24. Model Synchronisation, Code Generation and Round-Trip Engineering for the Consistency of Macromodels

Code Generation as Apps for RAG

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http://st.inf.tu-dresden.de/teaching/most

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1)Single-source principle and macromodel principle

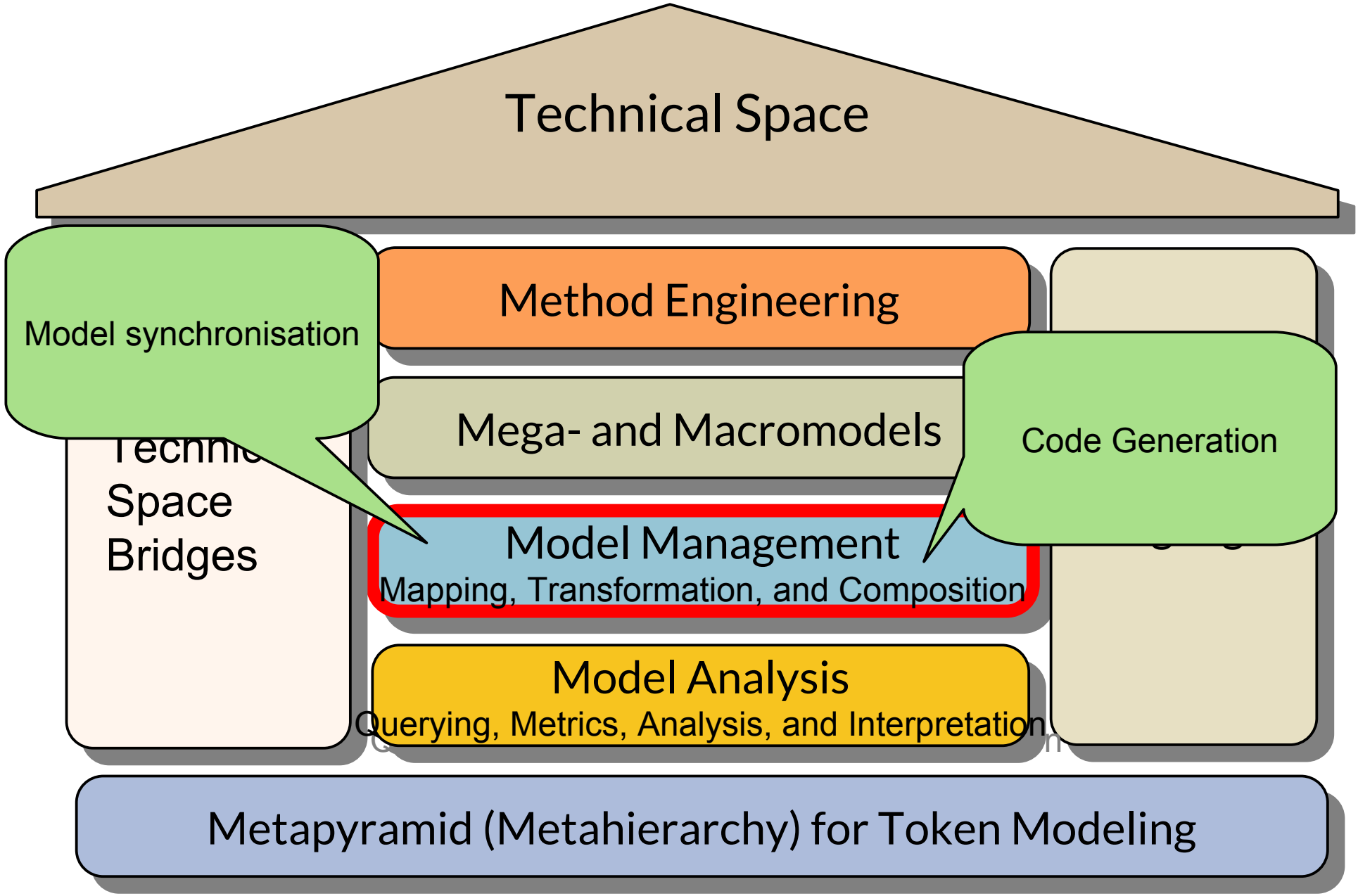
2)Code generation techniques

- Template-based Code generation

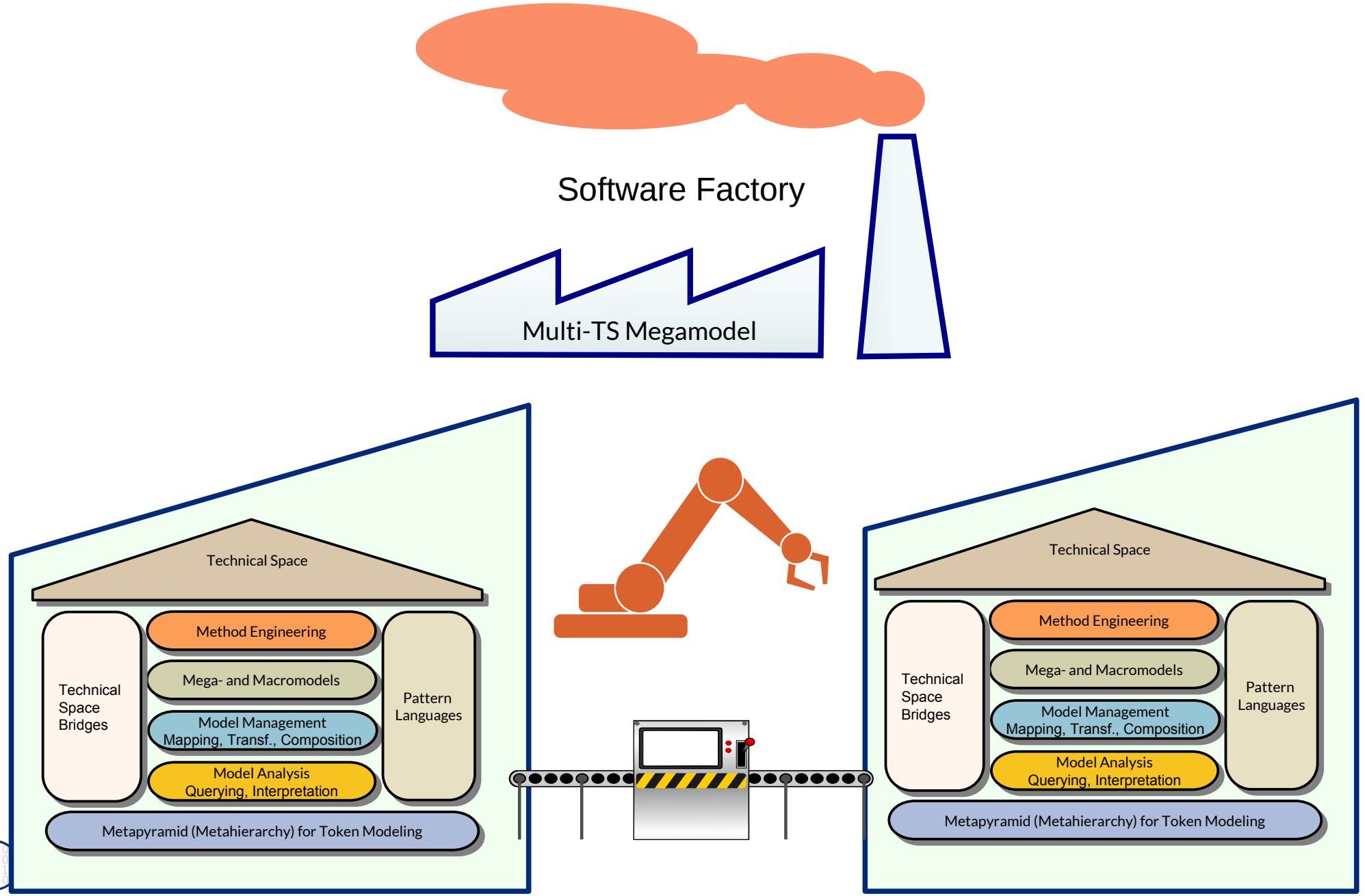
3)Re-parsing

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

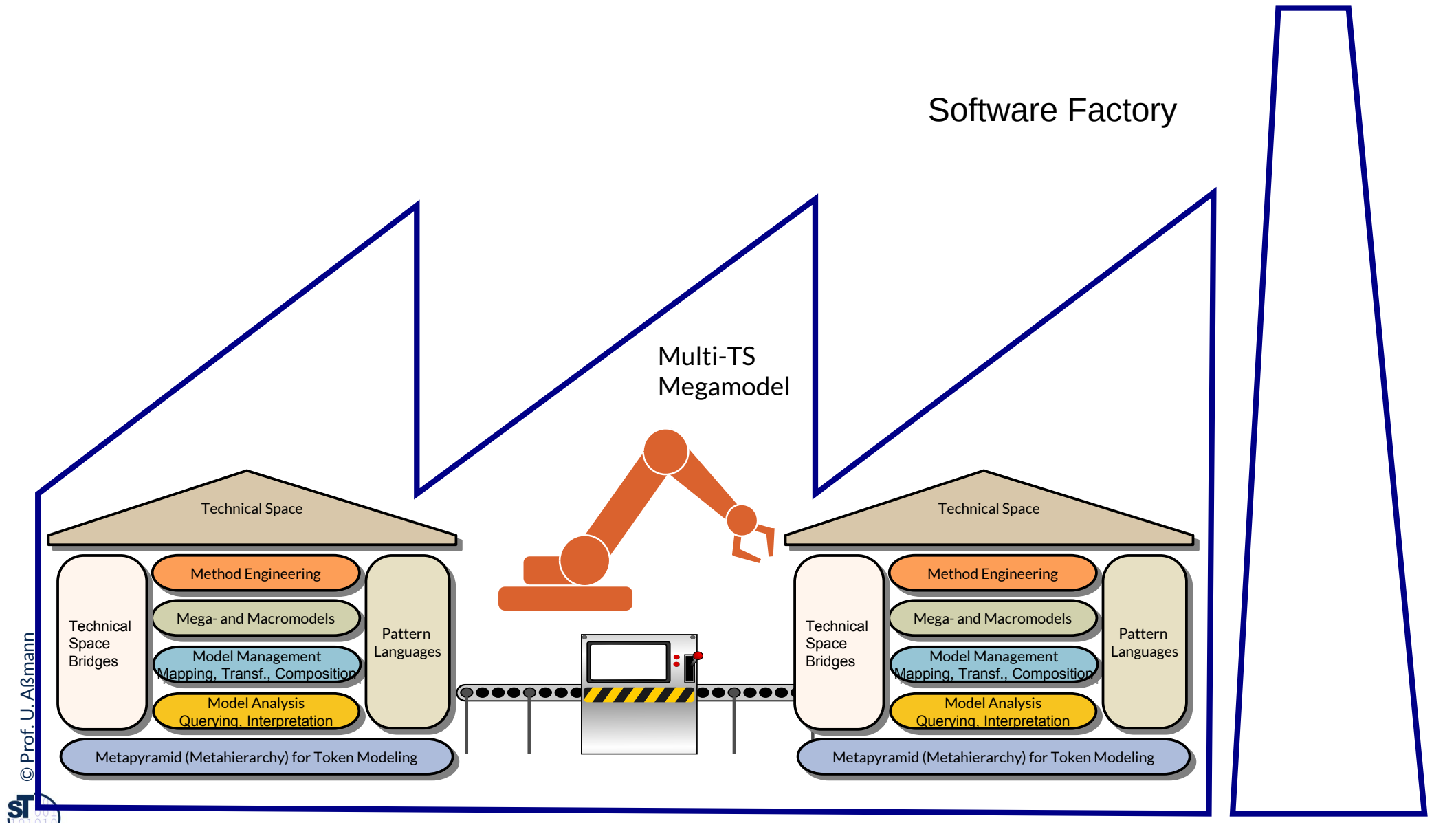
Q10: The House of a Technical Space



Q11: A Software Factory's Heart: the Multi-TS Megamodel



Q12: A Software Factory's Heart: the M[illegible]egamodel



Literature

