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Meta Programming System: An Introduction

Till Schallau | September 28, 2020

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Meta Programming System

The **Meta Programming System** (MPS) [1] is a language workbench to create **Domain Specific Languages** (DSL).

MPS uses/provides:

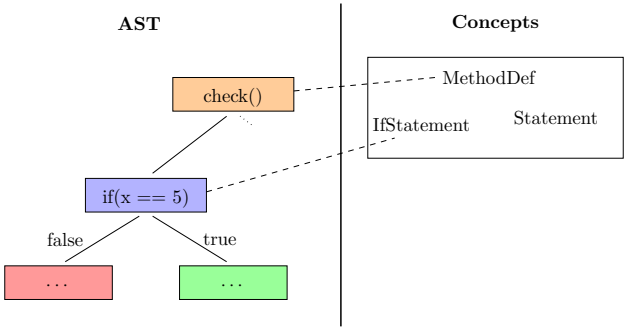
- Code storage in an **Abstract Syntax Tree** (AST)
- Projectional editing
- Code generation
- Language extension possibilities

[1] https://www.jetbrains.com/mps/

Abstract Syntax Tree

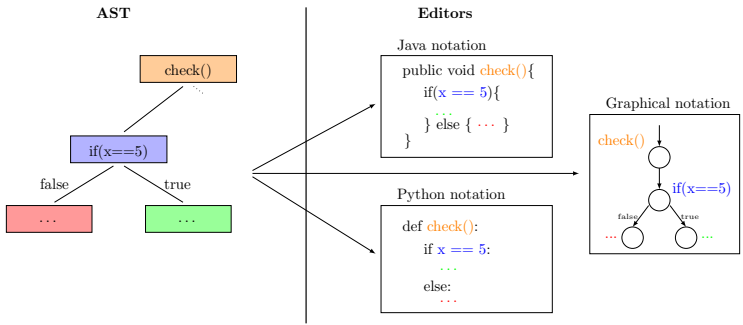
MPS is using an AST as its underlying model, therefore no specific parser is necessary.

The language definition is based on AST-nodes, which build the abstract syntax tree.



Projectional Editing

The **Projectional Editor** of MPS is a visual representation of the current AST. It is possible to have multiple editors with different presentation aspects.

