

Language Workbenches : The case of Xtext

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Material

[https://github.com/FAMILIAR-project/
HackOurLanguages-SIF](https://github.com/FAMILIAR-project/HackOurLanguages-SIF)

A Taxonomy of Languages

- General-purpose languages
- Domain-specific language
 - Internal vs external
 - Graphical vs textual
- This course: external, textual domain-specific language

Basic exercise

Jhipster (<http://www.jhipster.tech/>), let us consider the “last” version

How many languages are used in such a contemporary project?

1. List all software languages used in Jhipster
2. Classify them (GPL? External DSL? Internal DSL?)

Don’t forget APIs that look like (internal) DSLs

Plan

- Grammar and parsing
- Language workbenches, Xtext
- From grammar to metamodel
- From metamodel to grammar

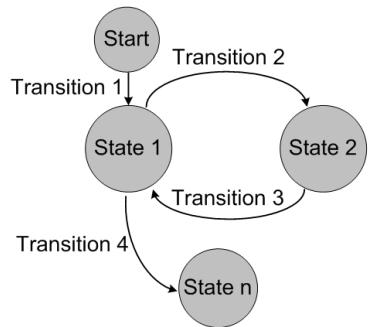
Contract

- Foundations and practice of Xtext
 - State-of-the-art language workbench (Most Innovative Eclipse Project in 2010, mature and used in a variety of industries)
- (Meta-)Models, Grammar, and Languages
 - Perhaps a more concrete way to see models, metamodels and model-driven engineering

BIBTEX



Graphviz



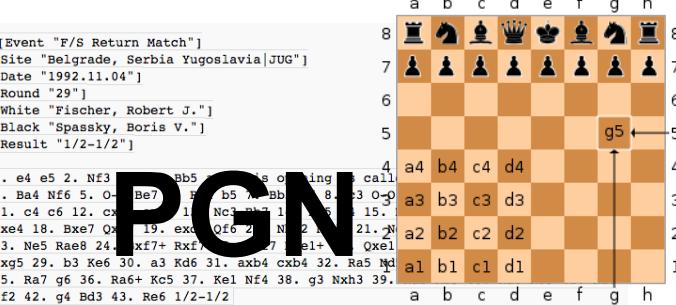
**Finite State
Machine**



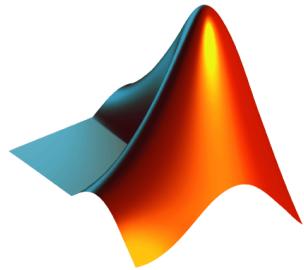
Domain-Specific Languages (DSLs)

```
[Event "F/S Return Match"]
[Site "Belgrade, Serbia Yugoslavia[JUG]"]
[Date "1992.11.04"]
[Round "29"]
[White "Fischer, Robert J."]
[Black "Spassky, Boris V."]
[Result "1/2-1/2"]
```

```
1. e4 e5 2. Nf3 Bb5 3. c3 Nc6 4. Bb5 Nf6 5. O-O Be7 6. Bb7 Bb5 7. Nc3 Bb7 8. e5 O-O 9. Nxe4 Nf6 10. Nf3 Nc6 11. c4 c6 12. c5 Nf6 13. Nc3 Bb7 14. Nf3 Nc6 15. Nxe4 Nf6 16. Nf3 Nc6 17. Nxe4 Nf6 18. Bxe7 Qe7 19. exd5 Qf6 20. Nf3 Nf6 21. Nxe4 Nf6 22. Nf3 Nf6 23. Ne5 Rae8 24. Bxf7+ Rxf7 25. Nf3 Nf6 26. Nxe4 Nf6 27. Nf3 Nf6 28. Nxe4 Nf6 29. b3 Ke6 30. a3 Kd6 31. axb4 cxb4 32. Ra5 Nd5 33. Nc3 Nf6 34. Nxe4 Nf6 35. Ra7 g6 36. Ra6+ Kc5 37. Ke1 Nf4 38. g3 Nxh3 39. Nf2 g4 40. Ra5 Nf6 41. Ra6+ Kc4 42. Ra4 Nf6 43. Re6 1/2-1/2
```



Make



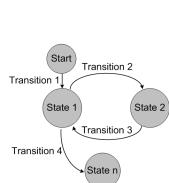
Matlab



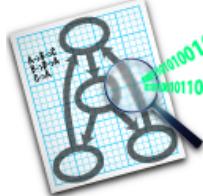
DSL = Syntax + Services

Specialized notation:

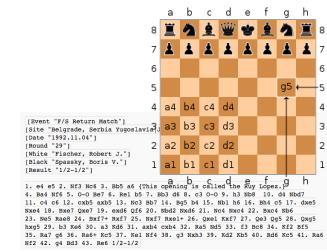
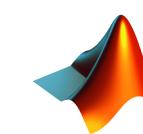
Textual or Graphical
Specific Vocabulary
Idiomatic constructs



BIBT_EX



SQL



Specialized tools/IDE:

Editor with auto-completion, syntax highlighting, etc.
Compiler
Interpreter
Debugger
Profiler
Syntax/Type Checker
...

Language workbenches

- Tools for reducing the gap between the design and implementation of (external) domain-specific languages
- The Killer App for DSLs? <http://www.martinfowler.com/articles/languageWorkbench.html>

Language Workbenches

Erdweg et al. SLE'13

		Ensō	Más	MetaEdit+	MPS	Onion	Rascal	Spoofax	SugarJ	Whole	Xtext
Notation	Textual	●	●		●	●	●	●	●	●	●
	Graphical	●	○	●			○			●	
	Tabular		●	●	●					●	
	Symbols			●	●					●	
Semantics	Model2Text		●	●	●	●	●	●	●	●	●
	Model2Model			●	●	●	●	●	●	●	●
	Concrete syntax			●	●	●	●	●	●		
	Interpretative	●		●	●		○	●		●	●
Validation	Structural	●	●	●	●	●	●	●	●	●	●
	Naming	○	●	●	●	●		●		●	○
	Types				●				●		●
	Programmatic	●			●	●	●	●	●		●
Testing	DSL testing				●		○	●		●	●
	DSL debugging	●		●	●		●			●	●
	DSL prog. debugging	●			●					●	●
Composability	Syntax/views	●		●	●	●	●	●	●	●	○
	Validation			●	●	●	●	●	●	●	●
	Semantics	●		●	●	●	●	●	●		●
	Editor services			●	●	●	●	●	●		●
Editing mode	Free-form	●		●		●	●	●	●		●
	Projectional		●		●	●				●	
Syntactic services	Highlighting	○	●	●	●	●	●	●	●	●	●
	Outline			●	●	●	●	●	●	●	●
	Folding	●	●	●	●	●	●	●	●	●	●
	Syntactic completion			●	●	●		●	●		●
	Diff	●		●	●	●	●	●	●		●
	Auto formatting	●	●	●	●	●	●	●		●	●
Semantic services	Reference resolution		●	●	●	●	●	●	●		●
	Semantic completion		●	●	●	●	●	●	●	●	●
	Refactoring	○	●	●	●		●	●		●	
	Error marking	●	●	●	●	●	●	●	●	●	●
	Quick fixes				●						●
	Origin tracking	●		●	●	●	●	●	●	●	●
	Live translation		●		●	●	○	●	●	●	●

Table 1: Language Workbench Features (● = full support, ○ = partial/limited support)

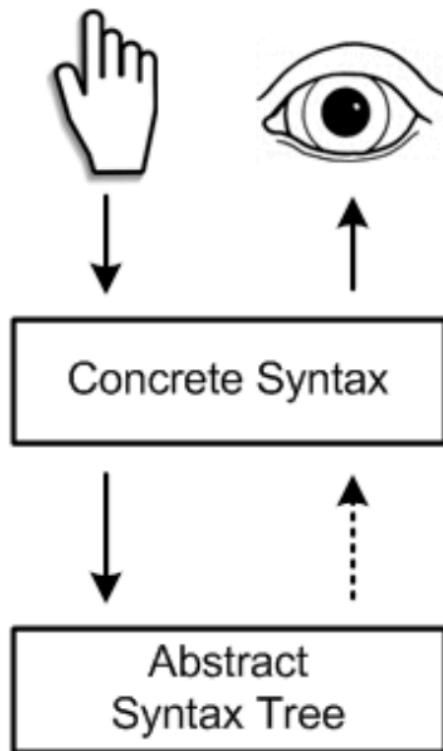
The screenshot shows the Eclipse IDE interface with the following details:

- Title Bar:** Java – strategoxt-sugar-papers/test/BookHandler.sugj – Eclipse – /Users/seba/tmp/ecli...
- Toolbar:** Includes icons for file operations (New, Open, Save, Print, Find, Copy, Paste, Cut, Undo, Redo), Transform, and navigation.
- Left Panel (BookHandler.sugj):** Displays Java code for `BookHandler`. The code imports `xml.Sugar`, `xml.Editor`, and `xml.schema.BookSchema`. It defines a class `BookHandler` with a method `appendBook` that takes a `ContentHandler` parameter and throws a `SAXException`. The method initializes a string `title` to "Sweetness and Power" and uses `@Validate` annotations on several XML elements. A warning icon is shown next to the `author` element, and an error icon is shown next to the `edition` element. A dropdown menu is open over the XML code, showing suggestions like `<{lib}author`, `<{lib}book`, `<{lib}edition`, and `<{lib}editions`.
- Right Panel (Outline View):** Shows the outline of the XML schema. It includes nodes for `BookHandler`, `appendBook`, `book`, `author`, `editions`, `isPublished`, and `getLanguage`.
- Bottom Left (Problems View):** Shows 1 error and 1 warning. The error is "expected element edition of namespace lib" at line 18, and the warning is "skipping validation of quoted attribute value" at line 14.
- Bottom Right (Resource View):** A table showing the resource and location of errors and warnings.
- Bottom Navigation:** Includes buttons for Writable, Smart Insert, and a status bar indicating the current line and column.

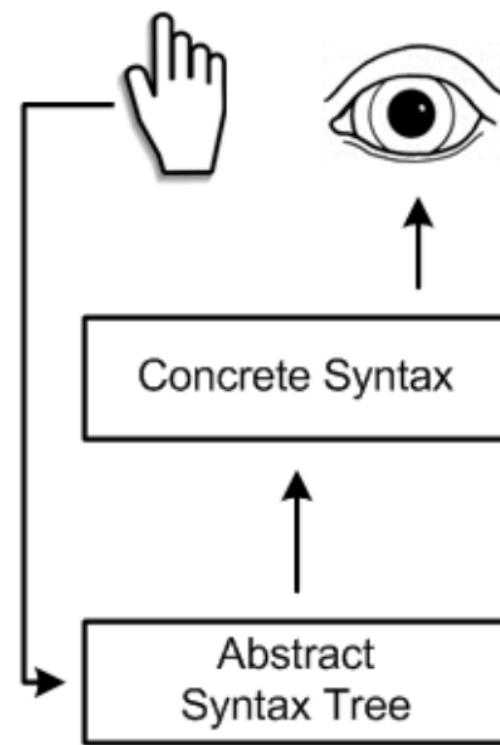
Sebastian Erdweg, Tillmann Rendel, Christian Kästner, and Klaus Ostermann. Sugarj: Library-based syntactic language extensibility. OOPSLA'11

Projectional editing

Parsing



Projection



Projectional editing

```
exported component Judge extends nothing {
    provides FlightJudger judger
    int16 points = 0;
    void judger_reset() <= op judger.reset {
        points = 0;
    } runnable judger_reset
    void judger_addTrackpoint(Trackpoint* tp) <= op judger.addTrackpoint {
        points += 0
            | tp->alt <= 2000 m | tp->alt >= 2000 m
            | tp->speed < 150 mps | 0 | 10
            | tp->speed >= 150 mps | 5 | 20
    } runnable judger_addTrackpoint
    int16 judger_getResult() <= op judger.getResult {
        return points;
    } runnable judger_getResult
} component Judge
```

Projectional Editing

```
exported statemachine FlightAnalyzer initial = beforeFlight {
    next(Trackpoint* tp)                                reset()
    beforeFlight [tp->alt == 0 m] -> airborne
    airborne   [tp->alt == 0 m && tp->speed == 0 mps] -> crashed
                [tp->alt == 0 m && tp->speed > 0 mps] -> landing
                [tp->speed > 200 mps && tp->alt == 0 m] -> airborne
                [tp->speed > 100 mps && tp->speed <= 200 mps &&
                 tp->alt == 0 m] -> airborne
    landing    [tp->speed == 0 mps] -> landed
                [tp->speed > 0 mps] -> landing
    landed     [ ] -> beforeFlight
    crashed    [ ] -> beforeFlight
}
```

```

SM.sdf3
System.Machine = [
  state machine [ID] [Extends]
  [{Element "\n"}*]
]

Extends.Extends =
[extends [ID]]

Extends.NoExtends = □

Element.State =
[state [ID]]

Element.Transition = [
transition from [StateRef] to
[Guard] [Actions]
]

names.nab
11 Machine(m, elems, extends) :
12   defines Machine m
13   scopes State, Variable
14
15 Extends(m) :
16   imports State, Variable from M
17
18 State(s) :
19   defines State s
20
21 StateRef(s) :
22   refers to State s
23
24 VarDef(x, c) :
25   defines Variable x of type t
26   where c has type t

types.ts
6 False() : BoolType()
7 True() : BoolType()
8
9
10 Var(x) : t
11 where definition of x : t
12
13 Or(e1, e2) + And(e1, e2) :
14   where e1 : BoolType()
15     else error "bool expected"
16     and e2 : BoolType()
17       else error "bool expected"
18
19 Eq(e1, e2) + Gt(e1, e2) :
20   where e1 : IntType()
21     else error "int expected"

generate.str
6
7 sm-to-java :
8   machine@Machine(m, exten
9   public class [m] [<ext
10  String current = [<
11    [vardefs]
12
13  String next(String e
14    [cond-stat*]
15    while(true) {
16      [uncond-stat*]
17    }
18  ]
19  ]
20  where ...
21
22
23
24

VendingMachine.ATOML
state Vend_Drink
state Vend_Sweet
state Empty
transition from Waiting to Vend_Drink: V
[drinks > 0] / drinks := drinks - 1
transition from Vend_Drink to Waiting: V
[drinks > 0 or sweets > 0]

VendingMachine.aterm
1 Machine(
2   "VendingMachine"
3   , NoExtends()
4   , [VarDef("drinks", Int("10")))
5   , VarDef("sweets", Int("20")))
6   , State("Waiting"))

```

The Spoofax Language Workbench

Spoofax is a platform for developing textual domain-specific languages with full-featured [Eclipse](#) editor plugins.

With the Spoofax language workbench, you can write the grammar of your language using the high-level SDF grammar formalism. Based on this grammar, basic editor services such as syntax highlighting and code folding are automatically provided. Using high-level descriptor languages, these services can be customized. More sophisticated services such as error marking and content completion can be specified using rewrite rules in the Stratego language.

