Domain-Specific Languages (DSL)

Software Systems (Computer & Embedded Systems Engineering)

Arjan Mooij

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An initiative of industry, academia and TNO

TU Delft Delft University of Technology

ESI

Objectives

At the end of the course, you should be able to:

- Explain the purpose of Domain-Specific Languages, including several application areas
- Explain the basics of grammars and parsing
- Create basic textual Domain-Specific Languages, including editor support, validation and generators

Assessment:

- Modeling assignment using Domain-Specific Languages (in groups of 2 students)
- Reflection document on Model-Based Development (individual)

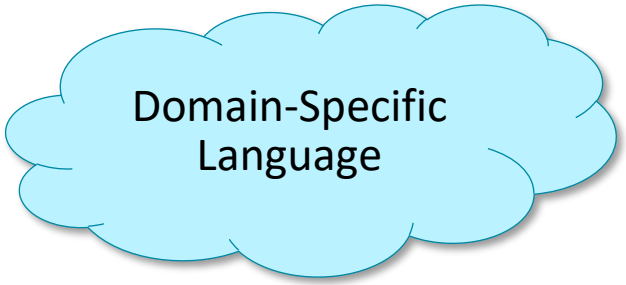
Motivation

Domain-Specific Languages (DSL)

What is Jargon?

Oxford dictionaries:

- **Special words or expressions**
  - used by a profession or group
  - that are difficult for others to understand

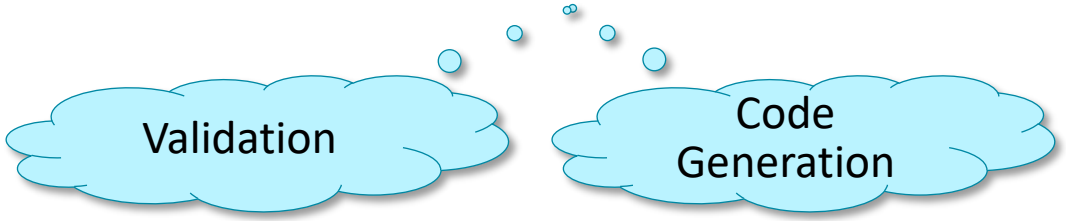


Wikipedia:

- **Terminology defined in relationship to**

  a specific activity, profession, group, or event
  - … a barrier to communication with those not familiar with the language

➢**A standard term may be given a more precise or unique usage**



What is a Domain-Specific Language?

- **What are your associations with the term Domain-Specific Language?**
- **Do you know any Domain-Specific Languages?**

Think → Pair → Share

What is a Domain-Specific Language?

General-purpose programming languages:

- C, C++, Java, Python, etc.

```c
#include <stdio.h>

int main(void)
{
    printf("hello, world\n");
}
```

Horizontal Domain-specific languages:

- HTML for web pages
- SQL for relational database queries

```html
<!DOCTYPE html>
<html>
  <head>
    <title>Hello HTML</title>
  </head>
  <body>
    <p>Hello World!</p>
  </body>
</html>
```

```sql
SELECT *
 FROM Book
 WHERE price > 100
 ORDER BY title;
```

Vertical Domain-specific languages:

- Specifically designed for a specific application by a single company

Canon ASML VANDERLANDE PHILIPS THALES

What about the other model-based techniques from this course?

- **PlantUML** **for** **Unified Modeling Language (UML)**

- **YAKINDU Statechart Tools** **for** **Finite-State Machines (FSM)**

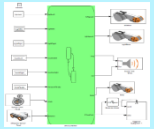
➔ **Horizontal DSLs**

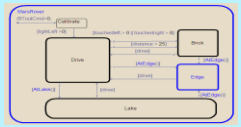
Generations of programming languages

4th generation

Higher abstraction &
Expressive power

Domain-Specific Language (DSL)





```
SELECT *
 FROM  Book
 WHERE price > 100.00
 ORDER BY title;
```

code generator

3rd generation

High-level programming languages
(Fortran, Cobol, C, Java, ..)

```
if (frameSize.height > screenSize.height) {
    frameSize.height = screenSize.height;
}
if (frameSize.width > screenSize.width) {
    frameSize.width = screenSize.width;
}
```

compiler

2nd generation

Assembly code

```
add     eax, edx
shl     eax, 2
add     eax, edx
shr     eax, 8
```

