CERN

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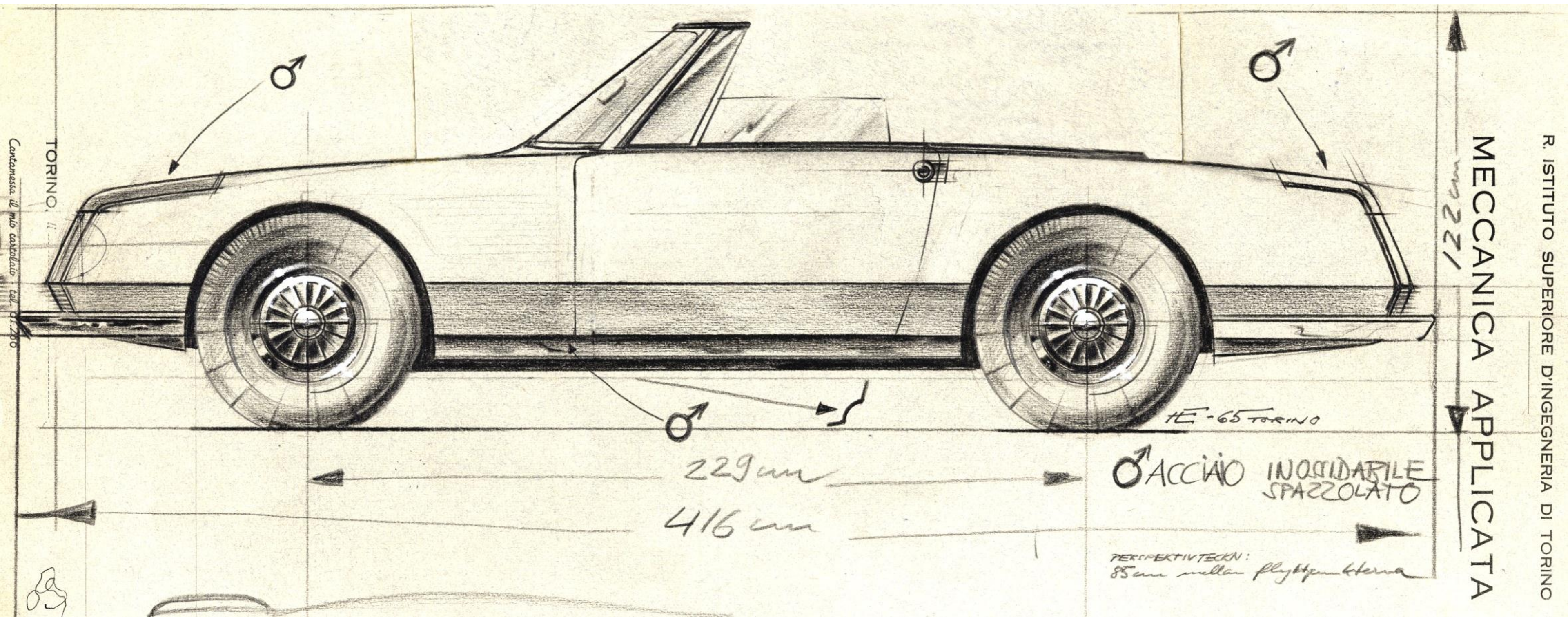
Domain-specific languages (DSLs): what, how and when?

ICE Tea
21/02/2014

Outline

- **Theory** *Concept of DSLs*
- **Technology** *Support for DSLs*
- **Reality** *Some details of the ST Example*



MECCANICA APPLICATA
R. ISTITUTO SUPERIORE D'INGEGNERIA DI TORINO
TORINO
122 cm
229 cm
416 cm
ACCIAIO INOSSIDABILE SPAZZOLATO
PERSPEKTIVTECKN:

*DSL | **Theory / Concept***

“Any fool can write code that a computer can understand.
Good programmers write code that humans can understand.”

(Martin Fowler)

What is a DSL?

- “a computer (programming) language of **limited expressiveness focused on a particular domain**” (Fowler)
- Opposite of “general purpose language” (GPL)
- “mini-language”

DSL examples

- SQL

```
SELECT   *
  FROM accelerators
  WHERE energy > 10000.0
  ORDER BY name;
```

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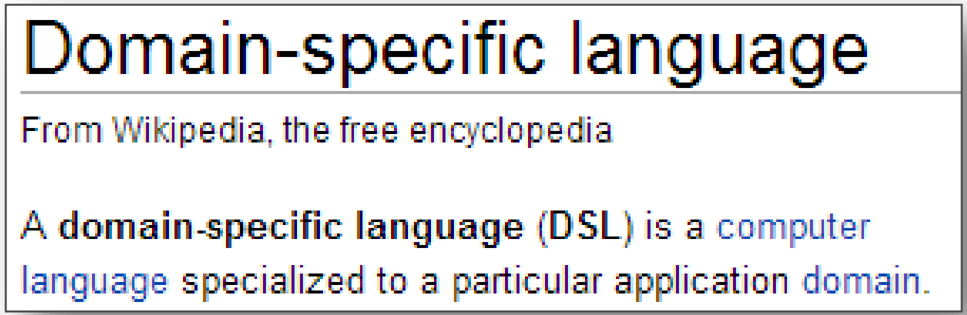
DSL examples

- SQL
- **Wiki markup** *(Wikipedia)*

A **'''domain-specific language'''** **('''DSL''')** is a **[[*computer language*]]** specialized to a particular application **[[Domain (software engineering)|*domain*]]**.



Domain-specific language

From Wikipedia, the free encyclopedia

A **domain-specific language** (DSL) is a computer language specialized to a particular application domain.

DSL examples

- SQL
- Wiki markup
- **Refrigerator** *(Bosch und Siemens Hausgeräte)*

```
compressor compartment cc {
        static compressor c1
        fan ccfan
}
```

DSL examples

- SQL
- Wiki markup
- Refrigerator
- **“Accelerators” language**

```
complex CERN {
        source H_source
        linear accelerator LINAC2 source: H_source
        circular accelerator PSB source: LINAC2
        circular accelerator PS source: PSB
        …
        fixedtarget experiment nTOF source: PS
}
```

GPL or DSL?