Meta Languages

Language definitions in Spoofax are constructed using the following meta-languages:

- The [SDF3](#) syntax definition formalism
- The [NaBL](#) name binding language
- The [TS](#) type specification language
- The [Stratego](#) transformation language

Xtext, a popular, easy-to-use model-based tool
for developping DSLs

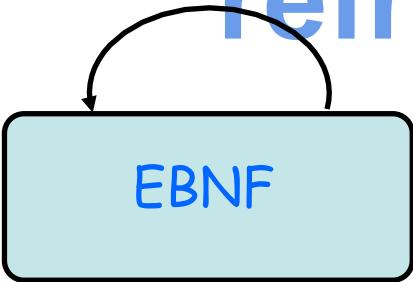
Your DSL in 5' (incl.
editors and serializers)

Your DSL in 5'

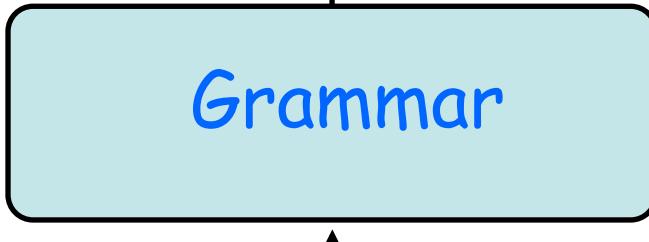
Short Demonstration

Foundations (or some course refresh)

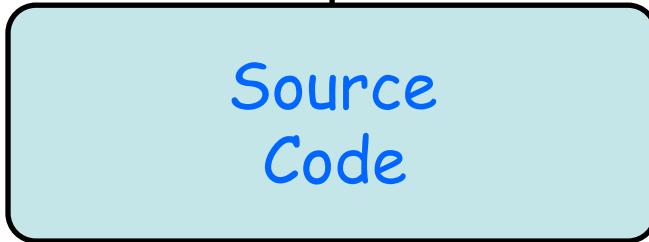
M³



M²



M¹



Java Grammar

```
CHARLITERAL
: '\'' 
| '\"' EscapeSequence
| '\"'
| '\\'
;

STRINGLITERAL
: '\"' 
| '\'' EscapeSequence
| '\"'*
| '\''
;

fragment
EscapeSequence
: '\\\''
| 'b'
| 't'
| 'n'
| 'r'
| '\\'
| '\\\\'
| '\\\''
| '\\\"'
| '\\b'
| '\\t'
| '\\n'
| '\\r'
| '\\\\\''
| '\\\\\"'
| '\\\\b'
| '\\\\t'
| '\\\\n'
| '\\\\r'
| '\\\\\\\\\''
| '\\\\\\\\\"'
| '\\\\\\\\b'
| '\\\\\\\\t'
| '\\\\\\\\n'
| '\\\\\\\\r'
| '\\\\\\\\\\\\\''
| '\\\\\\\\\\\\\"'
| '\\\\\\\\\\\\b'
| '\\\\\\\\\\\\t'
| '\\\\\\\\\\\\n'
| '\\\\\\\\\\\\r'
;

variableModifiers
: (
    FINAL
    | annotation
)*
;

classDeclaration
: normalClassDeclaration
| enumDeclaration
;
```

Java Program

```
/*
public class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello, World");
    }
}
```

```
classOrInterfaceDeclaration
: classDeclaration
| interfaceDeclaration
;

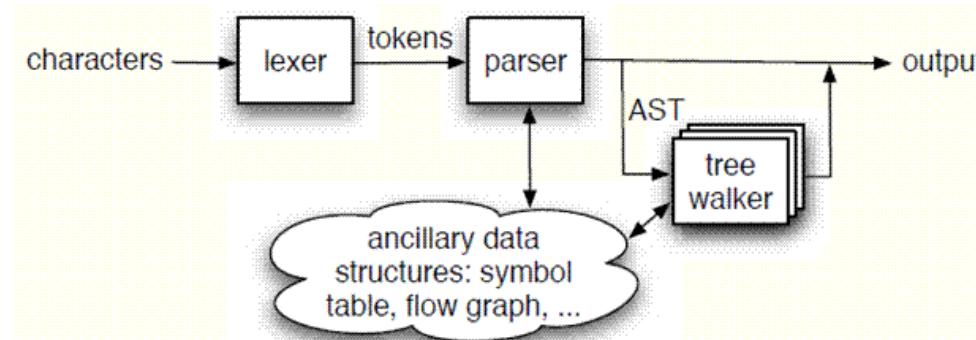
modifiers
: (
    annotation
    PUBLIC
    PROTECTED
    PRIVATE
    STATIC
    ABSTRACT
    FINAL
    NATIVE
    SYNCHRONIZED
    TRANSIENT
    VOLATILE
    STRICTFP
)*
;

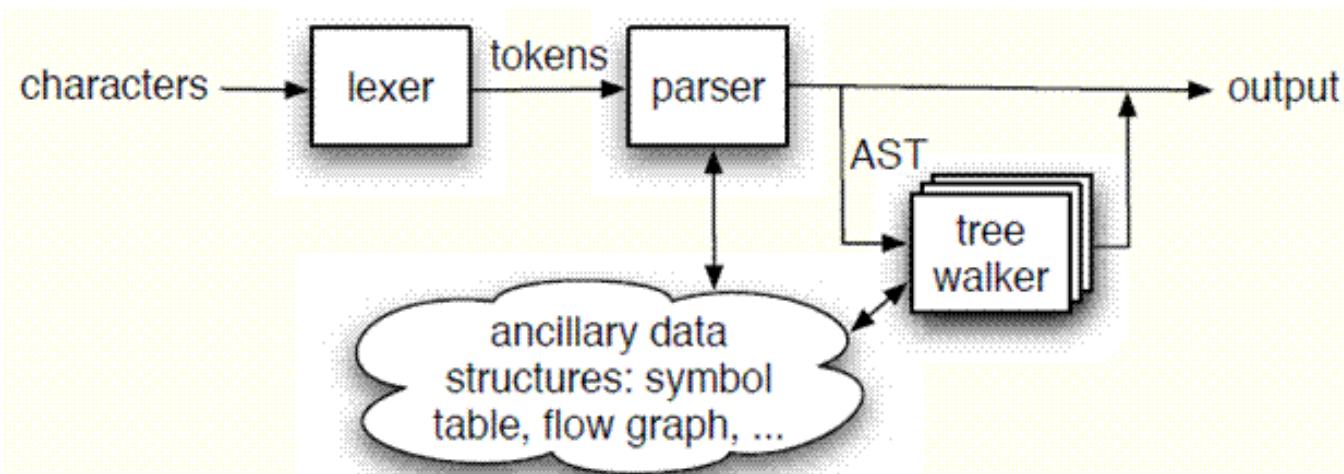
variableModifiers
: (
    FINAL
    | annotation
)*
;

classDeclaration
: normalClassDeclaration
| enumDeclaration
;
```

Compilation Process

- Source code
 - Concrete syntax used for specifying a program
 - Conformant to a grammar
- Lexical analysis
 - Converting a sequence of characters into a sequence of **tokens**
- Parsing (Syntactical analysis)
 - Abstract Syntax Tree (AST)





The Definitive
ANTLR
Reference

Building Domain-Specific Languages



Terence Parr

```

CHARLITERAL
:   '\'' 
    ( EscapeSequence
    | ~('\' | '\\\' | '\r' | '\n' )
    )
    '\''
;

STRINGLITERAL
:   """
    ( EscapeSequence
    | ~('\\\' | '"' | '\r' | '\n' )
    )*
"""

fragment
EscapeSequence
:   '\\' (
        'b'
        | 't'
        | 'n'
        | 'f'
        | '\r'
        | '\"'
        | '\\'
    )
;
```

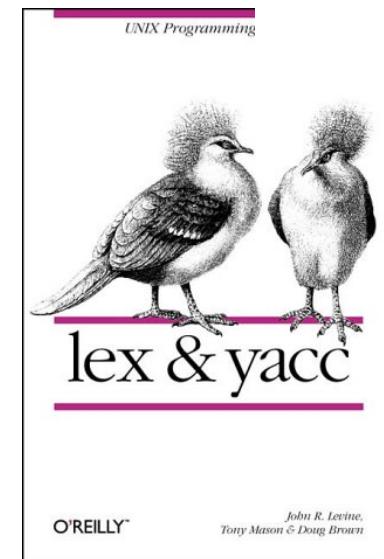
```

classOrInterfaceDeclaration
:   classDeclaration
|   interfaceDeclaration
;

modifiers
:   (
        annotation
        PUBLIC
        PROTECTED
        PRIVATE
        STATIC
        ABSTRACT
        FINAL
        NATIVE
        SYNCHRONIZED
        TRANSIENT
        VOLATILE
        STRICTFP
    )*
;

variableModifiers
:   (
        FINAL
        annotation
    )*
;

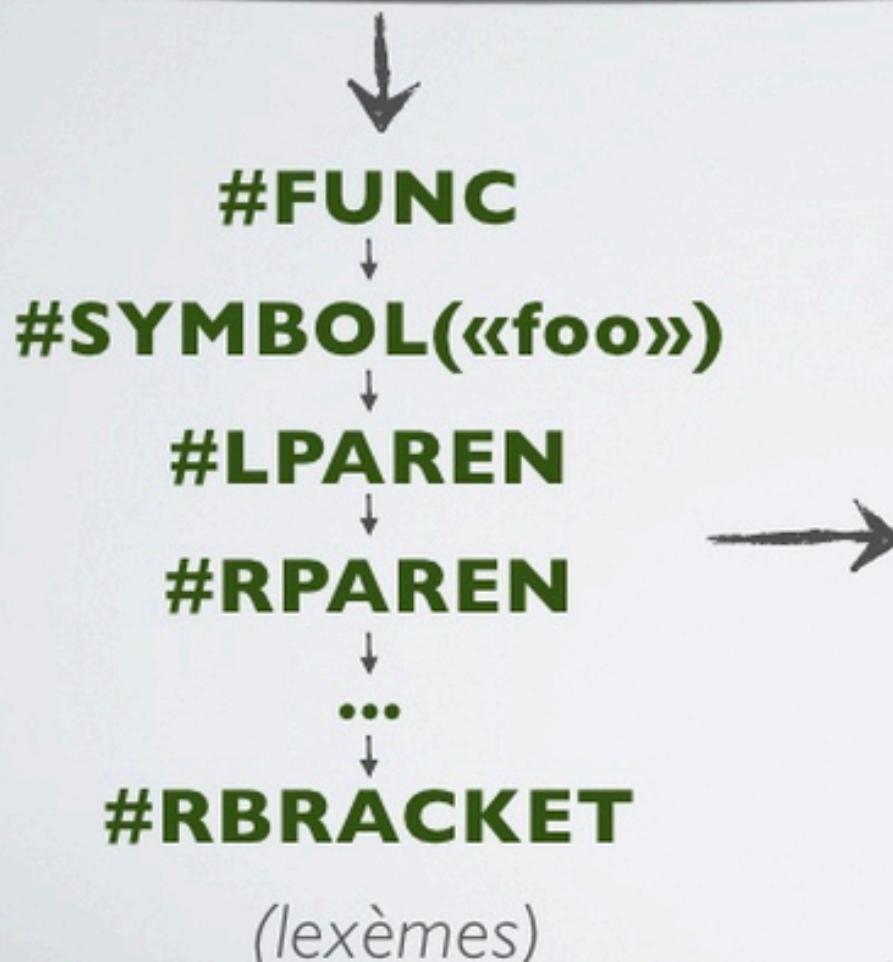
classDeclaration
:   normalClassDeclaration
|   enumDeclaration
;
```



O'REILLY®
John R. Levine,
Tony Mason & Doug Brown

EXEMPLE

```
function foo() {  
    echo «Hello, World !»;  
}  
(Syntaxe concrète)
```



```

class StringInterp {
    val int = 42
    val dbl = Math.PI
    val str = "My hovercraft is full of eels"

    println(s"String: $str Double: $dbl Int: $int Int Expr: ${int * 1.0}")
}

```

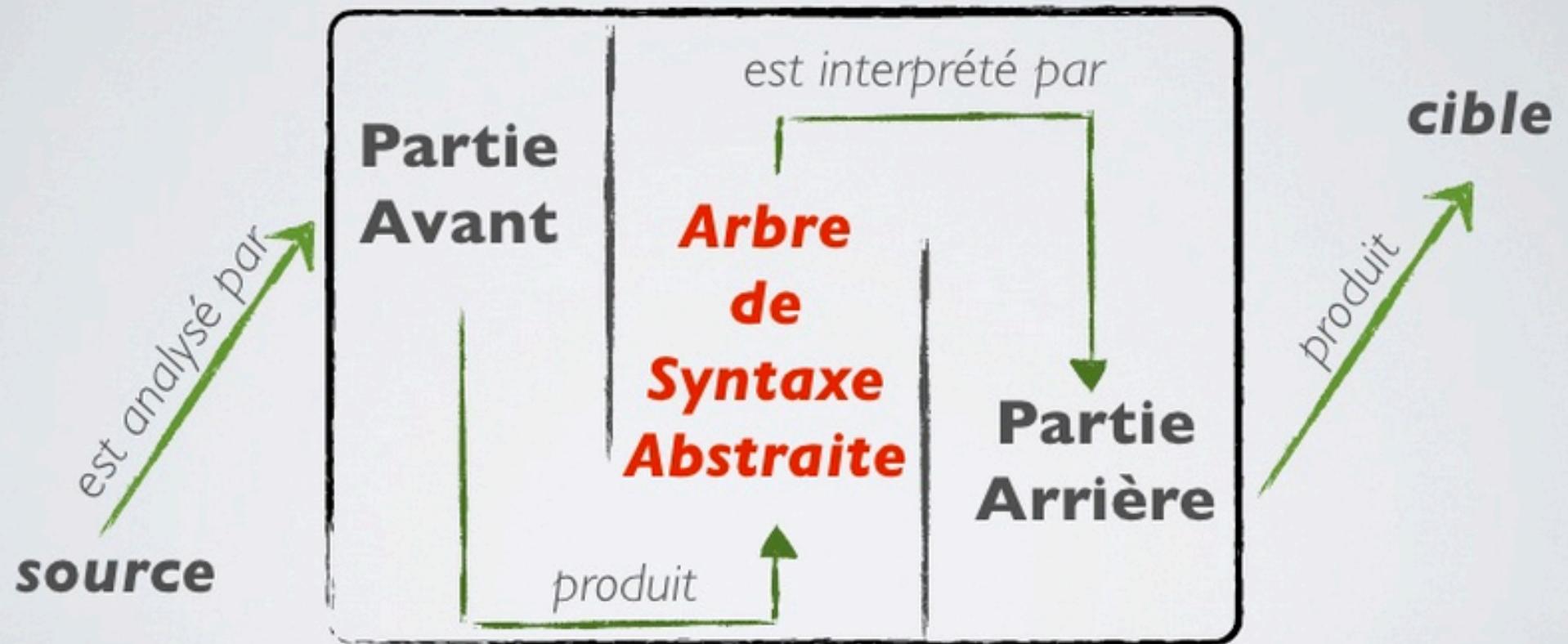
Scala AST (example)

```

Block(
  List(
    ClassDef(Modifiers(), TypeName("StringInterp"), List(), Template(
      List(Ident(TypeName("AnyRef"))), noSelfType, List(DefDef(Modifiers(), termNames.CONSTRUCTOR,
      List(),
      List(List())),
      TypeTree(), Block(List(Apply(Select(Super(This(typeNames.EMPTY), typeNames.EMPTY),
      termNames.CONSTRUCTOR), List()))), Literal(Constant(()))), ValDef(Modifiers(), TermName("int"),
      TypeTree(), Literal(Constant(42))), ValDef(Modifiers(), TermName("dbl"), TypeTree(),
      Literal(Constant(3.141592653589793))), ValDef(Modifiers(), TermName("str"), TypeTree(),
      Literal(Constant("My hovercraft is full of eels"))), Apply(Select(Ident(scala.Predef),
      TermName("println")), List(Apply(Select(Apply(Select(Ident(scala.StringContext), TermName("apply")),
      List(Literal(Constant("String: ")), Literal(Constant(" Double: ")), Literal(Constant(" Int: ")),
      Literal(Constant(" Int Expr: ")), Literal(Constant(""))))), TermName("s")),
      List(Select(This(TypeName("StringInterp")), TermName("str")), Select(This(TypeName("StringInterp")),
      TermName("dbl")), Select(This(TypeName("StringInterp")), TermName("int")),
      Apply(Select(Select(This(TypeName("StringInterp")), TermName("int")), TermName("$times")),
      List(Literal(Constant(1.0))))))), TermName("s"))),
      List(Literal(Constant(())))))))

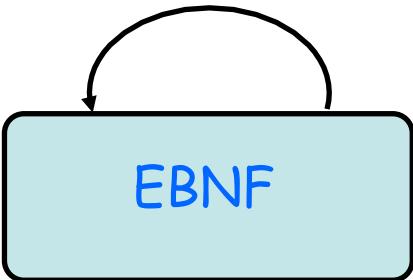
```

Compilation (en français)

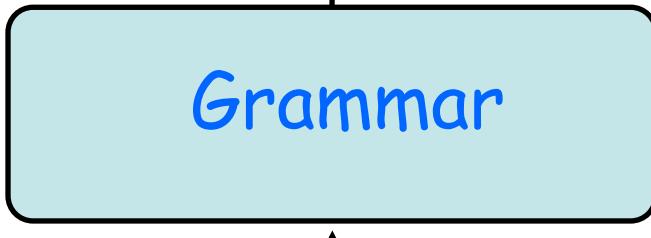


DSL? The same!