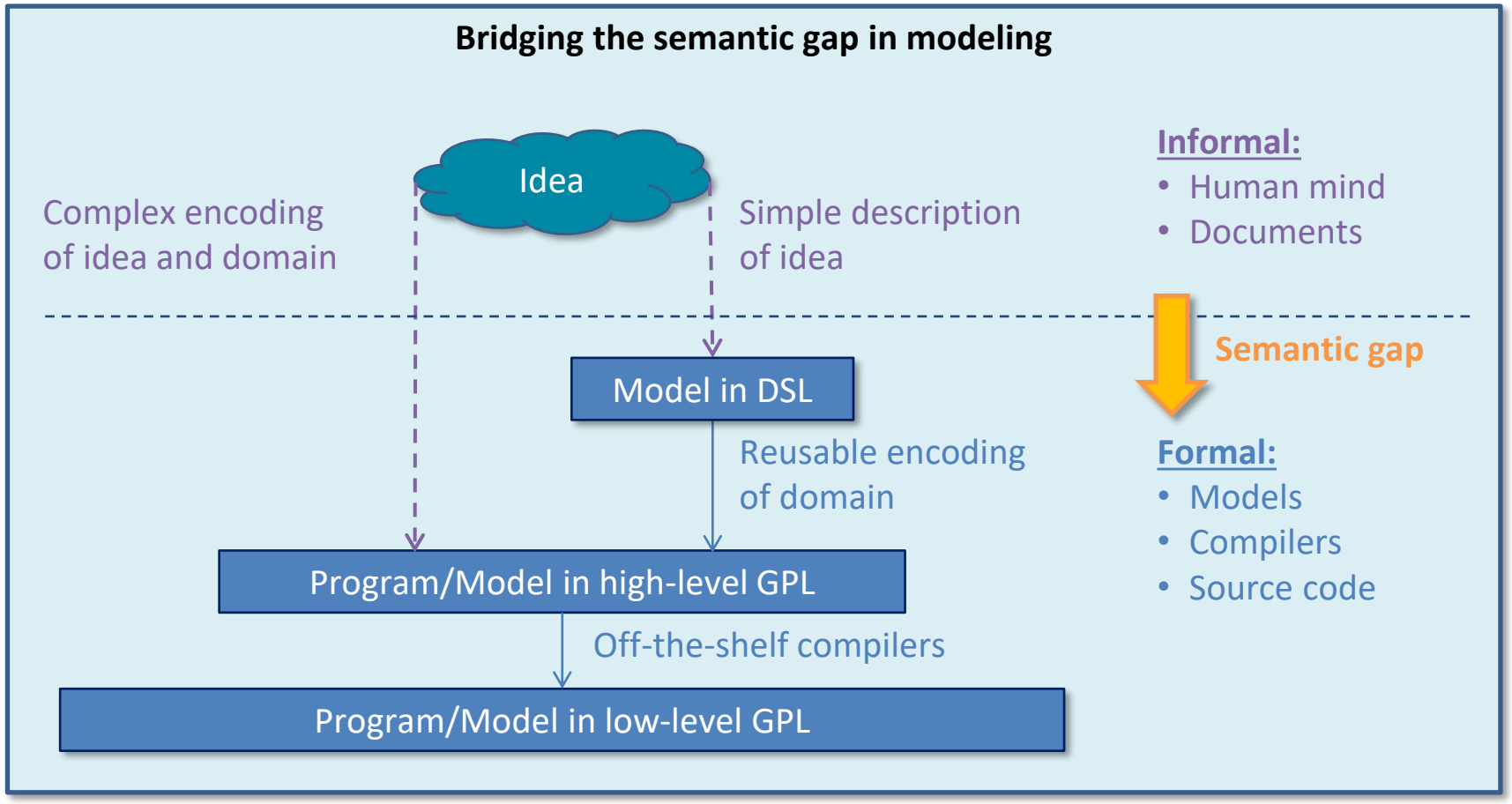
assembler

1st generation

Machine instructions

op	rs	rt	address
100011	00011	01000	00000 00001 000100

Modeling Perspective on DSLs



DSL as Central Artifact

```
restriction VeryCloseTableTopAndBeam
    activation
          Distance(TableTop, Beam) < 20 mm
    effects
        userGuidance "TableTop and Beam very close"
        relative limit TableTop*[Rotation, Translation],
                       Beam*[Rotation, Translation]
            at 0


restriction ApproachingTableTopAndBeam
    activation
          Distance(TableTop, Beam) < 35 mm + 15 cm
    effects
        userGuidance "TableTop and Beam approaching"
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```
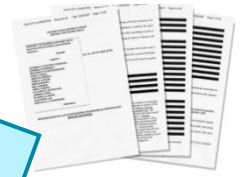

Xtext

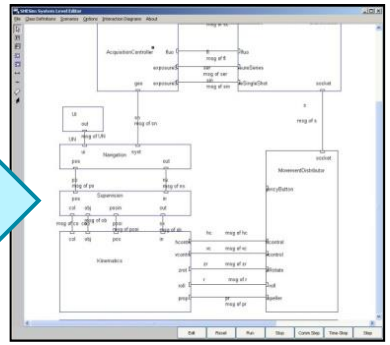
Xtend

Validation

Generate documentation

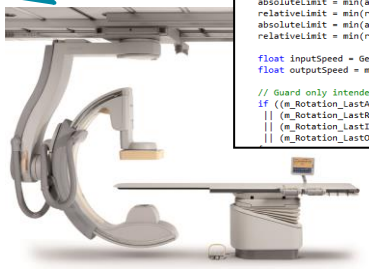


Generate analysis models



Generate source code

factor >30



```
float CObject_Beam::GetRotationScaling()
{
  float absoluteLimit = GEN_t_float_max;
  float relativeLimit = 1.;

  absoluteLimit = min(absoluteLimit, m_Rotation_AbsoluteLimit_DetectorRotationInBetween);
  absoluteLimit = min(absoluteLimit, m_Rotation_AbsoluteLimit_VeryCloseTableTopAndBeam);
  relativeLimit = min(relativeLimit, m_Rotation_RelativeLimit_ApproachingTableTopAndBeam);
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  relativeLimit = min(relativeLimit, m_Rotation_RelativeLimit_ApproachingTableBaseAndDetector);

  float inputSpeed = GetRequestedRotSpeed();
  float outputSpeed = min(inputSpeed * relativeLimit, absoluteLimit);

