Model-Driven Engineering Tools
Xtext and MPS

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Overview

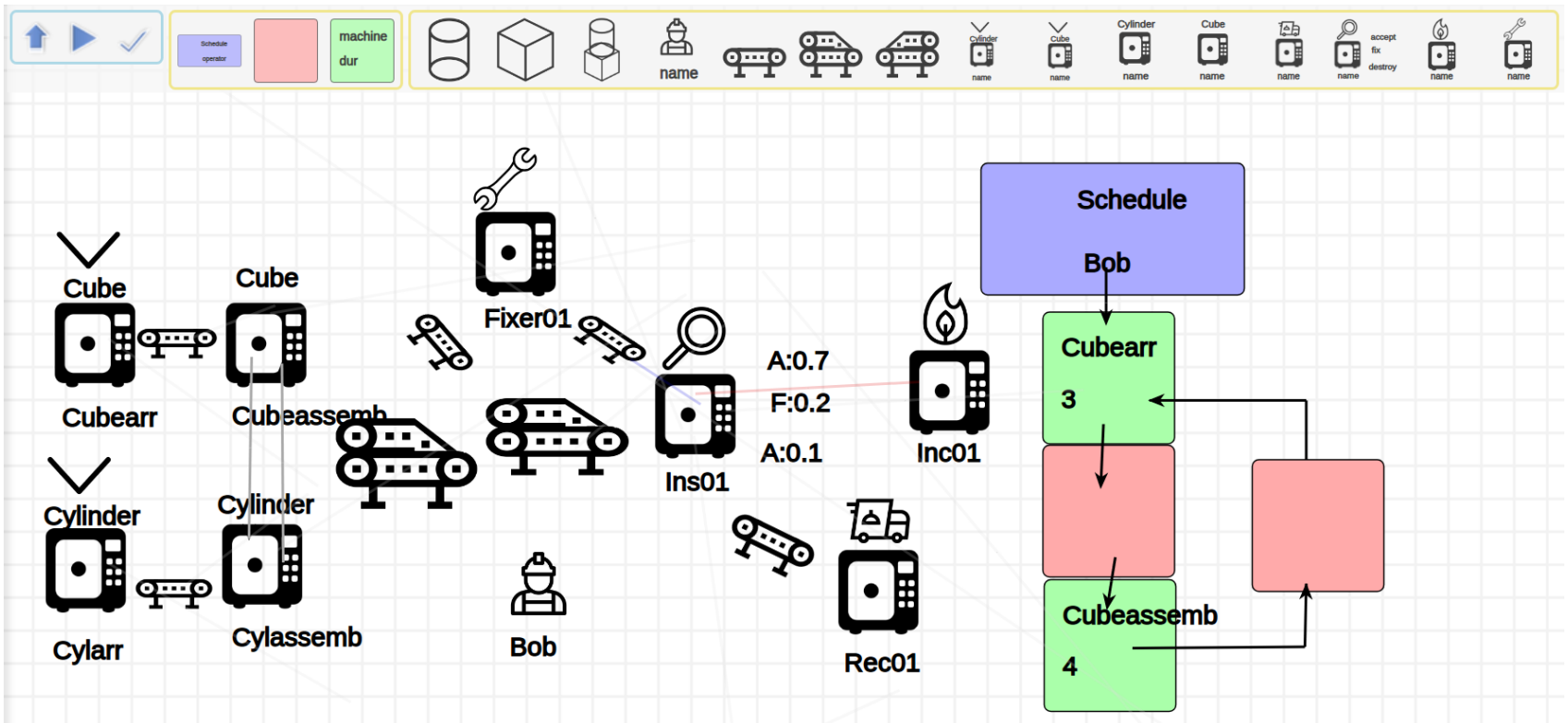
This presentation will present examples of the *ProductionSystem* language within two model-driven engineering tools: **Xtext** and **MPS**. We'll move through six topics when creating the *ProductionSystem* language in each tool:

- Meta-models and models
- Abstract and concrete syntax
- Constraints
- Modularizing languages
- Model-to-text generation
- Model-to-model transformation (briefly)

Outline

Production System Overview

Production systems are composed of *Machines* connected by *Segments*. *Items* travel along these segments and are operated upon by different machines operated by *Operators*. A *Schedule* language specifies the order for operators to operate the machines in