General purpose | **Domain-specific**

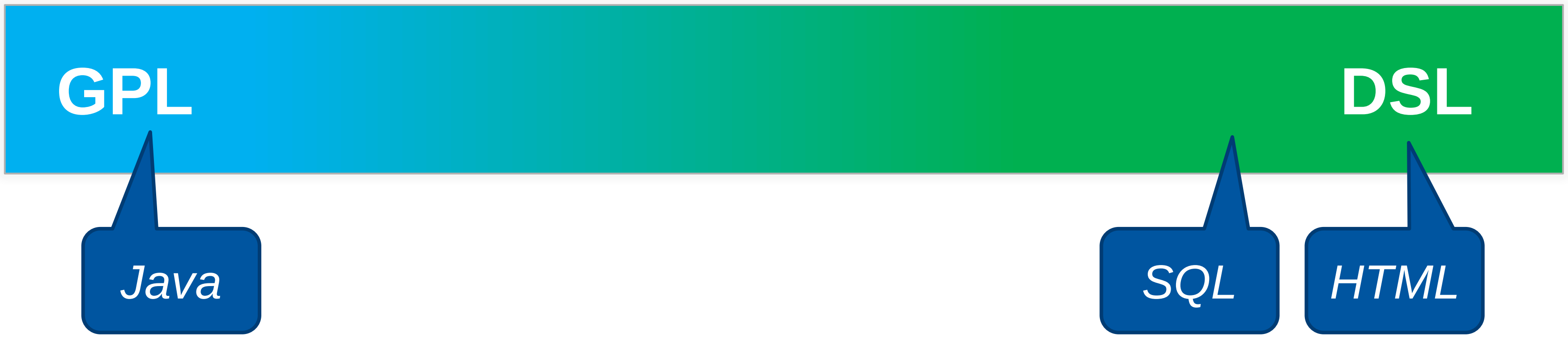
SQL vs. ST (Structured Text)

ST vs. Java

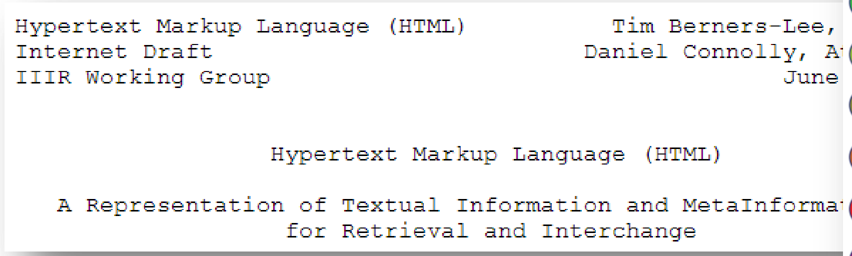
Java vs. English

– Is it just about *programming* languages?

GPL or DSL?



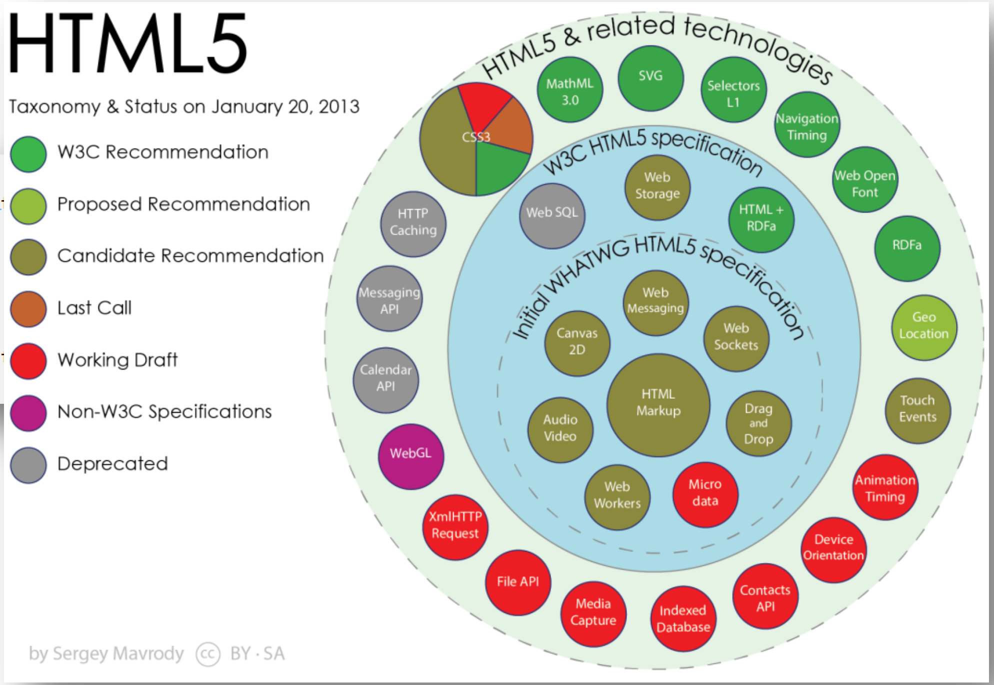
– HTML?



```
Hypertext Markup Language (HTML)          Tim Berners-Lee, 
Internet Draft                          Daniel Connolly, At
IIIR Working Group                                     June


                  Hypertext Markup Language (HTML)

   A Representation of Textual Information and MetaInforma
                    for Retrieval and Interchange
```



<h1>, <p>, <a href="">

Motivation for DSLs

- More **expressive**, less redundant
  - ⇒ More efficient
- Good **learning curve**
- Helps the **communication** with domain experts
  - "An algorithm must be seen to be believed." (D. Knuth)
- Can be **self-documenting**
- Domain-specific **validation**

Typical usage

- **Internal DSLs**: user is a developer
  - Usually transformed to another language

- External, but focused on **domain-specific users**
  - E.g. Mathematica
  - Processed internally

- But typically not for the broad public
  - Not graphical or “fool-proof” (free text) languages
- ~ When XML+XSD can be used

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Graphical or textual?