  // Guard only intended to reduce calls to logging
  if ((m_Rotation_LastAbsoluteLimit != absoluteLimit)
   || (m_Rotation_LastRelativeLimit != relativeLimit)
   || (m_Rotation_LastInputSpeed != inputSpeed)
   || (m_Rotation_LastOutputSpeed != outputSpeed))
```
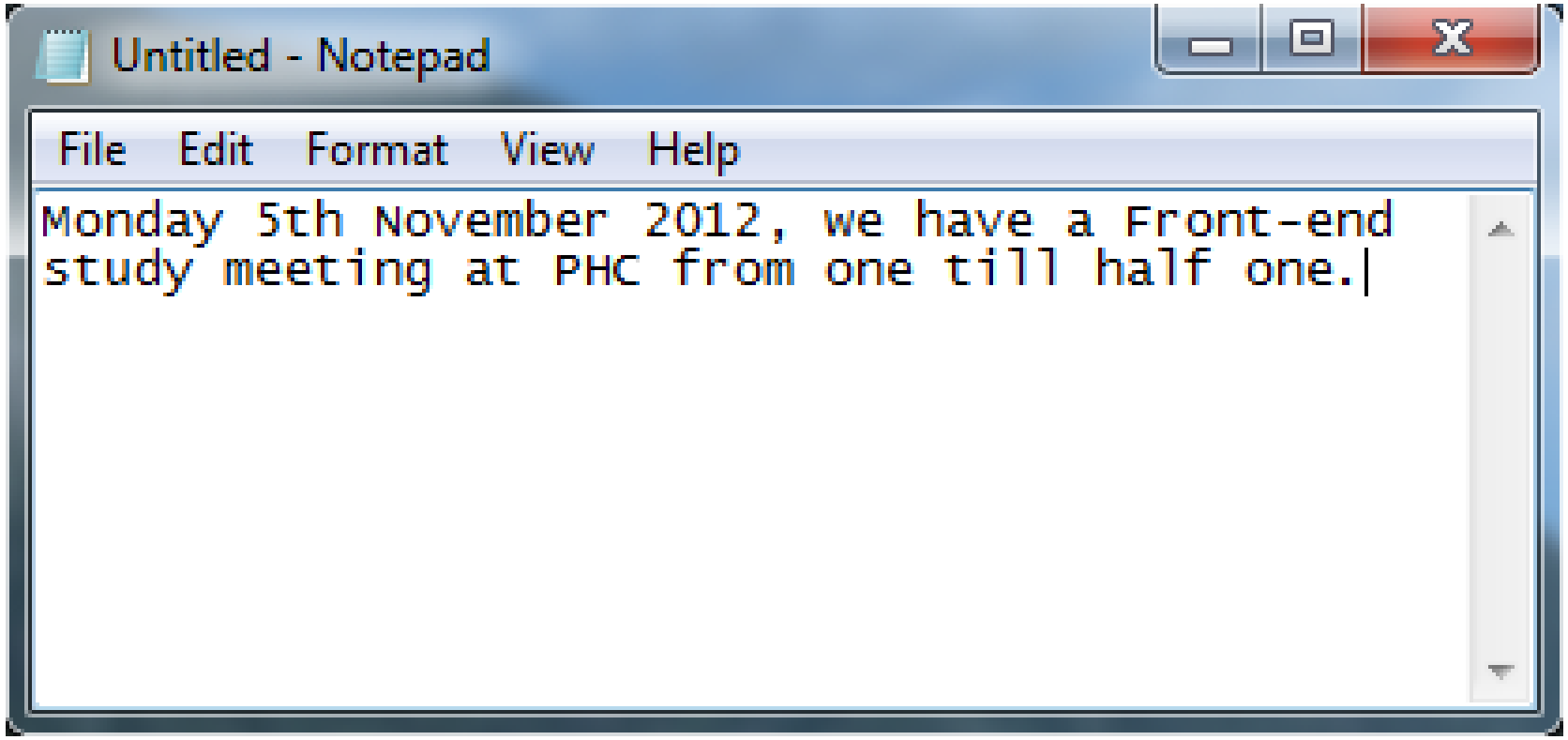
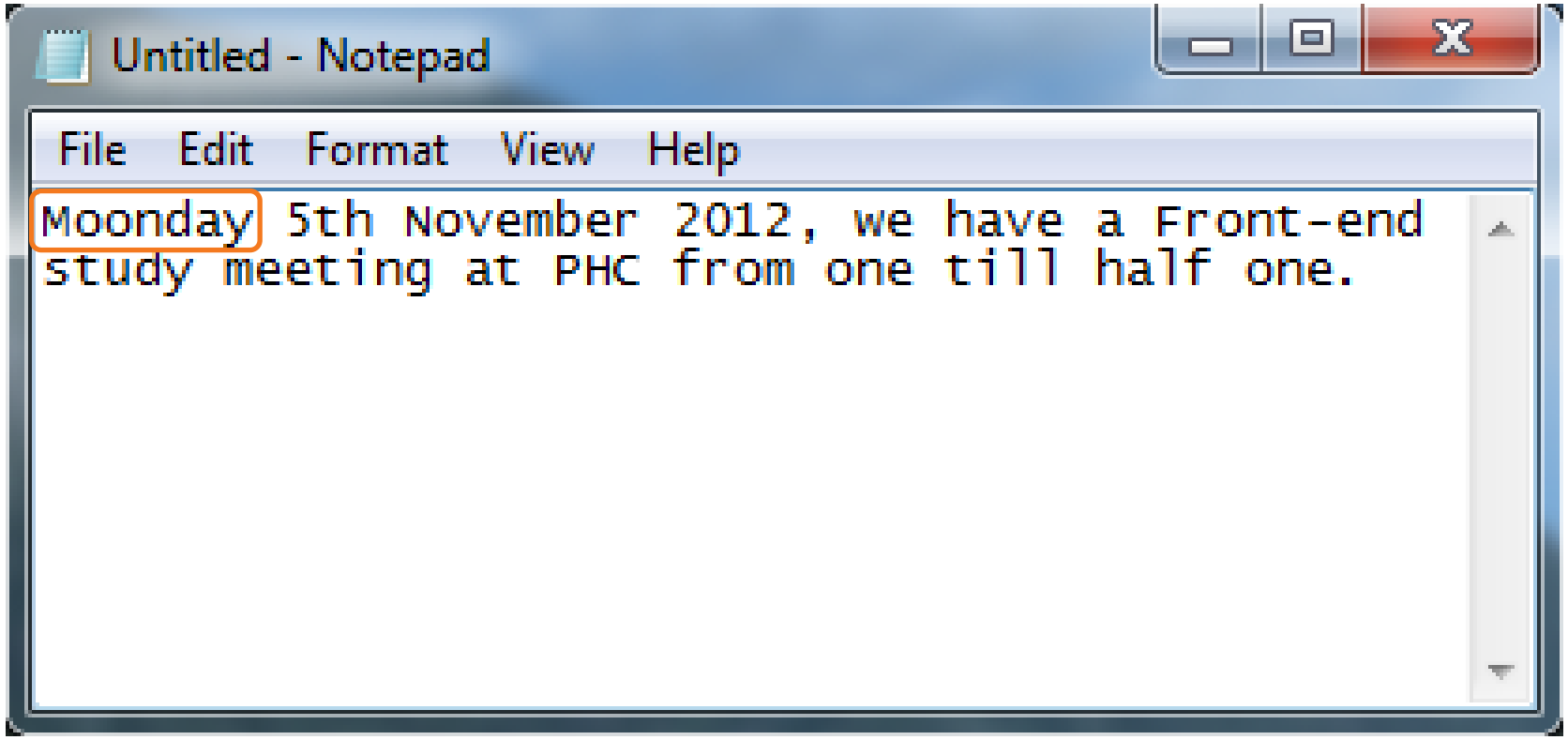
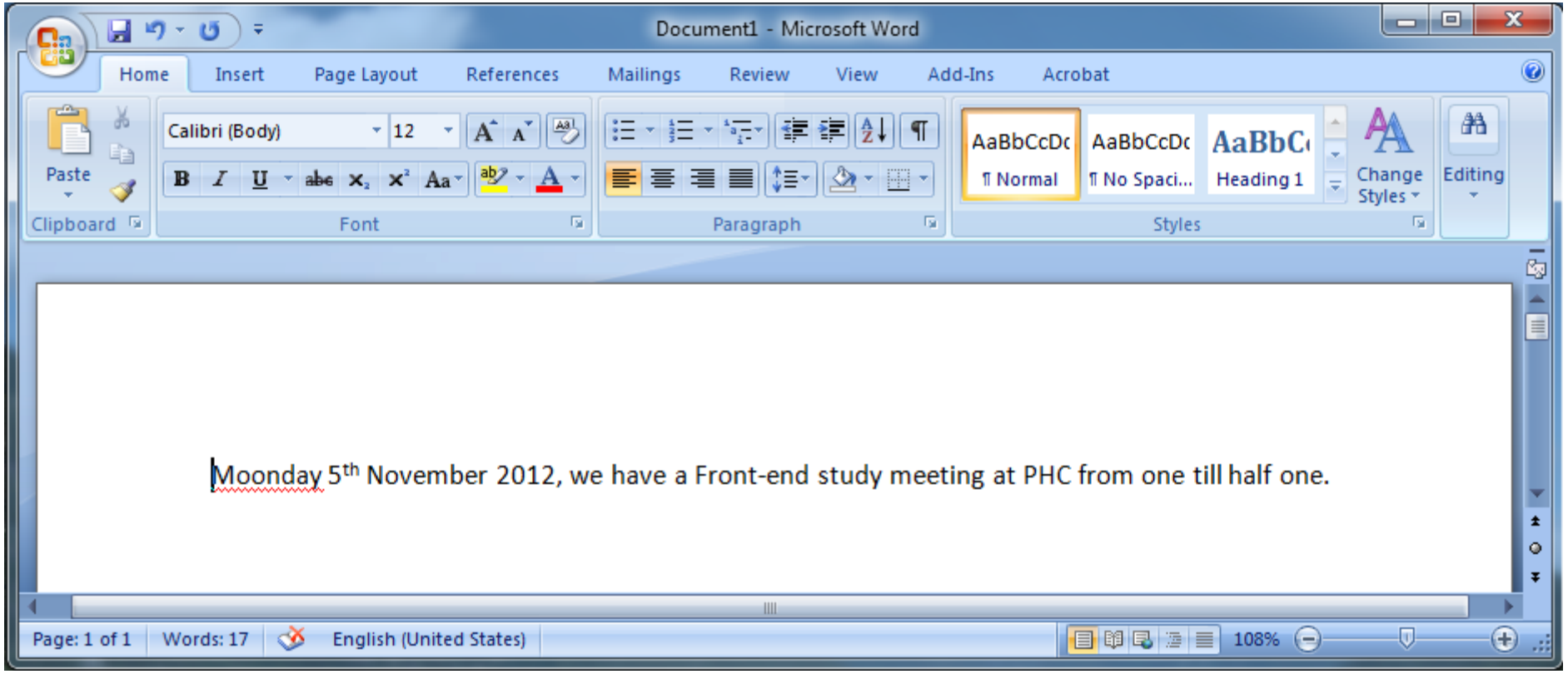

Microsoft Notepad: A Correct Sentence



Microsoft Notepad: No Problem Detected, but …



Microsoft Word: Spelling Error



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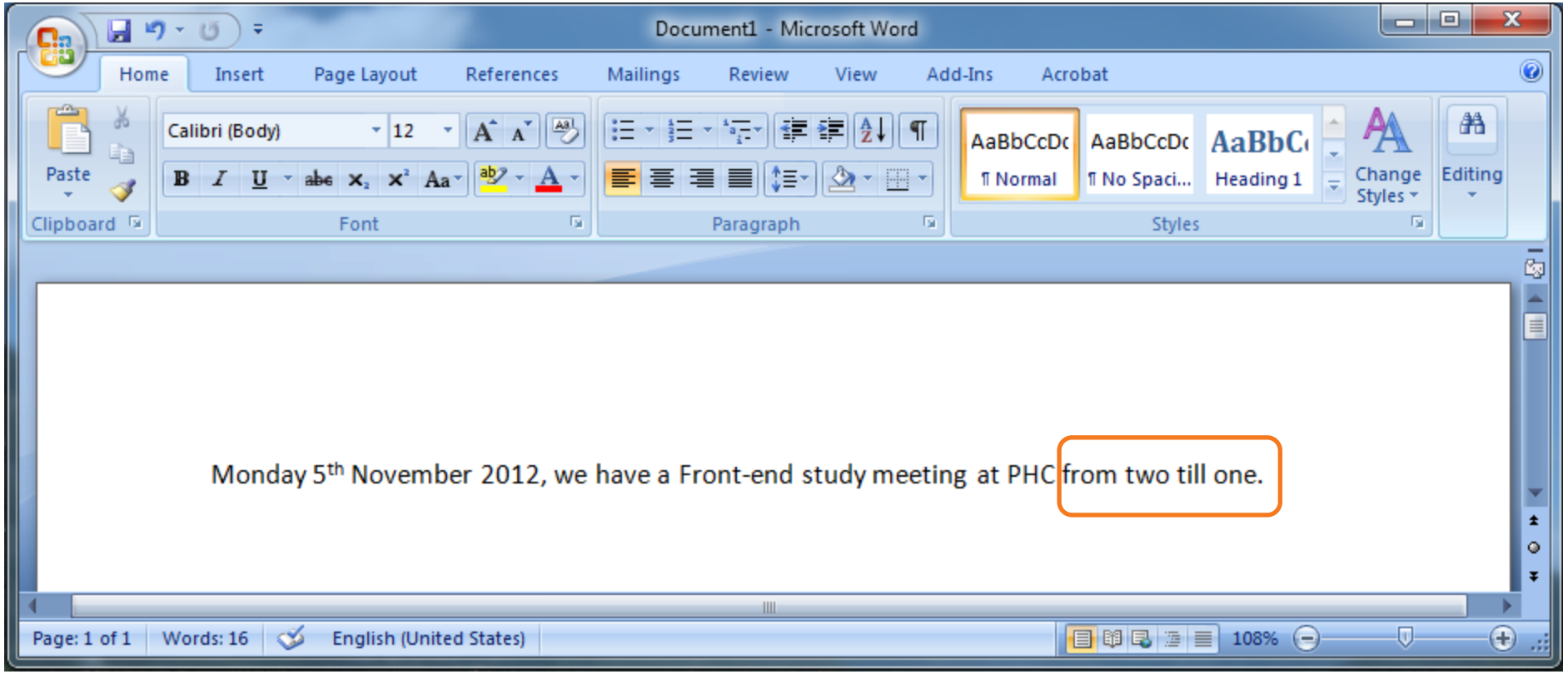
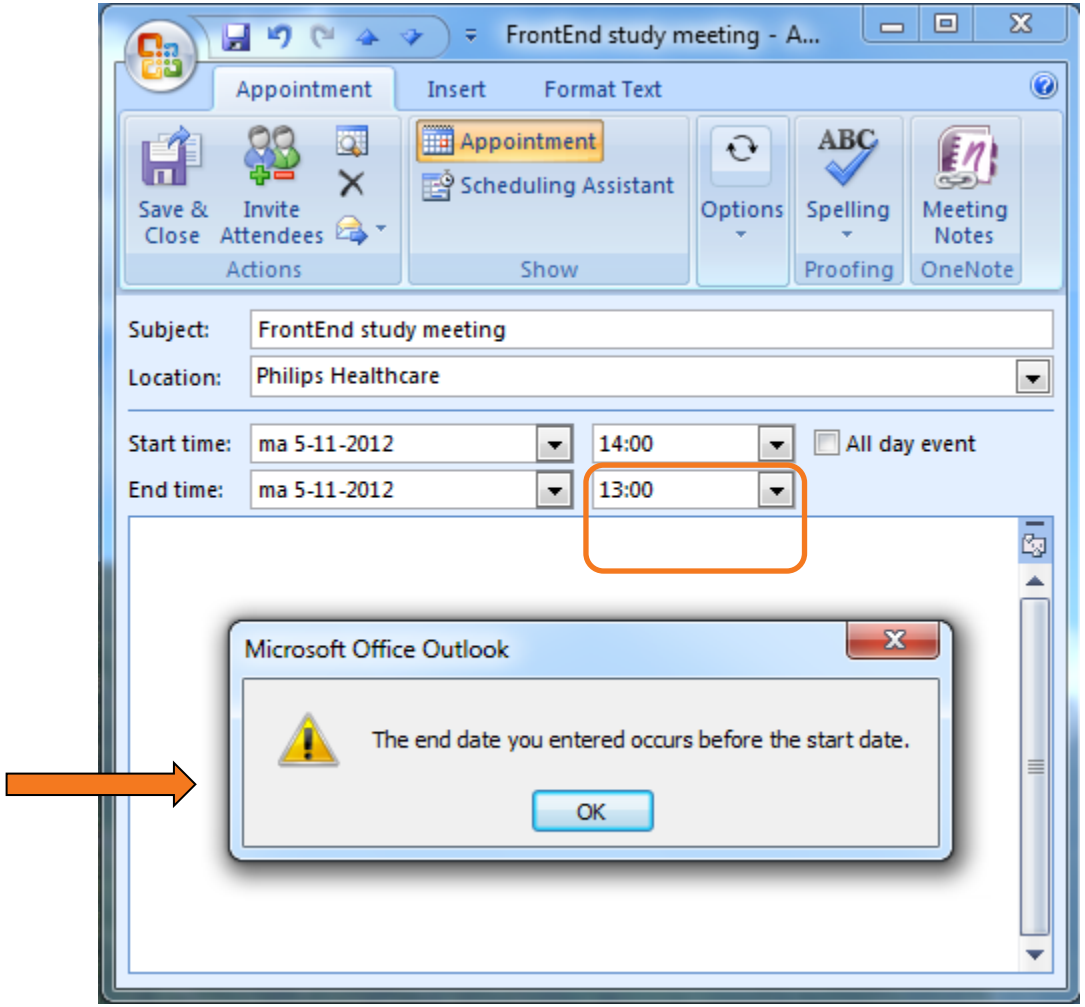


Microsoft Outlook: Wrong Times



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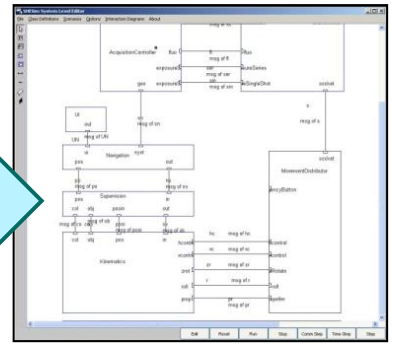