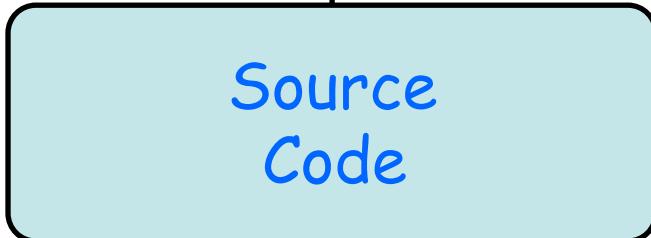
M³



M²



M¹



DSL Grammar

DSL specification/
program

UNIX Programming Tools



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*John R. Levine,
Tony Mason & Doug Brown*

The
Pragmatic
Programmers

The Definitive
ANTLR
Reference

Building Domain-
Specific Languages

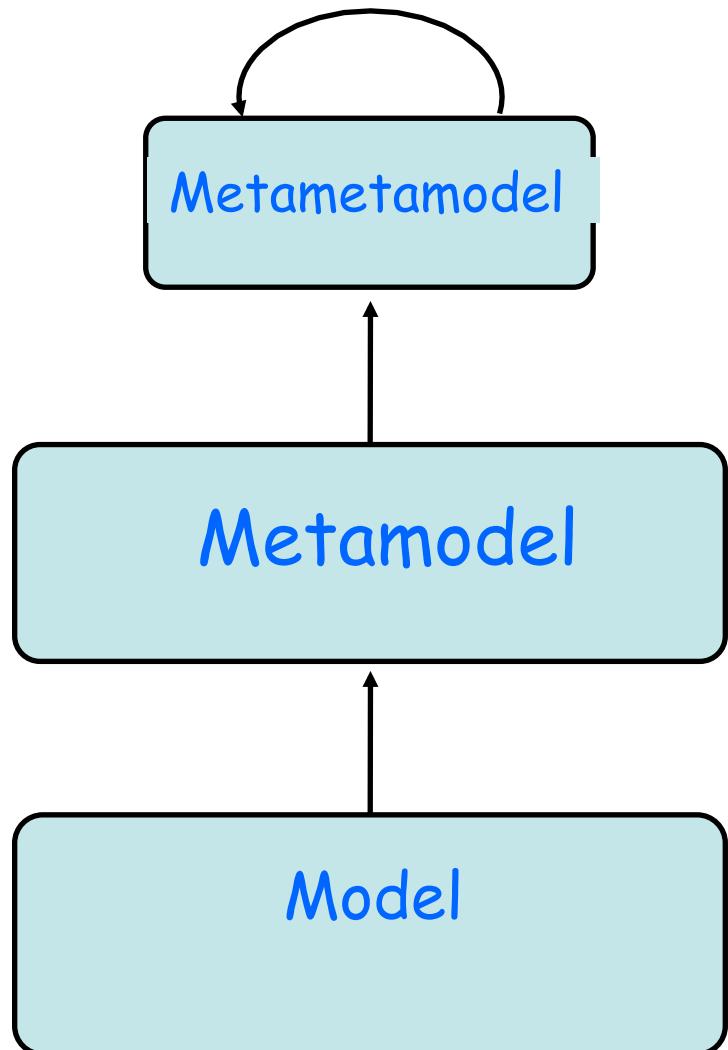
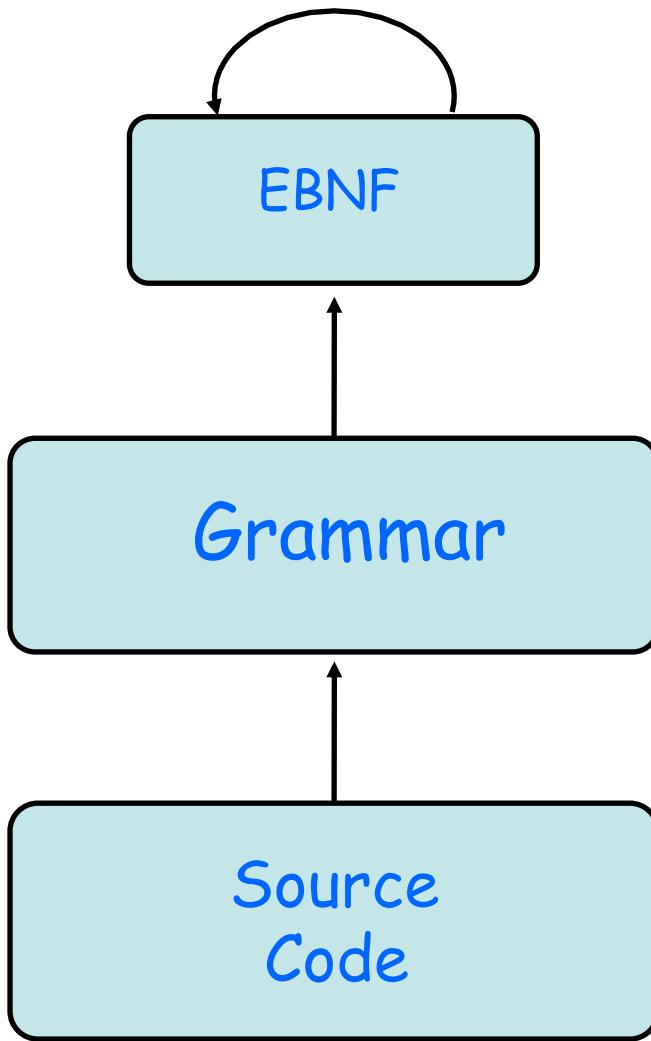


Terence Parr

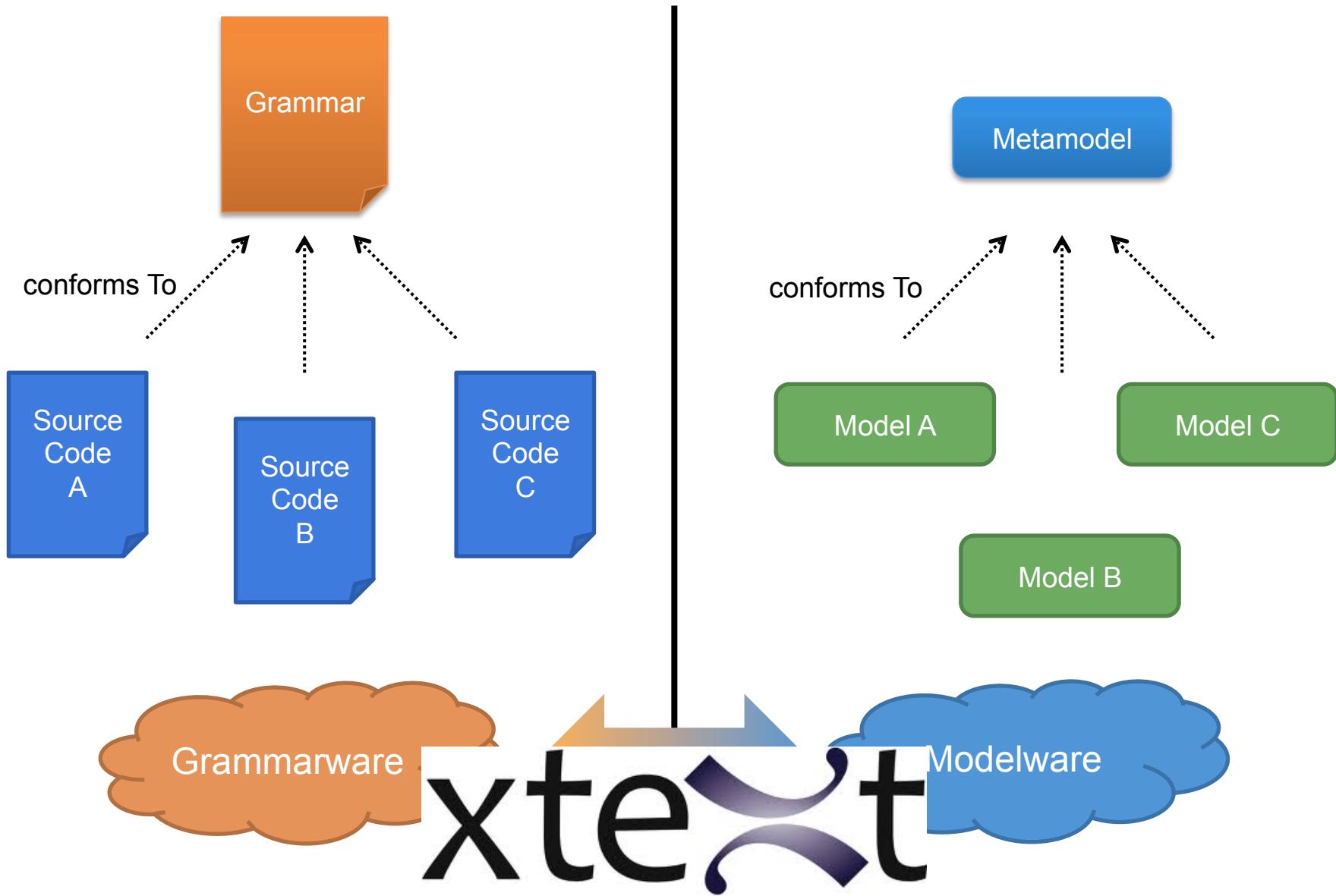
M³

M²

M¹



Language and MDE





Give me a **grammar**,

I'll give you (for free)

- * a comprehensive editor (auto-completion, syntax highlighting, etc.) in Eclipse
- * an Ecore metamodel and facilities to load/serialize/visit conformant models (Java ecosystem)
- * extension to override/extend « default » facilities (e.g., checker)

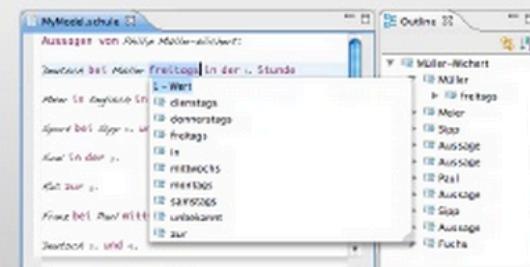
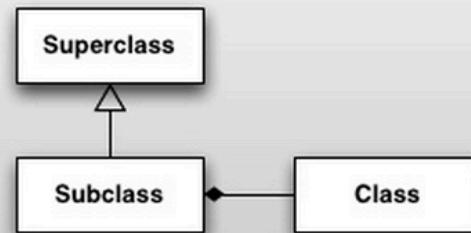
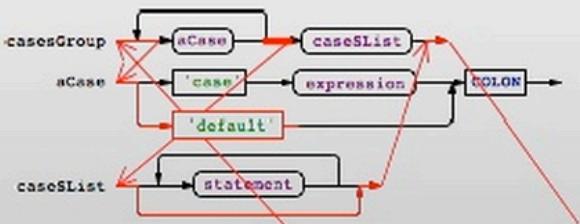
Model