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- www.programtransformation.org
- http://www.codegeneration.net/tiki-read_article.php?articleId=65
- Paul Bassett. Frame-based software engineering. IEEE Software, 4(4):9-16, 1987.
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- Chris Holmes, Andy Evans. A review of frame technology. University of York, Dept. of Computer Science, 2003
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- Optional
  - Völter, Stahl: Model-Driven Software Development, AWL 2005.
  - Falk Hartmann. Safe Template Processing of XML Documents. PhD thesis, Technische Universität Dresden, Fakultät Informatik, July 2011.
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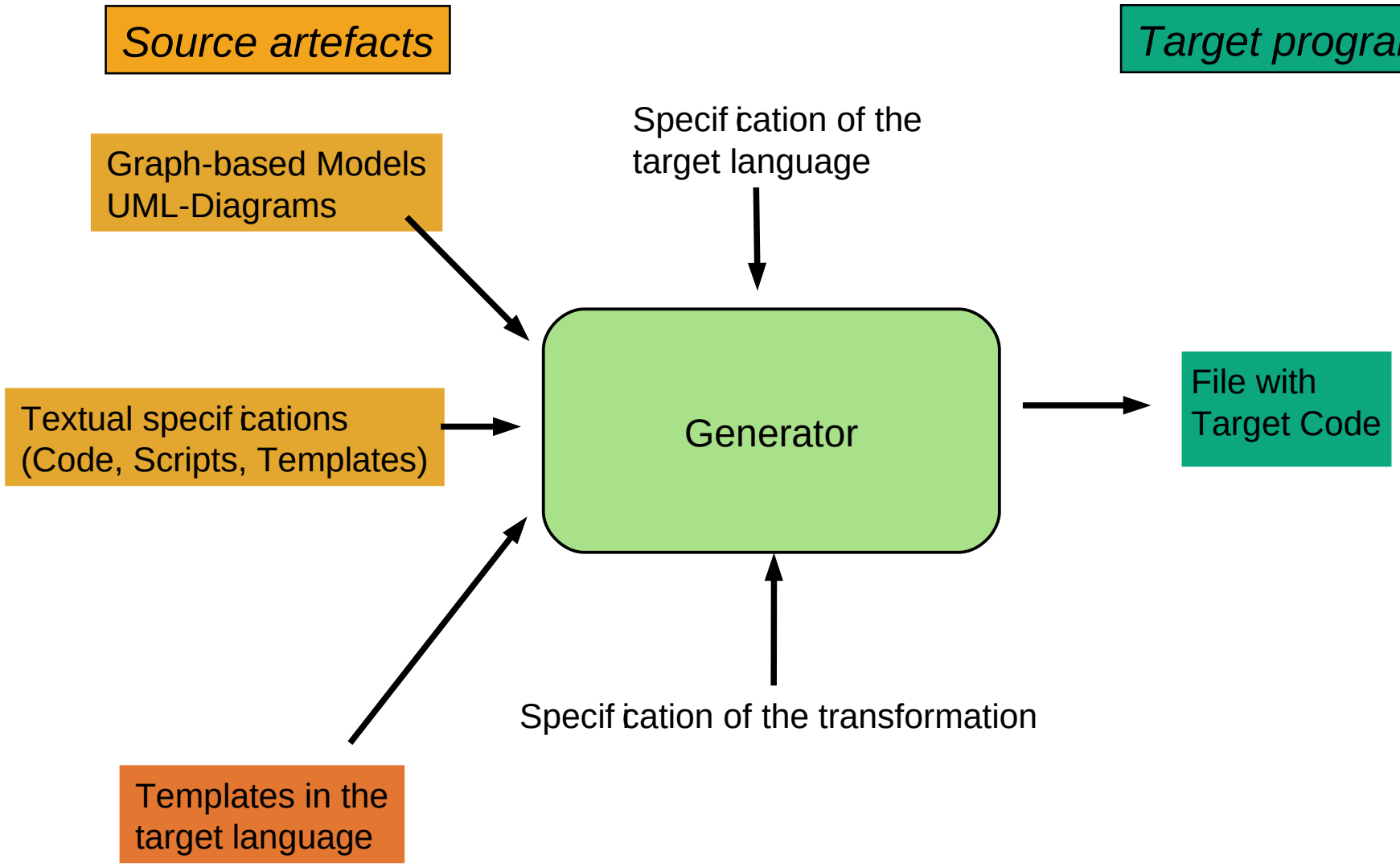
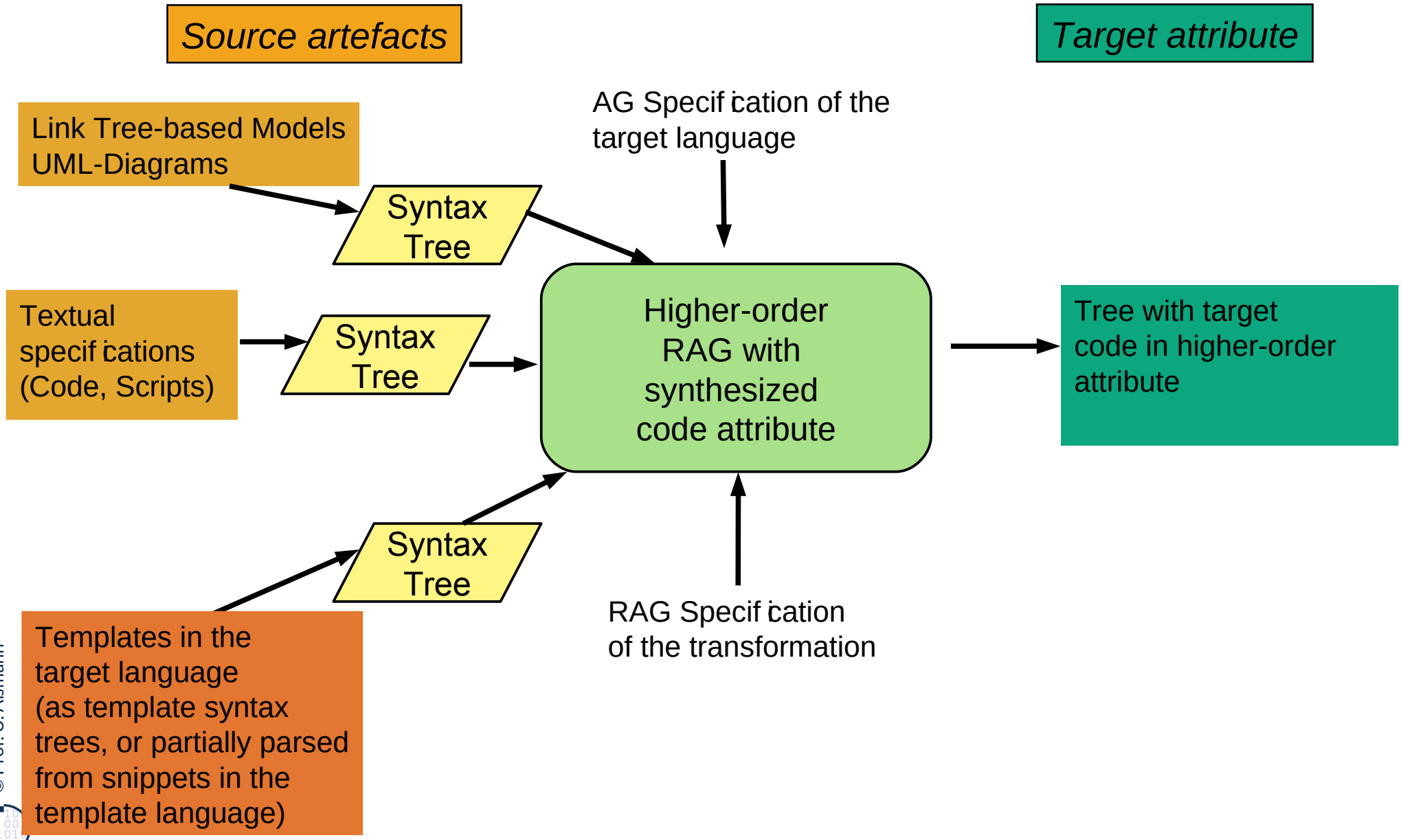
24.1 Model2Code Transformation (Code Generation)