Xtend

Validation

Generate documentation

Generate analysis models



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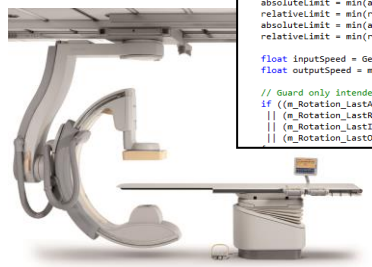
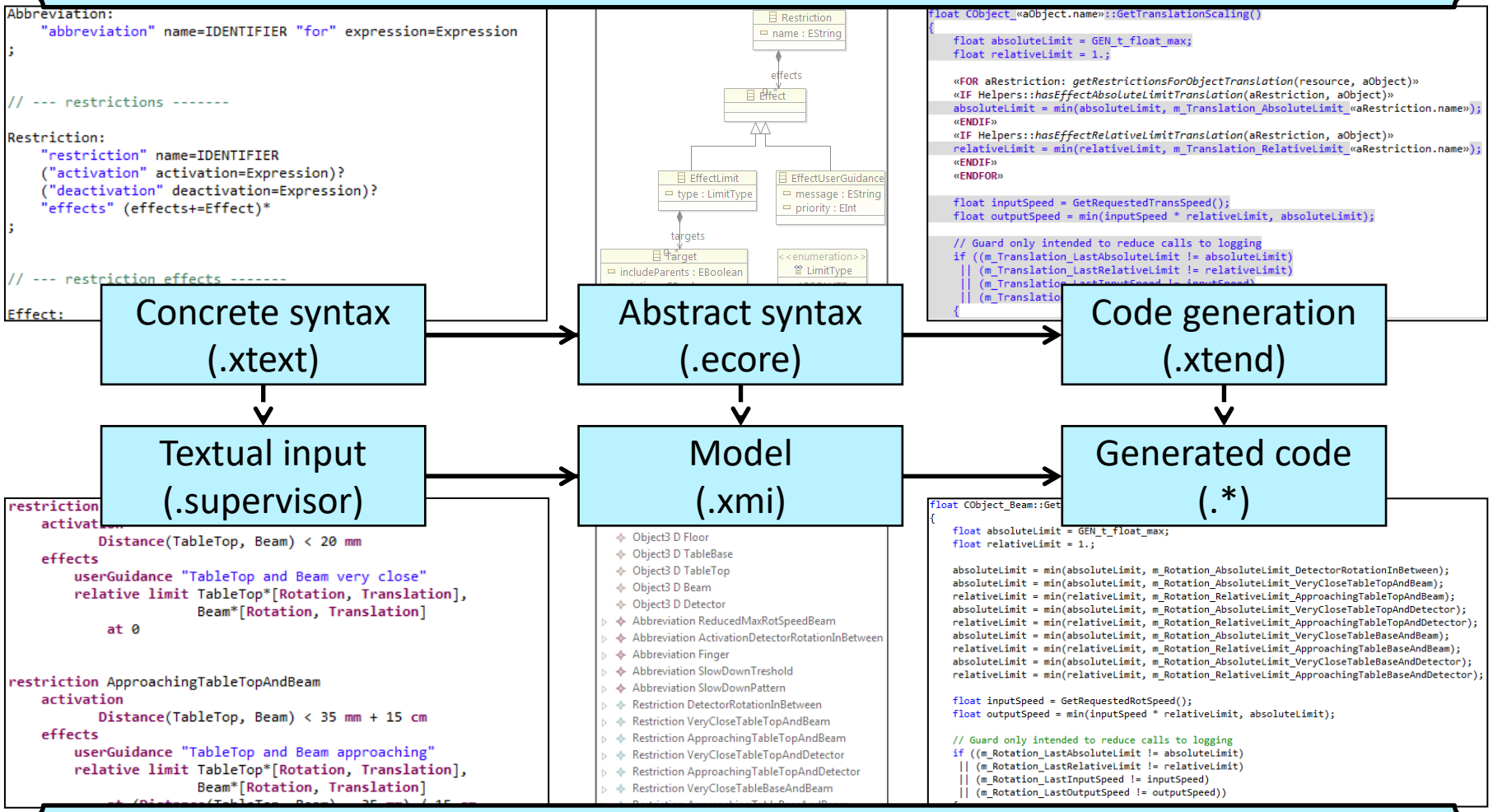


Metamodels and grammars

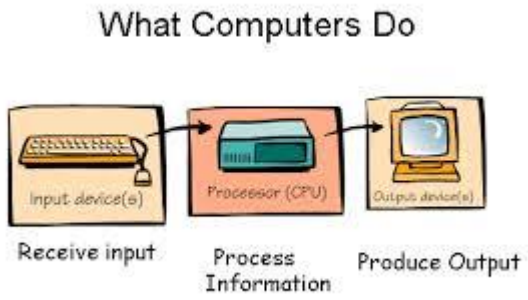
Domain-Specific Languages (DSL)

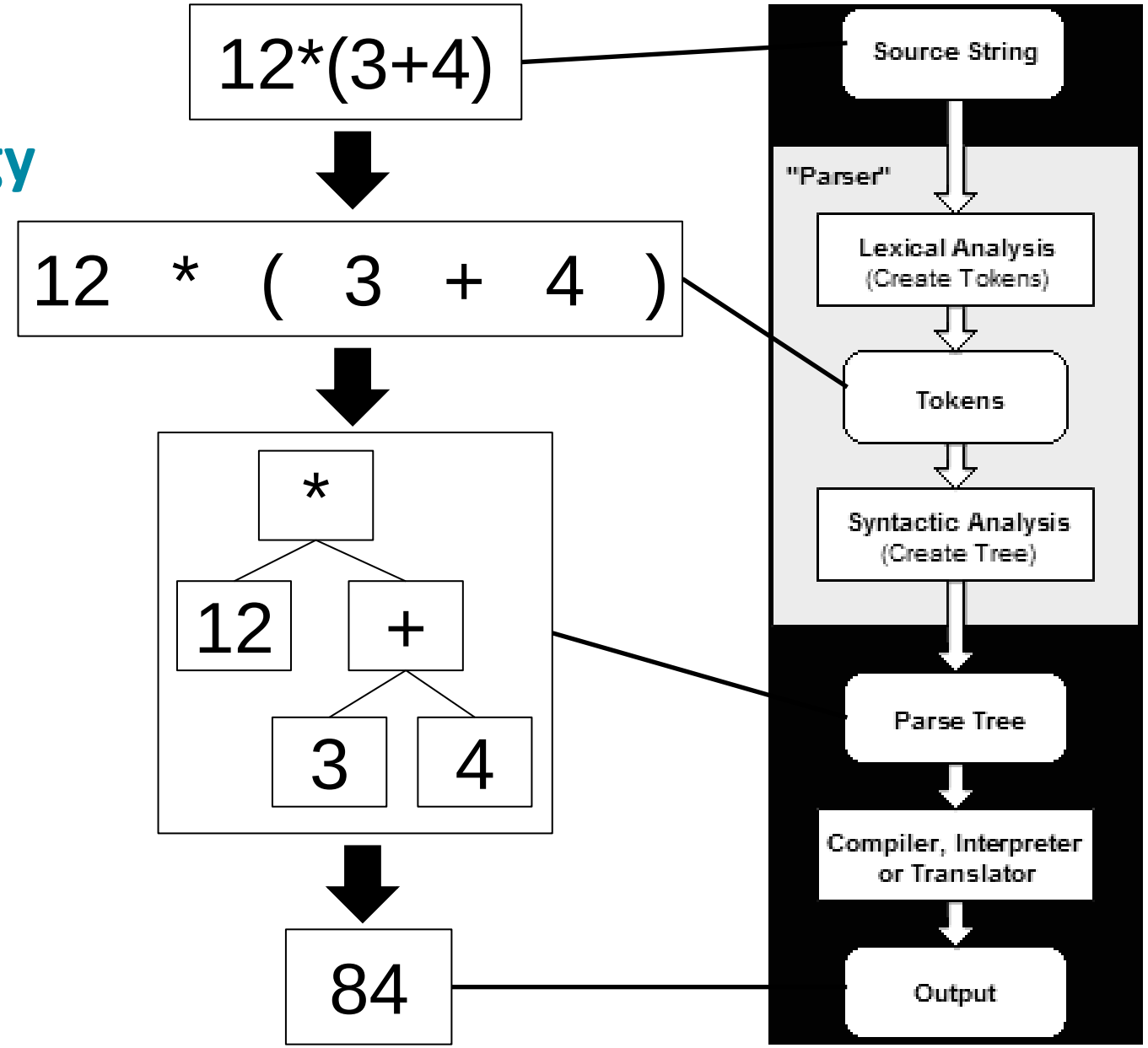
Meta level, for developing the general infrastructure



Instance level, for developing a specific system

Compiler Technology





Lexical Analysis

|	choice
?	optional
*	zero or more times
+	one or more times

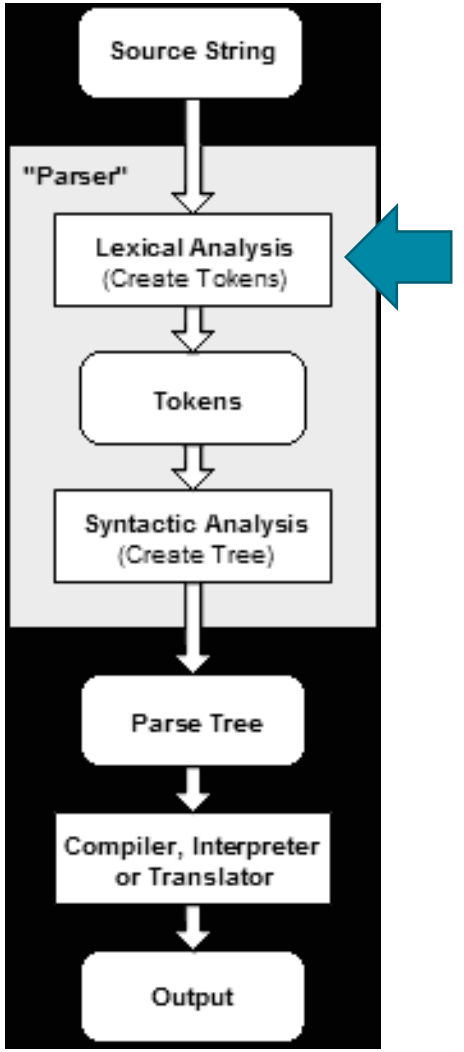
- **Regular expressions using Extended Backus-Naur Form (EBNF)**
  - Literal character sequences

    'while'

    '('
  - Custom terminal definitions