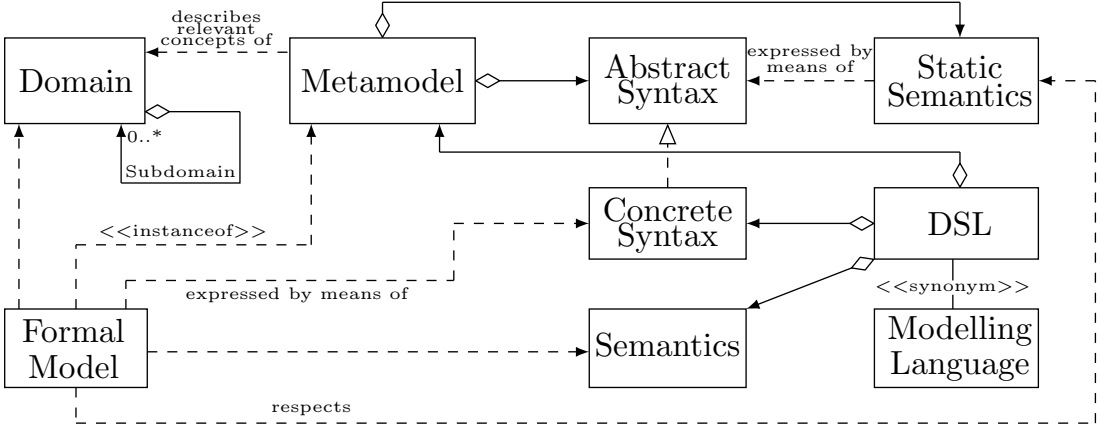


Hands-On

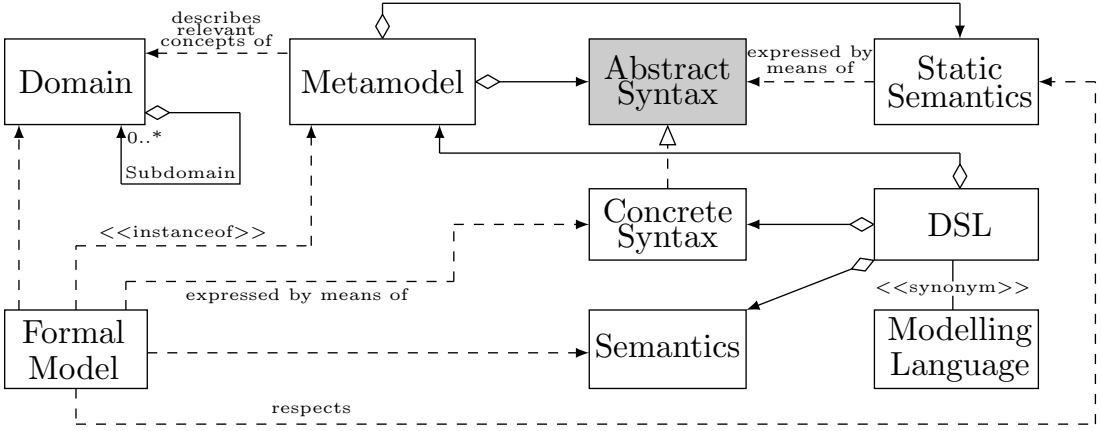
After this introduction into MPS, there is a repository with all necessary information under `https://github.com/tillschallau/mps-workshop`.

In the now upcoming Hands-On part work on the **exercises 3.1 - 4.1**

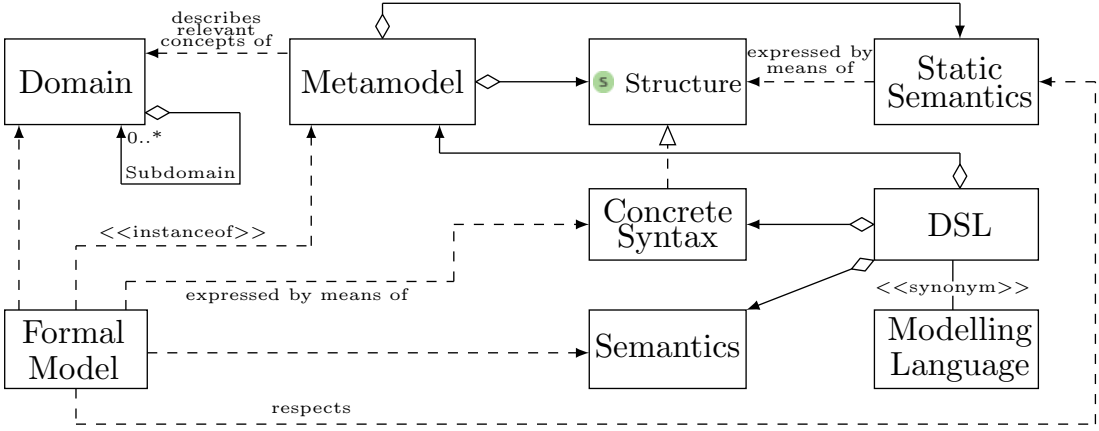
Model-Driven Engineering



Model-Driven Engineering



Model-Driven Engineering



Contents

Structure[2]

The structure of a language is defined as a **Concept** in MPS

Concept:

- Inheritance
- Implementation of Interface
- Properties:
  - Enumeration
  - Primitive Datatype
  - Constrained Datatype
- Children:
  - Any concept
  - Multiplicities ([1], [1..n], [0..n], [0..1])
- References:
  - Reference to another node

```
concept IfStatement extends    Statement
                    implements <none>

  instance can be root: false
  alias: if
  short description: <no short description>

  properties:
  << ... >>

  children:
  condition   : Expression[1]
  trueBranch  : Statement[1]
  falseBranch : Statement[0..1]

  references:
  << ... >>
```