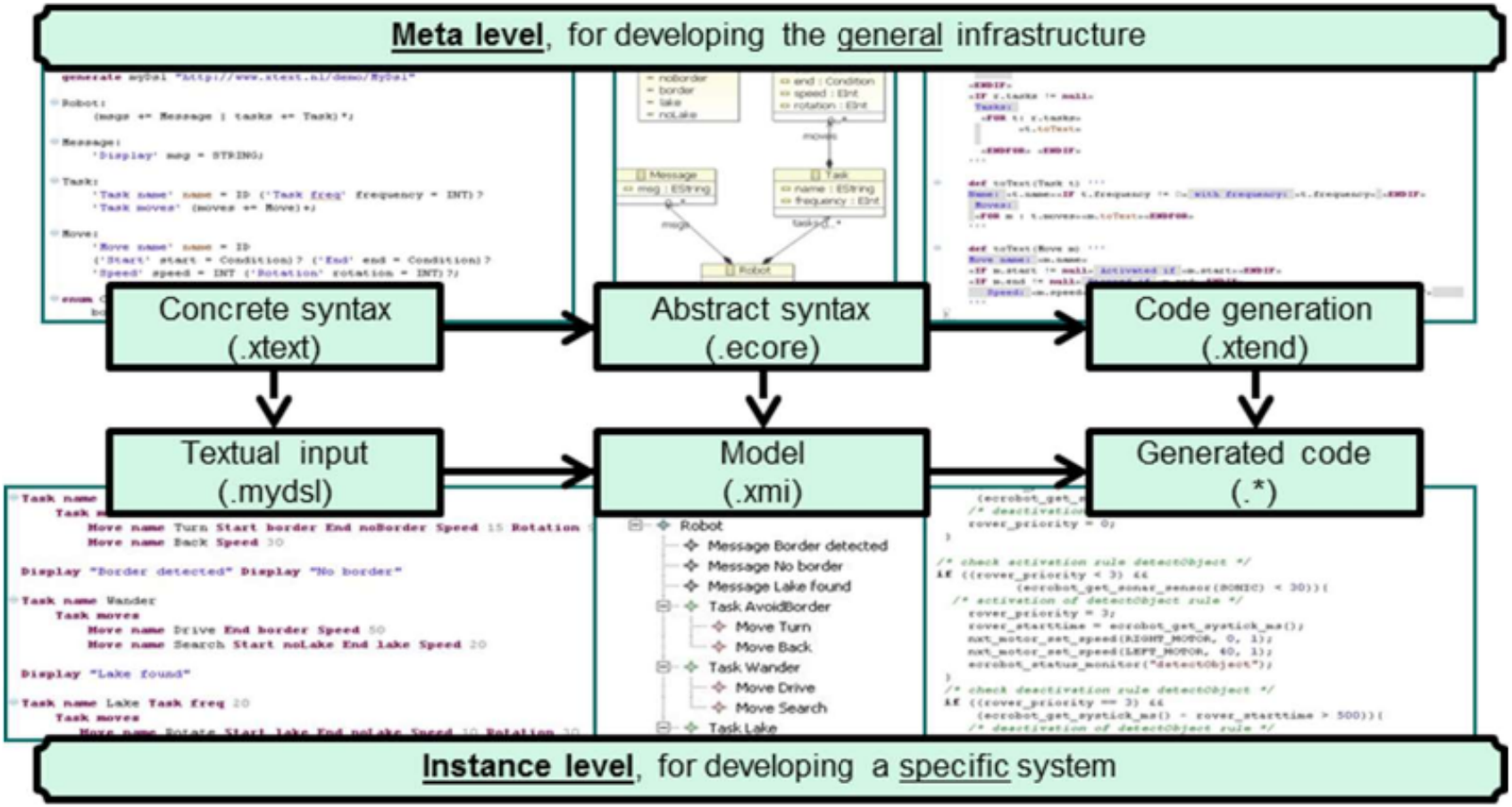


Outline

> *Xtext is a framework for development of programming languages and domain-specific languages (DSLs). With Xtext you define your language using a powerful grammar language. As a result you get a full infrastructure, including parser, linker, typechecker, compiler as well as editing support for Eclipse, any editor that supports the Language Server Protocol and your favorite web browser.*

Website: `https://www.eclipse.org/Xtext/`

Xtext Structure



- **Top:** A DSL is created by defining a grammar on the top level
- Xtext then generates plugin code to define an editor (parser, generation code, etc.)
- **Bottom:** This plugin runs in another instance of Eclipse
- The user can then write their models in this custom editor

Meta-model Example

Meta-model:

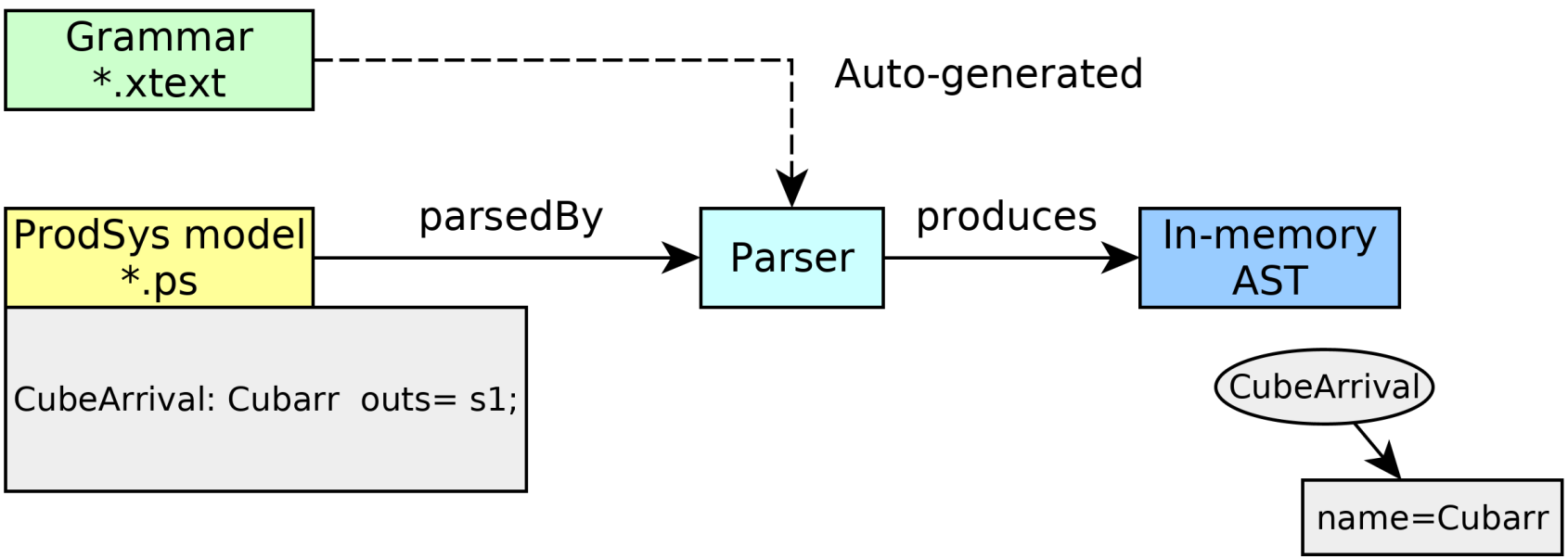
```
CylAssembler:
    'CylAssembler:' frag_SegmentData
        'linked=' linked=[CubeAssembler]
        ('currOp=' currOp = [Operator])?
    ';'
;
```

This grammar defines the abstract and concrete syntax for a cylinder assembler
Model:

```
CylAssembler: Cylassemb ins=s2 outs=J1 linked=Cubeassemb ;
```

This text is in the Production System editor, and defines a CylAssembler instance.

- The DSL meta-model is specified in Xtext using a textual grammar.
- The rules (generally) follow Extended Backus-Naur Form (EBNF).
- These rules define options for taking characters and producing data structures (the process of parsing).
- The model file is then parsed using this grammar to build the Abstract Syntax Tree (AST).



Production System Grammar

```
Assembler:
    CubeAssembler | CylAssembler
;
```

```
CylAssembler:
    'CylAssembler:' frag_SegmentData
        'linked=' linked=[CubeAssembler]
        ('currOp=' currOp = [Operator])?
    ';'
;
```

```
fragment frag_SegmentData returns Segment:
    name=ID
    ('ins=' ins   += [Segment]*)?
    ('outs=' outs  += [Segment]*)?
    ('items=' items += [Item]*)?
;
```

- This is the definition of a rule *CylAssembler* and a fragment
- Blue literals are the literal characters to find
- `name=ID` means that the attribute `name` is given a value by the token that matches the built-in rule `ID`
- Square braces are references, * is zero-or-more, ? is optional

Abstract and Concrete Syntax

```
Assembler:
    CubeAssembler | CylAssembler
;
```

```
CylAssembler:
    'CylAssembler:' frag_SegmentData
        'linked=' linked=[CubeAssembler]
        ('currOp=' currOp = [Operator])?
    ';'
;
```

```
fragment frag_SegmentData returns Segment:
    name=ID
    ('ins=' ins   += [Segment]*)?
    ('outs=' outs  += [Segment]*)?
    ('items=' items += [Item]*)?
;
```

- This grammar defines both the abstract and concrete syntax of the language
- Can define white-space aware languages (like Python) too

Pitfall: Dealing with Grammars

- Grammars are tricky to construct, very leaky abstraction
- Have to learn syntax and then carefully predict how parsing will happen

Issue: Ambiguous grammars

- Left recursion - Example: `Term: Term + Op`

Difficult to debug:

```
Decision can match input such as "RULE_ID" using multiple
alternatives: 1, 2
As a result, alternative(s) 2 were disabled for that input
```

Reason: Operator and another rule only had `name=ID`

Importing Languages

Here, the Schedule language refers to an *Operator* from the Production System language

```
import "http://www.uantwerpen.be/ProductionSystem" as PS

Schedule:
    'Sched' name=ID
    'operator:' operator=[PS::Operator|QualifiedName]
    steps+=Step+;
```