Transforming models into code (Programmüberführung)

MDSD-Code-Generators



MDSD-Code-Generators as Attributors of Syntax Trees

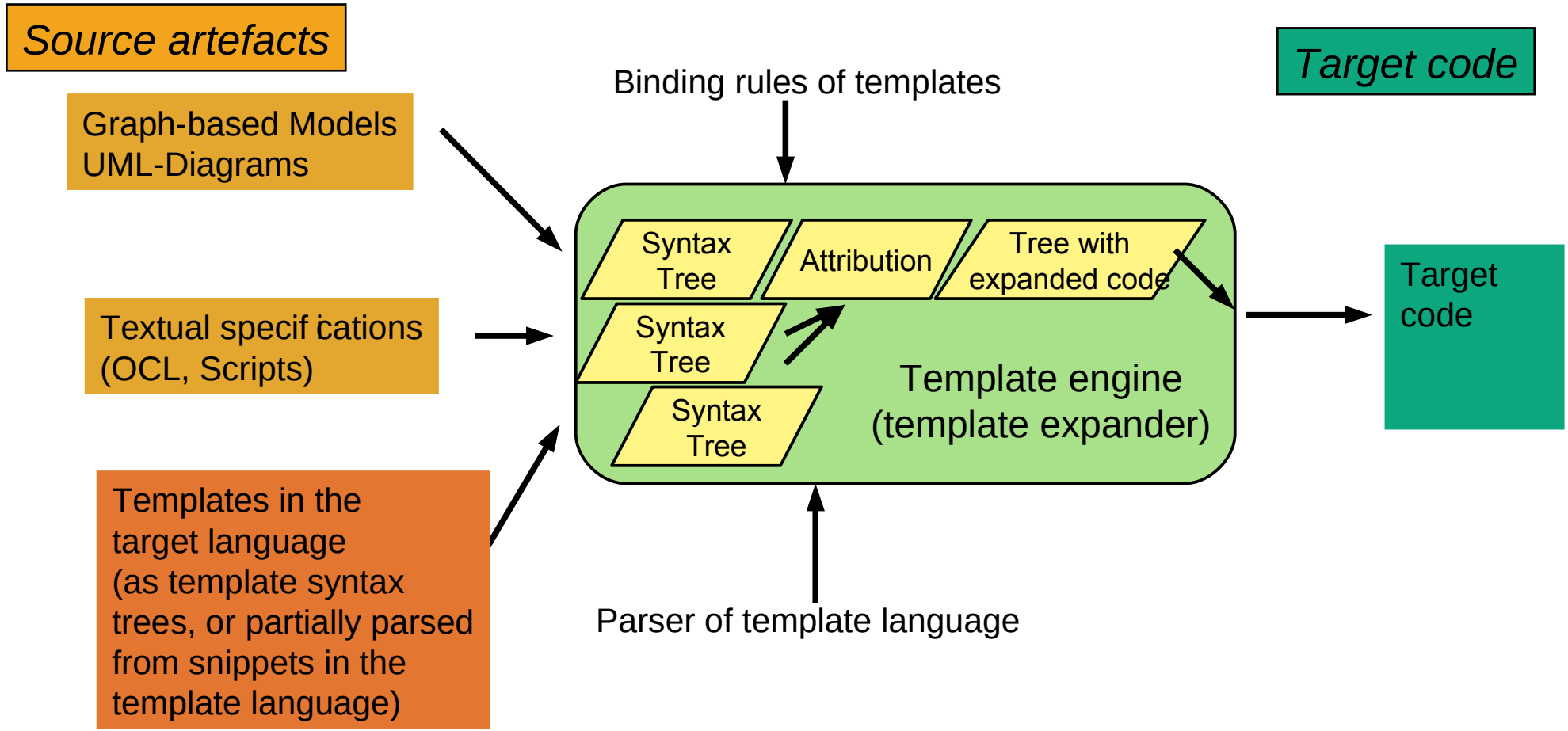


Kinds of Code Generators

- A **code selector** is a transformation system (term, link trees, graphs) covering the input models with rules (**code coverage**) transforming the model elements once
- A **code scheduler** orders instructions in an optimized manner
  - Code scheduling runs after code selection
- **Metaprogramming code generators**:
  - A **template expander** generates code by filling code templates with *inset snippets*
  - An **invasive fragment composer (invasive software composition)** composes templates in a typed and wellformed way (CBSE)

