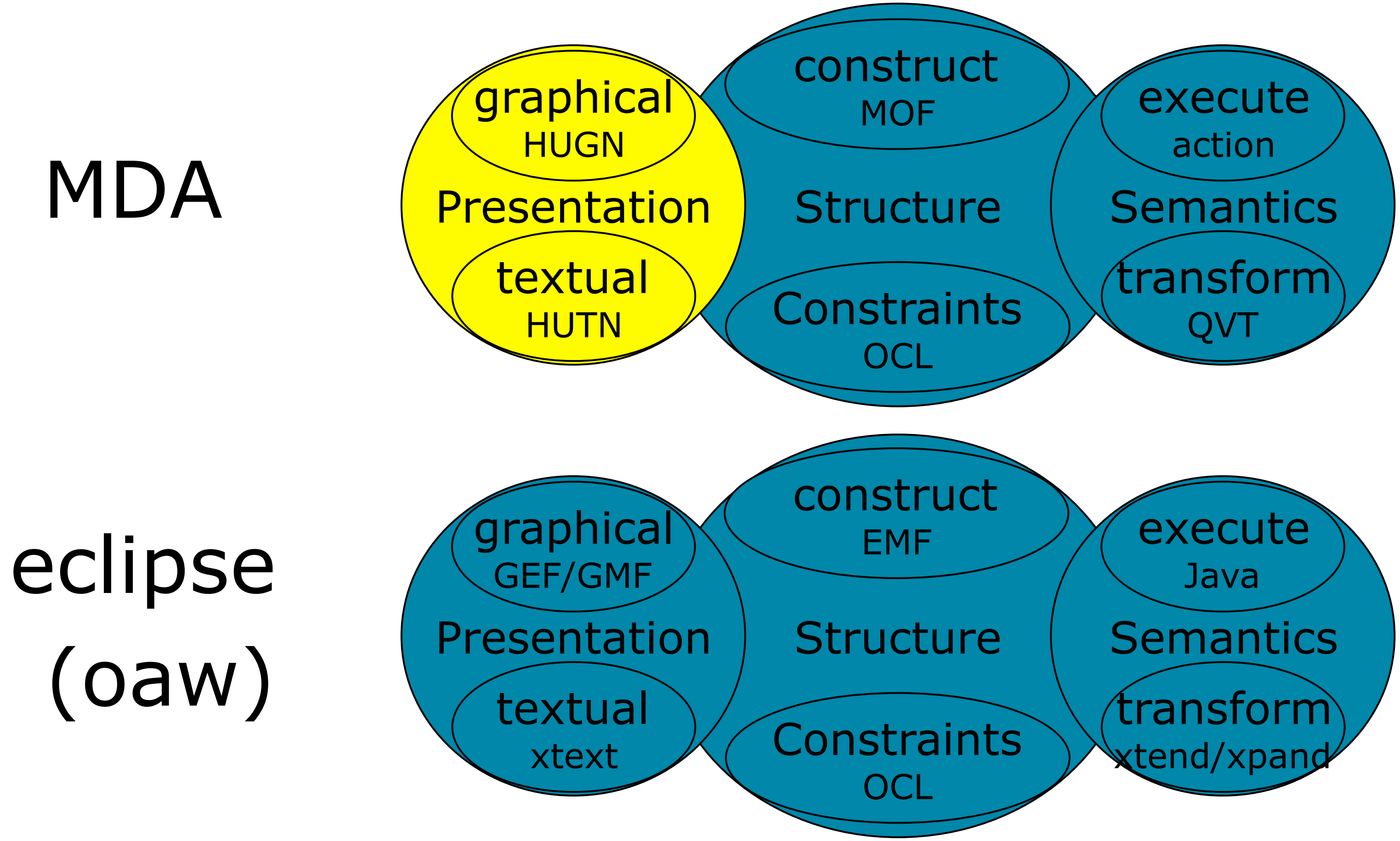