Grammar

Xtext
Generator



Xtext Runtime

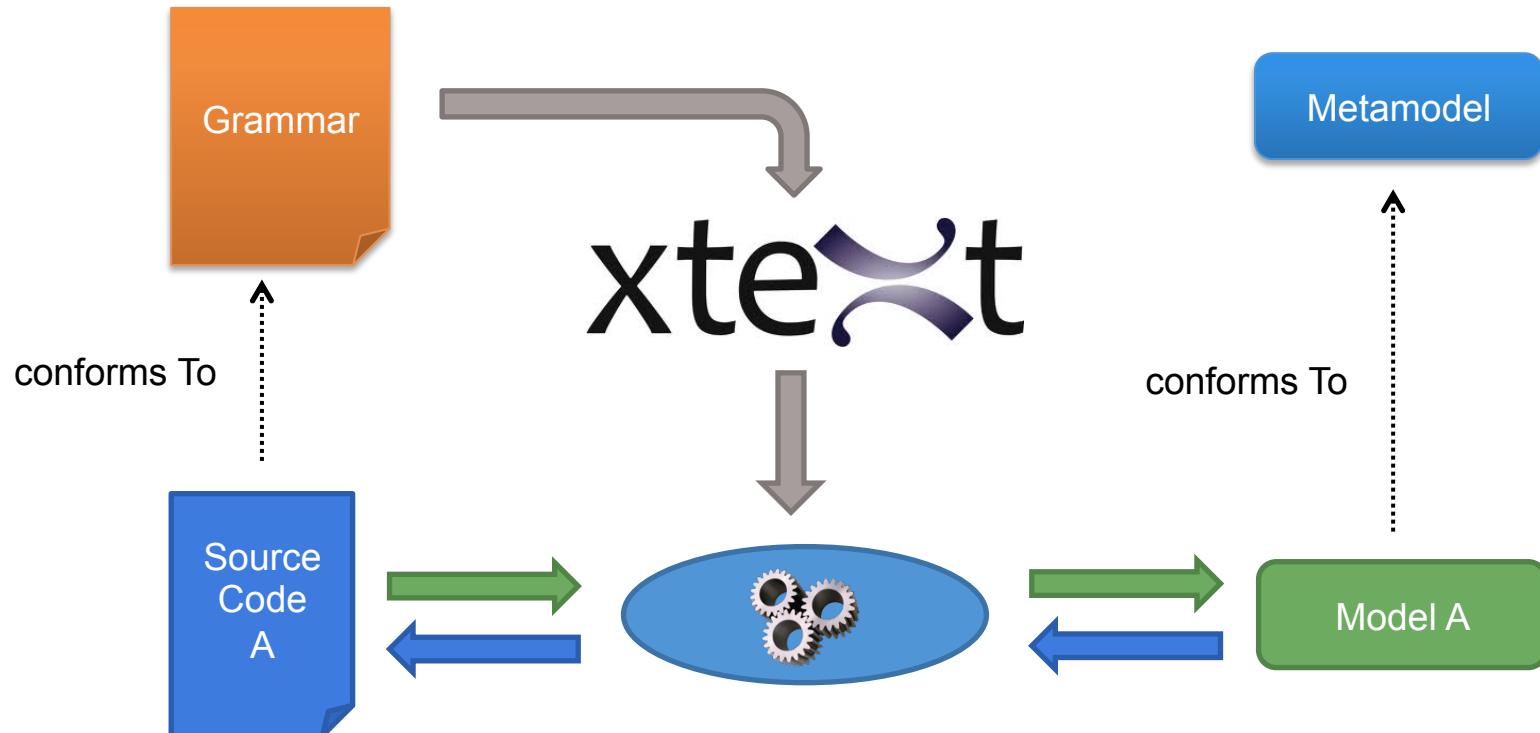


LL(*) Parser

ecore meta model

editor

Xtext, Grammar, Metamodel

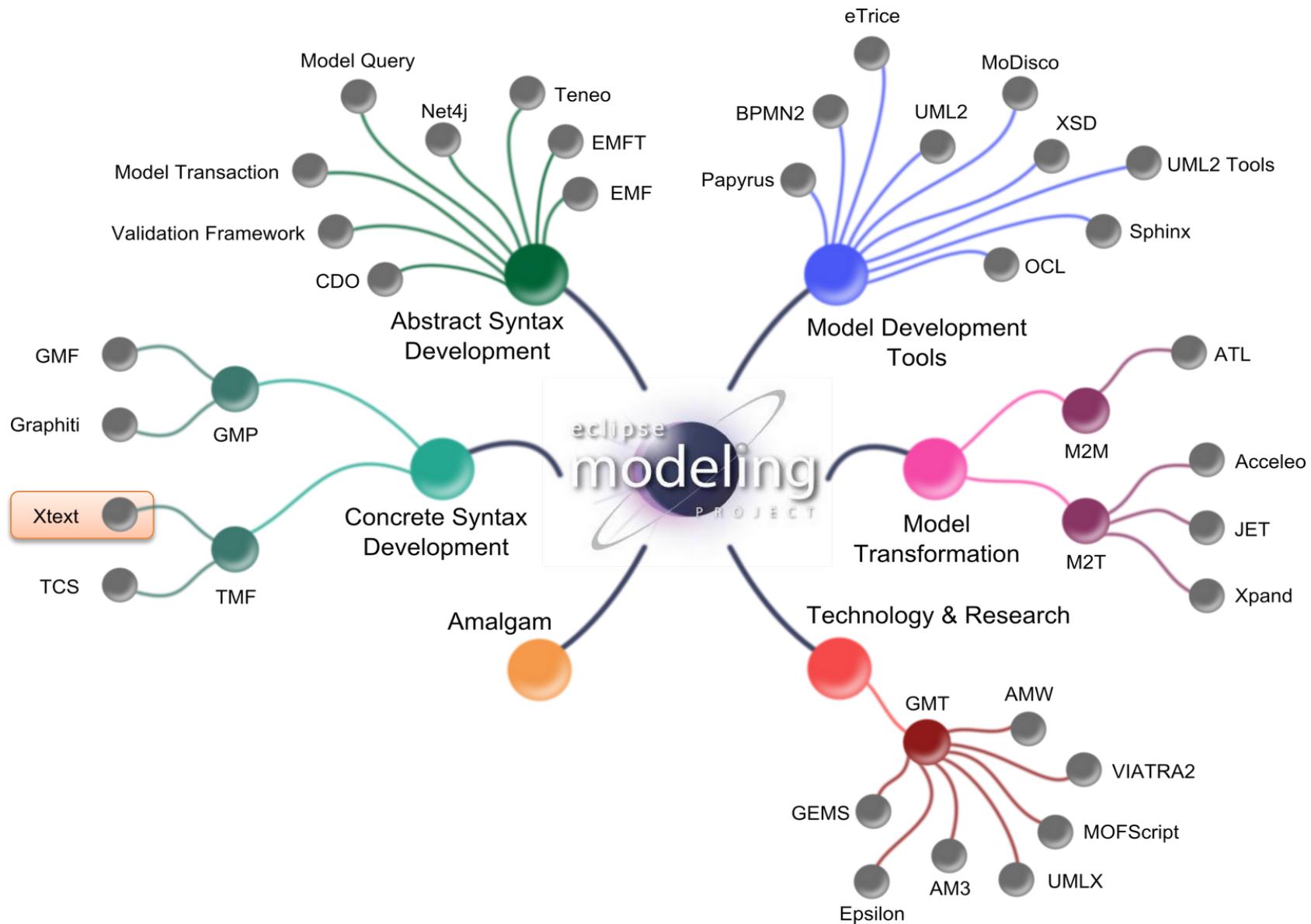


Xtext Project

- Eclipse Project
 - Part of Eclipse Modeling
 - Part of Open Architecture Ware
- Model-driven development of Textual DSLs
- Part of a family of languages
 - **Xtext**
 - Xtend
 - Xbase
 - Xpand
 - Xcore



Eclipse Modeling Project



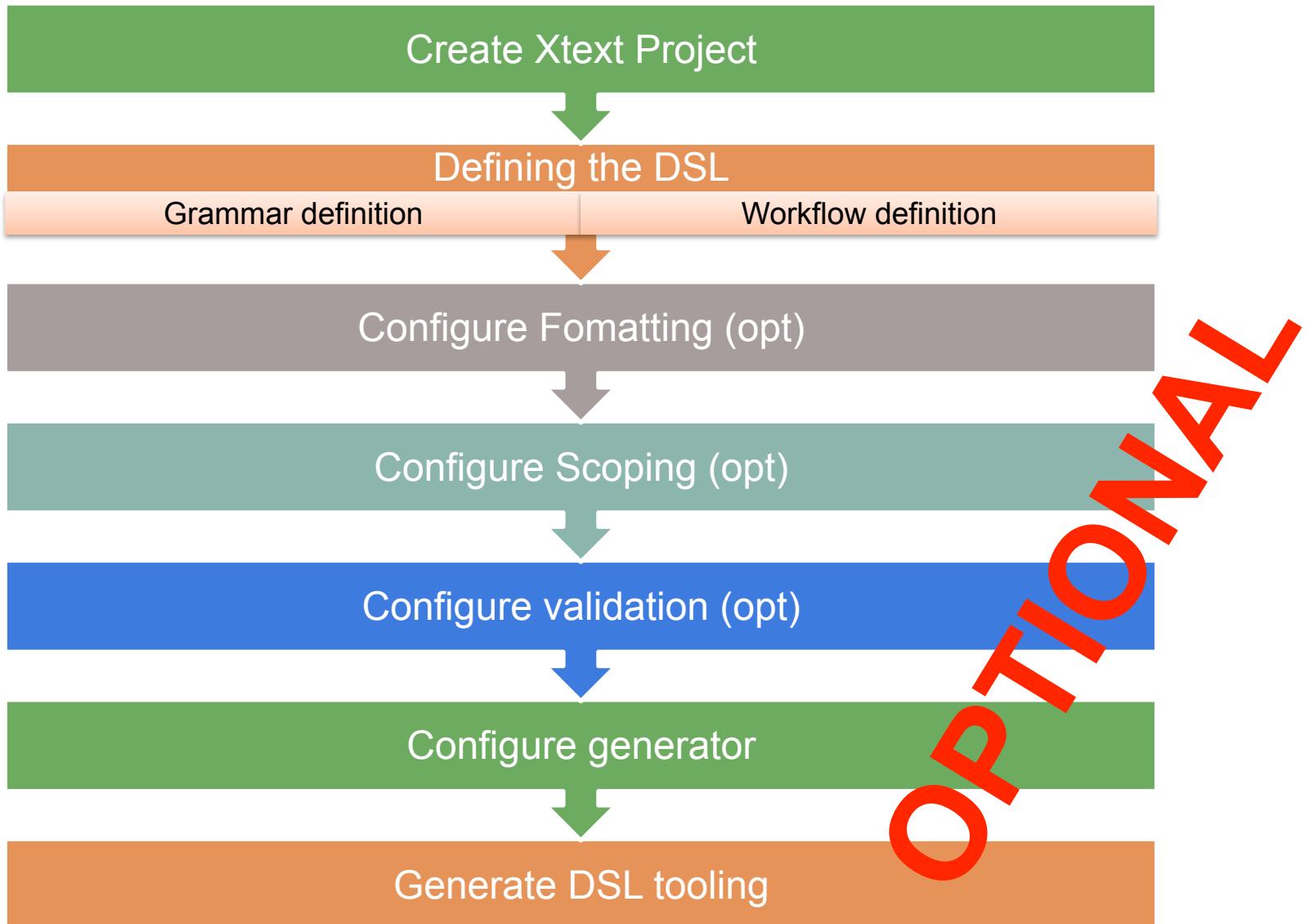
The Grammar Language of Xtext

- Corner-stone of Xtext
- A... DSL to define textual languages
 - Describe the concrete syntax
 - Specify the mapping between concrete syntax and domain model
- From the grammar, it is generated:
 - The domain model
 - The parser
 - The tooling

Main Advantages

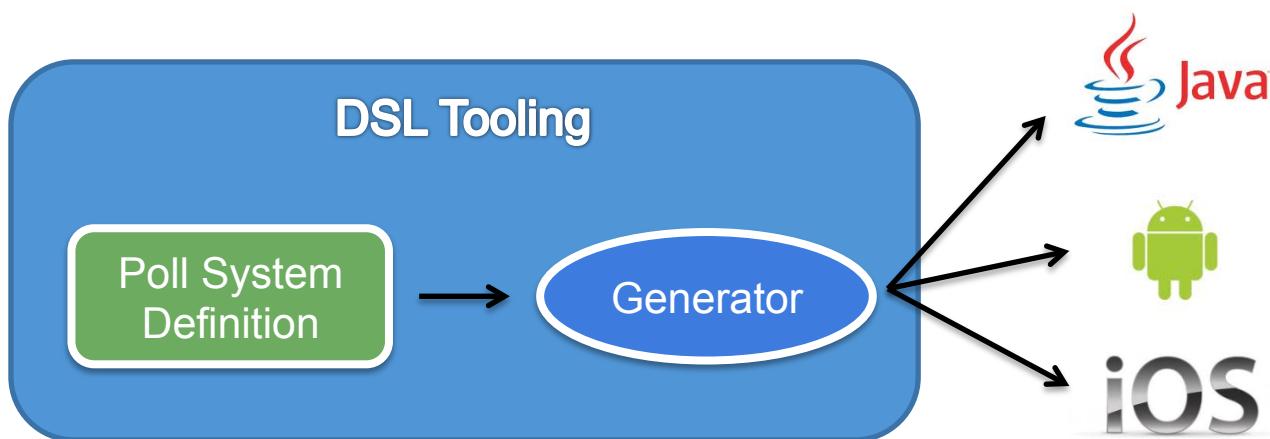
- Consistent look and feel
- Textual DSLs are a resource in Eclipse
- Open editors can be extended
- Complete framework to develop DSLs
- Easy to connect to any Java-based language

Development Process



A first example

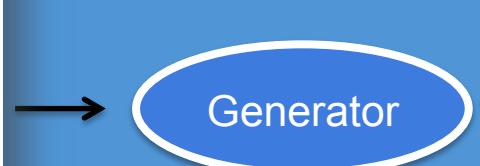
- Poll System application
 - Define a Poll with the corresponding questions
 - Each question has a text and a set of options
 - Each option has a text
- Generate the application in different platforms



Something like...

DSL Tooling

```
PollSystem {  
    Poll Quality {  
        Question q1 {  
            "Value the user experience"  
            options {  
                A : "Bad"  
                B : "Fair"  
                C : "Good"  
            }  
        }  
        Question q2 {  
            "Value the layout"  
            options {  
                A : "It was not easy to locate elements"  
                B : "I didn't realize"  
                C : "It was easy to locate elements"  
            }  
        }  
    }  
    Poll Performance {  
        Question q1 {  
            "Value the time response"  
            options {  
                A : "Bad"  
                B : "Fair"  
                C : "Good"  
            }  
        }  
    }  
}
```



Xtext Grammar

Grammar
definition →

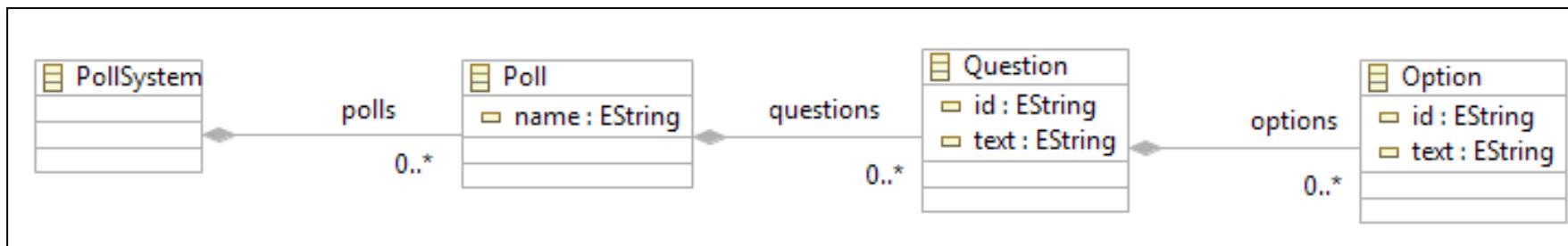
```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    
Poll:
    'Poll' name=ID '{' questions+=Question+'}';

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}'} '}';

Option:
    id=ID ':' text=STRING;
```



Xtext Grammar

Grammar
reuse

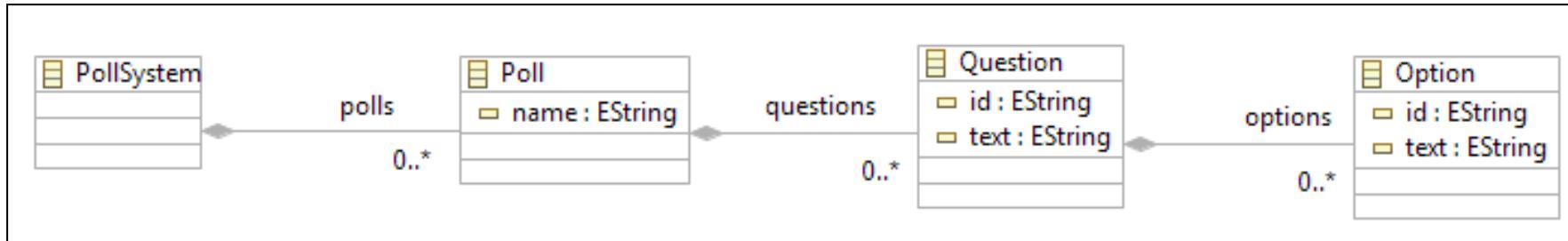
```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    
Poll:
    'Poll' name=ID '{' questions+=Question+'}';

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}'}' ';

Option:
    id=ID ':' text=STRING;
```



Xtext Grammar

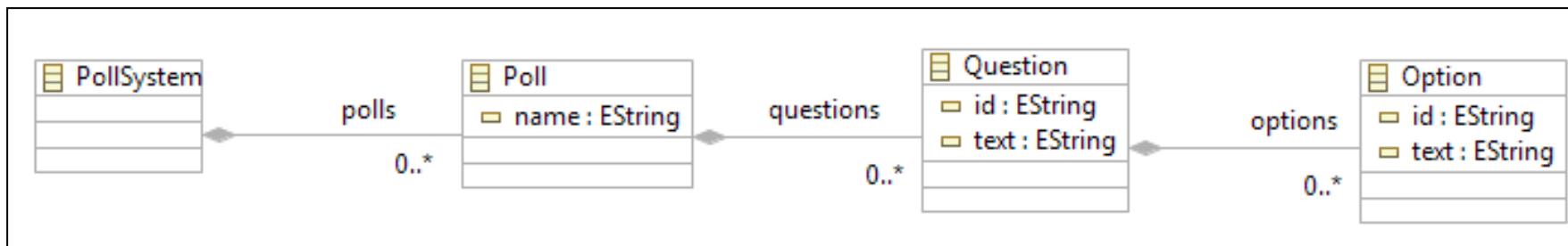
```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    
Poll:
    'Poll' name=ID '{' questions+=Question+'}'';

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}';
    
Option:
    id=ID ':' text=STRING;
```

Derived
metamodel



Xtext Grammar

Parser Rules

```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

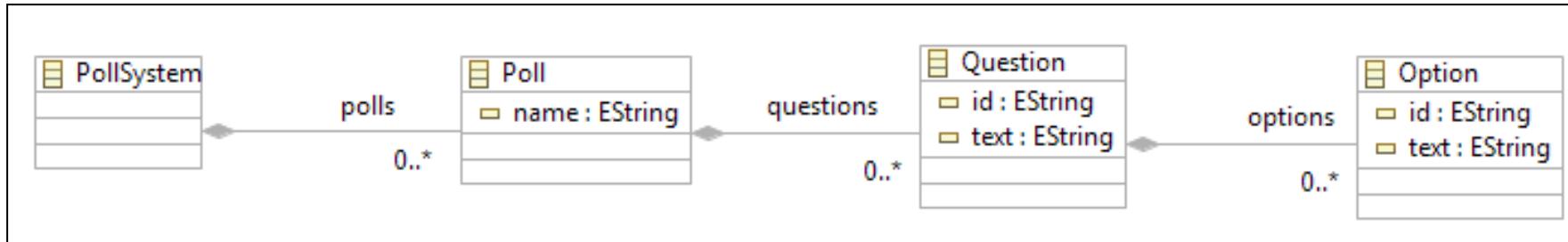
generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    }

Poll:
    'Poll' name=ID '{' questions+=Question+ '}';
    }

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}';
    }

Option:
    id=ID ':' text=STRING;
```



Xtext Grammar

```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

generate poll "http://www.miage.fr/xtext/Poll"
```

PollSystem:

```
→ 'PollSystem' '{' polls+=Poll+ '}';

```

Poll:

```
→ 'Poll' name=ID '{' questions+=Question+ '}';

```

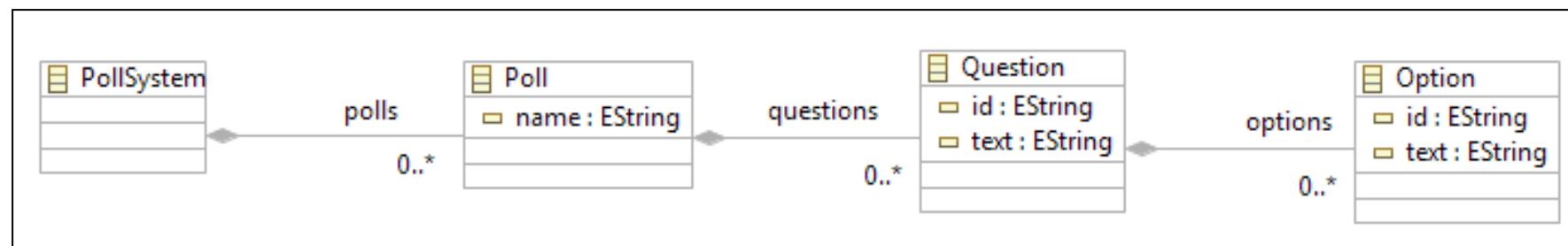
Question:

```
→ 'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}'} '}';