In the Schedule model:

```
Sched sched1
operator: be.uantwerpen.Prod1.Alice
```

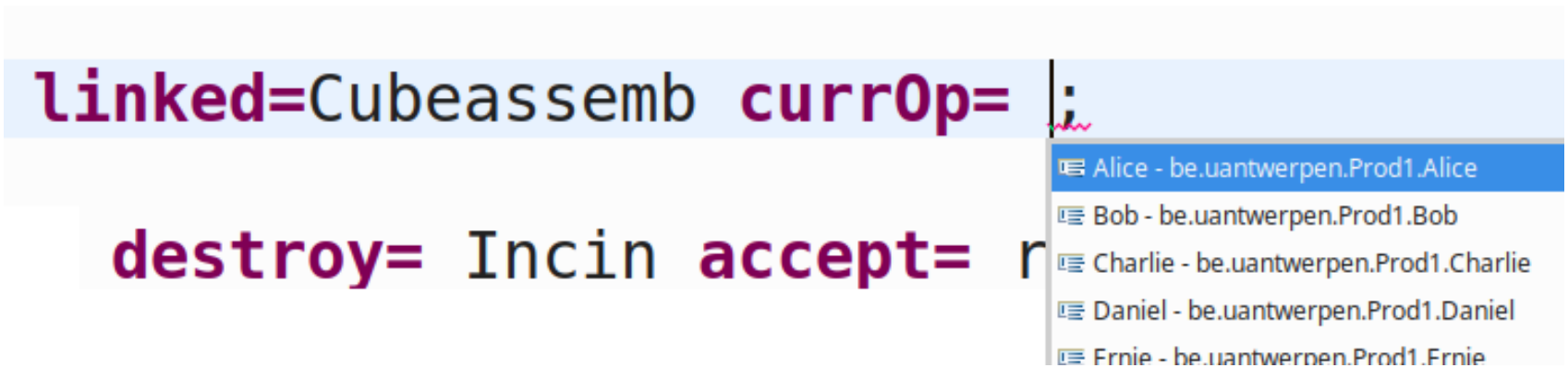
Can refer to any Operator in ProductionSystem models in the same folder (automatically)

Trick: Must add `referencedResource` in `GenerateSchedExample.mwe2`

Editor Features

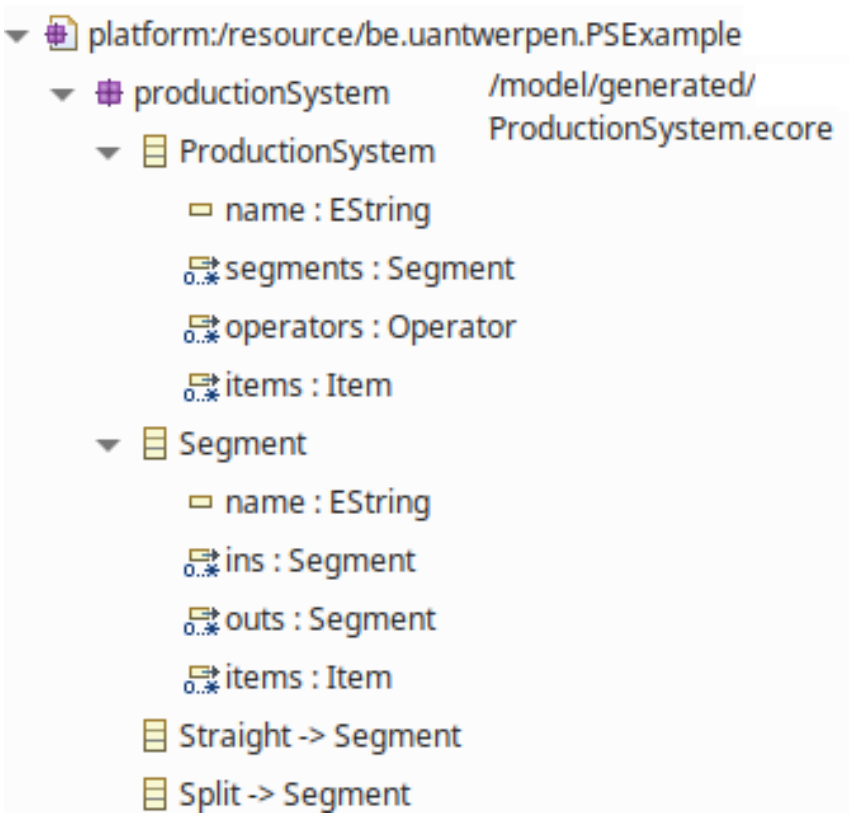
From the grammar, Xtext is able to do:

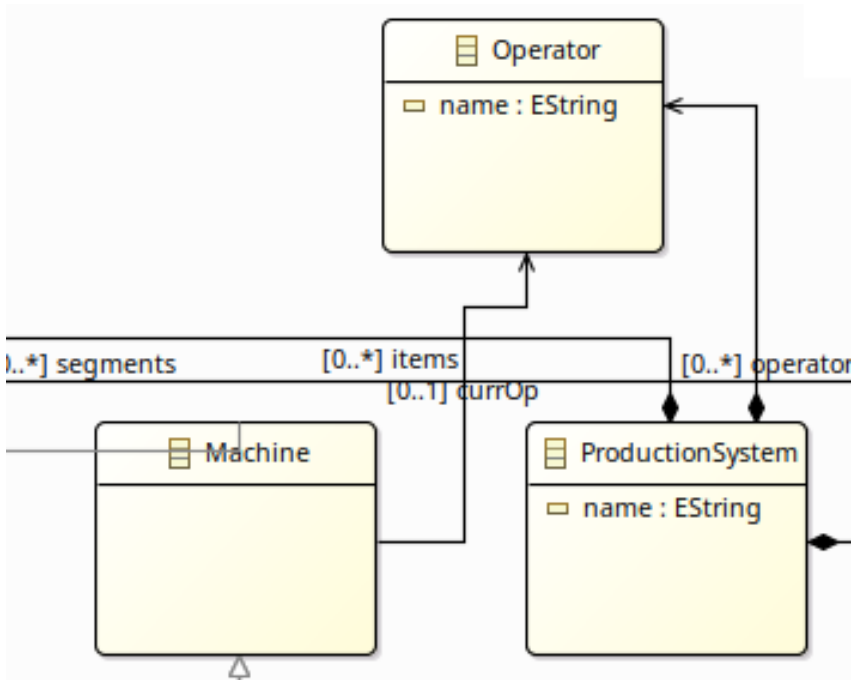
- Auto-complete
  - Text and references
  - Can customize the scope
- Custom warnings and errors



Ecore Metamodel

Xtext also automatically generates an Ecore metamodel file (*.ecore)



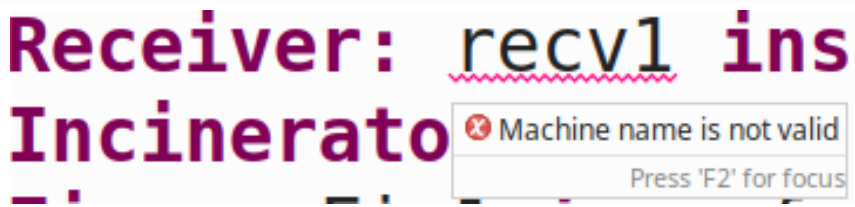


Visualized using Ecore Diagram Editor plugin

Constraints

- Arbitrary Java code written in the `ProductionSystemValidator.java` file
- Constraints validated while written code or on button press

```
@Check
public void checkMachineName(Machine machine) {
    Pattern p = Pattern.compile("[A-Z][a-z]*[0-9]*");
    Matcher m = p.matcher(machine.getName());
    if (!m.matches()) {
        error("Machine name is not valid",
              ProductionSystemPackage.Literals.SEGMENT__NAME,
              INVALID_NAME);
    }
}
```



Model-to-Text Generation

- Template-based code (or string concatenation) written in the `ProductionSystemGenerator.xtend` file

```
var name = resource.allContents.filter(ProductionSystem).head.getName()
fsa.generateFile(name + '.dot',
    '''
    digraph «name» {
    «FOR seg : resource.allContents.filter(Segment).toIterable»
        «FOR out_seg : seg.outs»
            «seg.name» -> «out_seg.name»;
        «ENDFOR»
    «ENDFOR»
    «FOR inspect : resource.allContents.filter(Inspection).toIterable»
        «inspect.name» -> «inspect.accept.name» [color=green];
        «inspect.name» -> «inspect.fix.name» [color=blue];
        «inspect.name» -> «inspect.destroy.name» [color=red];
    «ENDFOR»
```

Generates DOT code for generating a graph

Model-to-Model Transformation (ATL)

- Can write Atlas Transformation Language (ATL) rules to transform a model
- Uses .ecore files as metamodel and .xmi files as model

```
module PSTrans;
-- @path PS=/ProductionSystem.ecore
-- @path PN=/PN.ecore
create OUT: PN from IN: PS;

rule Arrival2Petri {
    from
        s: PS!Arrival
    to
        p1: PN!Place (
            name <- 'P_' + s.name
        ),
```

Also see Epsilon - `https://www.eclipse.org/epsilon/`

Conclusion

Pros:

- Xtext is easy way to build up a language, editor, generator...
- Integrates well with Eclipse ecosystem
- Provides metamodel and models in plain files or Ecore files

Cons:

- Have to become familiar with parsing
- Very difficult to understand how to achieve something
- Lack of documentation, support is from 2-3 people on forums

Tutorials:

- `https://www.eclipse.org/Xtext/documentation/102_domainmodelwalkthrough.html`
- `http://www.cs.ru.nl/J.Hooman/DSL/Creating_a_Domain_Specific_Language_(DSL)_with_Xtext.pdf`

