Bidirectional Transformation of NL requirements to and from UML class model for MDD

Master Thesis

Markus Bimassl - 01026122

Content

Thesis Inspiration and Goals

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- Search Strategy and General Findings
- Transformation Approaches
- Tools Used
- Transformed UML Elements

Prototype

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Thesis Inspiration and Goals

Thesis Inspiration

- One goal of RE: **reduce the risk of misinterpretation**.
- Restricting syntax reduces the risk of misinterpretation -> Models
- **Problems** with Models:
  - **Time**-intensive
  - **Knowledge** required
  - Keeping Models and NL **consistent** is challenging

Thesis Goals

G1 Get an overview over the existing **state of the research field**.

G1.1 **Compare** existing **approaches**.

SLR

G2 **Create a working software tool** that enables fully-automatic bidirectional transformation between requirements in NL and a UML class model.

Proto

Systematic Literature Review

Research Questions and general Findings

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Research Questions

RQ.1

How many fully automatic solutions for the transformation of requirements in NL/UML to UML/NL were developed?

RQ.2

Which **techniques were used** in the fully automatic solutions?

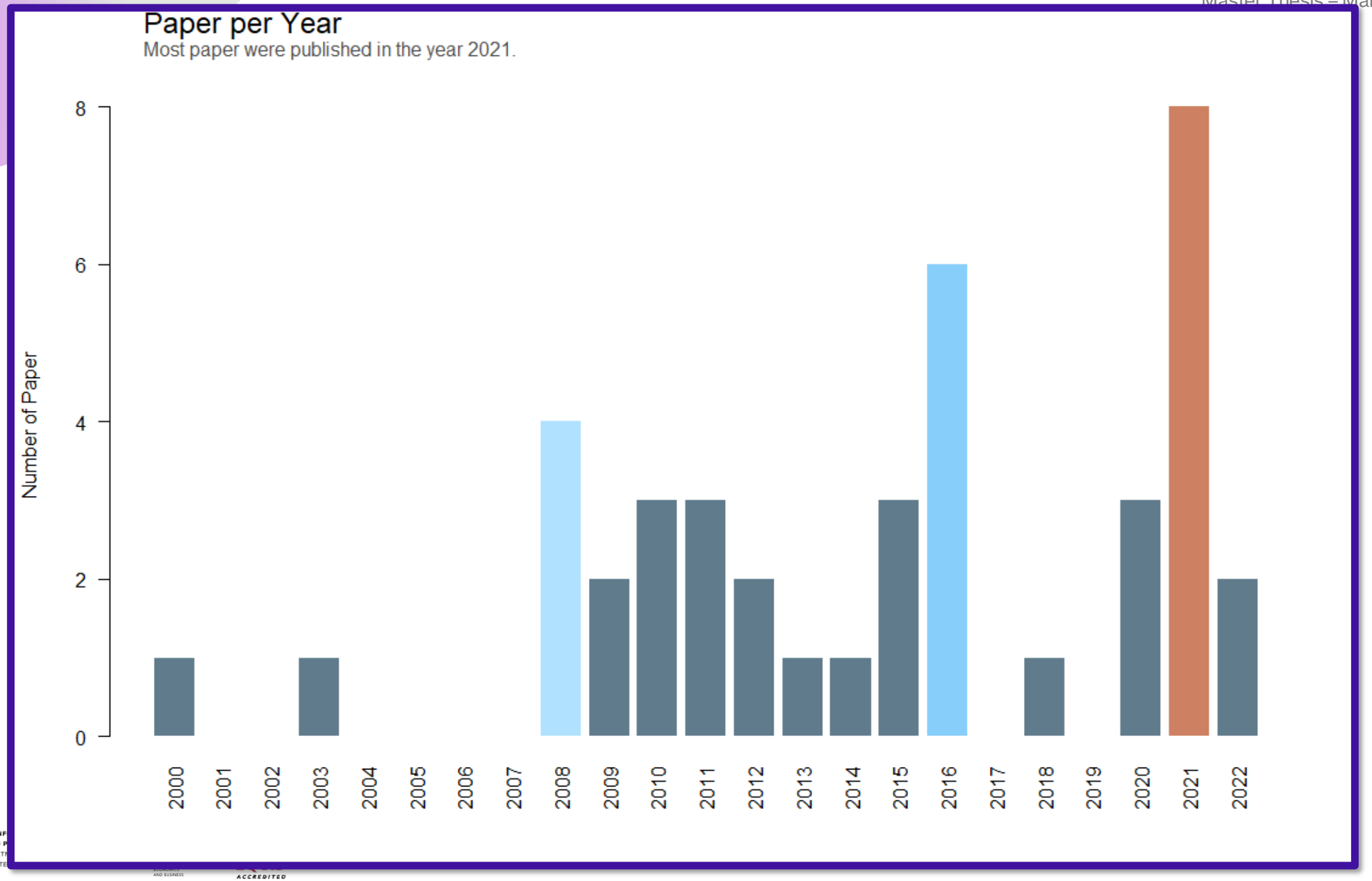
RQ.3

Which **other tools** were integrated in the solutions?

RQ.4

Which **elements of a UML class model** were transformed in the solutions?

General Findings


Paper per Year
Most paper were published in the year 2021.
Number of Paper
0
2
4
6
8
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

Systematic Literature Review

Transformation Approaches

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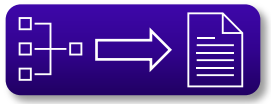
Transformation Approaches

Text-to-Model (**T2M**)