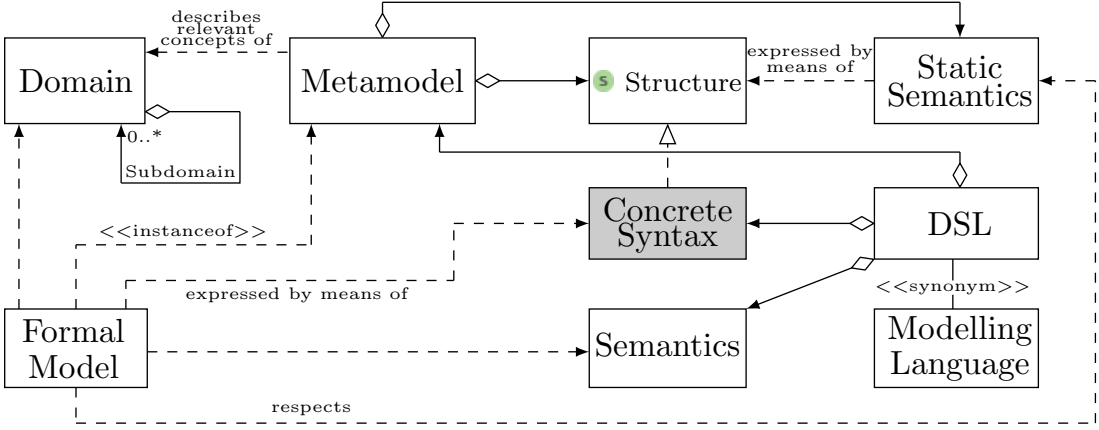
[2] https://www.jetbrains.com/help/mps/structure.html

Hands-On

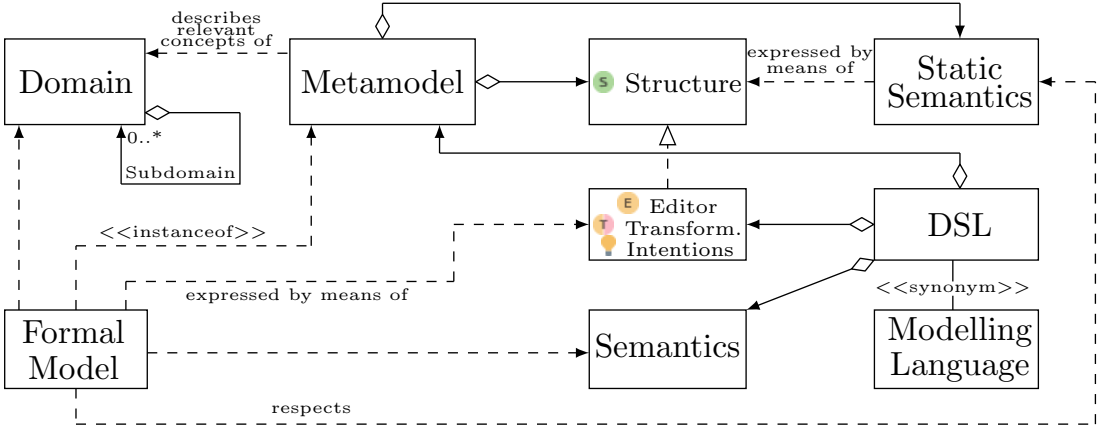
Exercise 4.2

Contents

Model-Driven Engineering



Model-Driven Engineering



Editor[3]

Types of Cell Models:

- **Constant cell**: `<constant>`
- **Property cell**: `{property}`
- **Child cell**: `%child%`
- **Referent cell**: `(%reference%->{name})`
- **Child list cell**: `(>%child%/empty cell: <default><)`
- **Model access**: `*model access*`
- **Collection cell**: `[- -]` (indent layout) or
  `[> <]` (horizontal) or
  `[/ /]` (vertical)