	General purpose	Domain specific
Textual		🟦
Graphical		

- Learning curve
- Efficiency
- Understandability

- Depends on the goals,
  but graphical does not kill the textual language

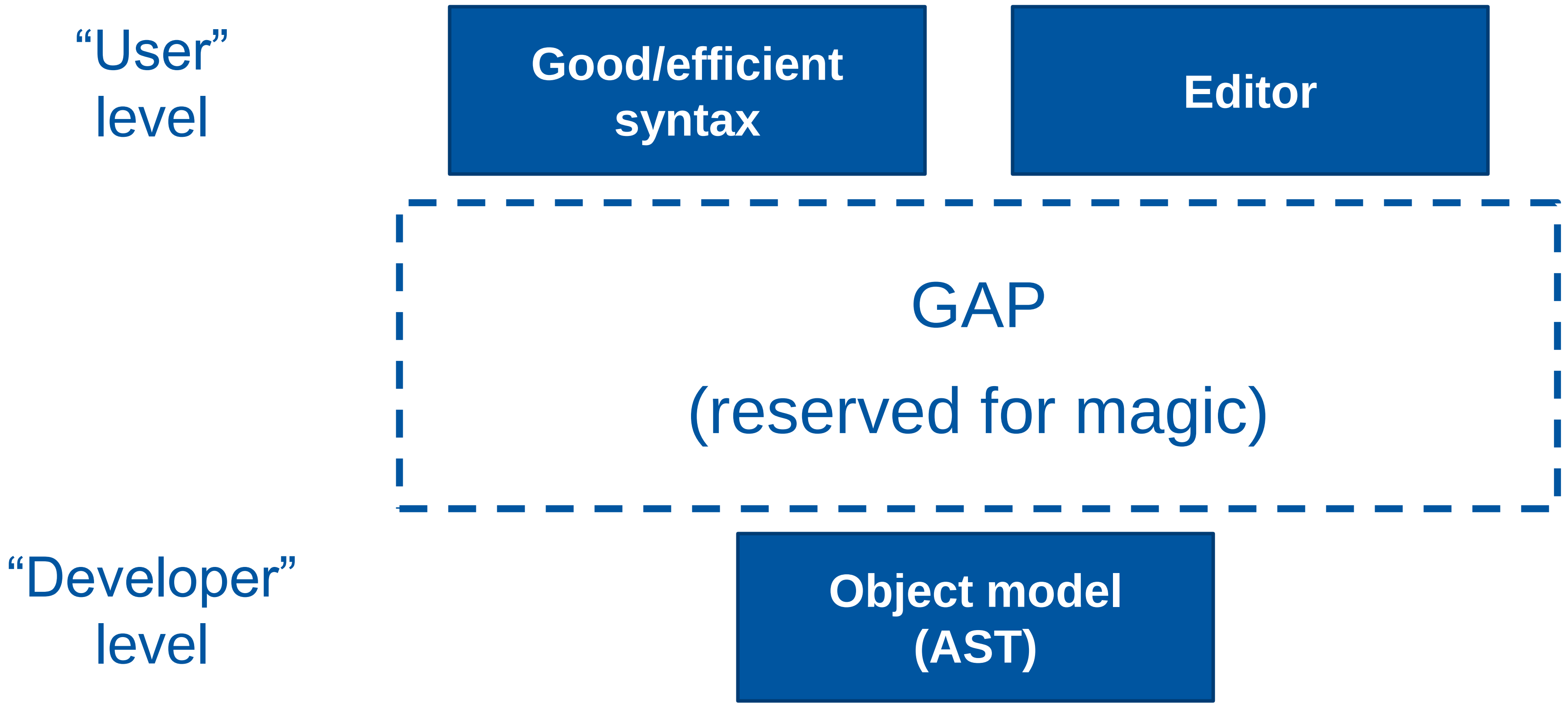
Pro et contra

- Pros
  - **optimised** for humans
  - comfortable, **efficient**
  - easier **communication**

- Cons
  - cost of building:
    - Usually you need a lexer.
    - And a parser.
    - And an internal data model.
    - And an editor.
    - Preferably with syntax highlight, content assist, …

DSL | ***Technology***

What do we want?



Solutions

	User demands	Developer demands
DSL, without support	Syntax is good, but no editor (N++) ☺☹	Text instead of AST ☹
XML+XSD	Syntax is more difficult, no good editor ☹	Object model can be obtained “easily” ☺
DSL, with support	Syntax is good, useful editor ☺	Object model can be obtained “easily” ☺

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Tool support

- **Xtext** (itemis)
  - **Widely used**
  - Textual input
  - External parser

- **MPS** (JetBrains)
  - Textual & various graphical inputs
  - Different philosophy (no parsing)

- **Spoofax**
  - Academic (research)
  - Textual input
  - Advanced parser

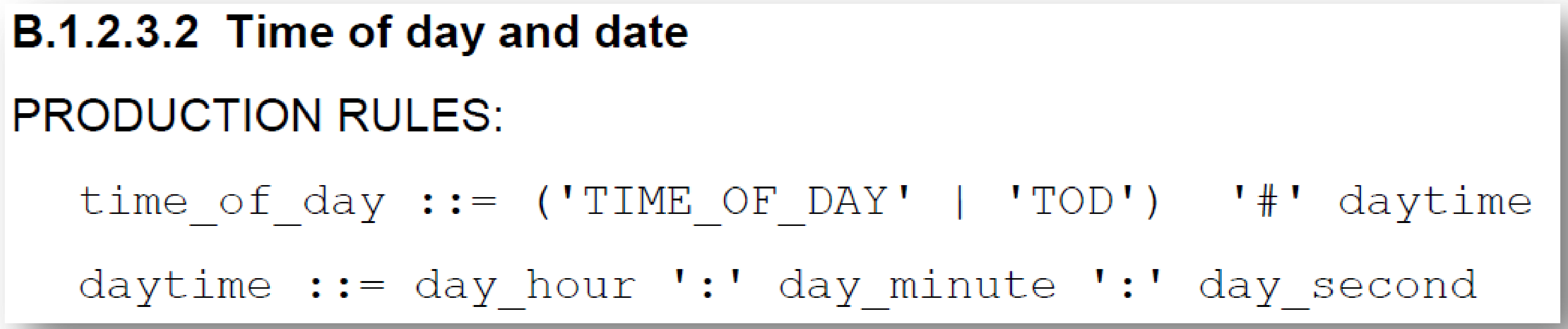
Xtext

- Eclipse and EMF-based
- Big community
  - "Stackoverflow Driven Development"
  - XtextCON May 27-28, Kiel (Germany)
- Open source, actively maintained
  - Last stable release: Feb 12, 2014
- They eat their own dogfood (Xtend)
- Based on the **extended grammar** of the language

(Formal) grammar

- grammar = description of the language
- definition of the **syntax**

- elements: **rules** (recursive)



B.1.2.3.2 Time of day and date

PRODUCTION RULES:

```
  time_of_day ::= ('TIME_OF_DAY' | 'TOD')  '#' daytime

  daytime ::= day_hour ':' day_minute ':' day_second
```