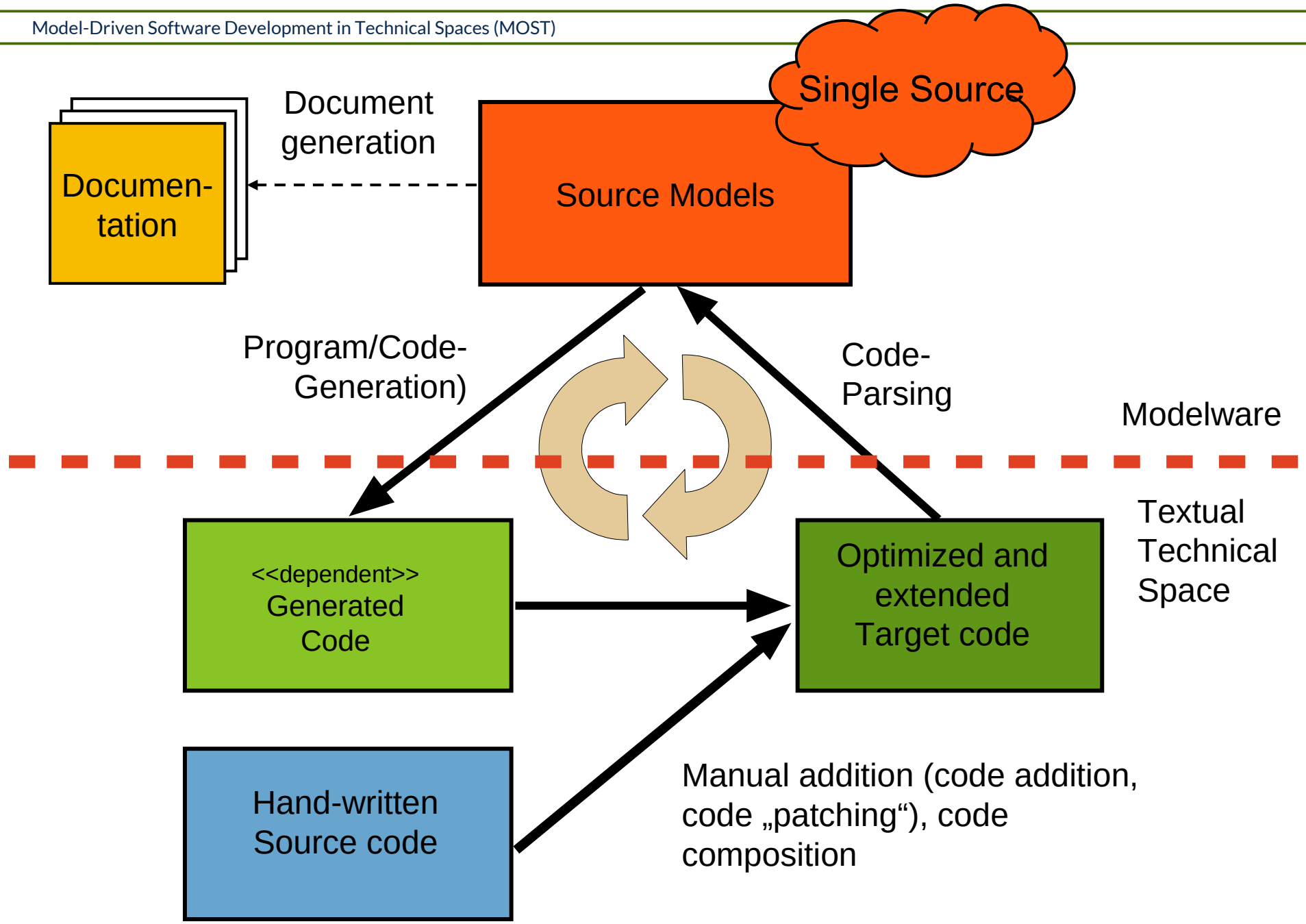
MDSD-Code-Generators as Template Expanders

- A **template engine** hides the tree construction, attribution with code attributes, and pretty-printing under a simple interface
- It provides a function `tempparse(): String in TemplateLanguage → Tree`
- Template engines are *apps* of higher-order RAG

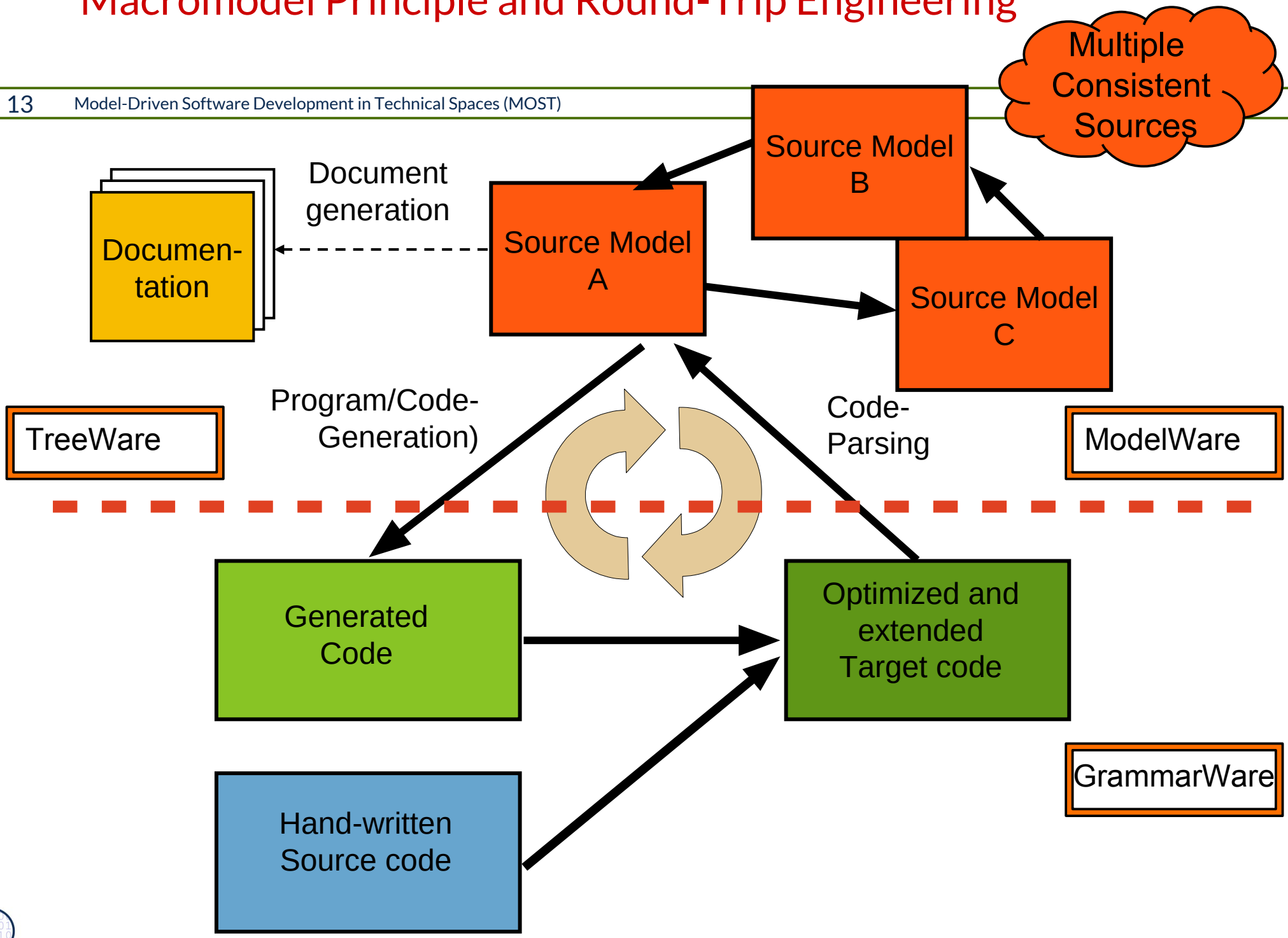


24.1.1 Single-Source Principle and Macromodels

Single-Source-Principle, Code Addition, and Round-Trip Engineering



Macromodel Principle and Round-Trip Engineering



Single Source Principle and Macromodel Principle

- A **Single-Source-Technology** with automatic synchronisation and consistency between one model (single source), code, tests
  - 1997 introduced by Peter Coad in the Together-CASE-tool, now in all CASE tools
- A **Macromodel Technology** with automatic synchronisation and consistency between ALL models, code, tests, and documentation (all models of a megamodel)
- In a macromodel, there are always ***derived models***
  - Generated code (this chapter)
  - Generated documentation (Chapter on documenation)
  - Generated test suites and data