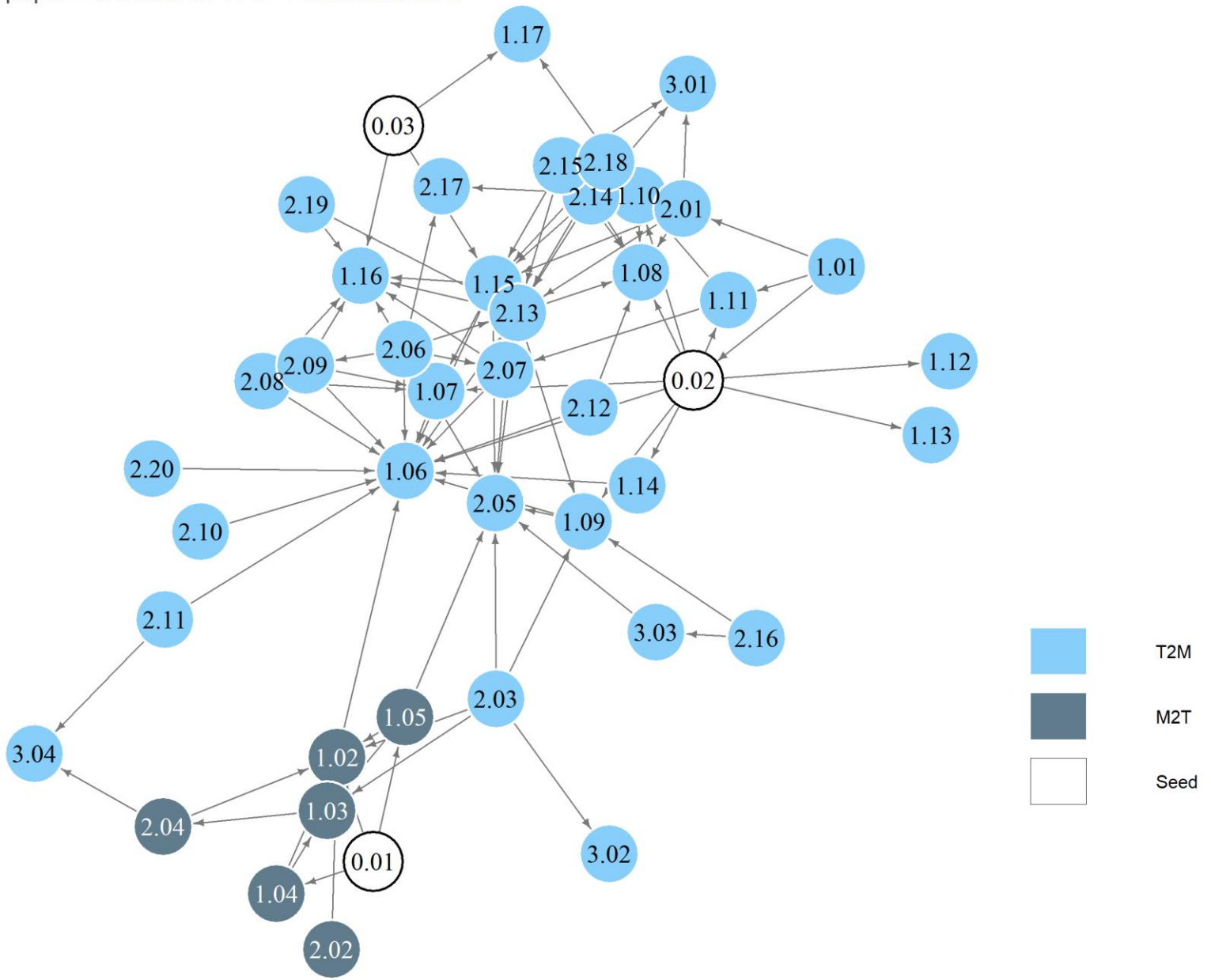


Model-to-Text (**M2T**)

- No included study focused on both directions.

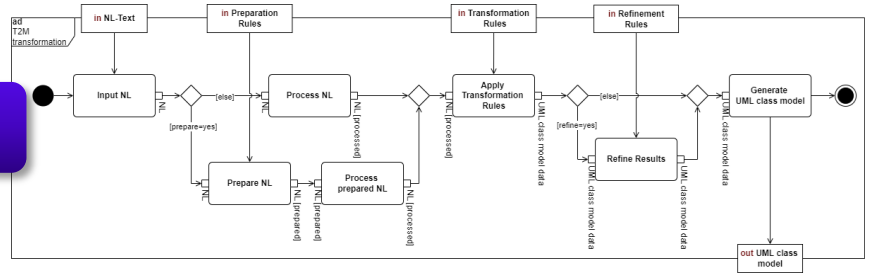
Transformation Types

Most papers focused on T2M-Transformation.