```

Option:

```
id=ID ':' text=STRING;
```



Xtext Grammar

```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

generate poll "http://www.miage.fr/xtext/Poll"

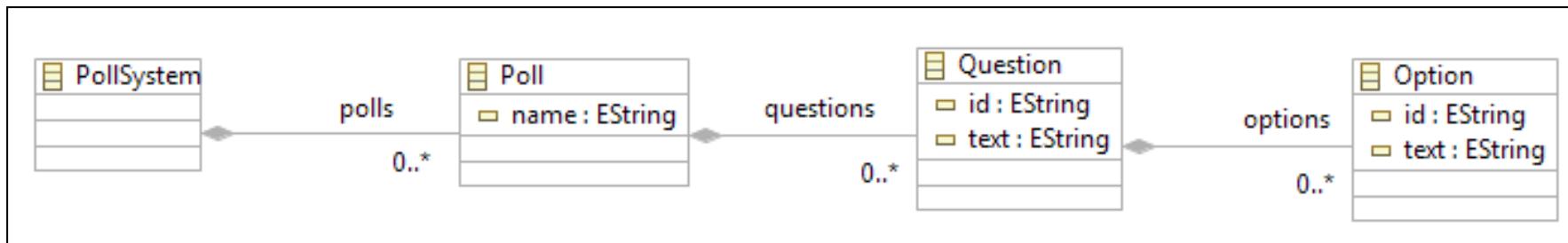
PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    ^ Multivalue assignment

Poll:
    'Poll' name=ID '{' questions+=Question+ '}';
    ^ Simple assignment

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}'} '}';

Option:
    id=ID ':' text=STRING;
```

(not here → **?= Boolean assignment**)



Xtext Grammar

```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

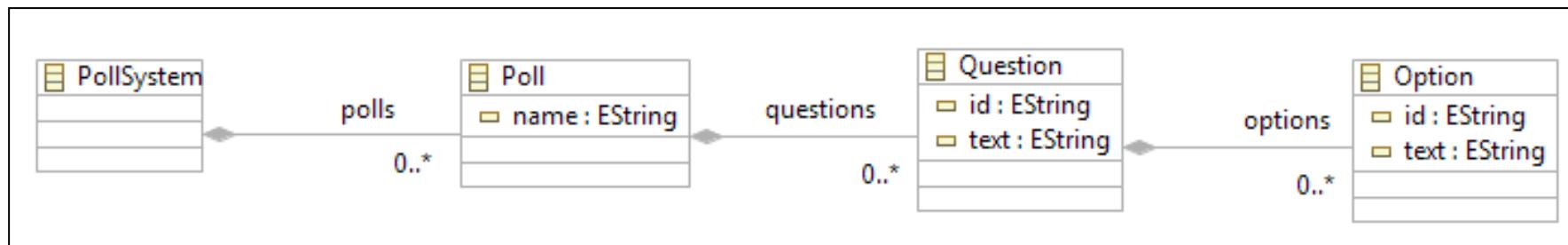
generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    ^Cardinality (others: * ?)

Poll:
    'Poll' name=ID '{' questions+=Question+ '}';

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}'}';

Option:
    id=ID ':' text=STRING;
```



Xtext Grammar

```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals
```

```
generate poll "http://www.miage.fr/xtext/Poll"
```

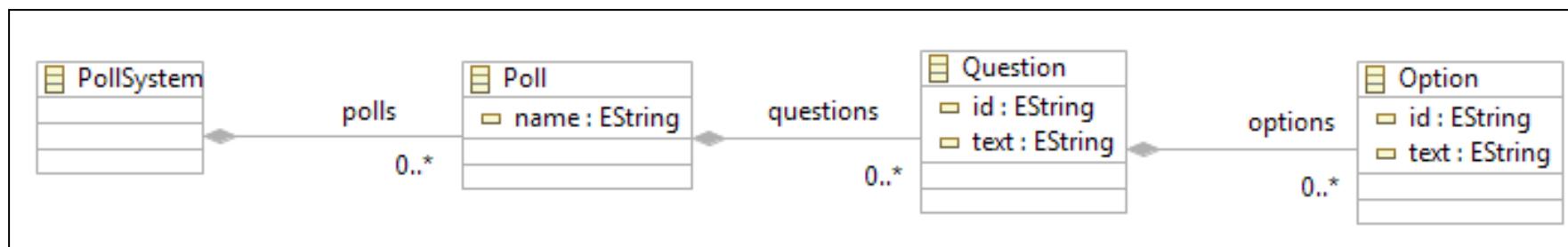
```
PollSystem:  
    'PollSystem' '{' polls+=Poll+ '}' ;
```

```
Poll:  
    'Poll' name=ID '{' questions+=Question+'}';
```

Question:
 'Question' id=ID '{{ text=STRING 'options' '{{ options+=Option+' }}'}};

```
Option:  
    id=ID `::` text=STRING;
```

Containment



Grammar and Programs/Specifications/Models

```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

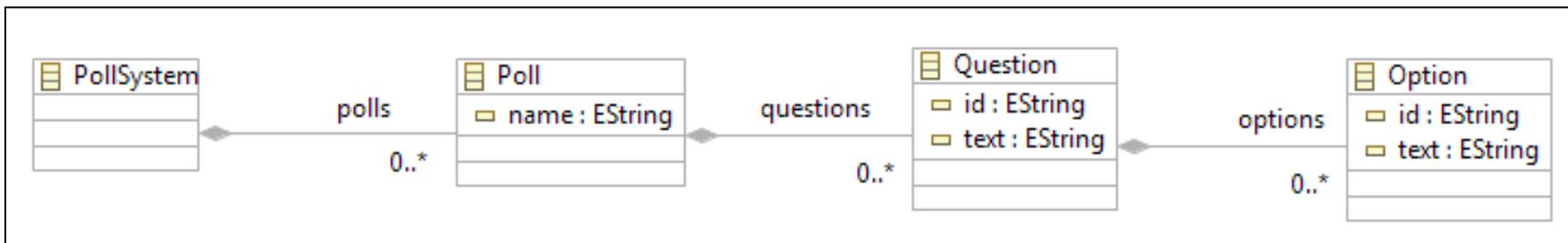
generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    
Poll:
    'Poll' name=ID '{' questions+=Question+'}'';

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}'}';

Option:
    id=ID ':' text=STRING;
```

```
PollSystem {
    Poll Quality {
        Question q1 {
            "Value the user experience"
            options {
                A : "Bad"
                B : "Fair"
                C : "Good"
            }
        }
        Question q2 {
            "Value the layout"
            options {
                A : "It was not easy to locate elements"
                B : "I didn't realize"
                C : "It was easy to locate elements"
            }
        }
    }
    Poll Performance {
        Question q1 {
            "Value the time response"
            options {
                A : "Bad"
                B : "Fair"
                C : "Good"
            }
        }
    }
}
```



Grammar and Programs/Specifications/Models

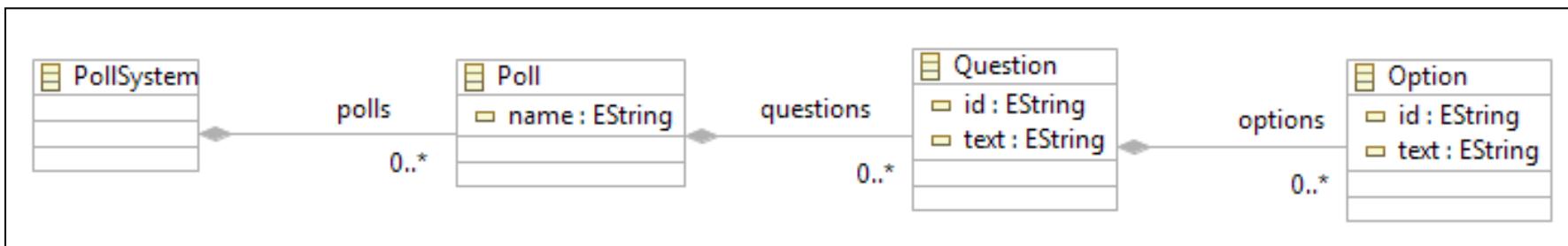
```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    
Poll:
    'Poll' name=ID '{' questions+=Question+'}'';

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}';
    
Option:
    id=ID ':' text=STRING;
```

```
PollSystem {
    Poll Quality {
        Question q1 {
            "Value the user experience"
            options {
                A : "Bad"
                B : "Fair"
                C : "Good"
            }
        }
        Question q2 {
            "Value the layout"
            options {
                A : "It was not easy to locate elements"
                B : "I didn't realize"
                C : "It was easy to locate elements"
            }
        }
    }
    Poll Performance {
        Question q1 {
            "Value the time response"
            options {
                A : "Bad"
                B : "Fair"
                C : "Good"
            }
        }
    }
}
```



Grammar and Programs/Specifications/Models

```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

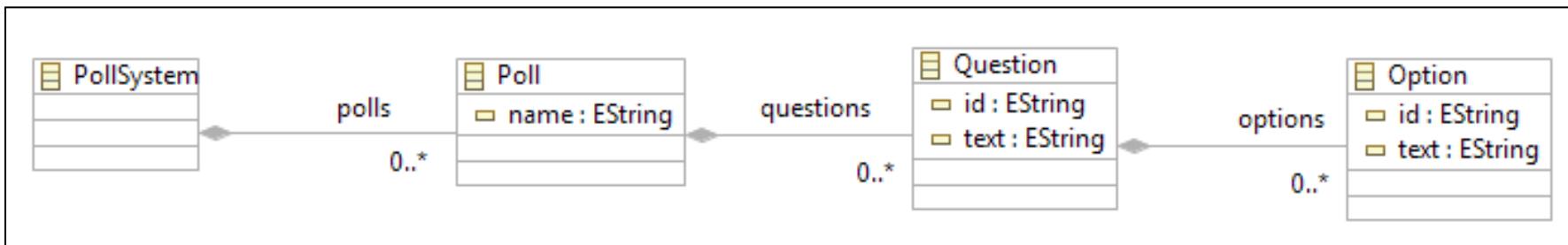
generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    
Poll:
    'Poll' name=ID '{' questions+=Question+'}'';

Question:
    'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}'}';

Option:
    id=ID ':' text=STRING;
```

```
PollSystem {
    Poll Quality {
        Question q1 {
            "Value the user experience"
            options {
                A : "Bad"
                B : "Fair"
                C : "Good"
            }
        }
        Question q2 {
            "Value the layout"
            options {
                A : "It was not easy to locate elements"
                B : "I didn't realize"
                C : "It was easy to locate elements"
            }
        }
    }
    Poll Performance {
        Question q1 {
            "Value the time response"
            options {
                A : "Bad"
                B : "Fair"
                C : "Good"
            }
        }
    }
}
```



Grammar and Programs/Specifications/Models

```
grammar fr.miage.xtext.Poll with org.eclipse.xtext.common.Terminals

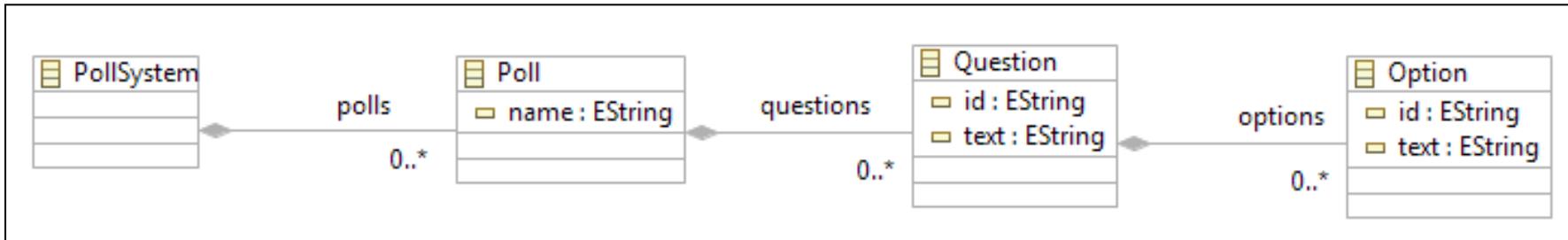
generate poll "http://www.miage.fr/xtext/Poll"

PollSystem:
    'PollSystem' '{' polls+=Poll+ '}';
    
Poll:
    'Poll' name=ID '{' questions+=Question+'}'';

Question:
    'Question' id=ID '{' text=STRING options='{' options+=Option+ '}'}';

Option:
    id=ID ':' text=STRING;
```

```
PollSystem {
    Poll Quality {
        Question q1 {
            "Value the user experience"
            options {
                A : "Bad"
                B : "Fair"
                C : "Good"
            }
        }
        Question q2 {
            "Value the layout"
            options {
                A : "It was not easy to locate elements"
                B : "I didn't realize"
                C : "It was easy to locate elements"
            }
        }
    }
    Poll Performance {
        Question q1 {
            "Value the time response"
            options {
                A : "Bad"
                B : "Fair"
                C : "Good"
            }
        }
    }
}
```



Quizz Time

Questionnaire.xtext

```
1 grammar org.xtext.example.mydsl.Questionnaire with org.eclipse.xtext.common.Terminals
2
3 generate questionnaire "http://www.xtext.org/example/mydsl/Questionnaire"
4
5 @PollSystem:
6     'PollSystem' '{' polls+=Poll+ '}';
7
8 @Poll:
9     'Poll' name=ID '{' questions+=Question+ '}';
10
11 Question : 'Question' ID? '{' text=STRING 'options' options+=Option+ '}';
12
13 Option : id=ID ':' text=STRING ;
```

Is an empty file a valid program wrt the grammar
Questionnaire.xtext? Why?

Quizz Time

```
grammar org.xtext.example.mydsl.Questionnaire with org.eclipse.xtext.common.Terminals

generate questionnaire "http://www.xtext.org/example/mydsl/Questionnaire"

PollSystem:
    {PollSystem} 'PollSystem' '{' polls+=Poll* '}';

Poll:
    'Poll' name=ID '{' questions+=Question+ '}';

Question : 'Question' ID? '[' text=STRING 'options' options+=Option+ ']';

Option : id=ID ':' text=STRING ;
```

PollSystem {

}

Is this program (see right-hand side) valid wrt grammar?

Quizz Time

Quetionnaire.xtext X

```
1 grammar org.xtext.example.mydsl.Quetionnaire with org.eclipse.xtext.common.Terminals
2
3 generate questionnaire "http://www.xtext.org/example/mydsl/Questionnaire"
4
5 @PollSystem:
6     'PollSystem' '{' polls+=Poll+ '}';
7
8 @Poll:
9     'Poll' name=ID '{' questions+=Question+ '}';
10
11 Question : 'Question' ID '{' text=STRING 'options' options+=Option+ '}';
12
13 Option : id=ID ':' text=STRING ;
```

Is this program (see right-hand side) valid wrt grammar?

```
PollSystem {
    Poll p1 {
        Question {
            "Q1"
            options o1 : "R1"
        }
    }
}
```

Xtext, your DSL in
5' (incl. editors and
serializers)

Live Demonstration with
Questionnaire language

The screenshot shows the Eclipse IDE interface with the Package Explorer and a code editor.