Synchronization

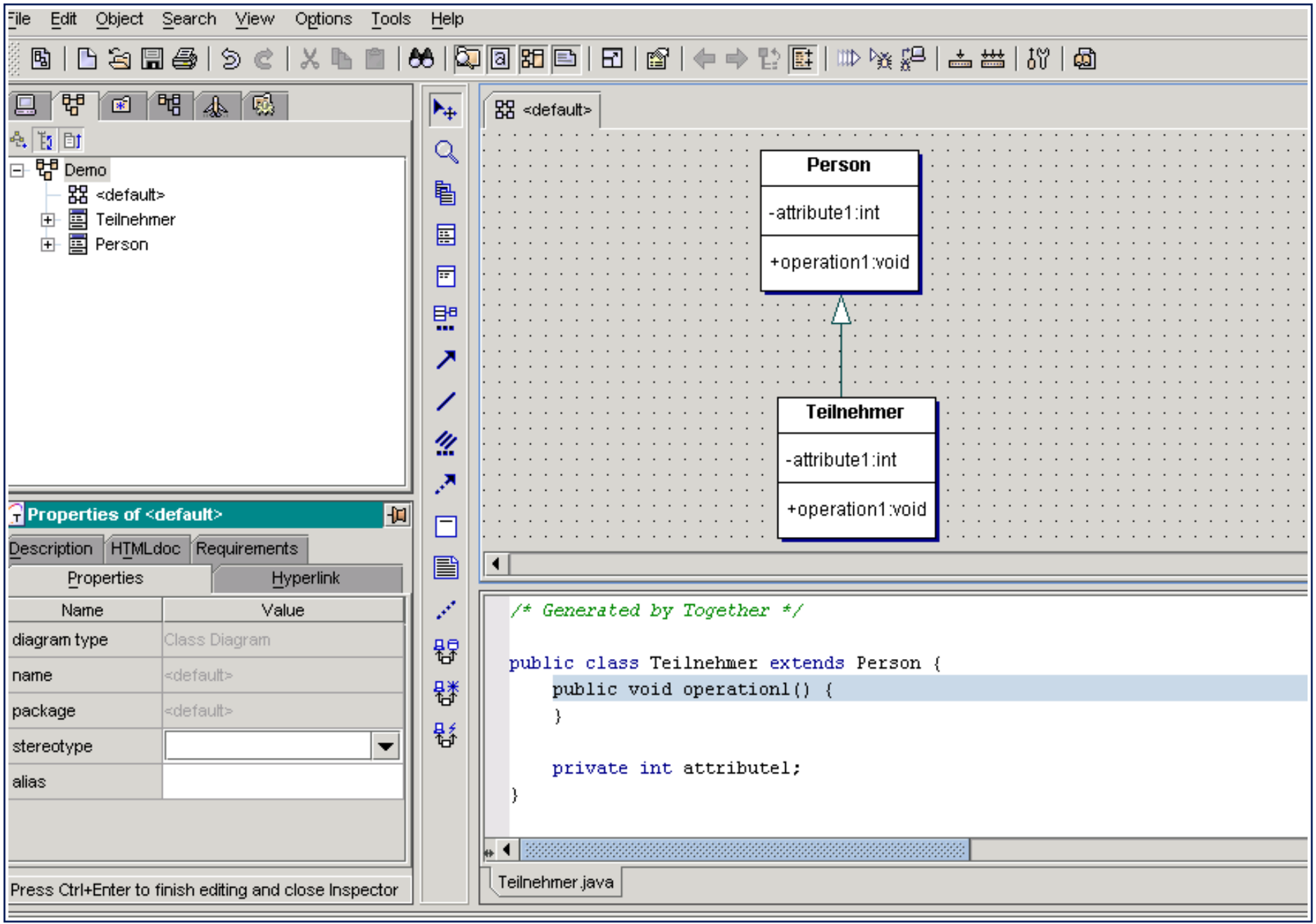
- Technically, the Single-Source-Principle and the Macromodel principle needs **Round-Trip-Engineering** (RTE) between ModelWare and GrammarWare, to achieve
  - **Model-to-code synchronisation** with
    - **Codegeneration** into several programming languages
    - **Template-based codegeneration** inserts code snippets itno code templates
    - **Code reparsing** of the changed source code into models
  - **Model-to-model synchronization** with
    - **Bidirectional transformations** (with TGG)
    - **View based transformations** (with SUM)

Example: Round-Trip Engineering in Together (P. Coad, Borland)

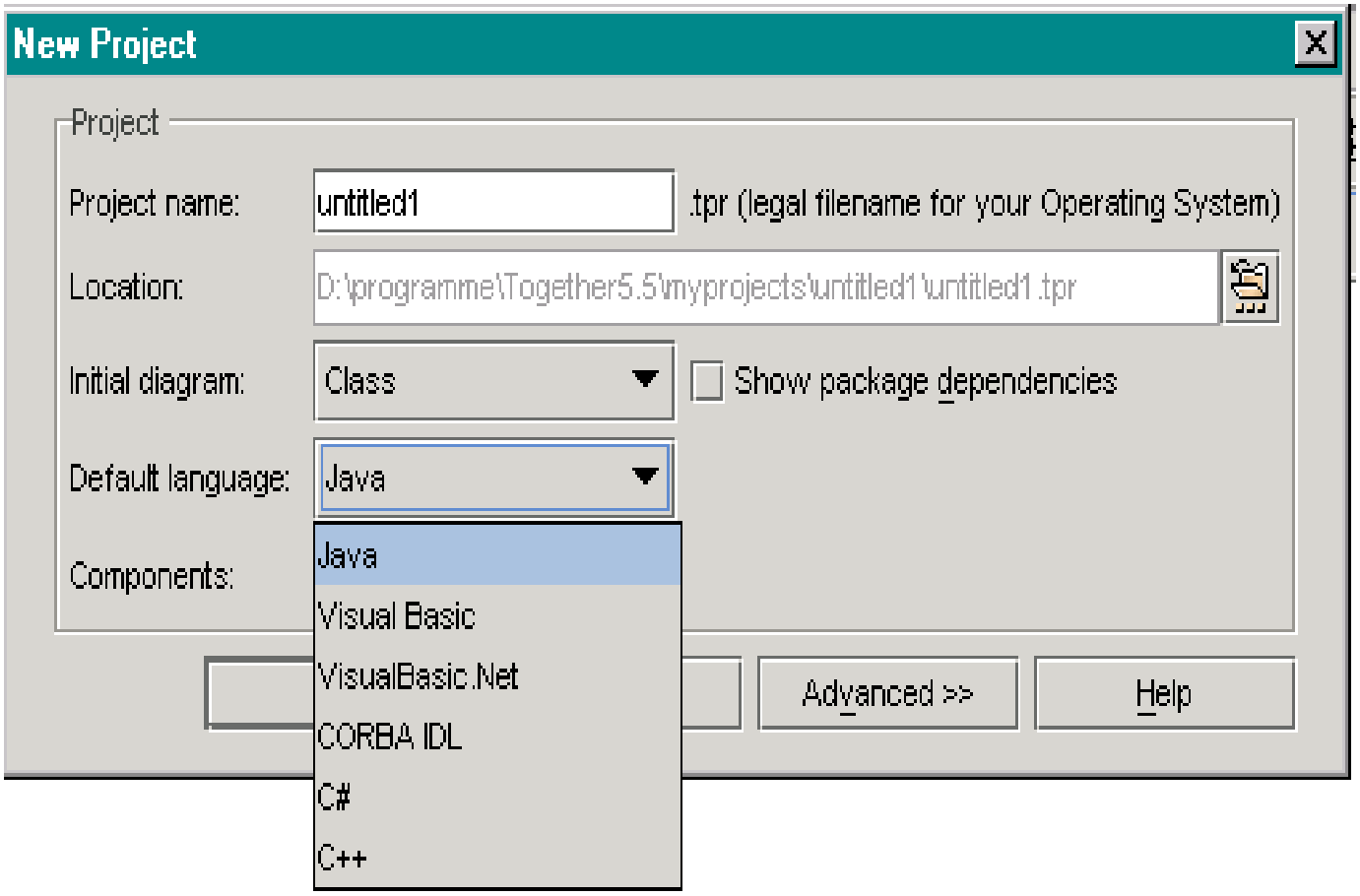
- In 1998, the CASE tool Together was the first to provide a Single-Source-Technology with automatic synchronisation and consistency between UML model, code and documentation
- Supported Programming Languages: Java, Visual Basic, VisualBasic.Net, CORBA IDL, C++, C#
  - Synchronisation by reparsing of generated, modified and extended code
- Round-trip Engineering:
  - Changes of class diagrams will be transformed to code
  - Changes of code reparsed to class diagrams
  - Reverse Engineering of entire projects

http://www.borland.com/downloads/download_together.aspx
http://www.borland.com/de-DE/Products/Requirements-Management/Together/Testimonials
https://en.wikipedia.org/wiki/Borland_Together