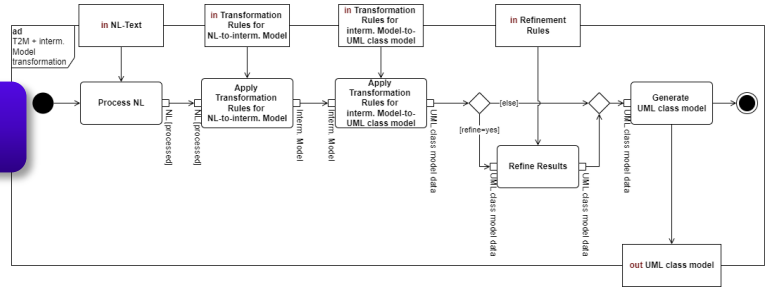


Text-to-Model Approaches

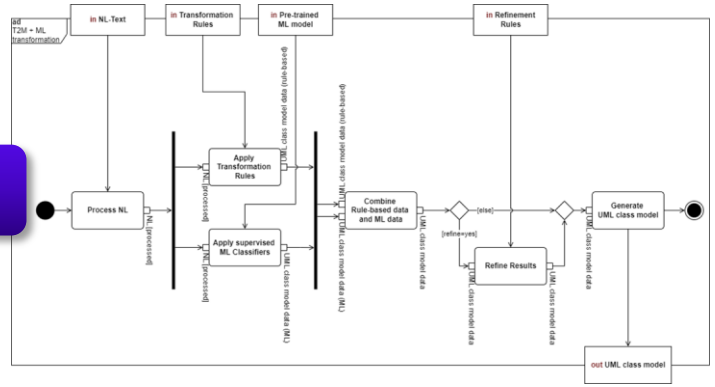
Basic



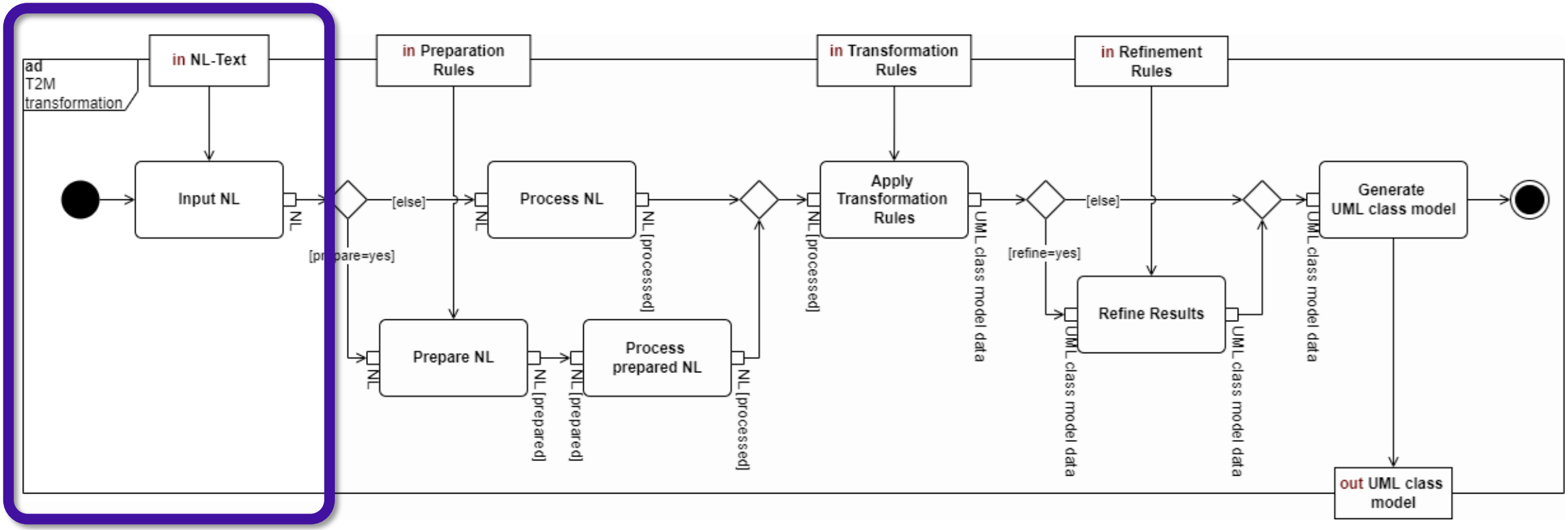
With Intermediate Model



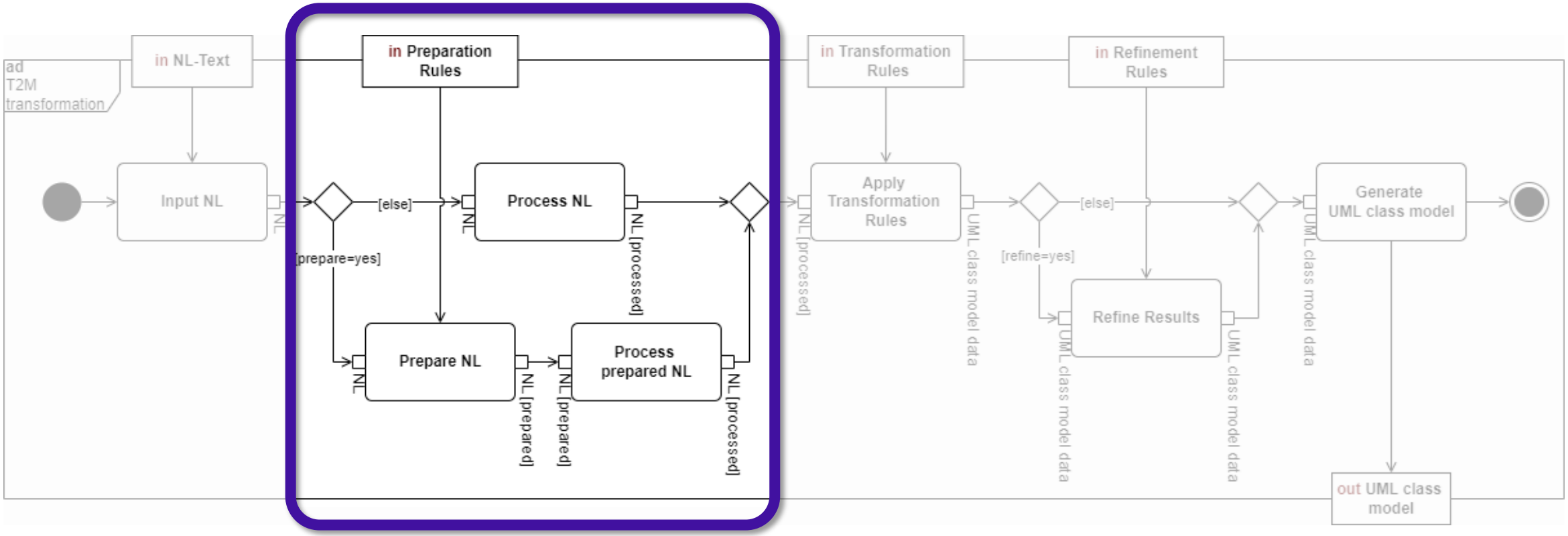
With Machine Learning



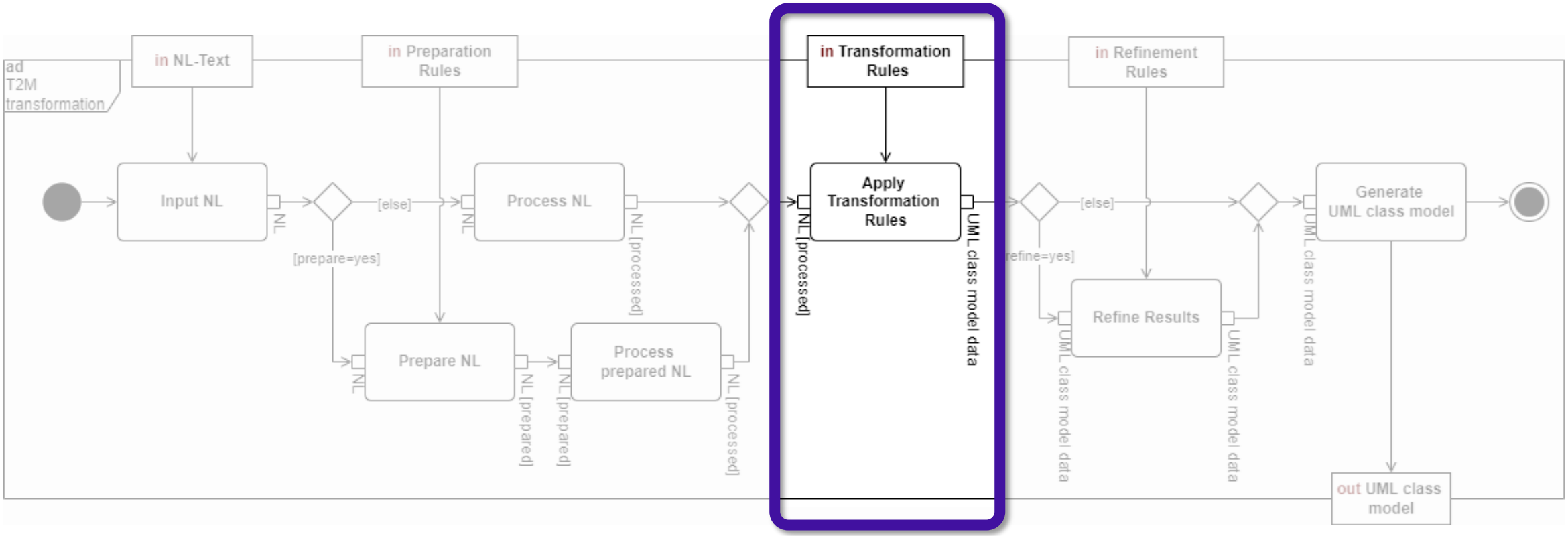
T2M - Basic


ad
T2M
transformation
in NL-Text
in Preparation Rules
in Transformation Rules
in Refinement Rules
Input NL
NL
[else]
[prepare=yes]
Process NL
NL
NL [processed]
Prepare NL
NL
NL [prepared]
Process prepared NL
NL [prepared]
NL [processed]
Apply Transformation Rules
NL [processed]
UML class model data
[refine=yes]
[else]
Refine Results
UML class model data
UML class model data
Generate UML class model
UML class model data
out UML class model