```
terminal INT: ('0'..'9')+;
terminal ID: '^'?('a'..'z'|'A'..'Z'|'_') ('a'..'z'|'A'..'Z'|'_'|'0'..'9')*;
```

  - Terminals that are imported by default in Xtext:
    - ID
    - INT
    - STRING
    - ML_COMMENT (= multi-line comment) ← Hidden by default
    - SL_COMMENT (= single-line comment) ← Hidden by default
    - WS (= whitespace, tab, newline) ← Hidden by default



Syntactic Analysis

|	choice
?	optional
*	zero or more times
+	one or more times

Context-free grammars in terms of tokens

- More expressive than regular expressions, e.g., recursion to parse nested brackets

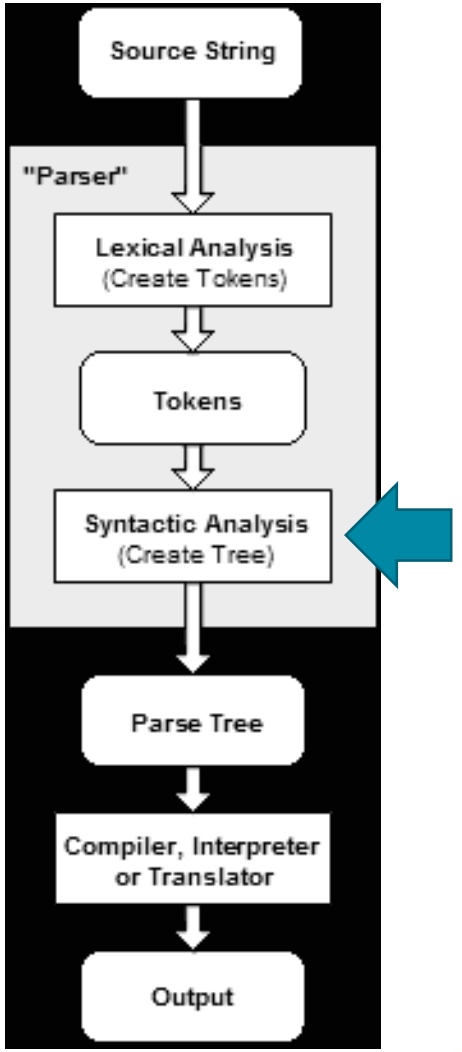
```
Task name AvoidBorder Task freq 100
    Task moves
        Move name Turn Start border End noBorder Speed 15 Rotation 90
        Move name Back Speed 30
```

Robot: (Message | Task)*

Message: 'Display' STRING

Task: 'Task' 'name' ID ('Task' 'freq' INT)?
'Task' 'moves' (Move)+

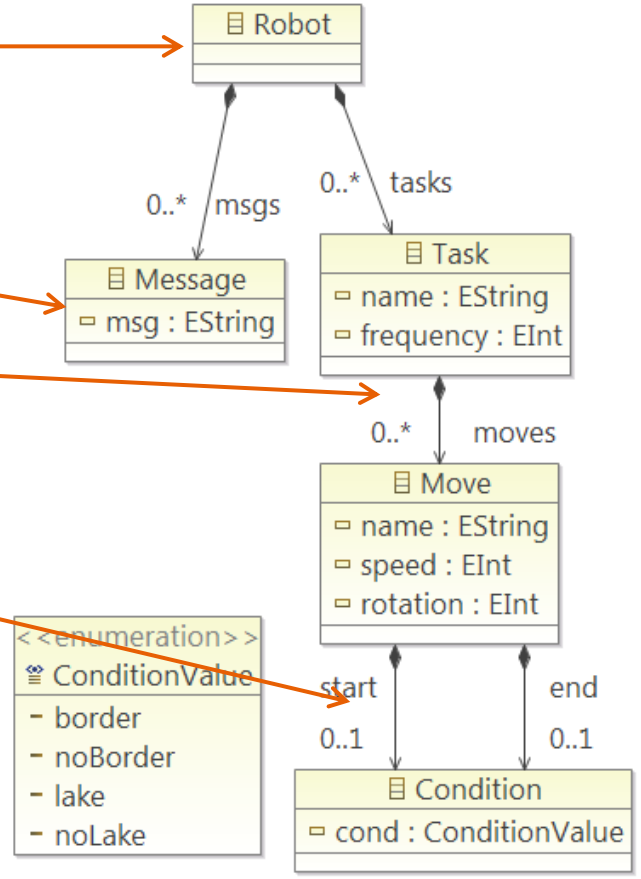
Move: 'Move' 'name' ID
('Start' Condition)? ('End' Condition)?
'Speed' INT ('Rotation' INT)?

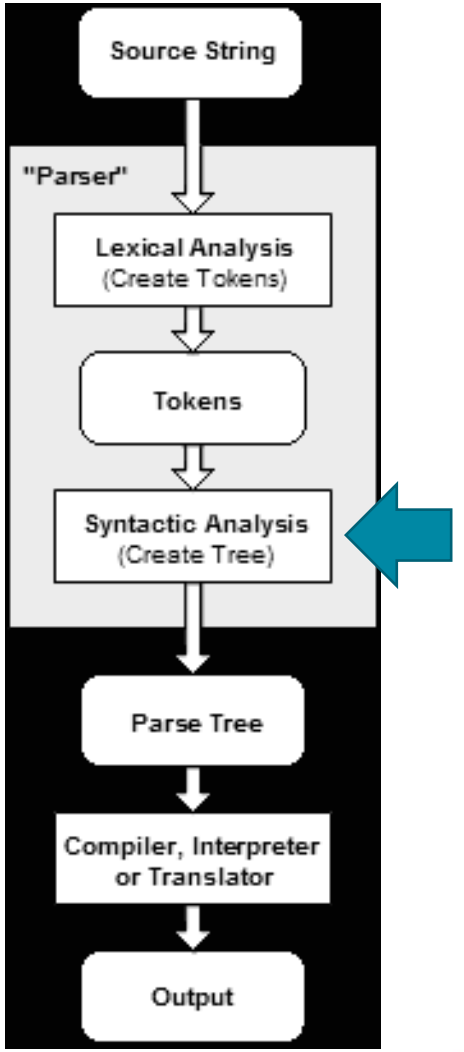


Abstract Syntax