Together Screenshot



Code Generation in Different Languages in Together

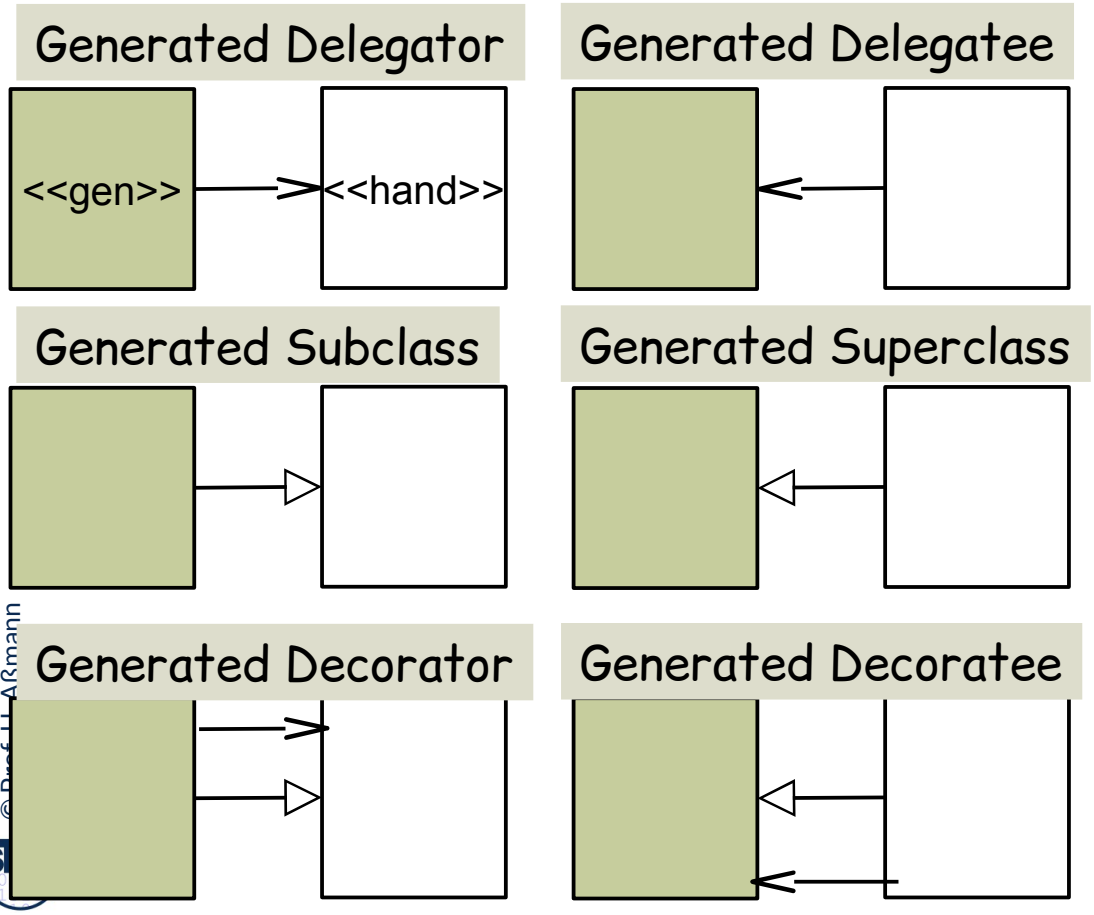


- Supports roles: Business Modeler, Designer, Developer and Programmer
- Appropriate views can be conf gured
- Code template based code generation

24.2 Technologies for Model-2-Code Generation

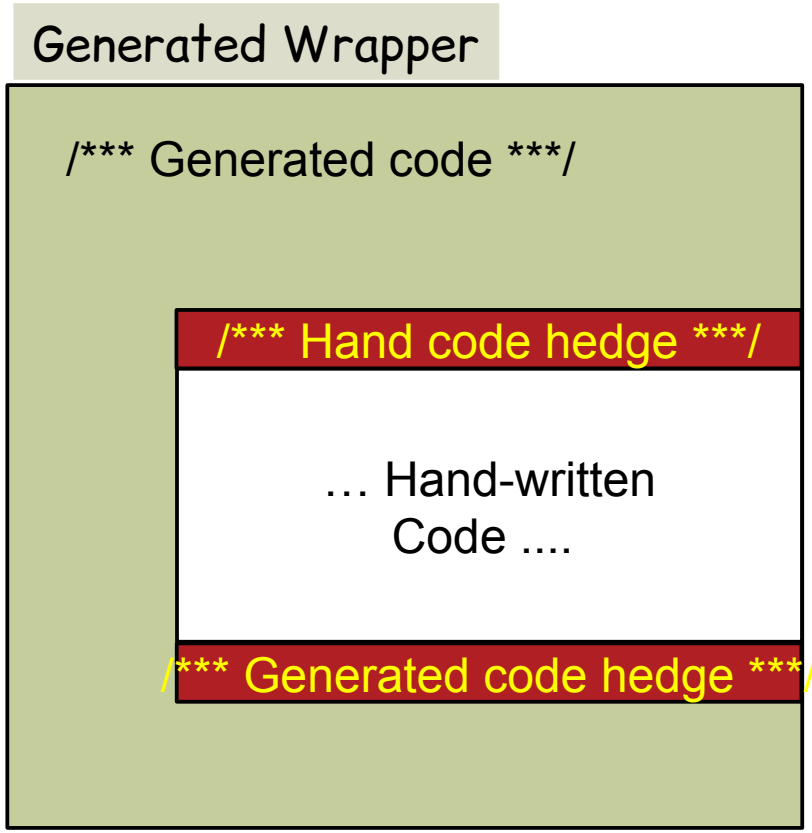
Composition of Separated Hand-Written and Generated Code

- **In separate files:** Coupling by implementation pattern [Völter/Stahl]
- Use class composition like delegation, TemplateMethod, Composite, Decorator, etc



In one file:

Coupling with **hegdes (Trennmarkierung)**

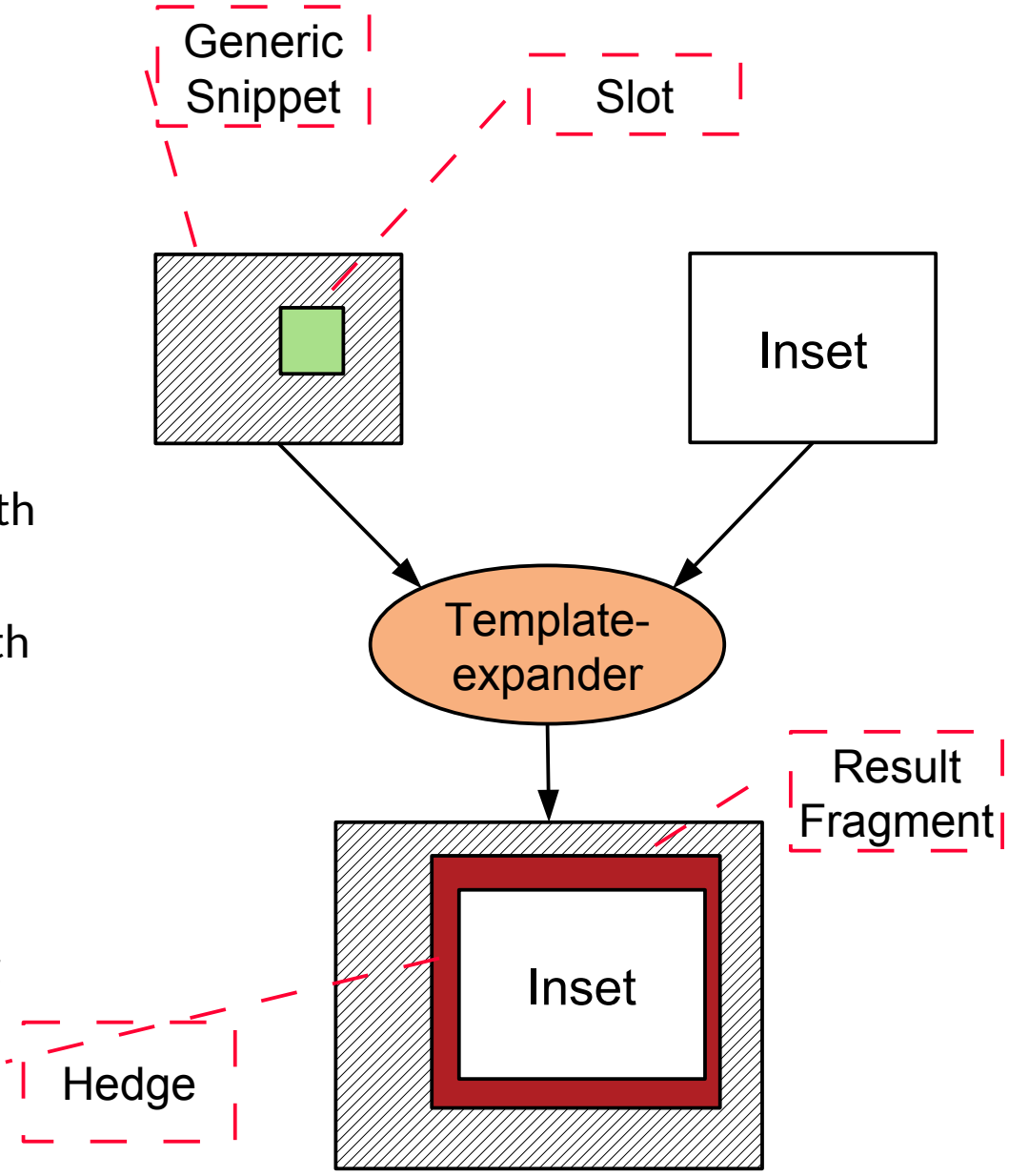


Composition of Generated and Hand Written Code in an RAG


```
eq Procedure.Code() {
   return Head.Code()+
          "/*** HEDGE BEGIN */"+
          GeneratedBody.Code()+
          „/*** HEDGE END */";
}
eq Head.Code() {
   return pparse("public „+Head.name+"()");
}
eq GeneratedBody.Code() {
   return Body.Code();
}
```