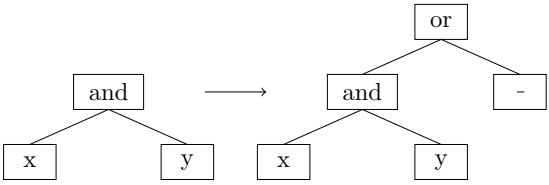
```
<default> editor for concept IfStatement
  node cell layout:
    [-
    if( % condition % ){
      % trueBranch %
    } ? else {
      ?% falseBranch %
    ? }
    -]

  inspected cell layout:
    <choose cell model>
```

[3] https://www.jetbrains.com/help/mps/editor.html

Transformations[4]

Transformations let you edit the AST by replacing and moving AST nodes

Example:
(x and y) type or should yield
((x and y) or _)




```
transformation menu for concept BooleanExpression : default

section({ side transform : right }) {
  action
    text (editorContext, node, model, pattern)->string {
      "or";
    }
    can execute <always>
    execute (editorContext, node, model, pattern)->void {
      node<BooleanExpression> oldRoot = node;
      node<OrExpression> newRoot
          = node.replace with new(OrExpression);
      newRoot.left = oldRoot;
    }
    <no additional features>
}
```

[4] https://www.jetbrains.com/help/mps/transformation-menu-language.html

Intentions[5]

Intentions:

- Provide Intention menu by pressing Alt+↵
- Execute predefined actions
- Can be used to correct errors (**error intention**)

Variants:

- Intention
- Universal Intention
- Surround With Intention
- Parameterized Intention

```
intention AddElseClause for concept IfStatement {
  error intention : false
  available in child nodes : false

  description(node, editorContext)->string {
    return "Add Else-Clause";
  }

  isApplicable(editorContext, node)->boolean {
    return node.falseBranch.isNotNull;
  }

  execute(node, editorContext)->void {
    node.falseBranch = new node<Statement>();
  }
}
```

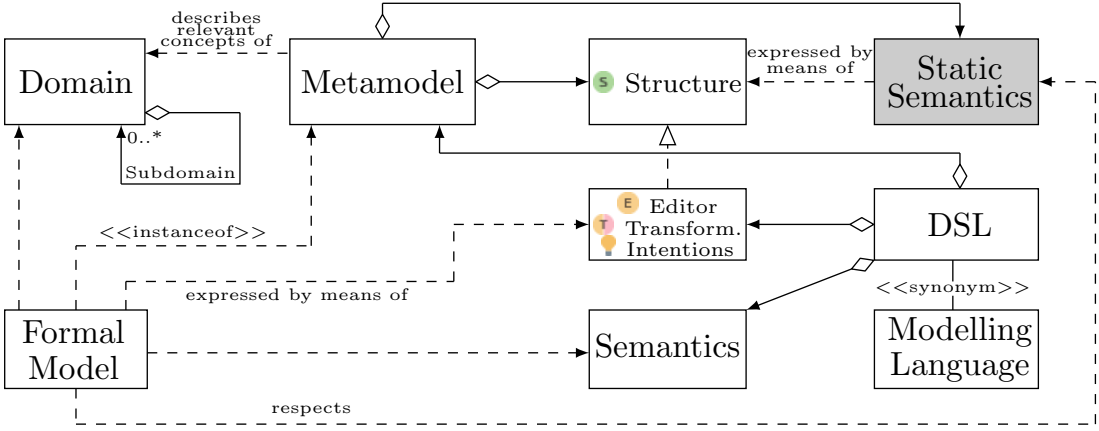
[5] https://www.jetbrains.com/help/mps/mps-intentions.html