  - from IEC 61131

Xtext grammar

- **enriched** grammar – **not just syntax**
- goal: generate “everything” from the grammar

```
Experiment:
	‘experiment' name=ID
	'source:'  source=[Accelerator];
```

```
experiment NA source: SPS
```

```
Accelerator:
    (linear?='linear' | circular?='circular')
    'accelerator' name=ID 'source:' source=[SrcOrAcc];
```

```
circular accelerator LHC source: SPS
```

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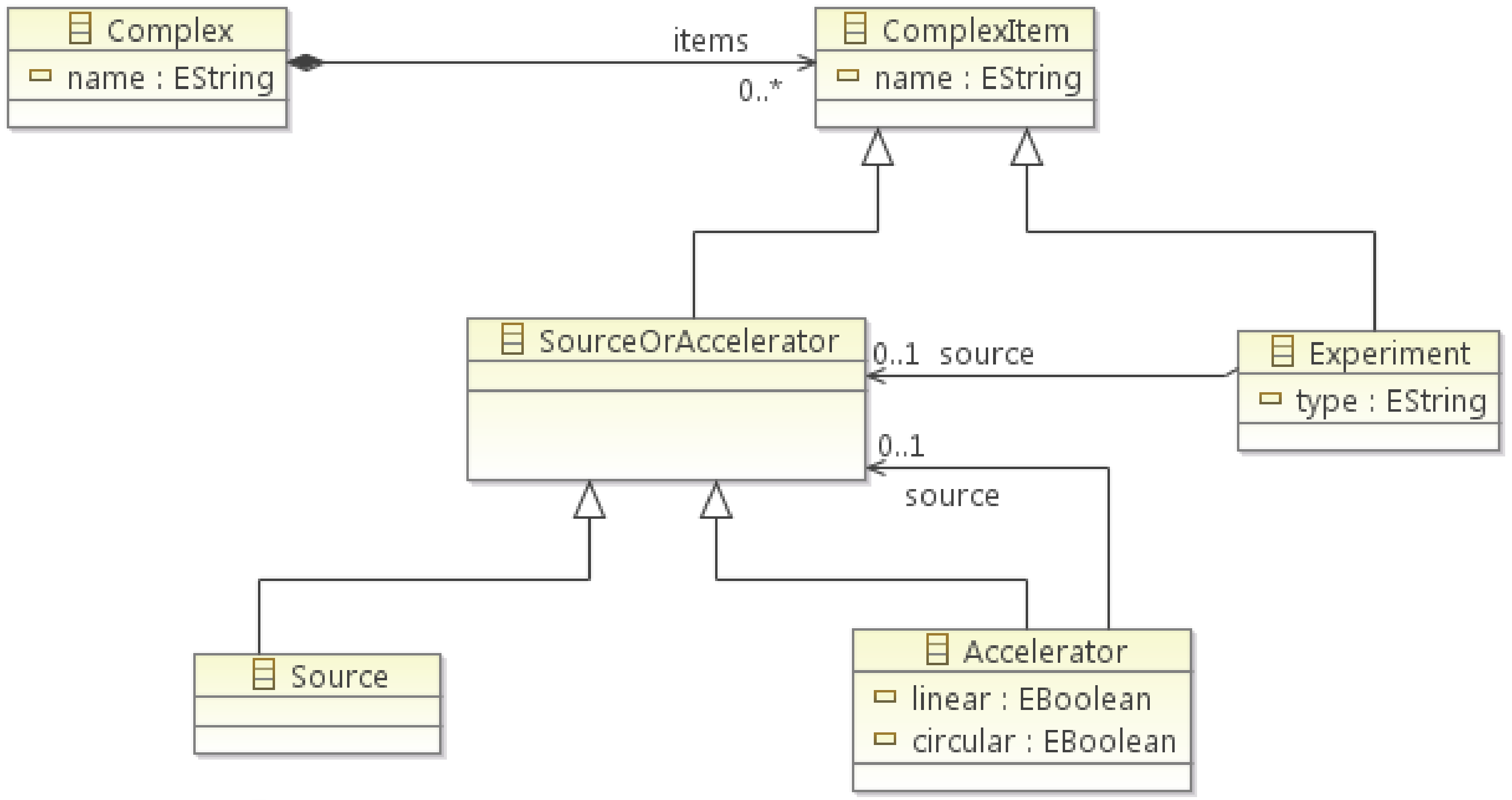
The full "Accelerators" grammar

```
grammar ch.cern.en.ice.tea.accelerator.AcceleratorGrammar with xtext.Terminals

Complex:
    'complex' name=ID '{' (items+=ComplexItem)* '}';
ComplexItem: (SourceOrAccelerator | Experiment);
SourceOrAccelerator: Source | Accelerator;
Source: 'source'   name=ID;
Accelerator:
    (linear?='linear' | circular?='circular') 'accelerator'   name=ID 'source:'
    source=[SourceOrAccelerator];
Experiment:
    type=('fixedtarget') 'experiment'   name=ID 'source:'
    source=[SourceOrAccelerator];
```

```
complex CERN {
    source H_source
    linear accelerator LINAC2 source: H_source
    circular accelerator PSB source: LINAC2
    circular accelerator PS source: PSB
    …
    fixedtarget experiment nTOF source: PS }
```