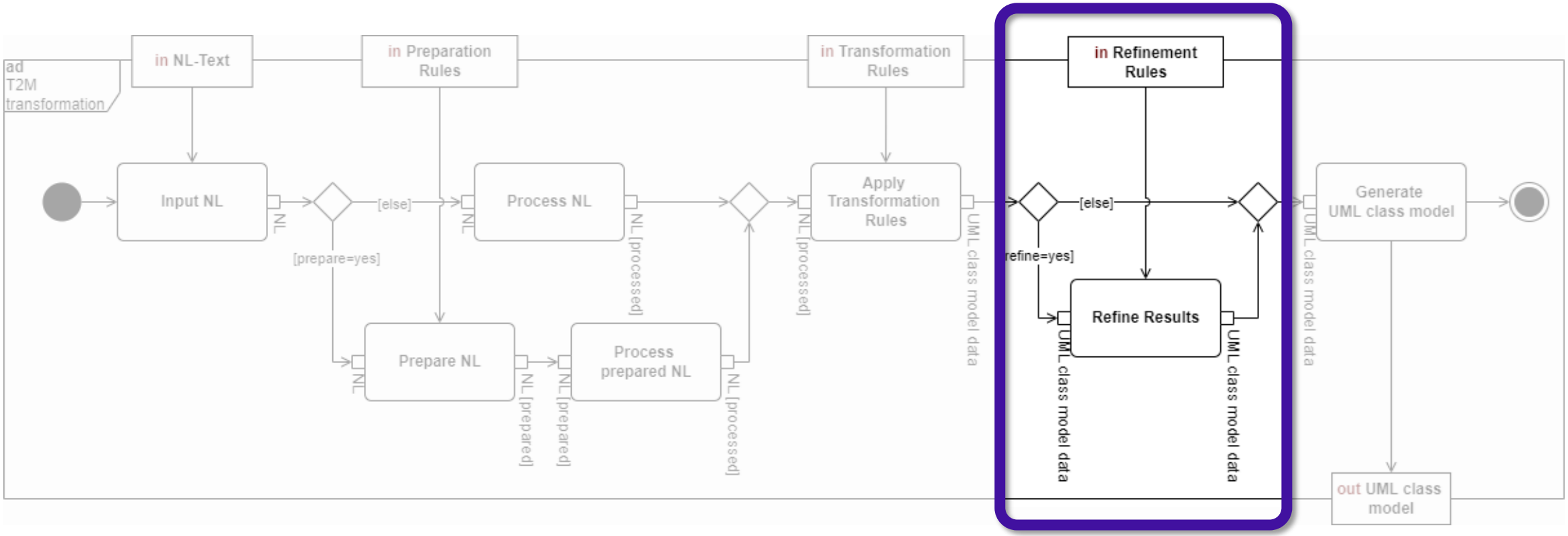
T2M - Basic


ad
T2M
transformation
in NL-Text
Input NL
NL
in Preparation
Rules
[else]
Process NL
NL
NL [processed]
[prepare=yes]
Prepare NL
NL
NL [prepared]
Process
prepared NL
NL [prepared]
NL [processed]
in Transformation
Rules
Apply
Transformation
Rules
NL [processed]
UML class model data
in Refinement
Rules
[refine=yes]
Refine Results
UML class model data
[else]
UML class model data
Generate
UML class model
out UML class
model

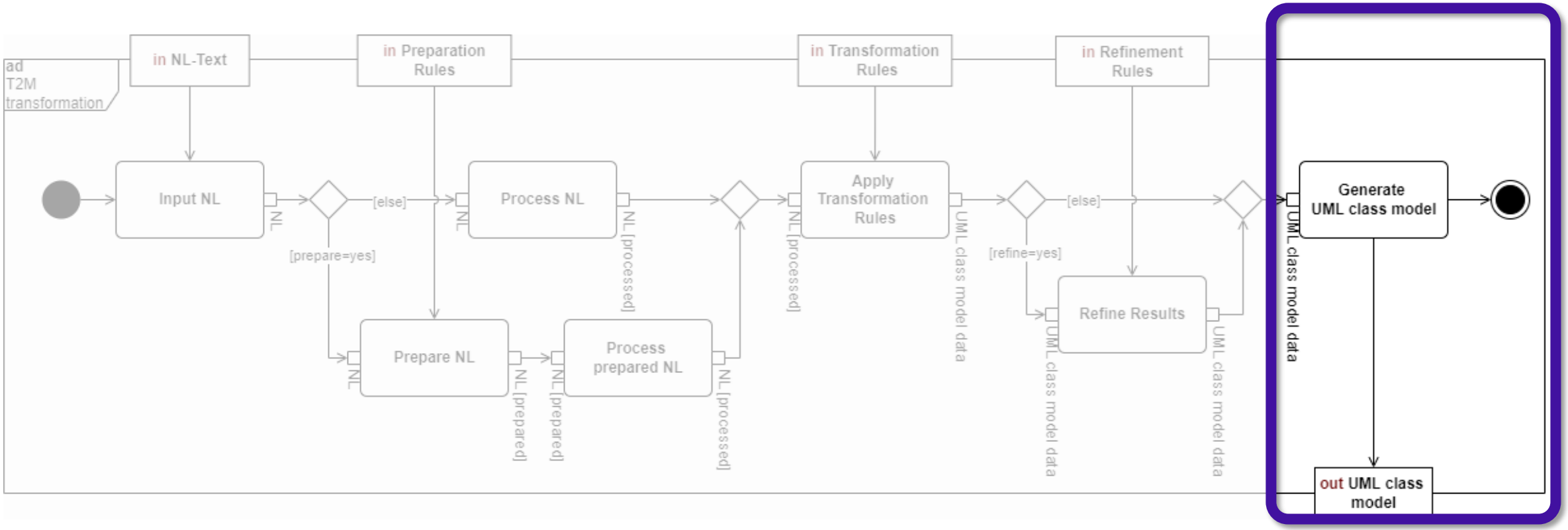
T2M - Basic


ad
T2M
transformation
in NL-Text
in Preparation Rules
in Transformation Rules
in Refinement Rules
Input NL
NL
[else]
[prepare=yes]
Process NL
NL
NL [processed]
Prepare NL
NL
NL [prepared]
Process prepared NL
NL [prepared]
NL [processed]
Apply Transformation Rules
NL [processed]
UML class model data
[else]
[refine=yes]
Refine Results
UML class model data
UML class model data
UML class model data
Generate UML class model
out UML class model