Hands-On

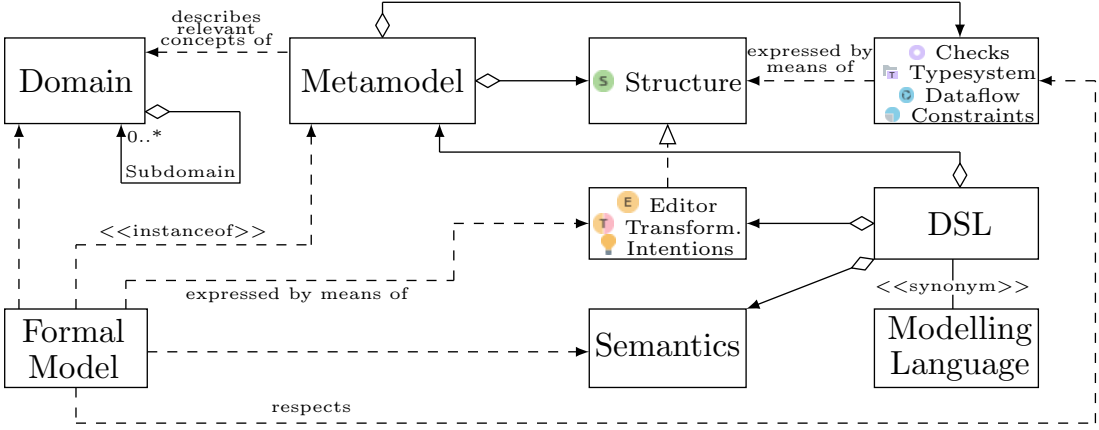
Exercises 4.3 - 4.5

Contents

Model-Driven Engineering



Model-Driven Engineering



Checking Rules[6]

Checks:

- Inspect the model for known error patterns
- Static code analysis
- Reports found errors/warnings/infos
- Can provide quick fixes for errors/warnings

```
checking rule UniqueVariables {
  applicable for concept = MethodDef as methodDef
  overrides <none>

  do {
    set<string> names = new hashset<string>;
    methodDef.variables.forEach({~it =>
      if (names.contains(it.name)) {
        error "Duplicate variable: " + it.name -> it;
      } else {
        names.add(it.name);
      }
    });
  }
}
```

[6] https://www.jetbrains.com/help/mps/typesystem.html

Quick Fixes[7]

Quick Fixes can be attached to the `error`, `warning` or `info` call in a checking rule via the Inspector menu

```
quick fix RemoveDuplicateNames

arguments:
<< ... >>

fields:
<< ... >>

description(node)->string {
  "Replace duplicate name";
}

execute(node)->void {
  node:Variable.name = node:Variable.name + "_d";
}
```

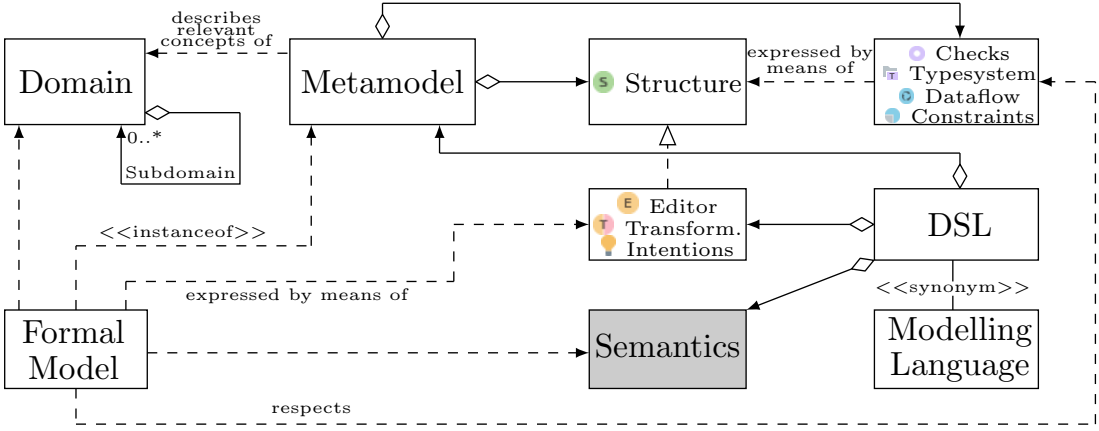
[7] https://www.jetbrains.com/help/mps/typesystem.html