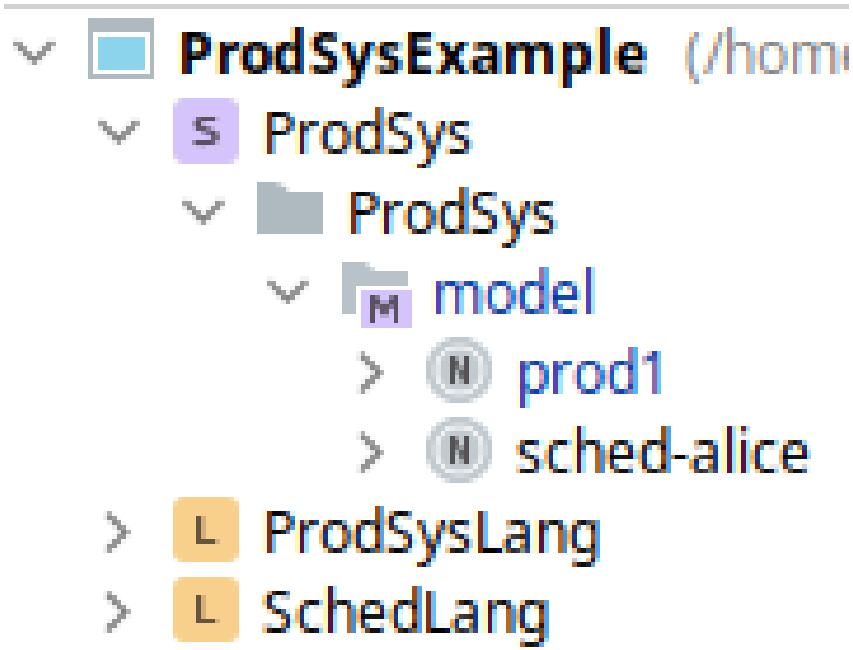
Outline

MPS Intro

The Meta-Programming System (MPS) is a language workbench to design domain-specific languages (DSLs). It uses projectional editing which allows users to overcome the limits of language parsers, and build DSL editors such as ones with tables and diagrams.

Website: `http://www.jetbrains.com/mps/`

MPS Structure

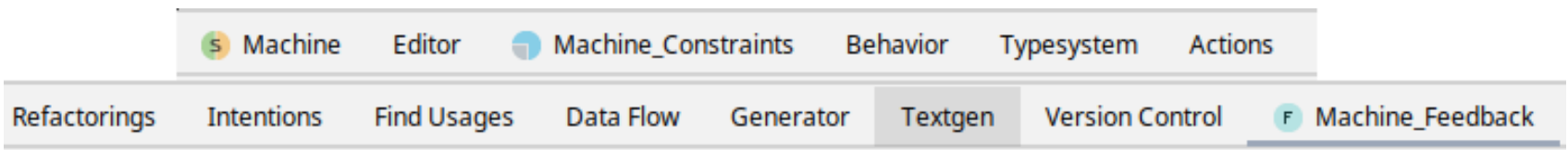


- MPS is very explicit about DSLs
- DSLs are defined in `languages` (the orange L in the figure) - the meta-model
- Multiple DSLs are then used in `solutions` (the purple S) - the models

Aspects

A unique feature of MPS is that the user defines *aspects* **for each concept**:

- *Structure* - The abstract syntax
- *Editor* - Definition of concrete syntax
- *Constraints* - Constraints on attributes and references
- *Behavior* - Java-like utility code, concept constructor
- *Typesystem* - Define typign rules (eg. MyString is a String)
- *textGen* - Simple text generation
- And a few more...



Structure Example

Language:

```
concept Inspection extends    BaseConcept
                   implements Machine
  instance can be root: false
  alias:
  short description:

  properties:
  children:
  references:
  fixSeg     : Segment[1]
  destroySeg : Segment[1]
  acceptSeg  : Segment[1]
```

The structure aspect defines the abstract syntax for an inspection machine
Model:

```
Inspection Inspec1 Ins: J2 Outs:          Items:          Fix fix_seg_in
                                                          Destroy Incin1
                                                          Accept recv_seg
```

This defines an Inspection machine in the model

Structure

- The AS for the Production System is defined in the *structure*
- Has explicit inheritance, properties, children, references, and cardinality

```
concept Inspection extends    BaseConcept
                   implements Machine
  instance can be root: false
  alias:
  short description:

  properties:
  children:
  references:
  fixSeg      : Segment[1]
  destroySeg  : Segment[1]
  acceptSeg   : Segment[1]
```

Editor aspect:

```
<default> editor for concept Inspection
  node cell layout:
    [> Inspection # frag_Segment # [/                                    <]
                                    [> Fix ( % fixSeg % -> { name } ) <]
                                    [> Destroy ( % destroySeg % -> { name } ) <]
                                    [> Accept ( % acceptSeg % -> { name } ) <]
                                    /]
```

- The *editor* aspect defines the concrete syntax for the concept
- This is very flexible, and can offer tables, diagrams, images in the syntax
  - Spectrum from textual to graphical syntax