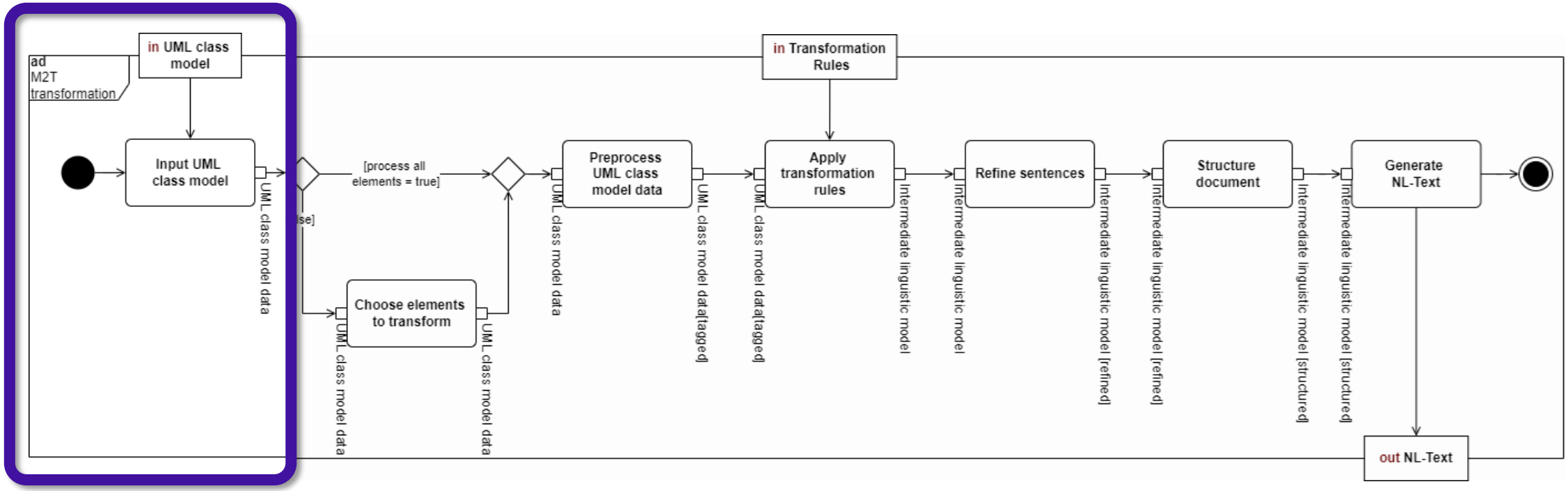
T2M - Basic


ad
T2M
transformation
in NL-Text
in Preparation
Rules
in Transformation
Rules
in Refinement
Rules
Input NL
NL
[else]
[prepare=yes]
Process NL
NL
NL [processed]
Prepare NL
NL
NL [prepared]
Process
prepared NL
NL [prepared]
NL [processed]
Apply
Transformation
Rules
NL [processed]
UML class model data
[else]
refine=yes]
Refine Results
UML class model data
UML class model data
UML class model data
Generate
UML class model
out UML class
model

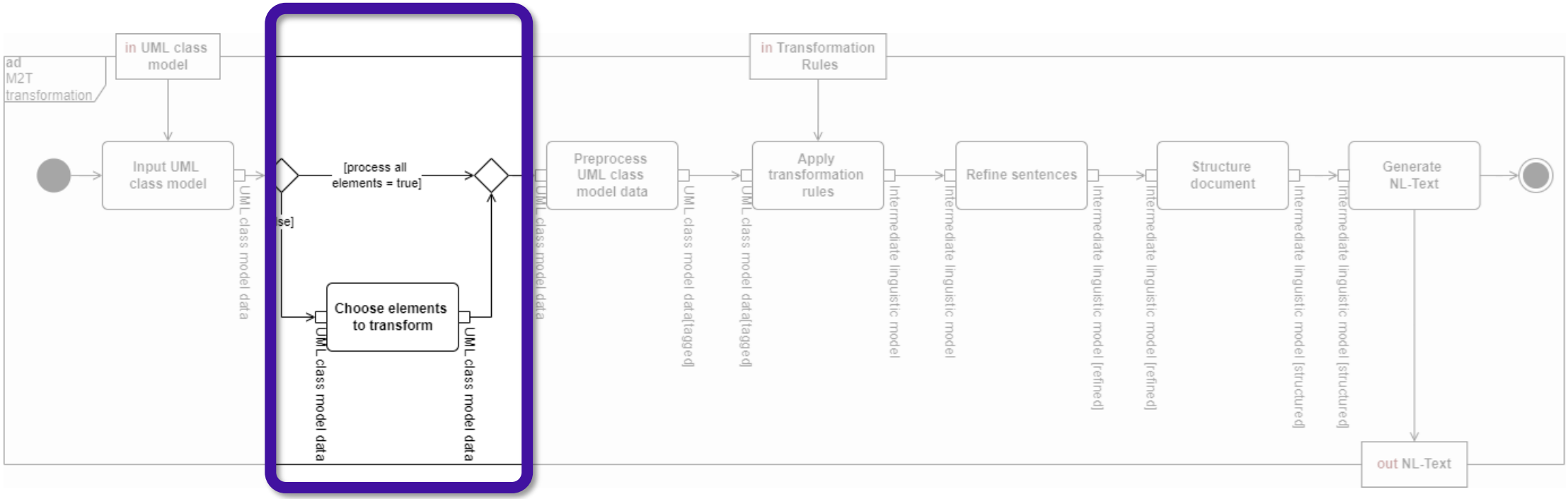
T2M - Basic


ad
T2M
transformation
in NL-Text
in Preparation Rules
in Transformation Rules
in Refinement Rules
Input NL
NL
[else]
[prepare=yes]
Process NL
NL
NL [processed]
Prepare NL
NL
NL [prepared]
Process prepared NL
NL [prepared]
NL [processed]
Apply Transformation Rules
NL [processed]
UML class model data
[refine=yes]
[else]
Refine Results
UML class model data
UML class model data
Generate UML class model
UML class model data
out UML class model