Hands-On

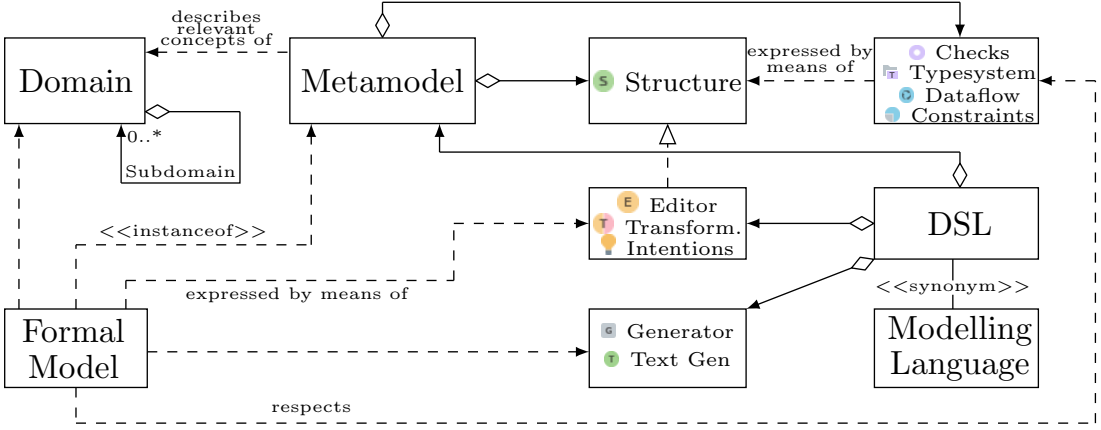
Exercise 4.6

Contents

Model-Driven Engineering



Model-Driven Engineering



Language Generation

In MPS there are two possible ways of generating (here: transforming) code.

Model-To-Model Transformation

Model-To-Text Transformation

[8] http://mbeddr.com/
[9] https://github.com/vaclav/MPS_CSharp

Language Generation

In MPS there are two possible ways of generating (here: transforming) code.

Model-To-Model Transformation

- Translate models into other models
- Predefined models exist:
  - Base Language (Java)
  - mbeddr (C and C extensions) [8]
  - MPS CSharp (C#) [9]
- Does not flush text into file
- Each predefined model has an associated Model-To-Text Transformation

Model-To-Text Transformation

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[9] https://github.com/vaclav/MPS_CSharp

Language Generation

In MPS there are two possible ways of generating (here: transforming) code.

Model-To-Model Transformation

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⇒

Model-To-Text Transformation

- Convert a model into text
- Give the output some reasonable layout
- Lets you define a file ending (e.g. `.java`)
- Flush text into a file

[8] `http://mbeddr.com/`
[9] `https://github.com/vaclav/MPS_CSharp`

Model-To-Model Transformation [10]

Each generator consists of **Mapping Configurations** that combines all templates

Some Generator Rules:

- **Root Mapping Rule:** Generates a root node in the output model
- **Reduction Rule:** Transforms a node based on a template
- **Mapping Label:** Helper for name consistency throughout generation