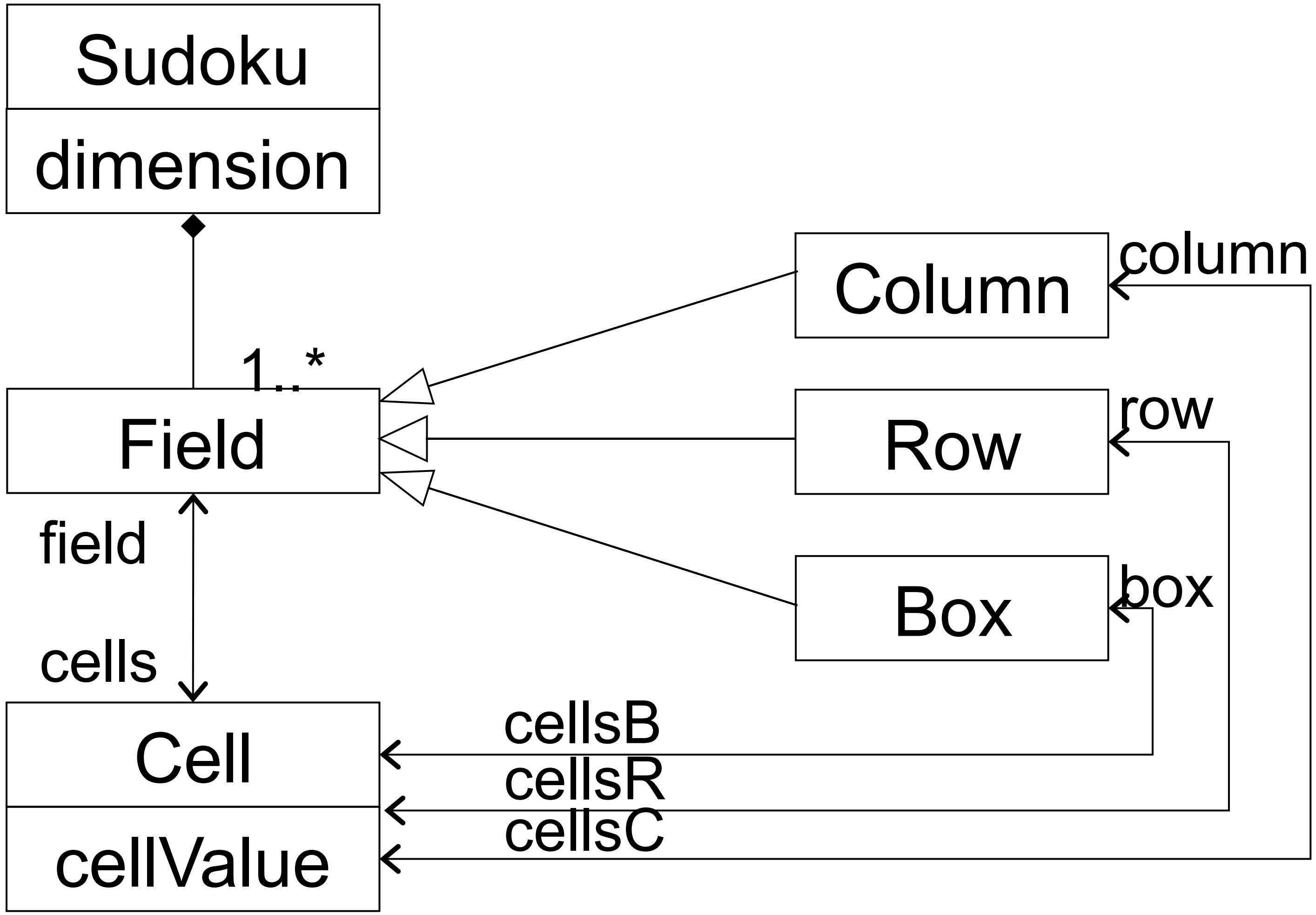
Meta-Languages in MDA and Eclipse