```
Robot:
    (msgs += Message  | tasks += Task)*
;
Message:
    'Display' msg = STRING
;
Task:
    'Task name' name = ID ('Task freq' frequency = INT)?
    'Task moves' (moves += Move)+
;
Move:
    'Move name' name = ID
    ('Start' start = Condition)? ('End' end = Condition)?
    'Speed' speed = INT ('Rotation' rotation = INT)?
;

Condition :
    cond = ConditionValue
;
enum ConditionValue:
    border | noBorder | lake | noLake
;
```





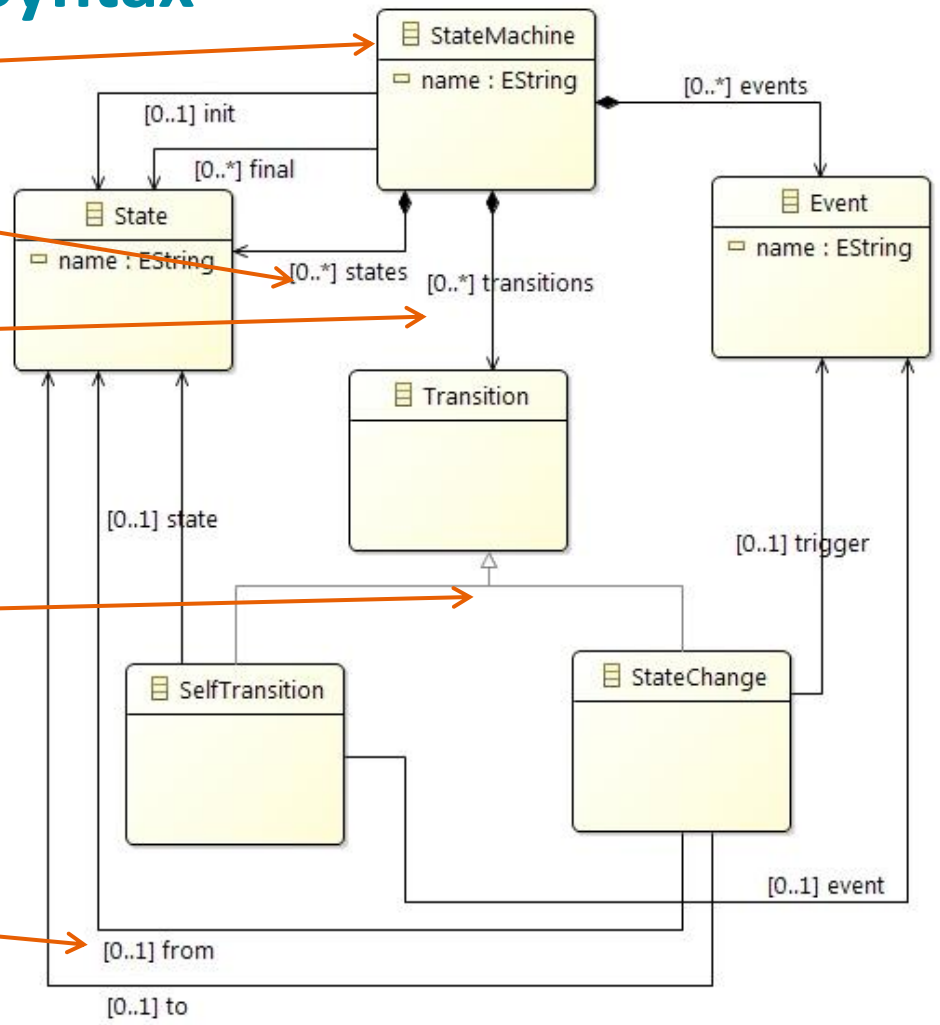
Concrete and Abstract Syntax

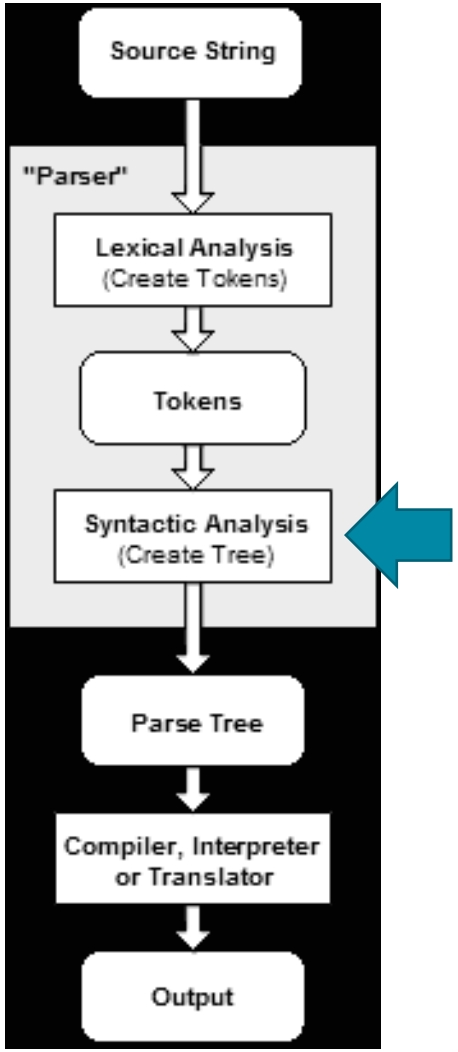
```
StateMachine:
    'StateMachine' name = ID
    'Init' init = [State]
    'States' states += State+
    'Events' events += Event+
    'Transitions'
       transitions += Transition*
    'Final' final += [State];