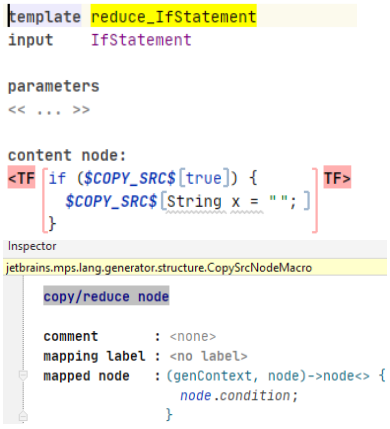
```
mapping configuration main
top-priority group    false
mapping labels:
  << ... >>
parameters:
  << ... >>
is applicable:
  <always>
conditional root rules:
  << ... >>
root mapping rules:
  concept          MethodDef --> MethodDef
  inheritors       false
  condition        <always>
  keep input root default
weaving rules:
  << ... >>

reduction rules:
  concept    IfStatement --> reduce_IfStatement
  inheritors false
  condition  <always>
```

[10] https://www.jetbrains.com/help/mps/generator-language.html

Templates [11]

Template Macros used in a **Template Fragment <TF TF>**:

- **Property $[]:** Computes value of a property
- **Reference ->$[]:** Computes referent node
- **IF[]:** Conditional generation of template code
- **$LOOP$[]:** Applies template to set of nodes
- **$CALL$[]:** Calls another template with parameters
- **$COPY_SRC$[]:** Copies node
- **$LABEL$[]:** Registers generated name into generation context



[11] https://www.jetbrains.com/help/mps/generator-language.html

Template Combination 1/4

Lets wrap the `MethodDef` concept into a newly created concept `ClassDef`

```
concept ClassDef extends    BaseConcept
                implements INamedConcept

  instance can be root: false
  alias: <no alias>
  short description: <no short description>

  properties:
  << ... >>

  children:
  method : MethodDef[1]

  references:
  << ... >>
```

Template Combination 2/4

The `ClassDef` generator template contains a statically generated method `print()`

The `ClassDef` generator template contains the generated output of the `MethodDef` concept

```
template ClassDef
input    ClassDef

parameters
<< ... >>

content node:
<TF public class $[ClassName] {                    TF>
     public void print() {
       System.out.println("...");
     }

     $COPY_SRC$[public void methodDef() {
                  <no statements>
                }]
}
```

Template Combination 3/4

To generate the method, generate its children:

- `Variables` (e.g. `$COPY_SRCL$[String s = "";]`)
- `Statements` (e.g. `$COPY_SRCL$[s = "";]`)

If we now want to call the `print`-method of the `ClassDef`-concept, the current template has to be enhanced, as the method is currently not available in our context.

```
template MethodDef
input    MethodDef

parameters
<< ... >>

content node:
<TF  public void $[methodDef]() {  TF>
       $COPY_SRCL$[String s = "";]

       $COPY_SRCL$[s = "";]
     }
```

Template Combination 4/4

To use the `print`-method, simulate the surrounding environment necessary for the generation (e.g. the surrounding class with its `print()`-method)

Mark the code that should be generated with the `Template Fragment` macro

```
template MethodDef
input    MethodDef
parameters
<< ... >>
content node:
public class ClassDef {
  public void print() {
    <no statements>
  }

  <TF public void $[methodDef]() {
    $COPY_SRCL$[String s = "";]

    $COPY_SRCL$[s = "";]
    print();
  } TF>
}
```

Hands-On

Exercise 4.7

TextGen [8]

The TextGen language operations:

- **append:** append text of the following kind:
  - **{string value}:** constant text
  - **\n:** line break
  - **$list{node.list}:** list without separator
  - **$list{node.list with ,}:** list with separator ","
  - **${node.child}**
- **with indent { code }:** increase indentation level for code
- **indent buffer:** apply indentation for current line
- **increase depth:** increase indentation level
- **decrease depth:** decrease indentation level

```
text gen component for concept ClassDef {
file name : <Node.name>
file path : <model/qualified/name>
extension : (node)->string {
  "java";
}
encoding : utf-8
text layout : <no layout>
context objects : << ... >>

  (node)->void {
    append {public class } ${node.name} {{\n};
    with indent {
      indent buffer;
      append ${node.method};
    }
    append {\n}};
  }
}
```

[8] https://www.jetbrains.com/help/mps/textgen.html

End of the workshop

Have a nice evening