Package Explorer:

- org.xtext.example.questionnaire
- src
- org.xtext.example.mydsl
- GenerateQuestionnaire.mwe2 (selected)
- Questionnaire.xtext
- src-gen
- xtend-gen
- JRE System Library [JavaSE-1.8]
- Plug-in Dependencies
- META-INF
- build.properties
- org.xtext.example.questionnaire.sdk
- org.xtext.example.questionnaire.tests
- org.xtext.example.questionnaire.ui

Code Editor (Questionnaire.xtext):

```
1 grammar org.xtext.example.mydsl.Questionnaire with org.eclipse.xtext.common.Terminals
2
3 generate questionnaire "http://www.xtext.org/example/mydsl/Questionnaire"
4
5 PollSystem:
6     'PollSystem' '{' polls+=Poll+ '}';
7
8 Poll:
9     'Poll' name=ID '{' questions+=Question+ '}';
10
11 Question : 'Question' id=ID '{' text=STRING 'options' '{' options+=Option+ '}' '}';
12
13 Option : id=ID ':' text=STRING ;
```

Package Explorer



Questionnaire.xtext

org.xtext.example.questionnaire

src

org.xtext.example.mydsl

GenerateQuestionnaire.mwe2

Questionnaire.xtext

src-gen

xtend-gen

JRE System Library [JavaSE-1.8]

Plug-in Dependencies

META-INF

build.properties

org.xtext.example.questionnaire.sdk

org.xtext.example.questionnaire.tests

org.xtext.example.questionnaire.ui

org.xtext.example.videogenerator

org.xtext.example.videogenerator.sdk

org.xtext.example.videogenerator.tests

org.xtext.example.videogenerator.ui

```
1 grammar org.xtext.example.mydsl.Questionnaire
2
3 generate questionnaire "http://www.xtext.org"
4
```

New

Open

Open With

Show In

Copy

Copy Qualified Name

Paste

Delete

Build Path

Refactor

Import...

Export...

Refresh

Assign Working Sets...

Validate

Run As

Debug As

Replace With

Team

Compare With

Properties

System' '{' polls+=Poll+ '}';

name=ID '{' questions+=Questi

Question' id=ID '{' text=\$1

=ID ':' text=STRING ;

1 MWE2 Workflow

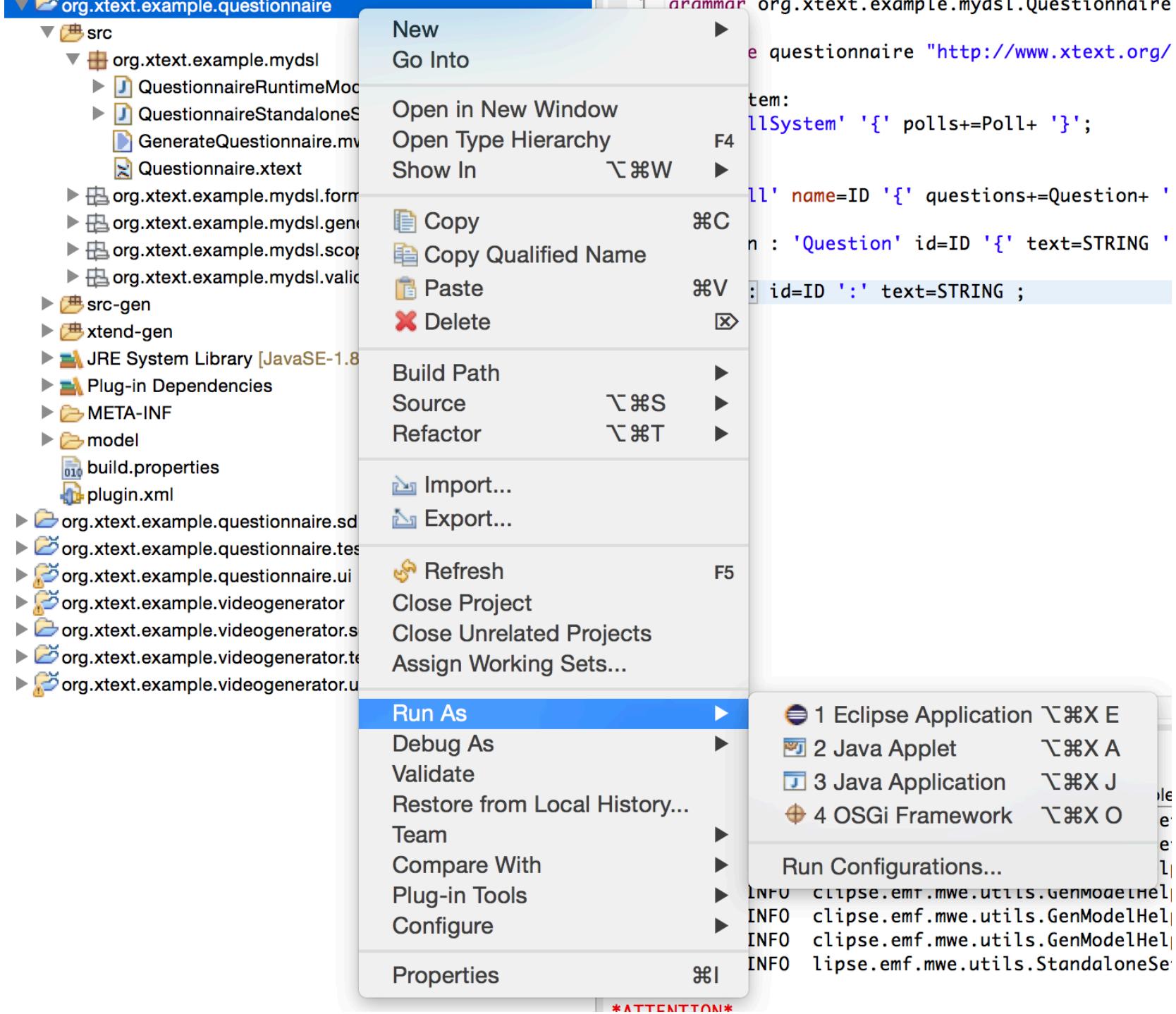
Run Configurations...

Problems Javadoc Declaration Console

<terminated> Generate Language Infrastructure (org.xtext.example.questionnaire) [Mwe2 Launch] /Library/Java/JavaVirtualMachines/jdk1.8.0_31.jdk/Contents/Home/bin/java (28 sept. 2014)

```
0 [main] INFO lipse.emf.mwe.utils.StandaloneSetup - Registering platform uri '/Users/macher1/Documents/workspaceIDM1516'
127 [main] INFO lipse.emf.mwe.utils.StandaloneSetup - Adding generated EPackage 'org.eclipse.xtext.Xbase.XbasePackage'
408 [main] INFO clipse.emf.mwe.utils.GenModelHelper - Registered GenModel 'http://www.eclipse.org/Xtext/Xbase/XAnnotations' from 'platform:/resource/Questionnaire/XAnnotations.genmodel'
413 [main] INFO clipse.emf.mwe.utils.GenModelHelper - Registered GenModel 'http://www.eclipse.org/xtext/xbase/Xtype' from 'platform:/resource/Questionnaire/Xtype.genmodel'
436 [main] INFO clipse.emf.mwe.utils.GenModelHelper - Registered GenModel 'http://www.eclipse.org/xtext/xbase/Xbase' from 'platform:/resource/Questionnaire/Xbase.genmodel'
436 [main] INFO clipse.emf.mwe.utils.GenModelHelper - Registered GenModel 'http://www.eclipse.org/xtext/common/JavaVMTypes' from 'platform:/resource/Questionnaire/JavaVMTypes.genmodel'
1005 [main] INFO lipse.emf.mwe.utils.StandaloneSetup - Adding generated EPackage 'org.eclipse.xtext.common.types.TypesPackage'

*ATTENTION*
It is recommended to use the ANTLR 3 parser generator (BSD licence - http://www.antlr.org/license.html).
Do you agree to download it (size 1MB) from 'http://download.itemis.com/antlr-generator-3.2.0-patch.jar'? (type 'y' or 'n' and hit enter)y
11812 [main] INFO erator.parser.antlr.AntlrToolFacade - downloading file from 'http://download.itemis.com/antlr-generator-3.2.0-patch.jar' ...
108842 [main] INFO erator.parser.antlr.AntlrToolFacade - finished downloading.
108848 [main] INFO ipse.emf.mwe.utils.DirectoryCleaner - Cleaning /Users/macher1/Documents/workspaceIDM1516/org.xtext.example.questionnaire
108849 [main] INFO ipse.emf.mwe.utils.DirectoryCleaner - Cleaning /Users/macher1/Documents/workspaceIDM1516/org.xtext.example.questionnaire
108849 [main] INFO ipse.emf.mwe.utils.DirectoryCleaner - Cleaning /Users/macher1/Documents/workspaceIDM1516/org.xtext.example.questionnaire
110353 [main] INFO clipse.emf.mwe.utils.GenModelHelper - Registered GenModel 'http://www.xtext.org/example/mydsl/Questionnaire' from 'platform:/resource/Questionnaire.genmodel'
113410 [main] INFO text.generator.junit.Junit4Fragment - generating Junit4 Test support classes
113428 [main] INFO text.generator.junit.Junit4Fragment - generating Compare Framework infrastructure
113584 [main] INFO .emf.mwe2.runtime.workflow.Workflow - Done.
```



**File**

Create a new file resource.



Enter or select the parent folder:

FooQuestionnaire



FooQuestionnaire

VideoGen1

File name:

Advanced >>



Cancel

Finish

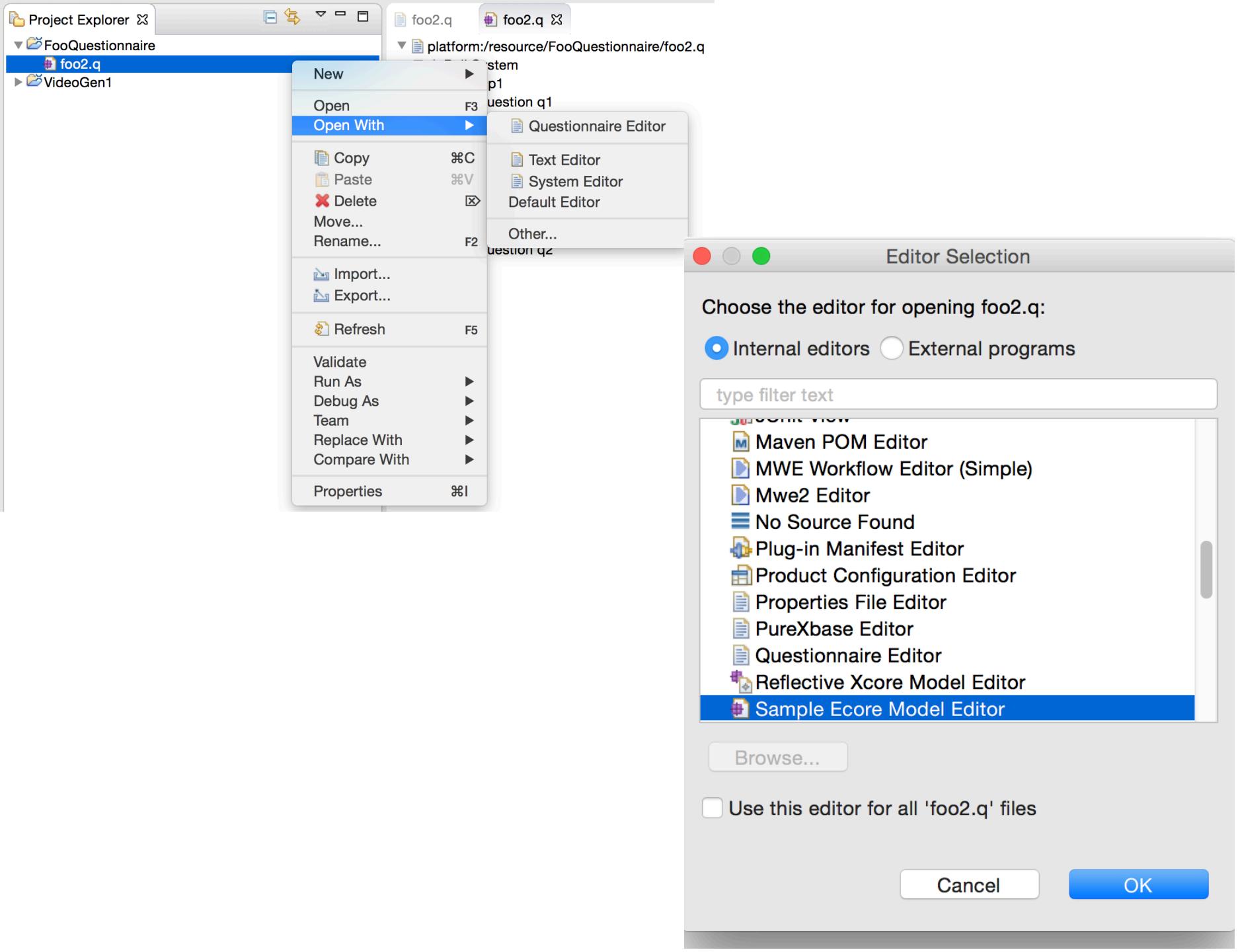
```
PollSystem {

    Poll p1 {
        Question q1 {
            "What is the best JavaScript framework for testing?"
            options [
                A1: "PhantomJS"
                A2: "Jasmine"
                A3: "Mocha"
                A4: "I prefer to develop my own framework"
            ]
        }

        Question q2 {
            "What is the best CSS preprocessor?"
            options [
                A1: "Less.js"
                A2: "Sass"
                A3: "Stylus"
                A4: "I don't care about preprocessing CSS"
            ]
        }
    }

    Poll p2 {
        Question q1 {
            "What is the best Java framework for testing?"
            options [
                A1: "JUnit"
                A2: "Jasmine"
                A3: "I prefer to develop my own framework"
            ]
        }

        Question q2 {
            "What is the best Java library for logging?"
            options [
                A1: "Log4J"
                A2: "java.util.logging"
                A3: "I don't care about logging"
            ]
        }
    }
}
```



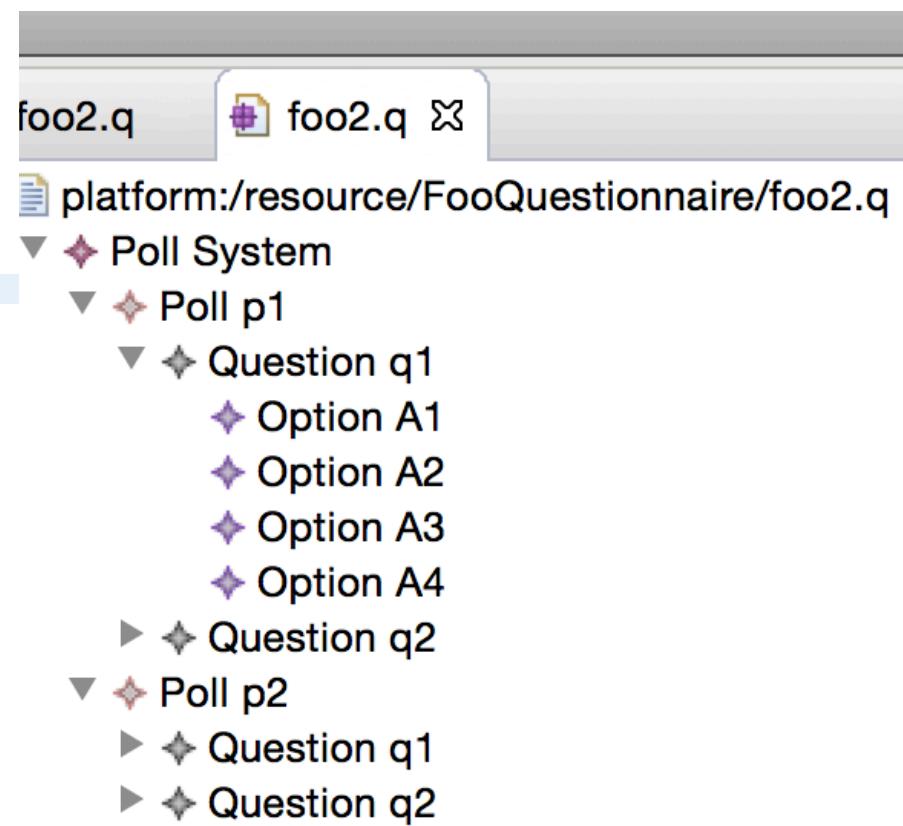
```
2.q ✎
ollSystem {

Poll p1 {
    Question q1 {
        "What is the best JavaScript framework for testing?"
        options [
            A1: "PhantomJS"
            A2: "Jasmine"
            A3: "Mocha"
            A4: "I prefer to develop my own framework"
        ]
    }

    Question q2 {
        "What is the best CSS preprocessor?"
        options {
            A1: "Less.js"
            A2: "Sass"
            A3: "Stylus"
            A4: "I don't care about preprocessing CSS"
        }
    }

Poll p2 {
    Question q1 {
        "What is the best Java framework for testing?"
        options {
            A1: "JUnit"
            A2: "Jasmine"
            A3: "I prefer to develop my own framework"
        }
    }

    Question q2 {
        "What is the best Java library for logging?"
        options {
            A1: "Log4J"
            A2: "java.util.logging"
            A3: "I don't care about logging"
        }
    }
}
}
```