State: name=ID;
Event: name =ID;

Transition:
    SelfTransition | StateChange;

SelfTransition:
    'FromTo' state = [State]
    'Event' event = [Event]
   ;
StateChange:
    'From' from = [State]
    'Trigger' trigger = [Event]
    'To' to = [State];
```

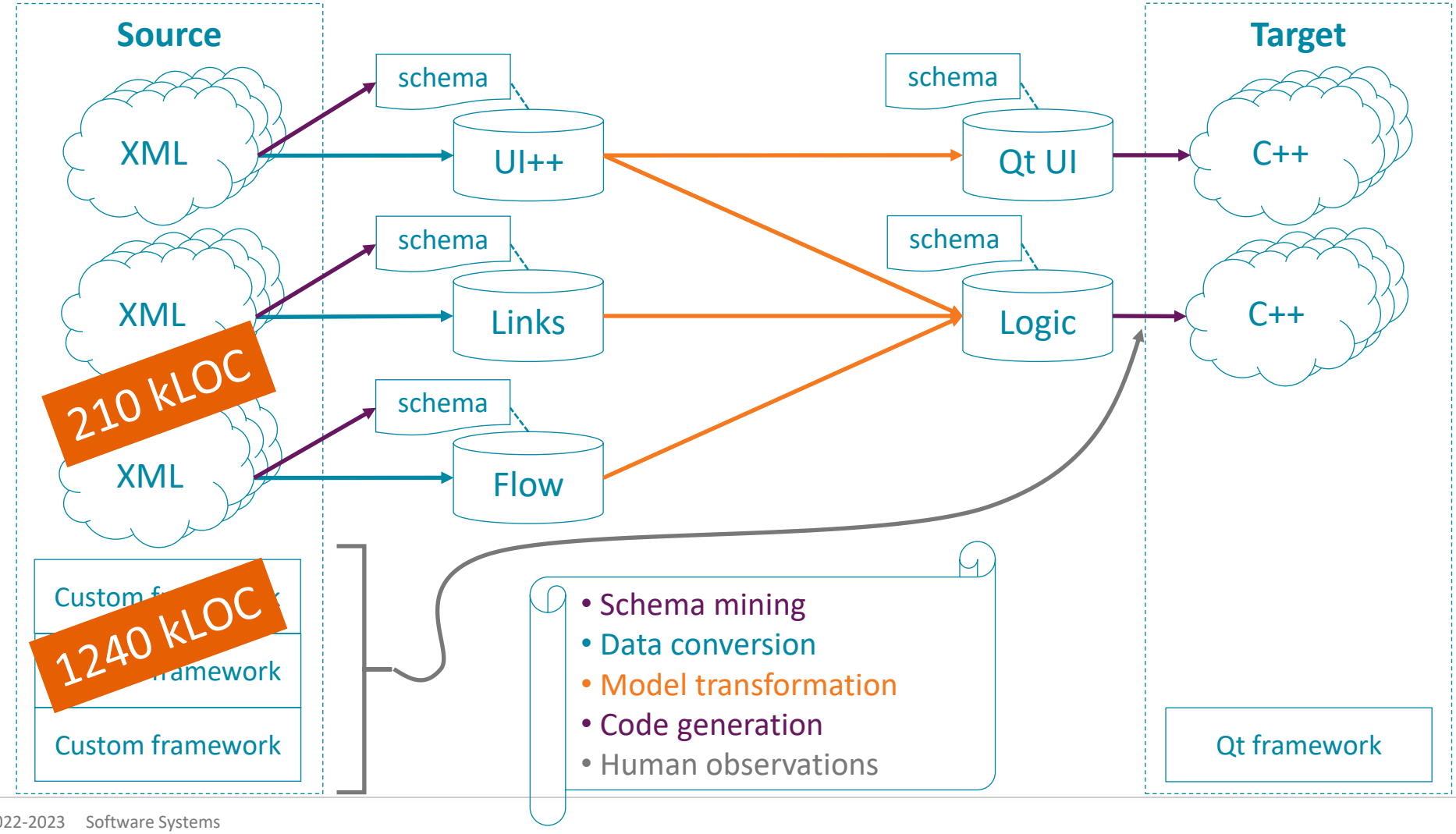




Field-service procedures at Philips IGT

Domain-Specific Languages (DSL)

Application: Migration



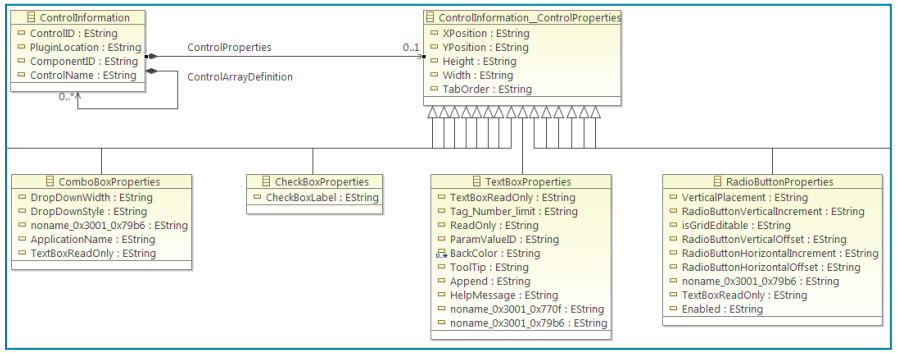
Application: Model extraction