Snippet Programming with RAG

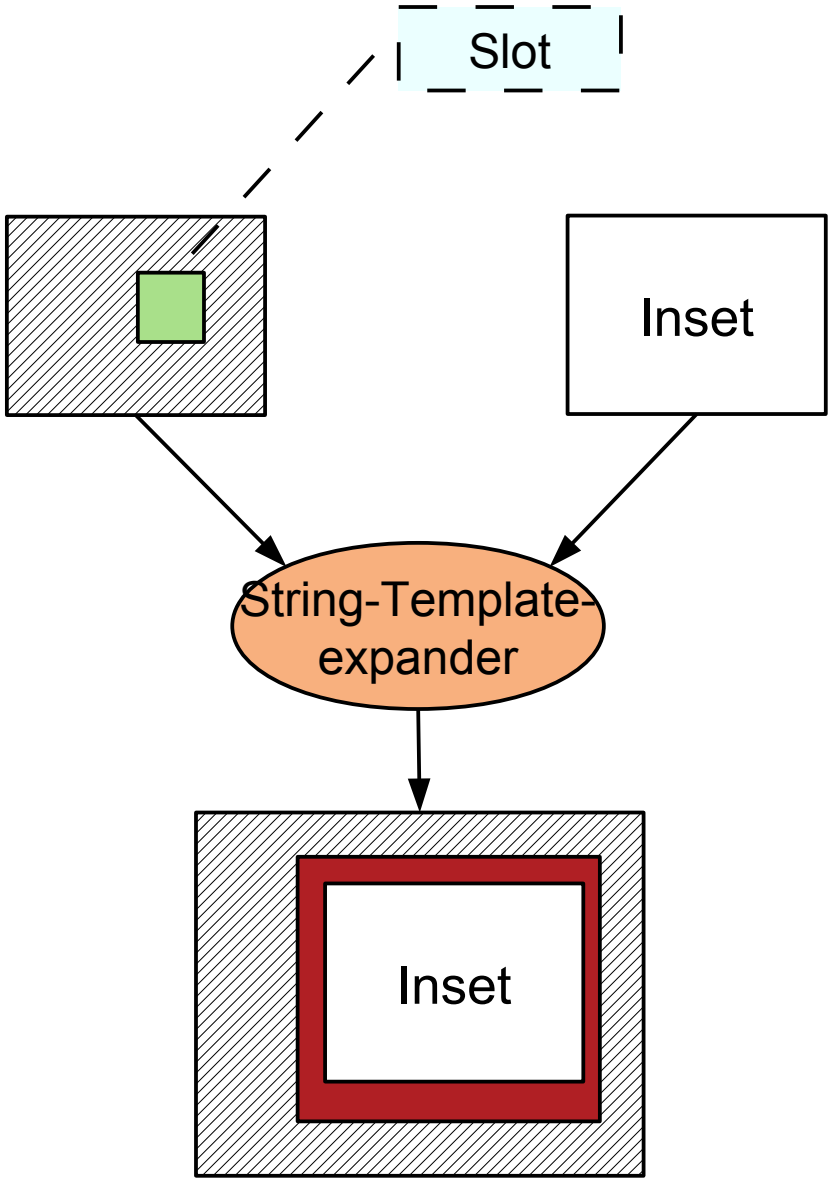
- **A fragment (snippet)** is a incomplete sentence of a language, derived from a nonterminal of the grammar, or described by a metaclass
- A **generic fragment (template, form, frame)** is a fragment with **slots (holes, code parameters, variation points)**, which can be *bound (filled, expanded)* with an **inset fragment** to a **result fragment**
- A extensible fragment is a fragment with **hooks (extension points)**, which can be *extended* to a fragment
- **Generic programming** is programming with generic fragments (templates).
- **Invasive programming** is programming with generic and extensible fragments (templates with hooks)
- ? CBSE course



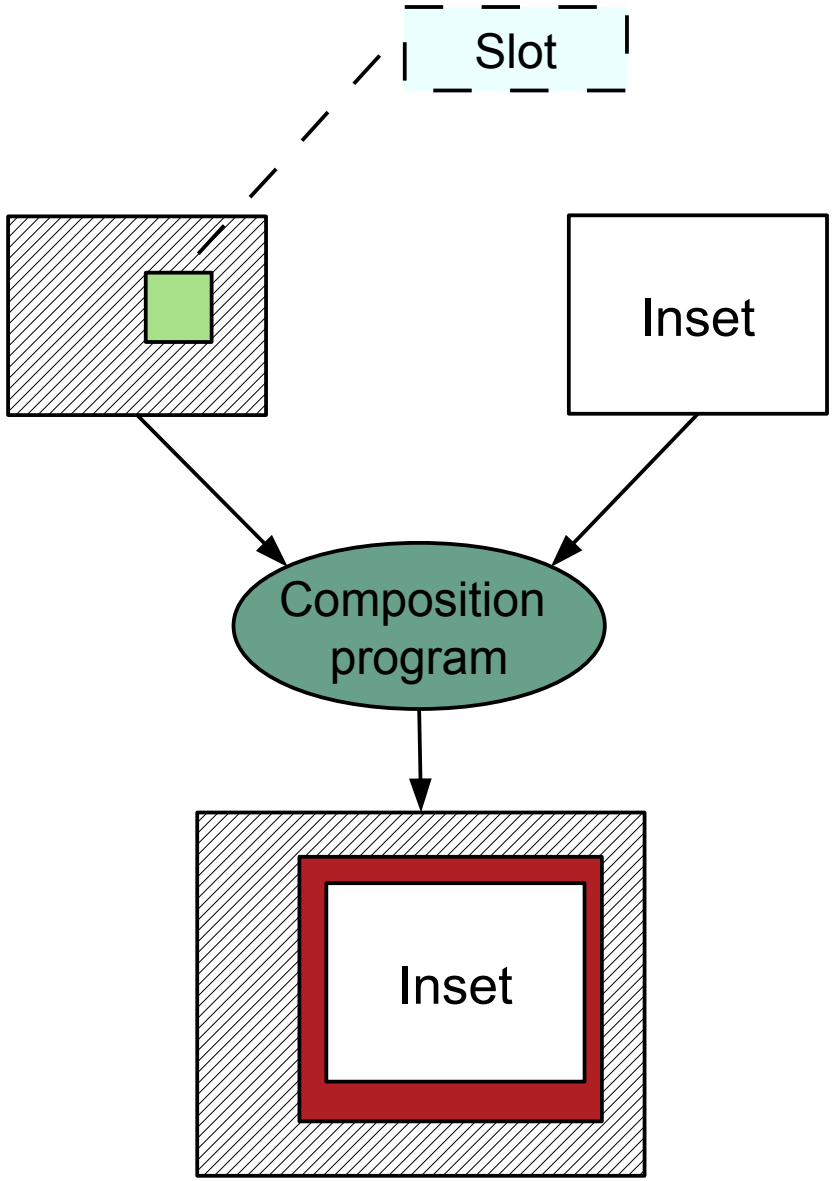
24.2.1 Template-based Code Generation (Schablonenbasierte Programmüberführung)

Template Expansion by Composition of Insets and Hedging

Coupling by string expansion



Coupling by composition program



Slots are Marked by Hedges

- **Hedges** are delimiters that do not occur in the base nor in the slot language
- **Slot hedges** are template2slot hedges marking the transition from the code language to the slot language
- **Inset hedges** are metaprogramming2code hedges marking the transition from the metaprogramming language to the code language

```
// code slot hedges << >>
template (superclass:CLASS, t:TYPE) {
  class Worker extends << superclass >>
{
        <<t>> attr = new <<t>>();
        <<t>> getAttr();
       void setAttr(<<t>>);
   }
}
```

Tools for Untyped Template Expansion

- **Frame processing** was invented in [P. Bassett] as an *untyped string template expansion technology*, universal for all textual languages [Holmes/Evans]
  - Frame processing is the main technology for web engineering today: it organizes reuse of page templates
  - The original frame processor used $ as a hedge symbol for slots (slot variables)
- **Macro processing** is not much different
  - Because only slot variables hold insets, macro parameters correspond to slot variables
- **XML template processing** engine XVCL [Jarzabek] is an XML-controlled frame processor
  - http://sourceforge.net/projects/fxvcl/files/XVCL%20Specification/Version%202.10/
- **String template engines** in use today
  - Apache Velocity http://velocity.apache.org/
  - Parr's template engine StringTemplate
  - Jenerator for Java http://www.voelter.de/data/pub/jeneratorPaper.pdf