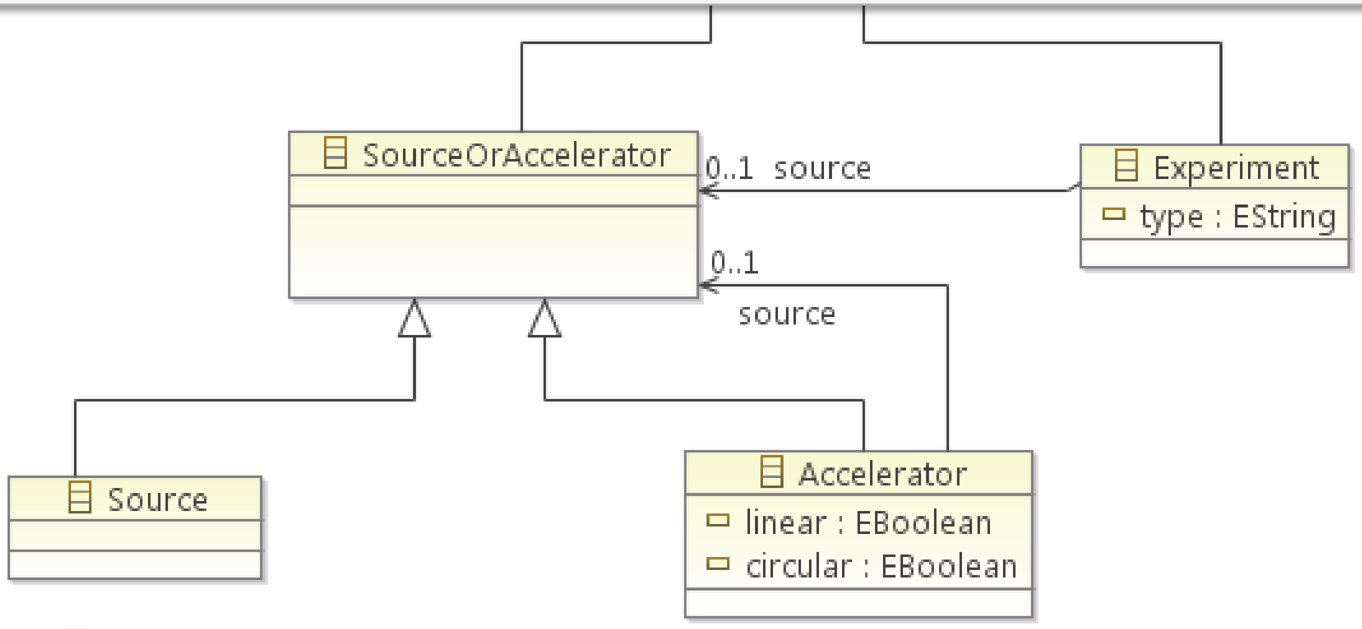
What have ~~the Romans~~ Xtext ever done for us?

- EMF object model
  - + parser
  - + reference handling



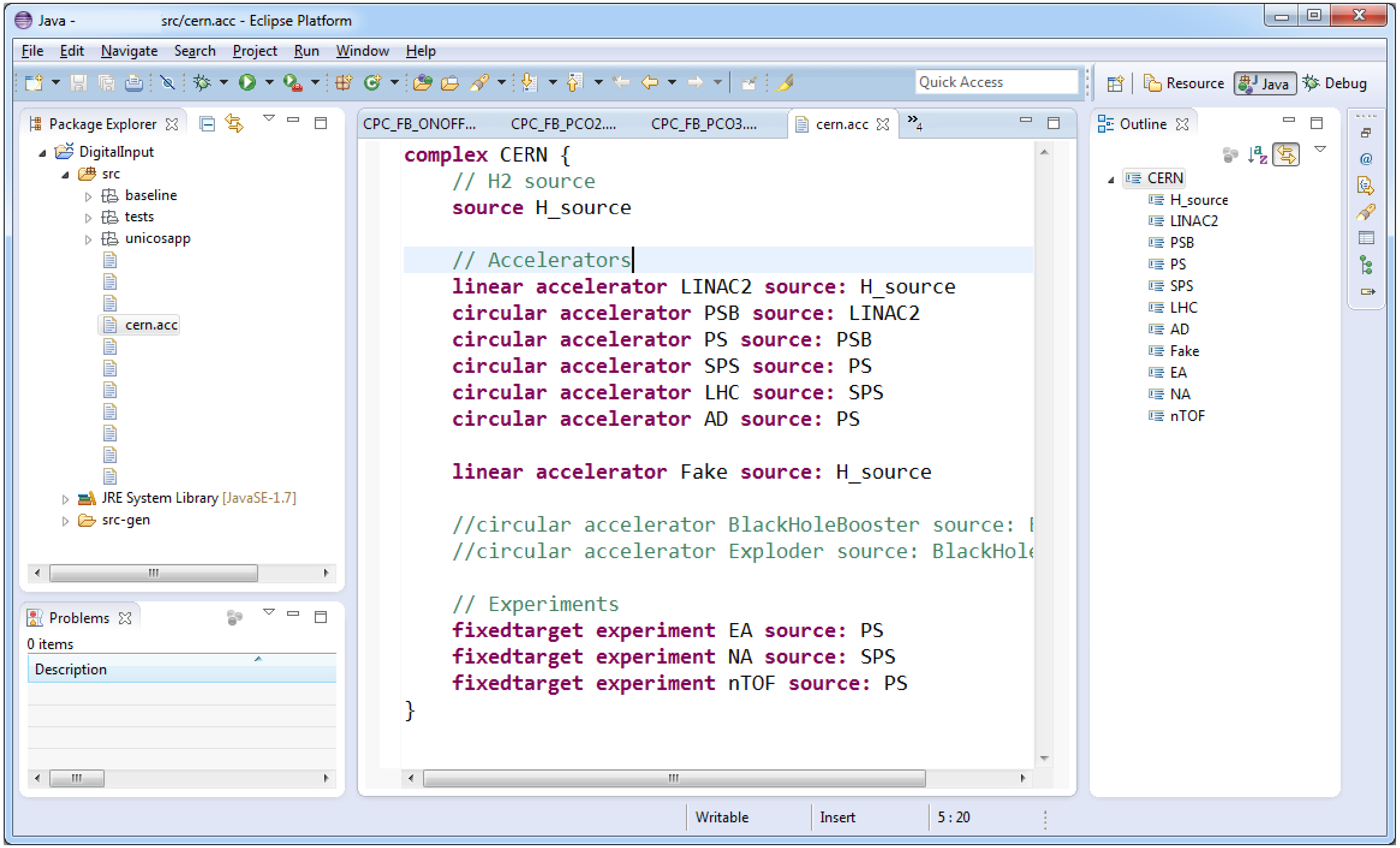
What have ~~the Romans~~ Xtext ever done for us?

```
public void printCircularAccSrcs(Collection<Accelerator> c) {
    for (Accelerator acc : c) {
        if (acc.isCircular()){
            System.out.println(acc.getSource().getName());
        }
    }
}
```