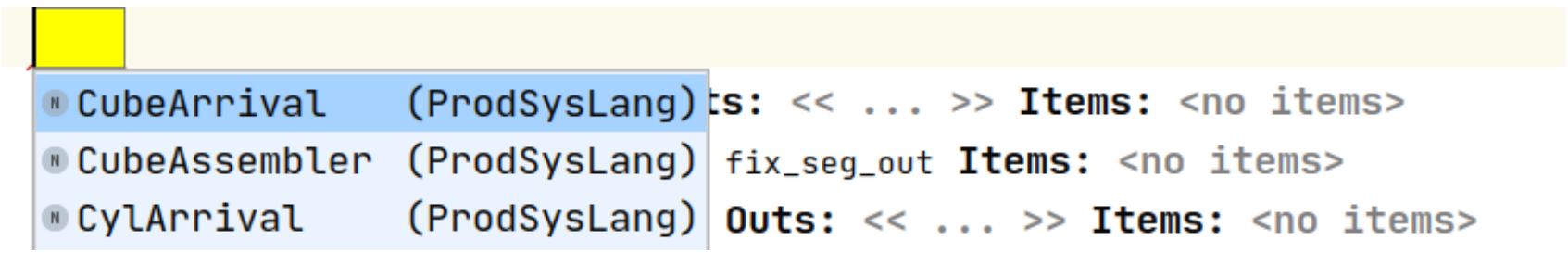
Model:

```
Inspection Inspec1 Ins: J2 Outs:          Items:          Fix fix_seg_in
                                                          Destroy Incin1
                                                          Accept recv_seg
```

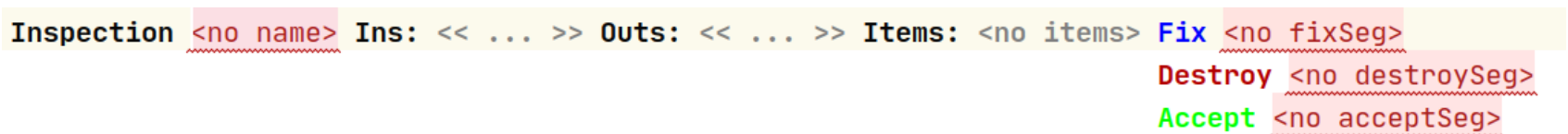
Projectional Editing

- But how can the user create an Inspection machine, what's the syntax?
- MPS uses *projectional editing*, where the user edits the Abstract Syntax Tree (AST) directly
- That is, MPS only lets the user create what is valid at that time

Creating a new machine with Ctrl-Space



After selecting the Inspection Machine



Pitfalls

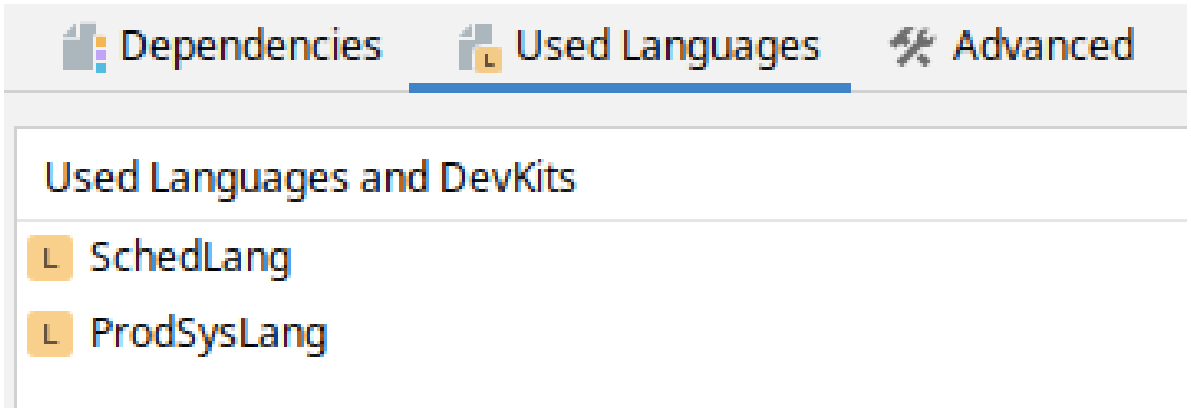
Two large pitfalls in MPS:

- Getting used to projectional editing
  - Not writing text like programming, but building up the model as a tree
- Languages and models are stored as MPS-specific XML
  - Can use version control inside MPS

```
<node concept="6EZK7" id="1OOs4CrBT3z">
<property role="TrG5h" value="sched-alice" />
<ref role="OT_FE" node="4t2UbpND4Ff" resolve="Alice" />
<node concept="6EZKv" id="4t2UbpNDbnB" role="6EZKo" />
<node concept="6EZKi" id="4t2UbpNDbnH" role="6EZKo">
<property role="6EZKh" value="4" />
<ref role="6EZKn" node="1OOs4CrBUhl" resolve="Cubearr" />
</node>
```