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 (xtext)

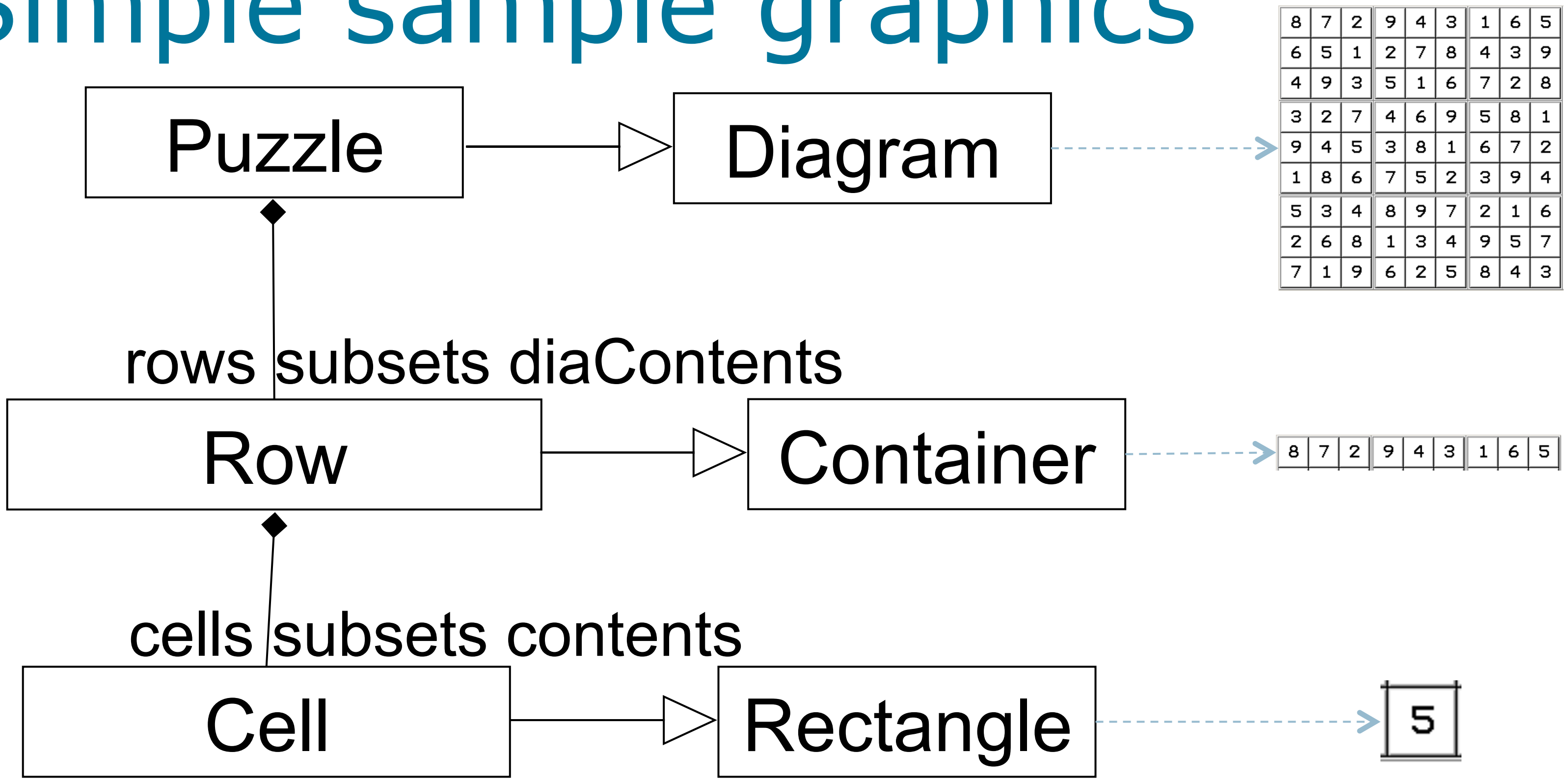
```
grammar my.pack.Sudoku
  with org.eclipse.xtext.common.Terminals
generate sudoku "http://www.eclipse.org/sudoku"

Puzzle :
  'puzzle'   dimension=INT ';'  Row+;

Row :
  'row' '(' (Cell ',')+ Cell ')' ;

Cell :
  cellValue = INT;
```