```
<DataObject ObjectType="PanelProperties">
    <Attribute Group="0x3001" Element="0x652c" PMSVR="IInt16">5</Attribute>
    <Attribute Name="XPosition" Group="0x3001" Element="0x7600" PMSVR="IInt16">0</Attribute>
    <Attribute Name="YPosition" Group="0x3001" Element="0x7601" PMSVR="IInt16">145</Attribute>
    <Attribute Name="Height" Group="0x3001" Element="0x7602" PMSVR="IInt16">35</Attribute>
    <Attribute Name="Width" Group="0x3001" Element="0x7603" PMSVR="IInt16">60</Attribute>
    <Attribute Name="TabOrder" Group="0x3001" Element="0x7609" PMSVR="IInt16">2</Attribute>
    <Attribute Name="LayerType" Group="0x3001" Element="0x77d1" PMSVR="IString">"Data"</Attribute>
</DataObject>
```

XML data

↙ ↘

Schema



Converted data

```
ControlProperties = PanelProperties {
    Dock = 5
    XPosition = 0
    YPosition = 145
    Height = 35
    Width = 60
    TabOrder = 2
    LayerType = "Data"
}
```

Application: Code generation

```
// --- node FULLAUTO (stage FullAutomatic) -------
node
    name = "FULLAUTO"
    transitions
        OK -> "STATIC"
        Cancel -> "FINALIZATION"
    stage = FullAutomatic
        part = ""
    UIResource
        assembly = "FSCGeneratorUIDefinitions"
        id = "FSCXGNTubeAdaptationAdjustmentFullAutoUIDef"
    mapping
        event id 21: element "C24"
        event id 20: element "C25"
        event id 10: element "C33" ScrollToLatest
        event id 22: element "C23"
        event id 23: element "ProgressBarCtrl" conversion "TubeLoadPowerFactorToStyleSheet"
        event id 11: element "C31"
        event id 100: element "C9" Append
        event name "ExecutionBegun": element "C35_ProcedureEvents"
        event name "PartCompleted": element "C35_ProcedureEvents"
```

DSL model

```
#include "stdafx.h"
#include "«fileName».h"

#include <QDoubleValidator>
#include <QMessageBox>

#include "Utility.h"

«FOR node : procedure.nodesUI»
«FOR mapping : node.mappingsId»
const ULONG «constant(node, mapping)» = «mapping.id»L;
«ENDFOR»
«FOR mapping : node.mappingsIdEvent»
const ULONG «constant(node, mapping)» = «mapping.id»L;
«ENDFOR»
«FOR action: node.actionsId»
const ULONG «constant(node, action)» = «action.id»L;
«ENDFOR»
«ENDFOR»

«fileName»::«fileName»(QString qstrProcedureName, CLSID component, QWidget *parent, bool bStubbed)
    : «NewFlowGeneratorHeader::parentClass(procedure)»(qstrProcedureName, component, parent, bStubbed)
    «FOR node: procedure.nodesUI»
    , m_qwidget_node«node.name»(NULL)
    «ENDFOR»
```

Template

Generated code

```
#include "stdafx.h"
#include "FlowFSCXGNTubeAdaptationAdjustment.h"

#include <QDoubleValidator>
#include <QMessageBox>

#include "Utility.h"

const ULONG FlowFSCXGNTubeAdaptationAdjustment_Preset_getset_C46 = 1L;
const ULONG FlowFSCXGNTubeAdaptationAdjustment_FULLAUTO_event_C24 = 21L;
const ULONG FlowFSCXGNTubeAdaptationAdjustment_FULLAUTO_event_C25 = 20L;
const ULONG FlowFSCXGNTubeAdaptationAdjustment_FULLAUTO_event_C33 = 10L;
const ULONG FlowFSCXGNTubeAdaptationAdjustment_FULLAUTO_event_C23 = 22L;
const ULONG FlowFSCXGNTubeAdaptationAdjustment_FULLAUTO_event_ProgressBarCtrl = 23L;
const ULONG FlowFSCXGNTubeAdaptationAdjustment_FULLAUTO_event_C31 = 11L;
const ULONG FlowFSCXGNTubeAdaptationAdjustment_FULLAUTO_event_C9 = 100L;

FlowFSCXGNTubeAdaptationAdjustment::FlowFSCXGNTubeAdaptationAdjustment(QString qstrProcedureName, CLSID component, QWidget *parent, bool bStubbed
    : BaseAdjustment(qstrProcedureName, component, parent, bStubbed)
    , m_qwidget_nodePreset(NULL)
    , m_qwidget_nodeFULLAUTO(NULL)
    , m_qwidget_nodeSTATIC(NULL)
```

Conclusion: It pays off!

Main challenges:

- **Extract the domain knowledge from the legacy software**
- **Avoid that the rejuvenated software resembles the legacy too much**

Industrial results:

- **Redesigned software: 20 times smaller code base than legacy software**
- **Model-based migration: 6 times less effort than manual**

More time for **innovation**!


Dirk Jan Swagerman


Gernot Eggen


Hans van Wezep


Martien van der Meij


Aron van Beurden

PHILIPS

Embedded Systems Innovation BY TNO


Arjan Mooij


Jozef Hooman

Closing remarks

Domain-Specific Languages (DSL)

General Tips and Tricks

- **It may help to first create an example instance, and afterwards create a grammar.**
  - "test-driven"
- **Look at the abstract syntax!**
  - E.g., check missing attribute names
- **Don't be too restrictive in the grammar; validation can be used for extra checks.**
- **Focus on specification (not on execution)**
- **A DSL is not a general-purpose programming language**
- **Use enumeration types when appropriate:**

```
enum ChangeKind :
        ADD     = 'add'
      | MOVE    = 'move'
;
```

Closing remarks

- **Lab session work:**
  - Follow the manual “Creating a Domain Specific Language (DSL) with Xtext” up to section 3.5
    - http://www.cs.ru.nl/J.Hooman/DSL/Creating_a_Domain_Specific_Language_(DSL)_with_Xtext.pdf
  - Modeling assignment
    - Create an Xtext grammar (+ some example instances)
    - Create validation and code generators