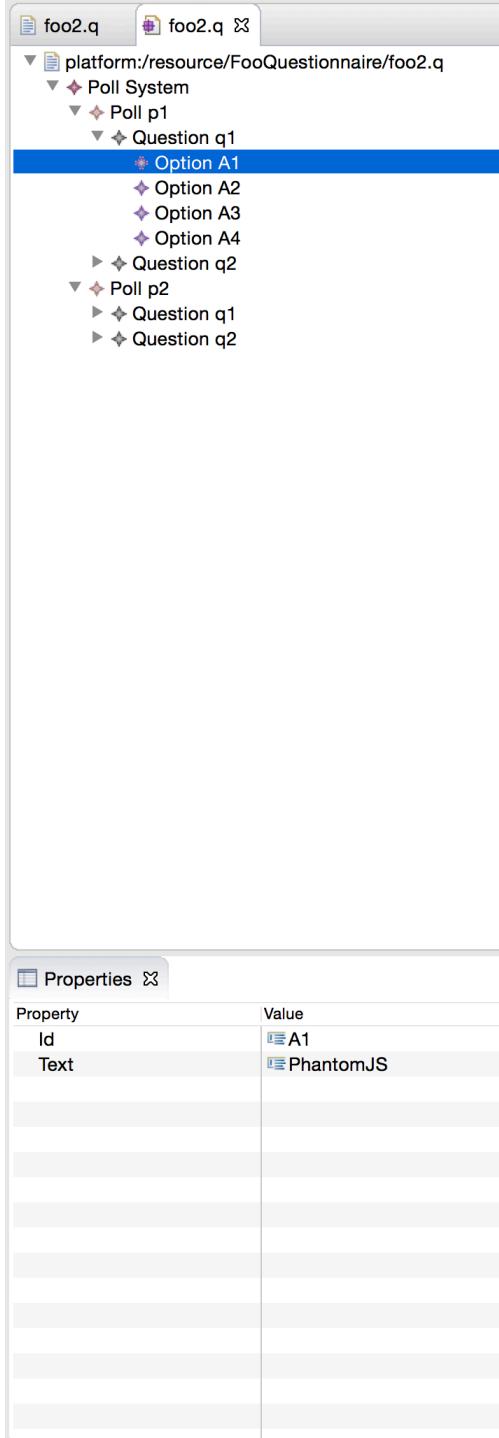
```
2.q ✎
ollSystem {

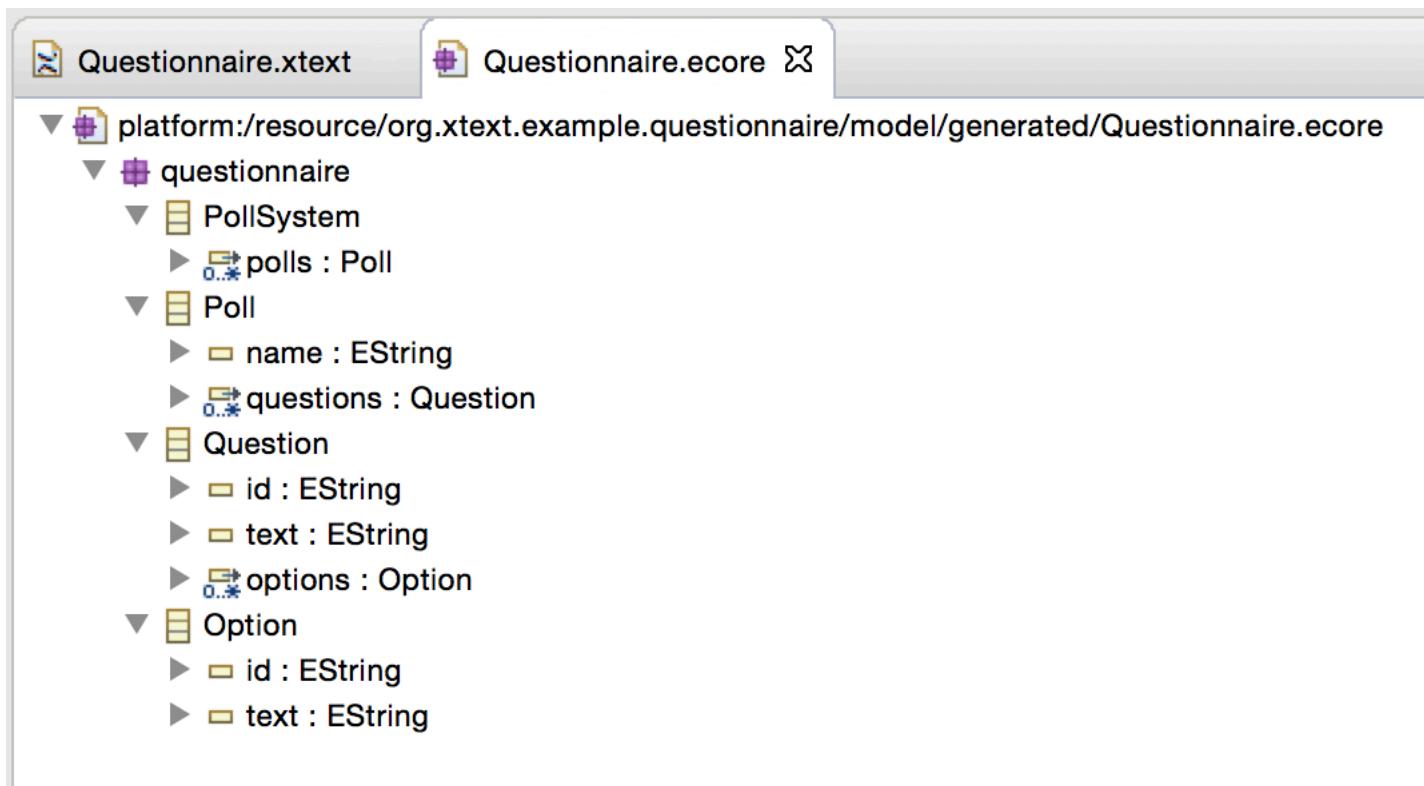
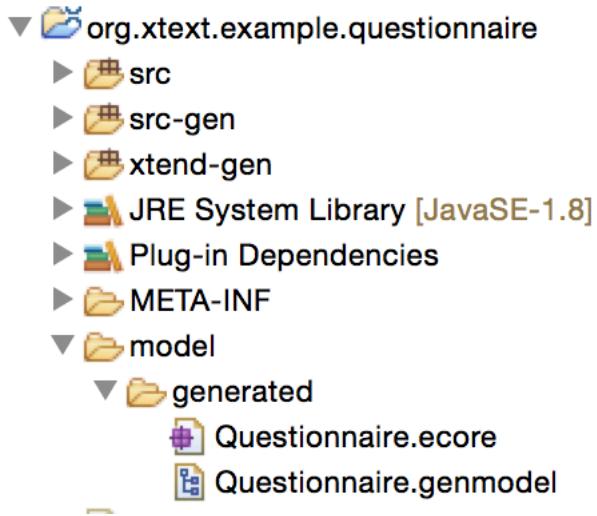
    Poll p1 {
        Question q1 {
            "What is the best JavaScript framework for testing?"
            options [
                A1: "PhantomJS"
                A2: "Jasmine"
                A3: "Mocha"
                A4: "I prefer to develop my own framework"
            ]
        }

        Question q2 {
            "What is the best CSS preprocessor?"
            options [
                A1: "Less.js"
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                A4: "I don't care about preprocessing CSS"
            ]
        }
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    Poll p2 {
        Question q1 {
            "What is the best Java framework for testing?"
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                A1: "JUnit"
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        Question q2 {
            "What is the best Java library for logging?"
            options [
                A1: "Log4J"
                A2: "java.util.logging"
                A3: "I don't care about logging"
            ]
        }
    }
}
```





Another example:

Chess

**“Queen to c7.
Check.”**



**“Rd2-c2,
rook at d2 moves to c2”**

Moves in Chess:

Rook at a1 moves to a5.

Piece Square Action Destination

Bishop at c8 captures knight at h3.

Piece Square Action Destination

N b1 x c3

Piece Square Action Destination

g2 - g4

Square Action Destination

Bishop at c8 captures knight at h3

$\mathbb{B} \text{ c8 x h3}$



P e2 – e4

p g7 – g5

Knight at b2 moves to c3

pawn at f7 moves to f5

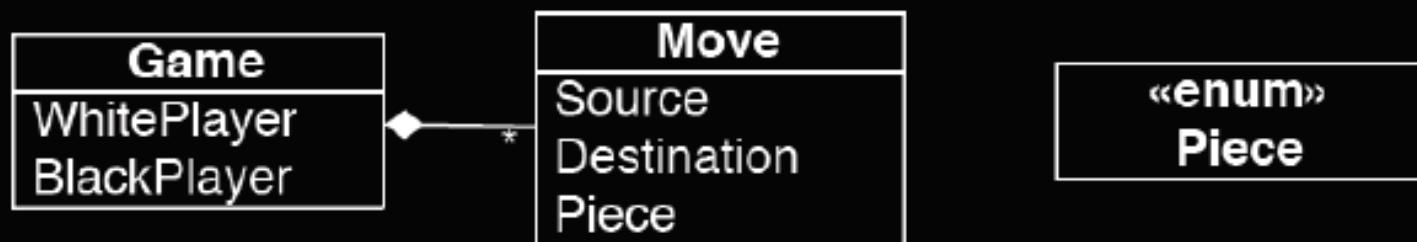
Q d1 – h5

1-0

Concrete Syntax

Constraints !!!

Abstract Syntax



Chess Example - Grammar

Game:

```
"White:" whitePlayer=STRING  
"Black:" blackPlayer=STRING  
(moves+=Move) +;
```

Move:

```
AlgebraicMove | SpokenMove;
```

AlgebraicMove:

```
(piece=Piece) ? source=Square (captures?='x' | '-') dest=Square;
```

SpokenMove:

```
piece=Piece 'at' source=Square  
(captures?='captures' capturedPiece=Piece 'at' | 'moves to')  
dest=Square;
```

terminal Square:

```
('a'..'h')('1'..'8');
```

enum Piece:

```
pawn    = 'P' | pawn = 'pawn' |  
knight  = 'N' | knight = 'knight' |  
bishop  = 'B' | bishop = 'bishop' |  
rook    = 'R' | rook = 'rook' |  
queen   = 'Q' | queen = 'queen' |  
king    = 'K' | king = 'king';
```

Chess Example - Model

White: "Mayfield"

Black: "Trinks"

pawn at e2 moves to e4

pawn at f7 moves to g5

K b1 - c3

f7 - f5

queen at d1 moves to h5

// 1-0

Yet another
example
VideoGen

bref.
CANAL à 30 ans.

ETAPE 1 : DONNE TON PRENOM

MATHIEU

→ OK

Online Generator

← → C bref30ans.canalplus.fr/#c

ETAPE 2 : CHOISIS 3 BONS SOUVENIRS



Variant





40 ans et pas une ride

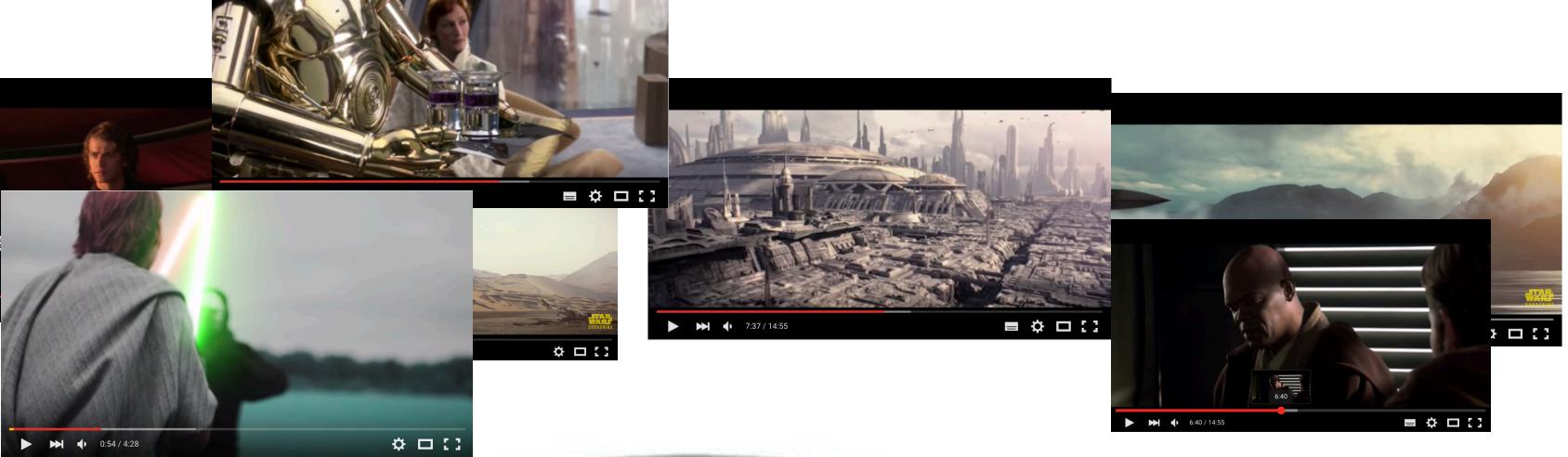
Découvrir un nouvel épisode...

Déjà 1768 épisodes générés !