Velocity String Template Language

- Velocity Template Language (VTL) is a frame processing language with
  - metaprograms in slots, written in a **slot language** (blue)
- {#, $} are slot hedges
- < (from XML) is the inset hedge

```
<html>
<body>
#set( $foo = "Velocity" )
Hello $foo World!
</body>
<html>
```

```
<HTML>
<BODY>
Hello $customer.Name!
<table>
#foreach($mud in $mudsOnSpecial)
   #if
( $customer.hasPurchased($mud) )
      <tr>
        <td>
          $flogger.getPromo( $mud )
        </td>
      </tr>
   #end
#end
</table>
```

http://velocity.apache.org/engine/releases/velocity-1.7

Velocity Template Language

- Velocity Template Language (VTL) is a simple scripting language in the spirit of TCL
- It has control structures (if, switch, foreach), assignments (set), and macros

http://velocity.apache.org/engine/releases/velocity-1.7

```
#macro( inner $foo )
  inner : $foo
#end

#macro( outer $foo )
   #set($bar = "outerlala")
   outer : $foo
#end

#set($bar = 'calltimelala')
#outer( "#inner($bar)" )
```

Problem: the result of string template expansion may not be syntactically correct, nor well-formed, target language (error-prone)

Typed Template Expansion

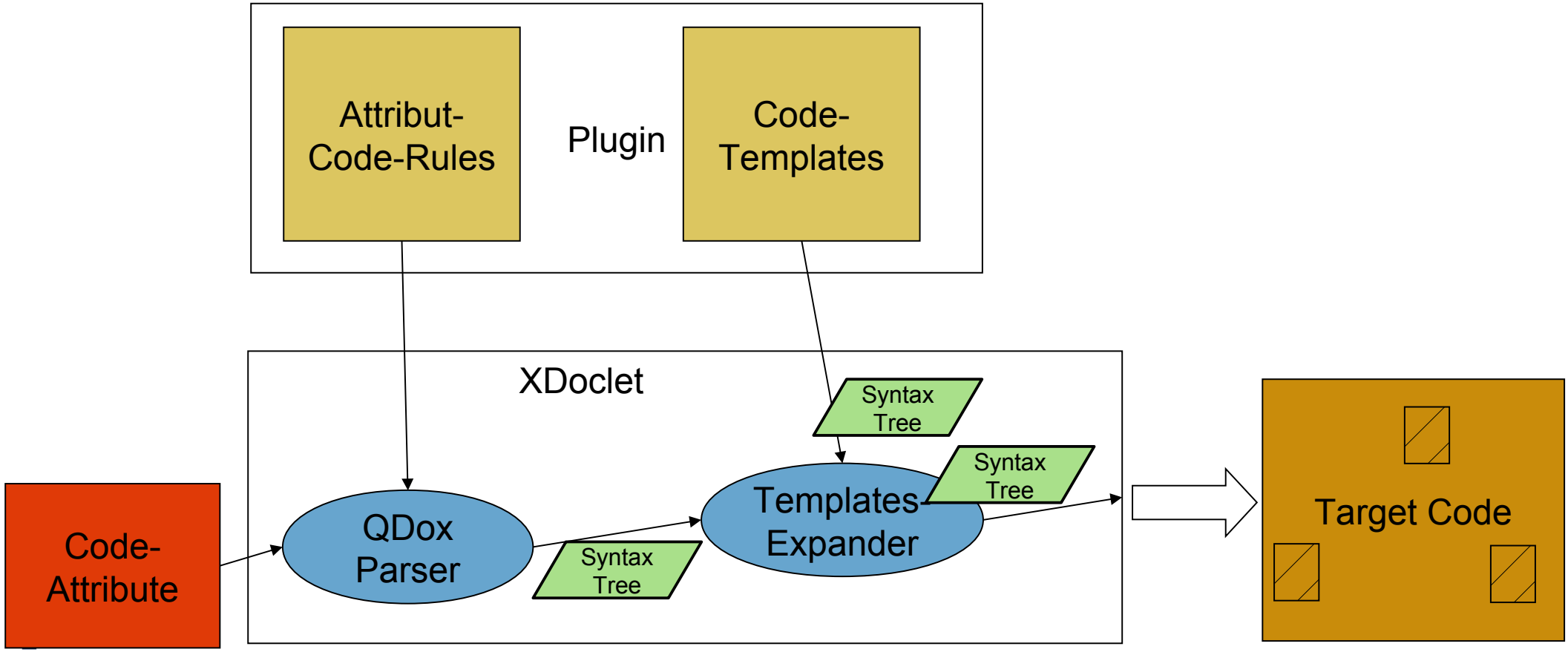
- Metamodel-controlled template engines
  - EMF: Xtend and Xpand scripting languages
  - XML slot markup language
  - Acceleo code generating system (see exercises)
- Invasive Software Composition provides fully typed and wellformed template expansion (see CBSE course)
  - Typed template expansion **and** -extension **and** weaving
  - Can be instantiated for arbitrary languages
  - http://www.the-compost-system.org (obsolete now)
  - http://www.reuseware.org
  - https://bitbucket.org/svenkarol/skat/wiki/Home

Semantic Macros

- **Semantic Macros** are metaprogramming procedures which are typed parameters and results.
  - A semantic macro is compiled to a fragment tree
    - which is instantiated by fragment parameters, type-checked on the metamodel, and copied to the instantiation spot
  - They allow for type-safe static metaprogramming.
  - In an higher-order RAG, a semantic macro can be instantiated in a higher- order attribute
- Examples:
  - Scheme
  - Scala http://scalamacros.org/
  - http://docs.scala-lang.org/overviews/macros/overview.html

Xdoclet (xdoclet.sf.net) for Metadata-Based Code Generation

- Xdoclet transforms attributes (metadata) into helper code (aka boilerplate code)
  - With template-based code generation
  - Metadata attributes *trigger* the filling of templates, used from a library



Slot Markup Languages

- A **slot markup language** is a special template language for *any* XML dialect
- The slot language is represented as an XML dialect itself (XSD schema) [Hartmann]
  - Uniform syntax for templates
  - XML tools are usable
  - Filling templates is
    - type-safe
    - and wellformed, because OCL constraints can be defined that are checked

24.3 Code Modification and Reparsing (Codemodifikation und -rückführung)

Example of Code Reparsing Technique

- Code-Reparsing in Fujaba:

http://www.fokus.fraunhofer.de/en/fokus_events/motion/ecmda2008/_docs/rs01_t03_ManuelBork_EMCDA2008_slides.pdf

- Parallel Parsing of Template and Generated Code, with comparison to resolve indeterministic situations of re-parsing

Vorgehen der Coderückführung

- **Aufgabe**: Erkennen geänderter „Code“-Teile und Rückführung in die Entwurfsmodelle
- **Prinzip**: Die modifizierte Quellcodedatei stammt in jedem Fall aus der Single-Source-Spezifikation eines CASE-Tools, in die der geänderte Programmcode zurückgeführt werden soll
  - Kennzeichnungen der Single Source-Spezifikation sind noch vorhanden.
  - Strukturierung der Quellcodefiles ist so, dass Abschnitte erkennbar sind und ihnen eindeutig die Objekte der Entwurfsspezifikation zugeordnet werden können, beispielsweise durch:
    - Trennmarkierungen (-kommentare oder -attribute, hedges) zwischen den Abschnitten (Markup) wird zum Erkennen der Grenzen benutzt
    - Vorhandensein von „Code“-Teilen als zielsprachenspezifische Freiräume (hooks)
    - Weitere Rückführinformationen gegebenenfalls aus dem Quellfilekopf oder -kommentaren

Quelle: Lempp, P., Torick R. J.. Software Reverse Engineering: An Approach to Recapturing Reliable Software; 4th Ann. Joint Conf. on Softw. Quality and Productivity, Crystal City, VA, March 1-3, 1988

- **Trace hedges** are hedge symbols inserted by a template expander to demarcate the template from the inset.

The End

- Why is code generation a good application for RAG? and not for Xcerpt?
- Explain the difference of the code generation patterns GeneratedDelegatee, GeneratedDelegator, GeneratedSuperClass, GeneratedSubclass!
- Why does code generation most often use synthesized attributes?
- What is the difference of a metadata attribute (annotation), and an attribute in an RAG?
- Why are template engines apps for RAGs?
- Think about GOTO statements in machine code, or in C programs.
  - How would you represent them in an RAG?
  - Why are AG not really appropriate for representing GOTOs?