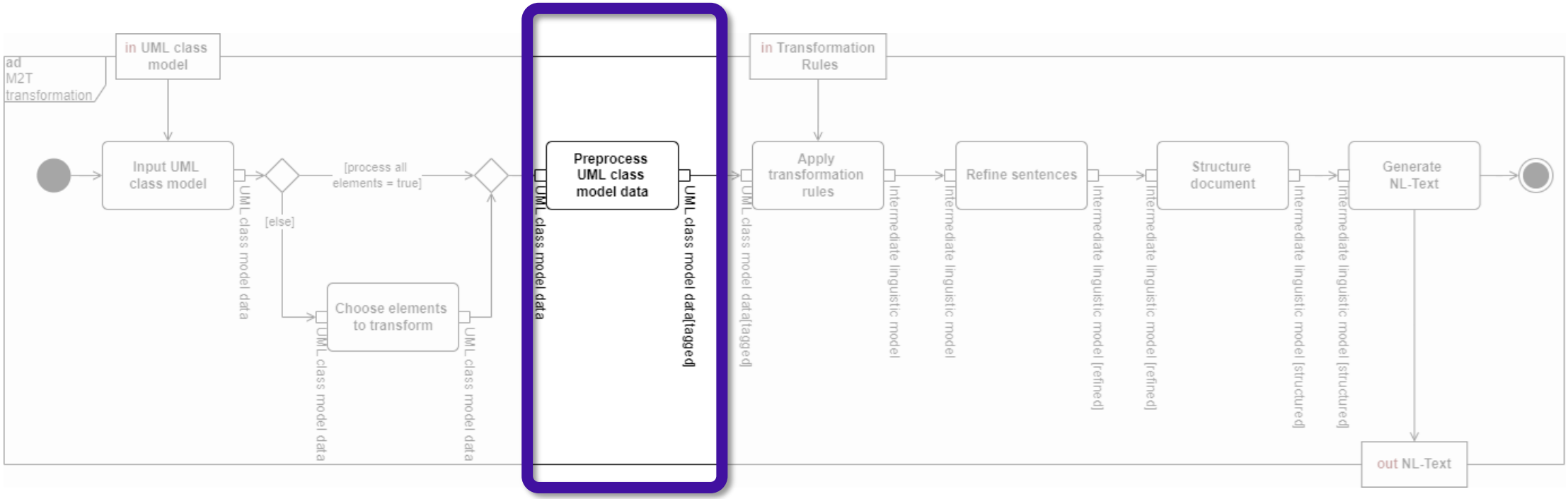
Model-to-Text Approach



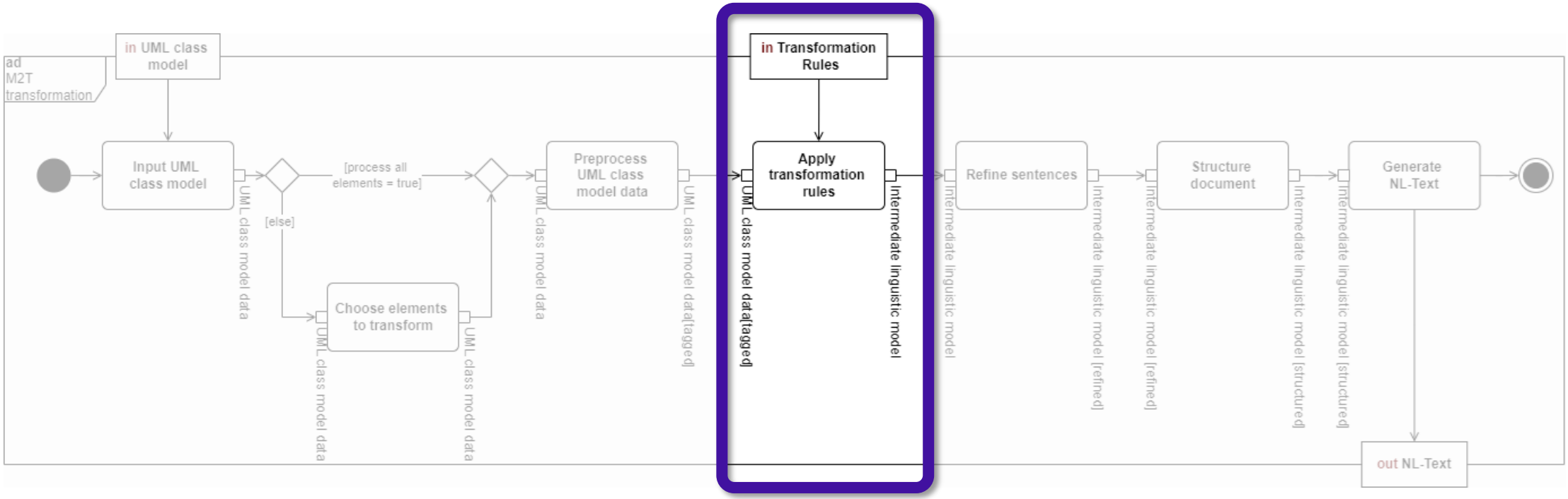
Model-to-Text Approach



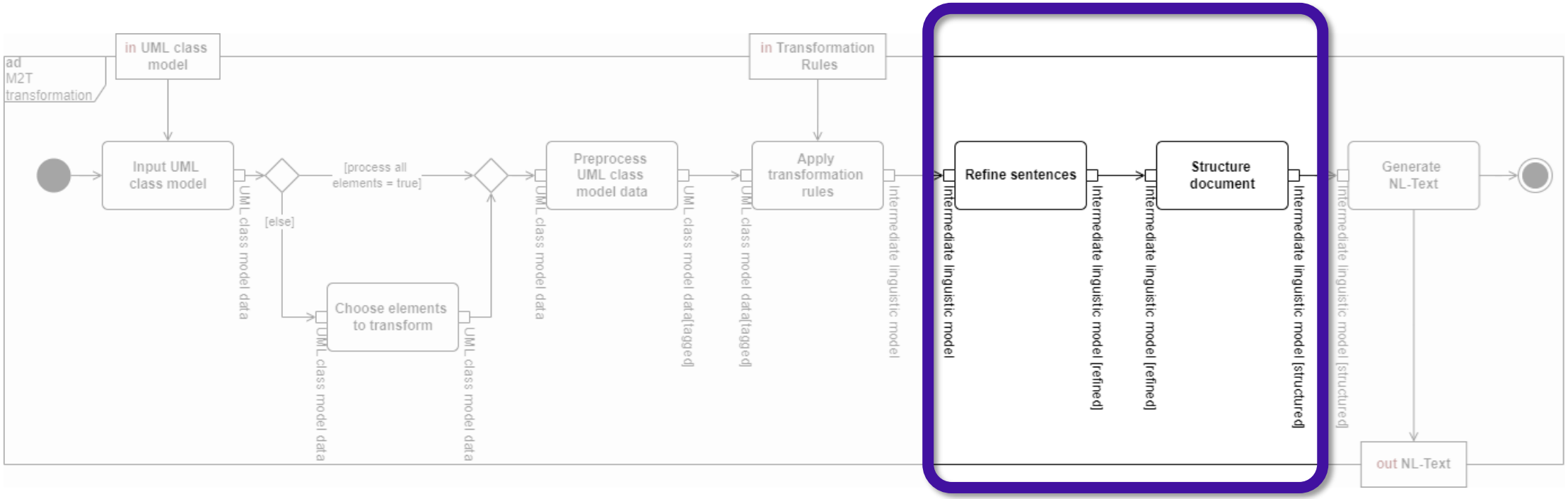
Model-to-Text Approach



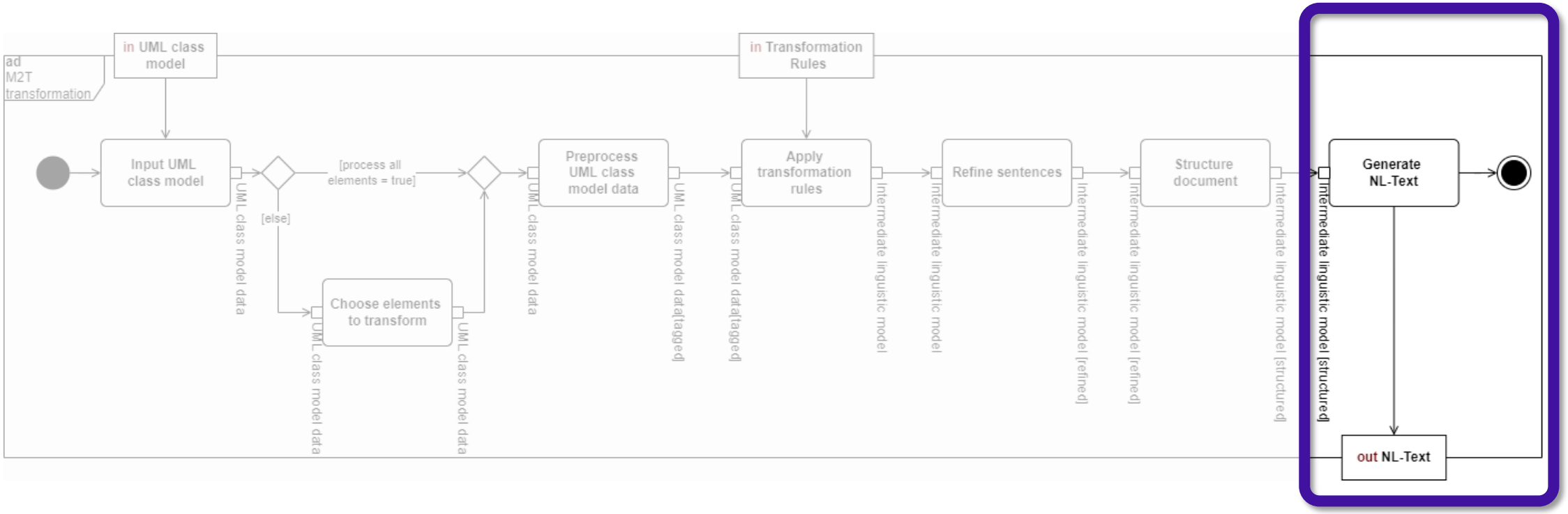
Model-to-Text Approach



Model-to-Text Approach



Model-to-Text Approach



Systematic Literature Review

Tools used

Tools used

NLP

- Natural Language Processing – Tools
- For text tokenization, POS tagging, dependency parsing, lemmatization,...