Simple sample graphics



Simple sample transformation

```
transformation swap1and6 (source, target: Sudoku){
  source Cell { cellValue = 1 }
  -> target Cell { cellValue = 6 };
  source Cell { cellValue = 6 }
  -> target Cell { cellValue = 1 };
  source Cell { cellValue = value }
  -> target Cell { cellValue = value };
    when{ cellValue <> 1 and cellValue <> 6; }
}
```

- *declarative versus operational*

Simple sample execution

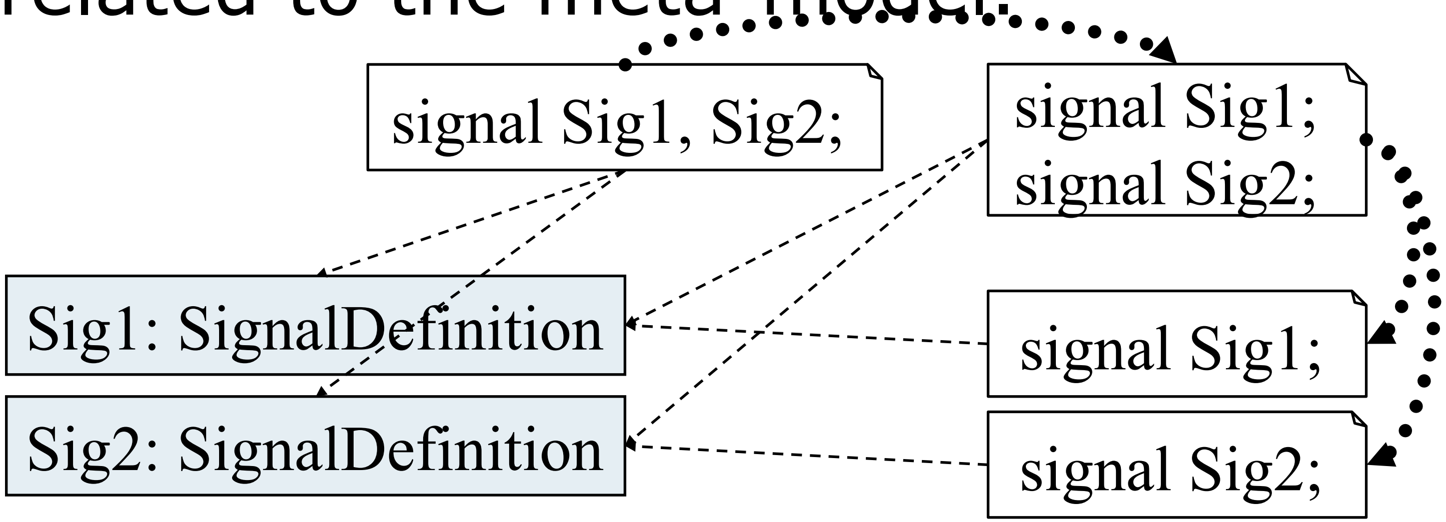
```
Run(s:Sudoku) =def
  forall f in self.field do RunF(f)
Runf(f:Field) =def
  choose c in self.cell with c.value=null
      and c.possible.size = 1
    choose v in c.possible do c.value:= v
  choose c in self.cell with c.value<>null
    forall cc in self.cell do
      delete c.value from cc.possible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

Problem area execution

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

Problem area Presentation

- 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.



Semantic Analysis (text2as)

- Transformation from concrete syntax to abstract syntax: connect definitions with uses
  - flow-of-control checks, e.g. join/break labels
  - name-related checks, e.g. begin/end construct names
- Mapping patterns (syntax:semantics)
  - Direct mapping (1:1) – direct match
  - Merge mapping (1:n) – shorthand notations, e.g. int a,b;
  - Partial description mapping (n:1) – several descriptions of the same thing

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

Summary

- Future compilers based on language descriptions.
  - A description of something can be executed on a computer if it is formal, complete and executable.
  - describe languages instead of compiler writing
  - need also agreement (standard)
  - definition of good languages is difficult: use patterns
- A formal language description includes three aspects: structure, syntax, semantics
- A formal language description allows tool generation on a computer.
  - Model access & exchange, front-end and back-end
  - 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.

Importance of DSL (abstract syntax)