Jean-Marc JEZEQUEL

Professeur des universités en informatique,
Directeur de l'IRISA depuis 2012

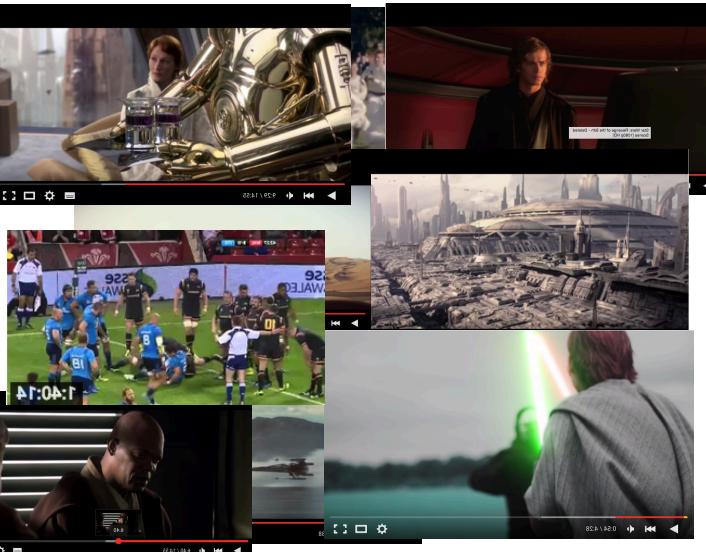




Generator
~ composition of
video sequences

**video
variants**





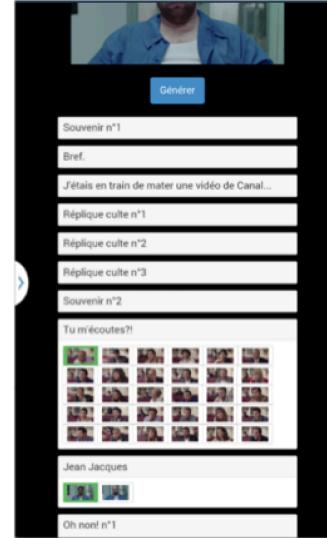
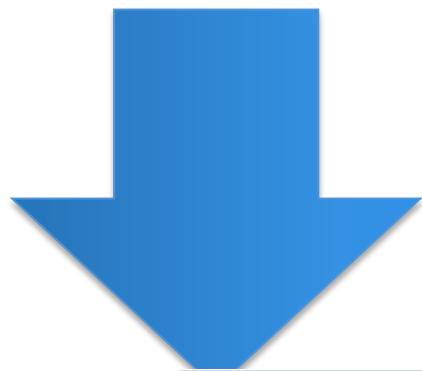
```

foo1.videogen ✎

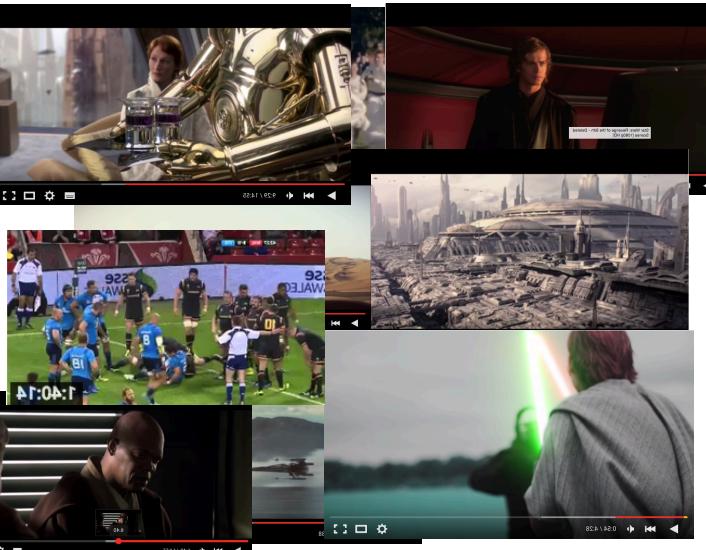
mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2Folder/v2.mp4"
alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}

alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"

```



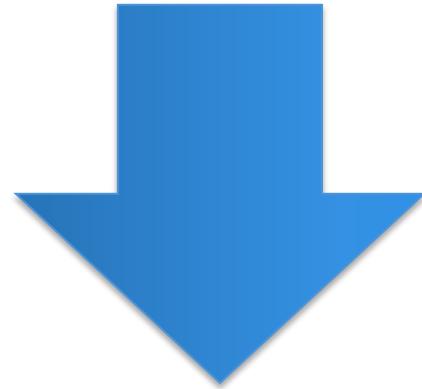
- ## Website/online
- Random generation
 - Configurator
 - Game
 - ...



```
foo1.videogen ✘

mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2Folder/v2.mp4"
alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
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    videoseq v33 "v3/seq1.mp4"
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    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```



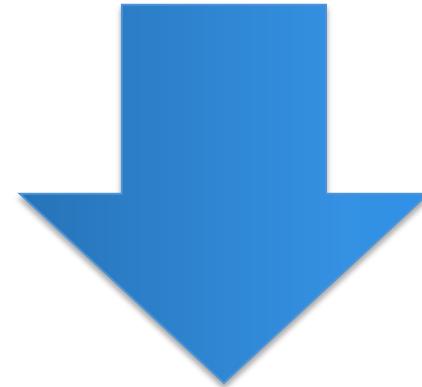
 FFmpeg

foo1.videoogen

```
mandatory videooseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videooseq v2 "v2folder/v2.mp4"
alternatives v3 {
    videooseq v31 "v3/seq1.mp4"
    videooseq v32 "v3/seq1.mp4"
    videooseq v33 "v3/seq1.mp4"
}

alternatives v4 {
    videooseq v41 "v4/seq1.mp4"
    videooseq v42 "v4/seq1.mp4"
}
mandatory videooseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```

#1 How to design,
create, and support
dedicated languages
(DSLs)?



#2 How to transform
models/programs?

#3 How to manage
variability/variants?

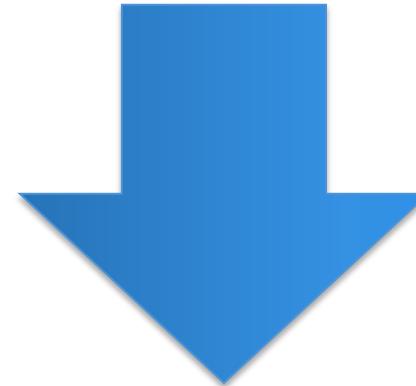
#4 How do
frameworks
internally work?

foo1.videoogen

```
mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2folder/v2.mp4"
alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}

alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```

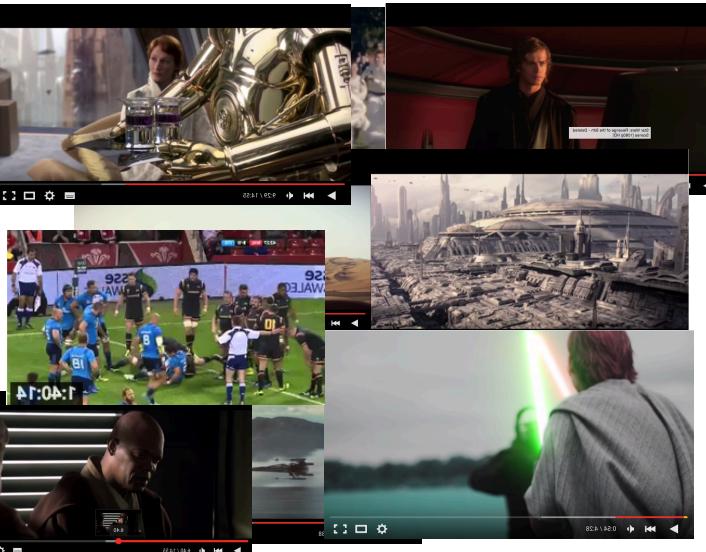
#1 How to design,
create, and
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(DSLs)?



#2 How to transform
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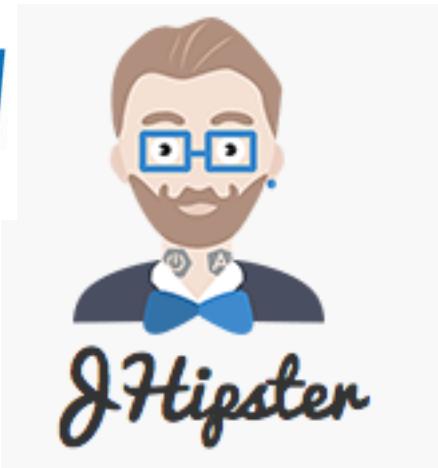
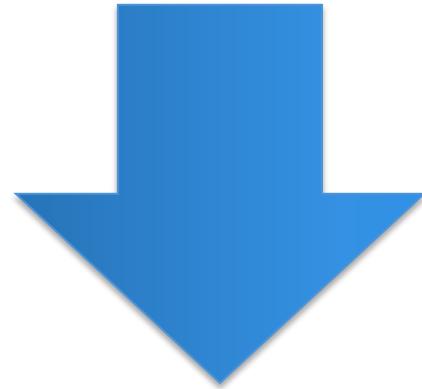
#4 How do
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```
foo1.videogen ✘

mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
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    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```



 FFmpeg

foo1.videoogen

```
mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2folder/v2.mp4"
⊖ alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}
⊖ alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```

Quizz Time

Write a Xtext grammar so that the specification below is conformant

```
foo1.videogen ✎
mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2Folder/v2.mp4"
@alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}
@alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```

Quizz Time (2)

Write a Xtext grammar so that the specification below is conformant; **what is the metamodel generated by Xtext?**

```
foo1.videogen ✘

mandatory videoseq v1 "https://www.youtube.com/watch?v=PJNi1uYhV5w"
optional videoseq v2 "v2folder/v2.mp4"
@alternatives v3 {
    videoseq v31 "v3/seq1.mp4"
    videoseq v32 "v3/seq1.mp4"
    videoseq v33 "v3/seq1.mp4"
}

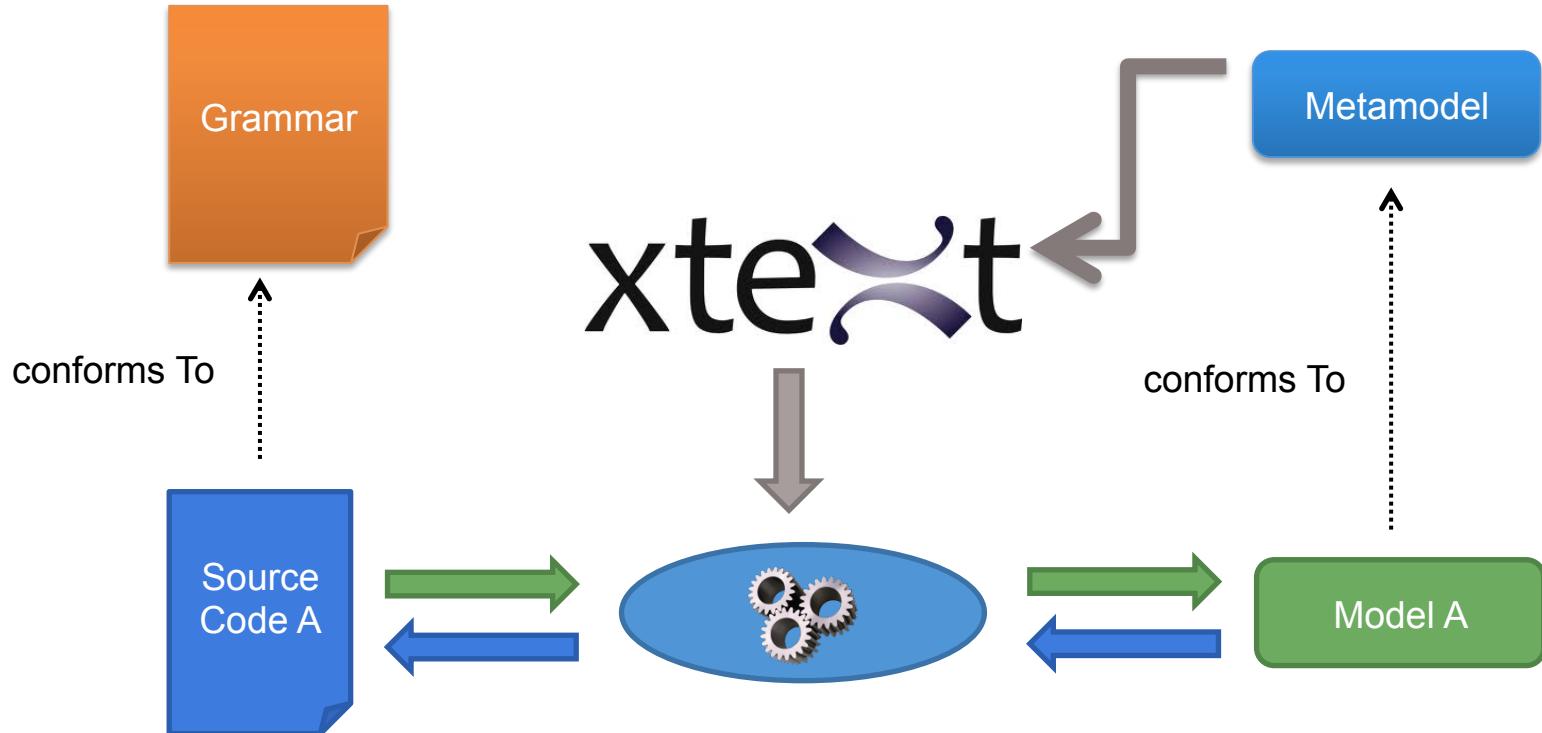
@alternatives v4 {
    videoseq v41 "v4/seq1.mp4"
    videoseq v42 "v4/seq1.mp4"
}
mandatory videoseq v5 "https://www.youtube.com/watch?v=ezKx-S0LiNQ"
```

From Metamodel

To

Grammar (other side)

From Metamodel to Grammar





Give me a **metamodel**,

I'll give you (for free)

- * a comprehensive editor (auto-completion, syntax highlighting, etc.) in Eclipse
- * a grammar and facilities to load/serialize/visit conformant models (Java ecosystem)
- * extension to override/extend « default » facilities (e.g., checker)



Give me a **metamodel**,

The grammar can be « weird » (i.e., not as concise and as comprehensible than if you made it manually)

[Same observation actually applies to the other side: generated metamodels (from grammar) can be weird as well, but you have at least some control in Xtext-based grammar]
[We will experiment in the lab sessions]

Live
Demonstration

New

Select a wizard

Create an Xtext project from existing Ecore models

Wizards:

Xtext

- ▼ Xtext
 - Xtext Project
 - Xtext Project From Existing Ecore Models**
- ▼ Continuous Integration
 - Build Xtext with Buckminster
- ▼ Examples
 - Xtext Domain-Model Example
 - Xtext Home Automation Example
 - Xtext Simple Arithmetics Example
 - Xtext State-Machine Example
- ▼ Examples
 - Xtext Examples
 - Xtext Domain-Model Example
 - Xtext Home Automation Example

?

< Back Next > Cancel Finish

New Xtext Project From Ecore

Select EPackages

Select the EPackages to generate an Xtext grammar for.

EPackages:

org.xtext.example.mydsl.questionnaire.QuestionnairePackage (default package)

Add... Set Default Remove

Entry rule:

PollSystem - questionnaire

?

< Back Next > Cancel Finish

Questionnaire.xtext Questionnaire.ecore Questionnaire.xtext Questionnaire.ecore Questionnaire2.xtext

```
// automatically generated by Xtext
grammar org.xtext.example.mydsl.Questionnaire2 with org.eclipse.xtext.common.Terminal

import "http://www.xtext.org/example/mydsl/Questionnaire"
import "http://www.eclipse.org/emf/2002/Ecore" as ecore

PollSystem returns PollSystem:
    {PollSystem}
    'PollSystem'
    '{'
        ('polls' '{' polls+=Poll ( "," polls+=Poll)* '}' )?
    '}';
    13
    14
    15
    16

Poll returns Poll:
    {Poll}
    'Poll'
    name=EString
    '{'
        ('questions' '{' questions+=Question ( "," questions+=Question)* '}' )?
    '}';
    24

EString returns ecore::EString:
    STRING | ID;
    27

Question returns Question:
    {Question}
    'Question'
    '{'
        ('id' id=EString)?
        ('text' text=EString)?
        ('options' '{' options+=Option ( "," options+=Option)* '}' )?
    '}';
    36

Option returns Option:
    {Option}
    'Option'
    '{'
        ('id' id=EString)?
        ('text' text=EString)?
    '}';
    44
```

Quizz Time

Explain (roughly) the « algorithm » of Xtext to generate a grammar from an ecore Metamodel

Wrap up

- Basic recap of grammar and parsing
- A tour of language workbenches and the specific case of Xtext
- From grammar to metamodel
 - Examples and algorithm
- From metamodel to grammar
- Now you can use Xtext

Contract

- Foundations and practice of Xtext
 - State-of-the-art language workbench (Most Innovative Eclipse Project in 2010, mature and used in a variety of industries)
- (Meta-)Models, Grammar, and Languages
 - Perhaps a more concrete way to see models, metamodels and model-driven engineering

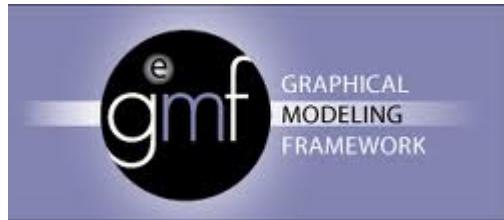
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- Markus Voelter et al. “DSL Engineering: Designing, Implementing and Using Domain-Specific Languages.” dslbook.org, 2013.
- Sven Efftinge, Moritz Eysholdt, Jan Köhnlein, Sebastian Zarnekow, Robert von Massow, Wilhelm Hasselbring, and Michael Hanus. Xbase: Implementing domain-specific languages for java. GPCE ’12
- Steven Kelly and Risto Pohjonen. Worst practices for domain-specific modeling. IEEE Software, 26(4):22–29, 2009.
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- Steven Kelly, Kalle Lyytinen, Matti Rossi, and Juha-Pekka Tolvanen. Metaedit+ at the age of 20. In Seminal Contributions to Information Systems Engineering, pages 131–137. Springer, 2013.
- Sebastian Erdweg, Tillmann Rendel, Christian Kästner, and Klaus Ostermann. Sugarj: Library-based syntactic language extensibility. OOPSLA'11

[http://martinfowler.com/bliki/
DomainSpecificLanguage.html](http://martinfowler.com/bliki/DomainSpecificLanguage.html)



Empirical Assessment of MDE in Industry

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