Modeling

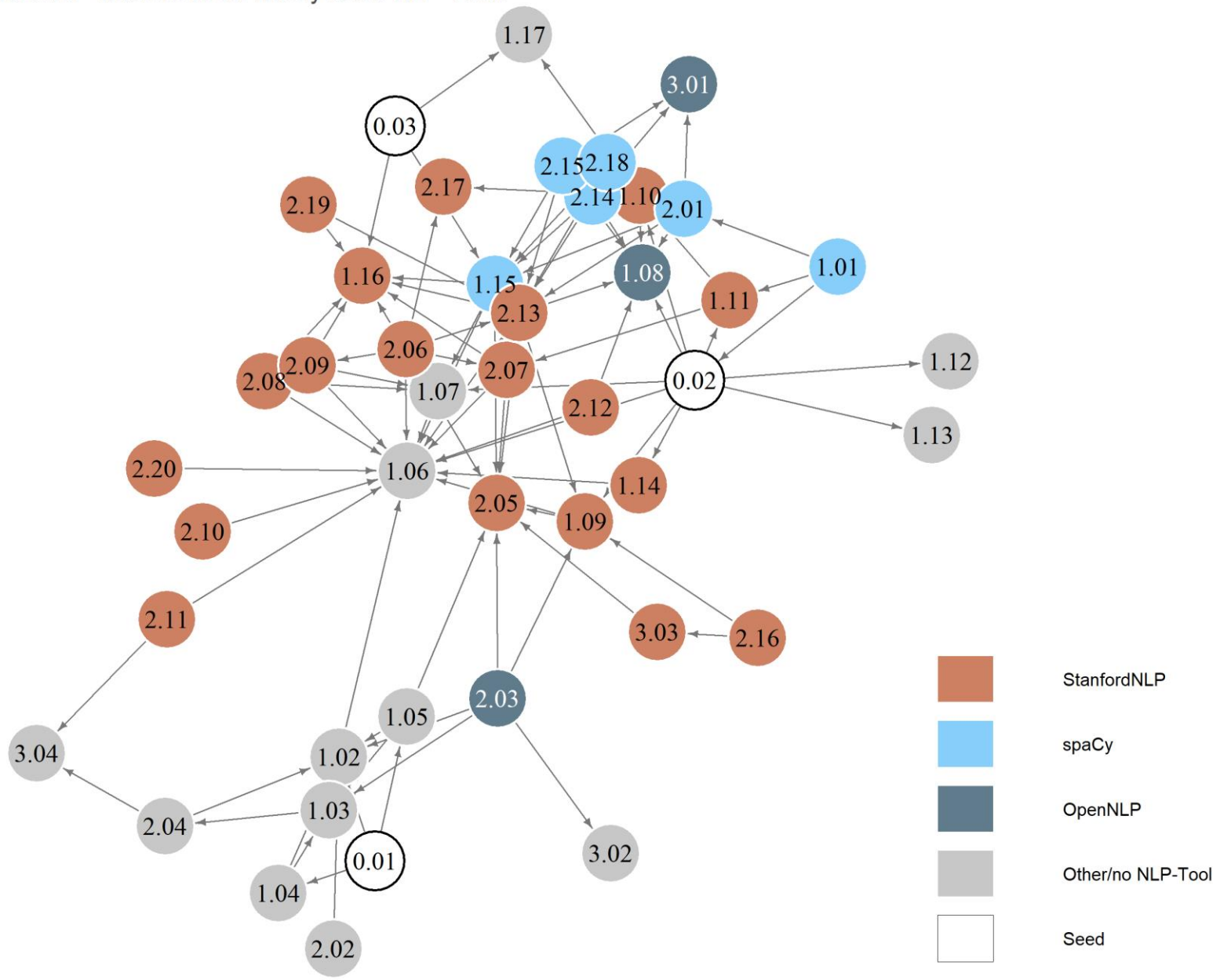
- Mainly for visualizing the UML class model

Other

- Frameworks and additional Machine Learning libraries.

NLP-Tools

StanfordNLP was the most widely used NLP-Tool.



Systematic Literature Review

Transformed UML Elements

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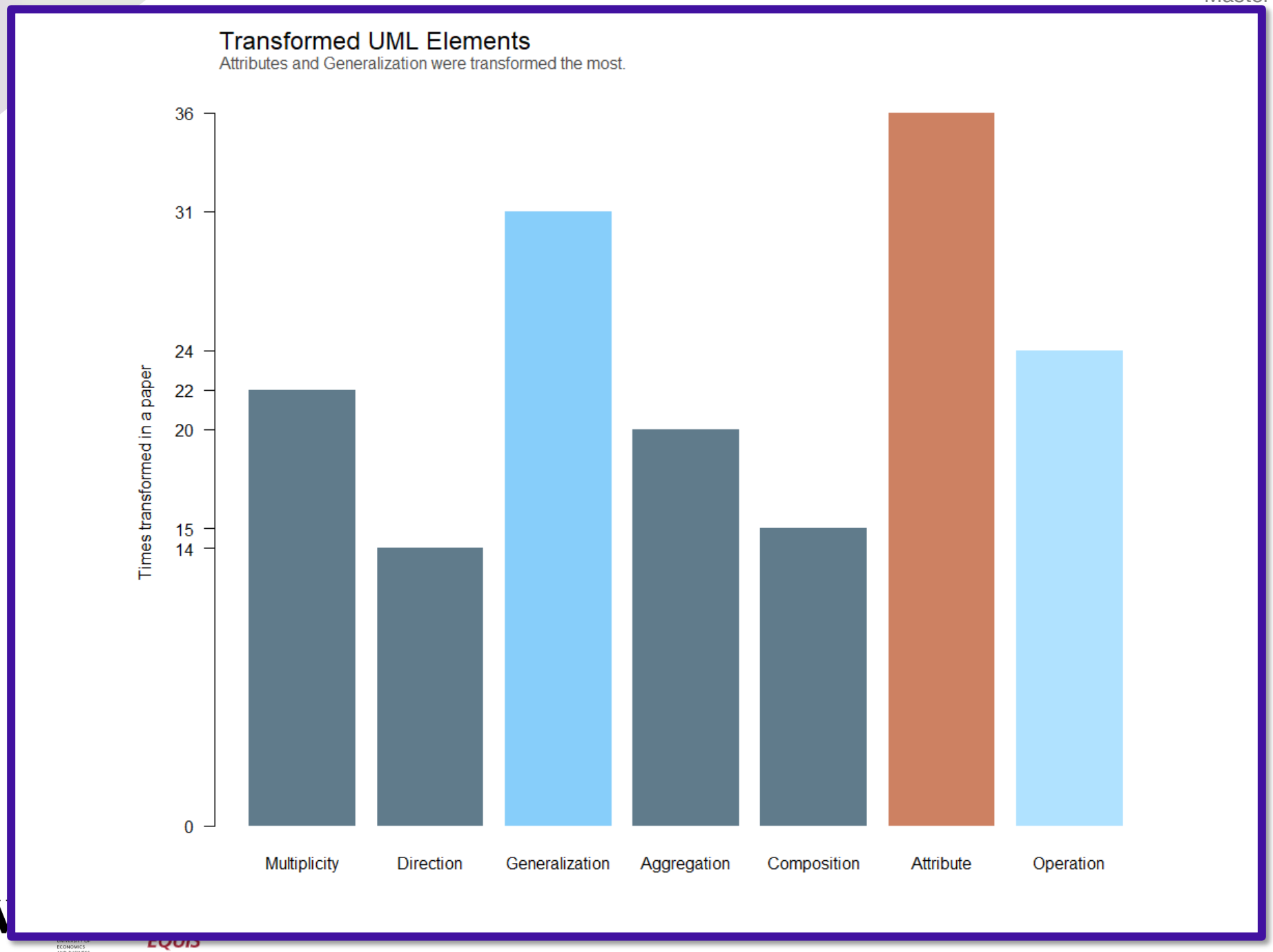
Transformed UML Elements
Attributes and Generalization were transformed the most.
Times transformed in a paper
36
31
24
22
20
15
14
0
Multiplicity
Direction
Generalization
Aggregation
Composition
Attribute
Operation