More Xtext features

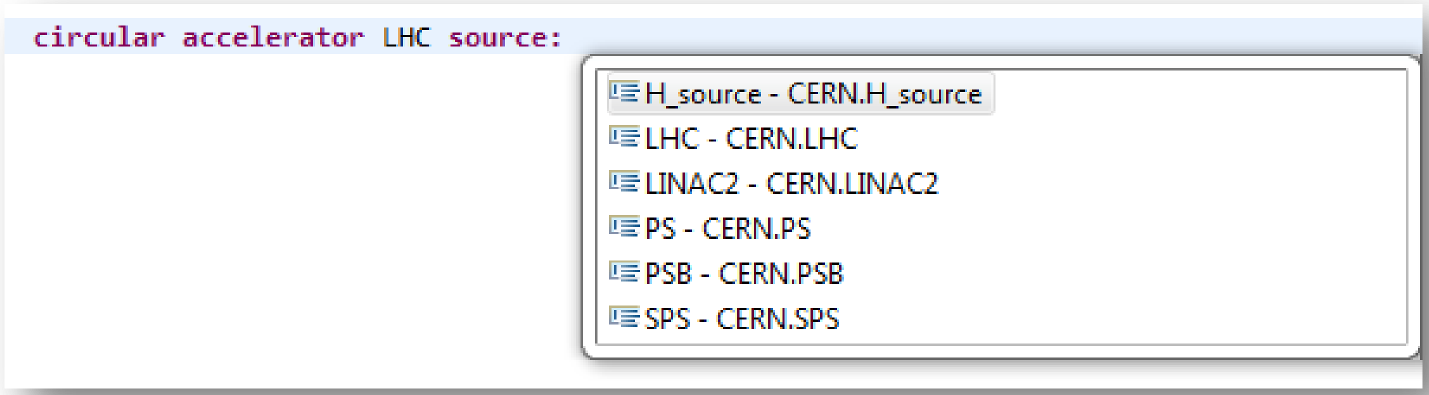
- fancy editor
  - **integrated into Eclipse**



```
complex CERN {
    // H2 source
    source H_source

    // Accelerators
    linear accelerator LINAC2 source: H_source
    circular accelerator PSB source: LINAC2
    circular accelerator PS source: PSB
    circular accelerator SPS source: PS
    circular accelerator LHC source: SPS
    circular accelerator AD source: PS

    linear accelerator Fake source: H_source

    //circular accelerator BlackHoleBooster source: 
    //circular accelerator Exploder source: BlackHole

    // Experiments
    fixedtarget experiment EA source: PS
    fixedtarget experiment NA source: SPS
    fixedtarget experiment nTOF source: PS
}
```

More Xtext features

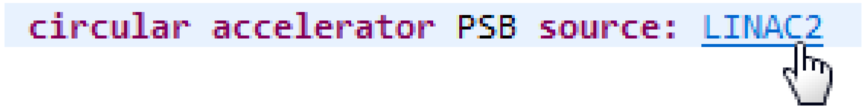
– fancy editor
  - integrated into Eclipse
  - **content assist**



```
circular accelerator LHC source:
```

H_source - CERN.H_source
LHC - CERN.LHC
LINAC2 - CERN.LINAC2
PS - CERN.PS
PSB - CERN.PSB
SPS - CERN.SPS

  - **references ("jump to")**



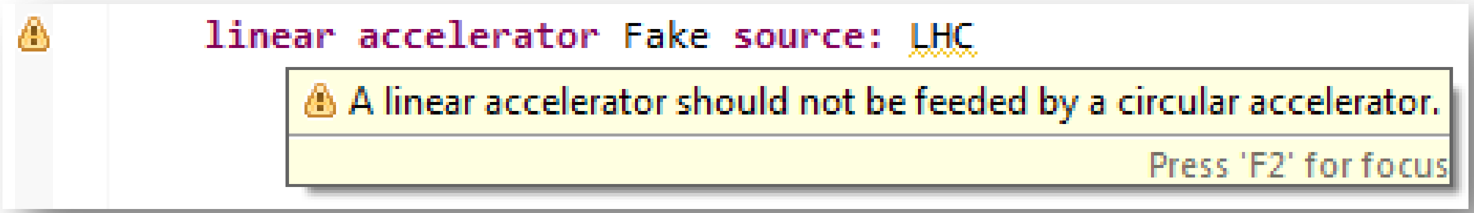
```
circular accelerator PSB source: LINAC2
```

  - …

“What a magic tool!”

- Eclipse built-in features
- **Everything comes from the grammar**
  - If the grammar is bad or “weak”: manual work
  - If external data is needed: manual work

  - **Example**: circular → linear transition is forbidden
    - Validation rule is needed (~ 5 lines of code)



```
linear accelerator Fake source: LHC
```

A linear accelerator should not be feeded by a circular accelerator.

Press 'F2' for focus

- + 20-30 LoC to fix the content assist

Code generation

- Not part of DSLs,
  but typically included

- Xtext encourages **Xtend**
  - Java “dialect”
  - Compiled to Java
  - Supports **templates**

```
A="5", B="3"; A+B="8"
```

```
"A=\"" + a + "\", B=\"" + b + "\"; A+B=\"" + (a+b) + "\""
```

```
'''A="«a»", B="«b»"; A+B="«a+b»"'''
```

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Code generation

Source

+

Templates

```
def static dispatch visualizeItem(Accelerator acc) '''
   «IF acc.circular»
      «acc.name» [label = "«acc.name»",
      shape=oval, fillcolor=darkolivegreen2];
   «ELSE»
      «acc.name» [label = "«acc.name»",
      shape=box, fillcolor=darkolivegreen3];
   «ENDIF»
   «acc.source.name» -> «acc.name»;
'''
```

→

```
LHC [label = "LHC", shape=oval,
       fillcolor=darkolivegreen2];

LINAC2 [label = "LINAC2", shape=box,
       fillcolor=darkolivegreen3];
```