Importing Languages

MPS makes it trivially easy to mix and extend languages




```
schedule sched-alice operator : Alice {

  steps :
    walking step
    machine step machine : Cubea
      duration : 4
```

Alice ^operators (ProdSys.model.prod1)
Bob ^operators (ProdSys.model.prod1)
Charlie ^operators (ProdSys.model.prod1)
Press Ctrl+Alt+B to Show item trace

Constraints

- Arbitrary Java-like code written in the constraints aspect
- Feedback aspect used for pop-up errors/warnings

Constraint aspect for *Machine* concept:

```
property {name}
  get <default>
  set <default>
  is valid (propertyValue, node)->boolean {
    propertyValue.matches("[A-Z][a-z]*[0-9]*");
  }
```

Model-to-Text Generation

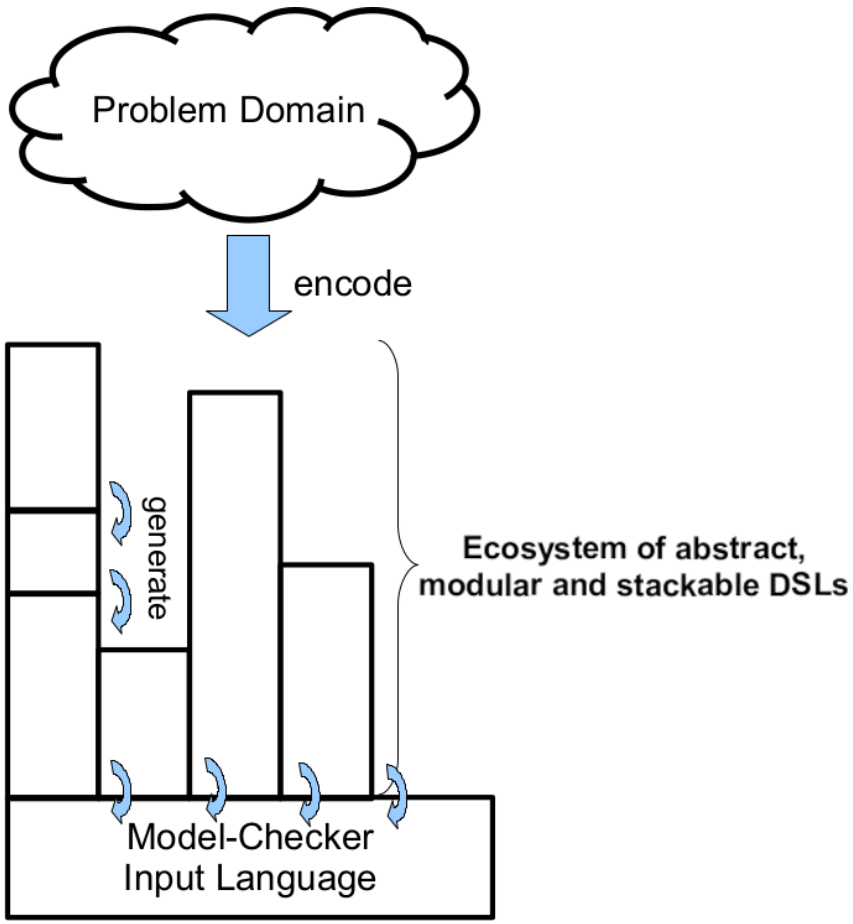
- MPS has a textGen aspect for simple text generation

```
text gen component for concept Inspection {
  (node)->void {
    append indent ${node.name} {->} ${node.acceptSeg.name} { [color=green]} \n;
    append indent ${node.name} {->} ${node.fixSeg.name} { [color=blue]} \n;
    append indent ${node.name} {->} ${node.destroySeg.name} { [color=red]} \n;
  }
}
```

Generates DOT code for generating a graph

Model-to-Model Transformation

- MPS implements model transformation as reduction rules
- Main purpose is to generate simpler and simpler models, then to generate code/text
- Example: Petri Net with inhibitor arcs → PN w/o IA → LoLA net
- Idea is to promote language "stacks"



Conclusion

Pros:

- Very easy to start building languages and models with different languages
- Variety of aspects, which are explicit for each concept
- Concrete syntax can be extended and flexible
- Good documentation and tutorials
- Can generate plugins for other Jetbrains IDEs, or whole language editors

Cons:

- Projectional editing can be difficult to get used to
- Languages and models are not stored as plain-text
- Doesn't operate in standard ecosystem

Tutorials:

- `https://www.jetbrains.com/help/mps/mps-calculator-language-tutorial.html`
- `https://dev.to/antoine/creating-a-simple-language-using-jetbrains-mps-c7d`

Outline

Conclusion

Two model-driven engineering tools have been presented by implementing the *Production System* language:

- **Xtext** - `https://www.eclipse.org/Xtext/`
- **MPS** - `https://www.jetbrains.com/mps/`

Questions or comments?