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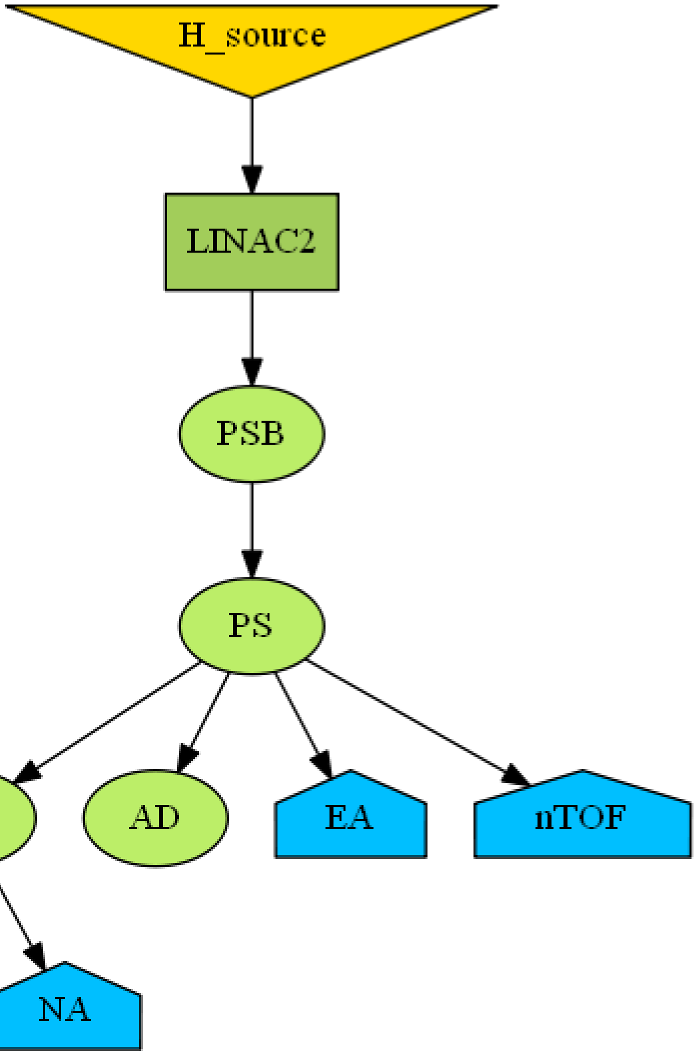
Code generation



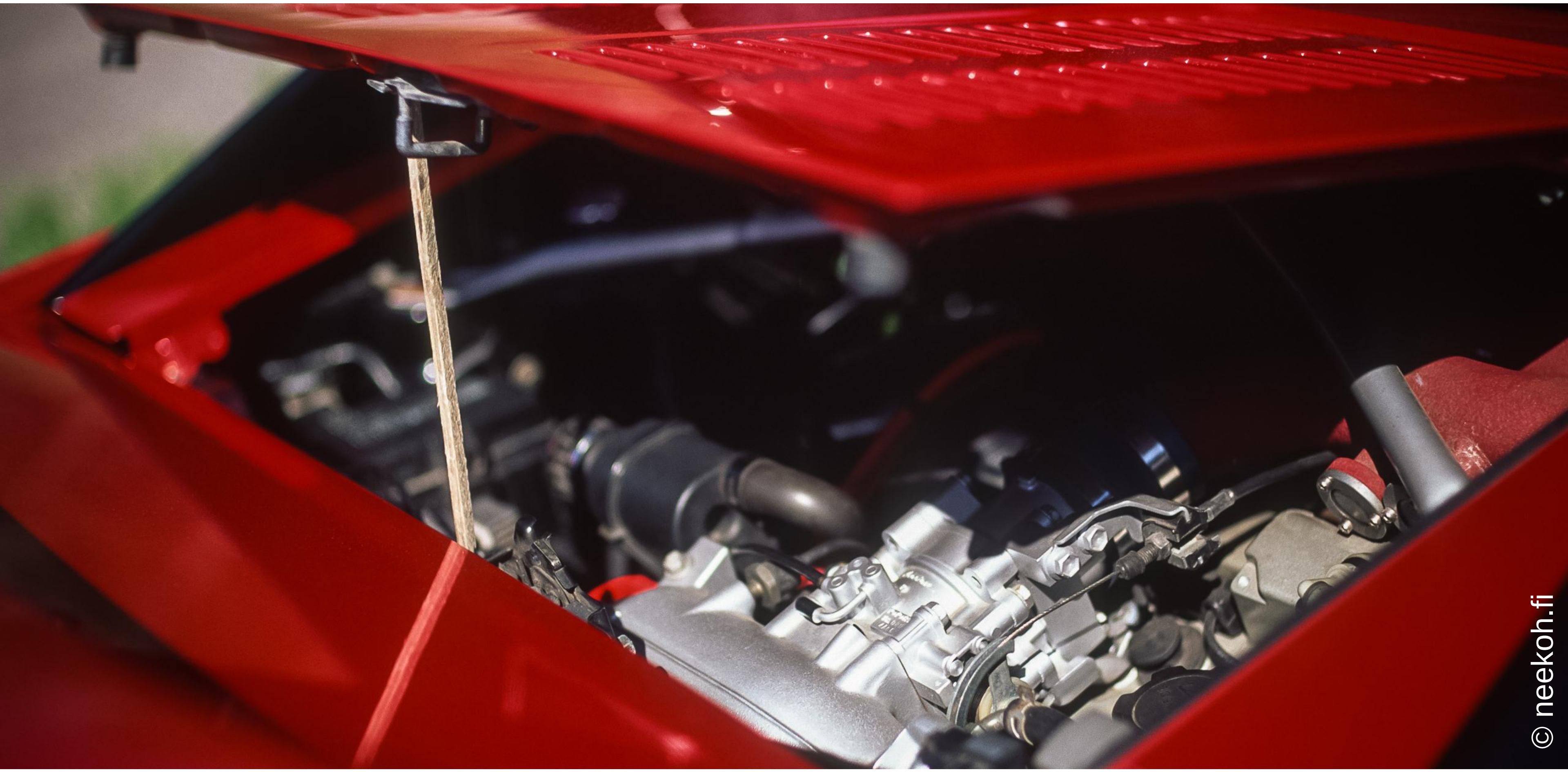
Difficult parts

- Validation

- Scoping
  - “Which *variable i* is accessed?”

- Expression handling
  - Parsing 5+a*b+c^2
  - Priority

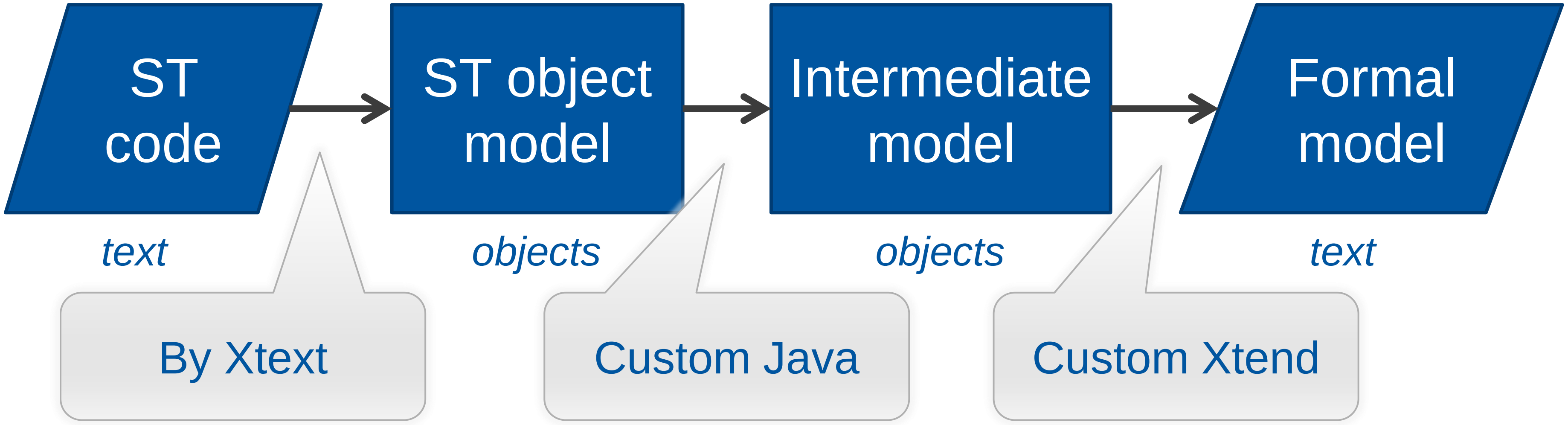
- Testing *the magical black box*



DSL | ***Reality (Some details from ST example)***

ST grammar for verification purposes

- Goal: generating formal models from ST code
- Method:



Example: struct vs. FB instance definition

```
VAR
     v1 : NamedStructure; // used-defined type (UDT)
     v2 : TON; // timer function block
```

```
StructureVariable:
     name=ID ':' structure=[StructureDeclaration];
FBVariable:
     name=ID ':' fb=[FBDeclaration];
```

– Xtext’s parser cannot distinguish between the two rules

```
StructureOrFBVariable:
     name=ID ':' structureOrFB=[StructureOrFBDeclaration];
```

– Grammar of var. definitions in the standard: ~ 6 pages

Example: variable assignment

- `v := TRUE;`

[Variable] ‘:=‘ Expression

- `v[0] := TRUE;`

[Variable] (‘[‘ index=INT ‘]’)? ‘:=‘ Expression

- `struct1.v := TRUE;`
- `struct1.array1[0].struct2.v := TRUE;`
- `DB100.struct1.array1[0,1].struct2.v := TRUE;`
- **General grammar + many validation rules**

Example: differences between the languages

ST	NuSMV

v1 := true;
V1 := True;
	V1 := TRUE;

Example: differences between the languages

ST	NuSMV

v1 := true;
V1 := True;
	V1 := TRUE;

v2 := 10.5;	V2 := 0sd32_10500;

Example: differences between the languages

ST	NuSMV

v1 := true;
V1 := True;
	V1 := TRUE;

v2 := 10.5;	V2 := 0sd32_10500;

v3 := 1;	V3 := TRUE;
	V3 := 0sd16_1;
	V3 := 0ud32_1;
	V3 := 0sd32_100;
	...

Example: scoping

```
FUNCTION_BLOCK FuncBlock
VAR
        v : INT;
END_VAR

v := 123;
DummyFunction(in := 1);
DummyFunction(in := 1, v := v);


...
```

But is ST a “mini-language”?

DSL | ***Summary and Conclusions***

Summary

- The concept is useful – for small, dedicated languages
- Tools help to develop the DSL toolchain

- New languages
  - Develop one, if it helps you and it will be **regularly used**

- For existing languages
  - If you need the **AST** for a “small” language: go for Xtext
  - If you need just an **editor**: Xtext or “plain Eclipse editor”
  - For **big languages** (C, Java, …): Xtext is not powerful enough

- Where can it be used at CERN?

Where can be useful for us?

- Specification language
- UNICOS User templates?
  - Supporting template-based code generation is difficult
  - JET, Velocity, Xtend, T4, … won’t provide validation, syntax highlight or content assist
  - How to provide grammar and validation rules?
  - Can be possible with (**not template-based**) custom solution
- Hopefully in many other cases…

Links

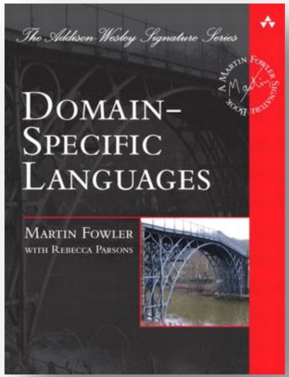
- Xtext
  https://www.eclipse.org/Xtext/
- Xtext documentation
  https://www.eclipse.org/Xtext/documentation/2.5.0/Xtext%20Documentation.pdf
- Xtext tutorial
  https://www.eclipse.org/Xtext/documentation.html#FirstFiveMinutes
- MPS
  http://www.jetbrains.com/mps/
- Spoofax
  http://strategoxt.org/Spoofax

Books

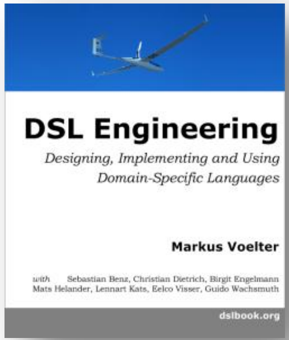
- M. Fowler: **Domain-Specific Languages** (2010)
  Available on SafariBooks

- L. Bettini: **Implementing Domain-Specific Languages with Xtext and Xtend** (2013)
  Available on SafariBooks

- M. Völter: **DSL Engineering** (2013)
  Available on dslbook.org


The Addison-Wesley Signature Series
A Martin Fowler Signature Book
Domain-Specific Languages
Martin Fowler
with Rebecca Parsons

Community Experience Distilled
Implementing Domain-Specific Languages with Xtext and Xtend
Learn how to implement a DSL with Xtext and Xtend using easy-to-understand examples and best practices
Lorenzo Bettini
PACKT open source


DSL Engineering
Designing, Implementing and Using Domain-Specific Languages
Markus Voelter
with Sebastian Benz, Christian Dietrich, Birgit Engelmann Mats Helander, Lennart Kats, Eelco Visser, Guido Wachsmuth
dslbook.org

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