Prototype

Bidirectional **T**ransformation of **Re**quirements in **N**atural language and **U**ML class models

BiT-ReNU

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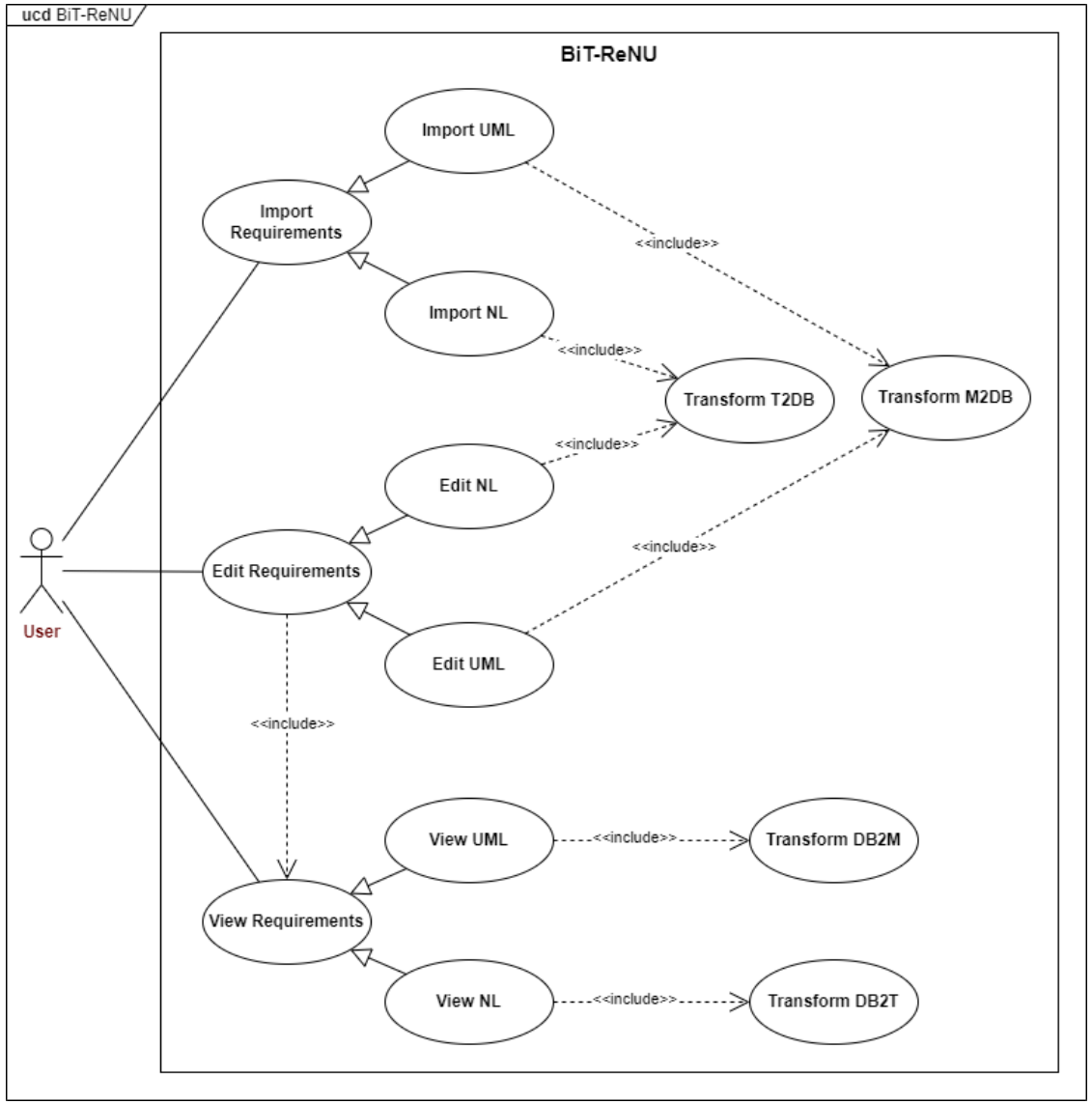
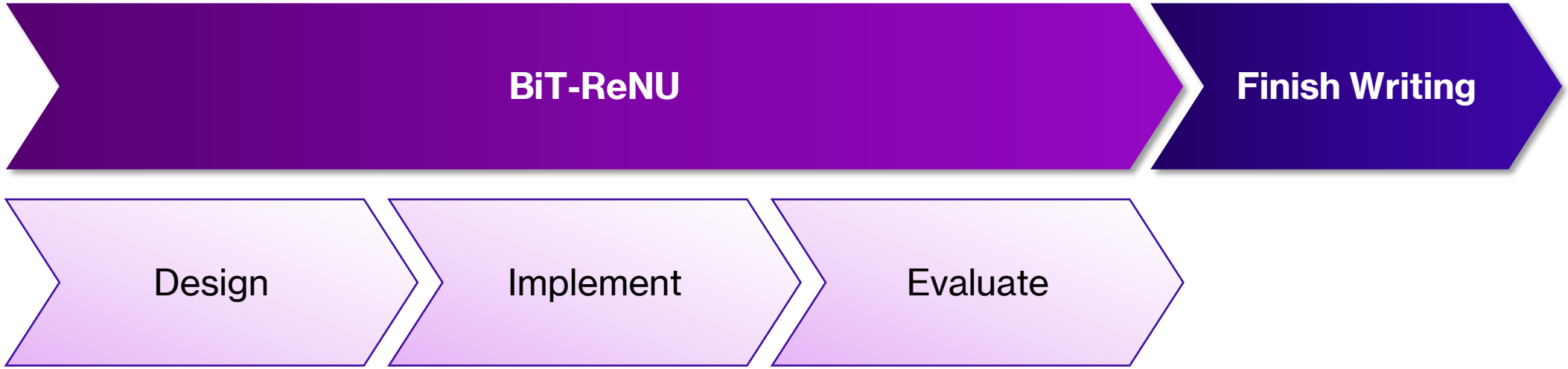
BiT-ReNU


ucd BiT-ReNU
BiT-ReNU
Import UML
Import Requirements
Import NL
<<include>>
Transform T2DB
Transform M2DB
Edit NL
Edit Requirements
Edit UML
User
View UML
Transform DB2M
View Requirements
View NL
Transform DB2T

Moving Forward

Moving Forward

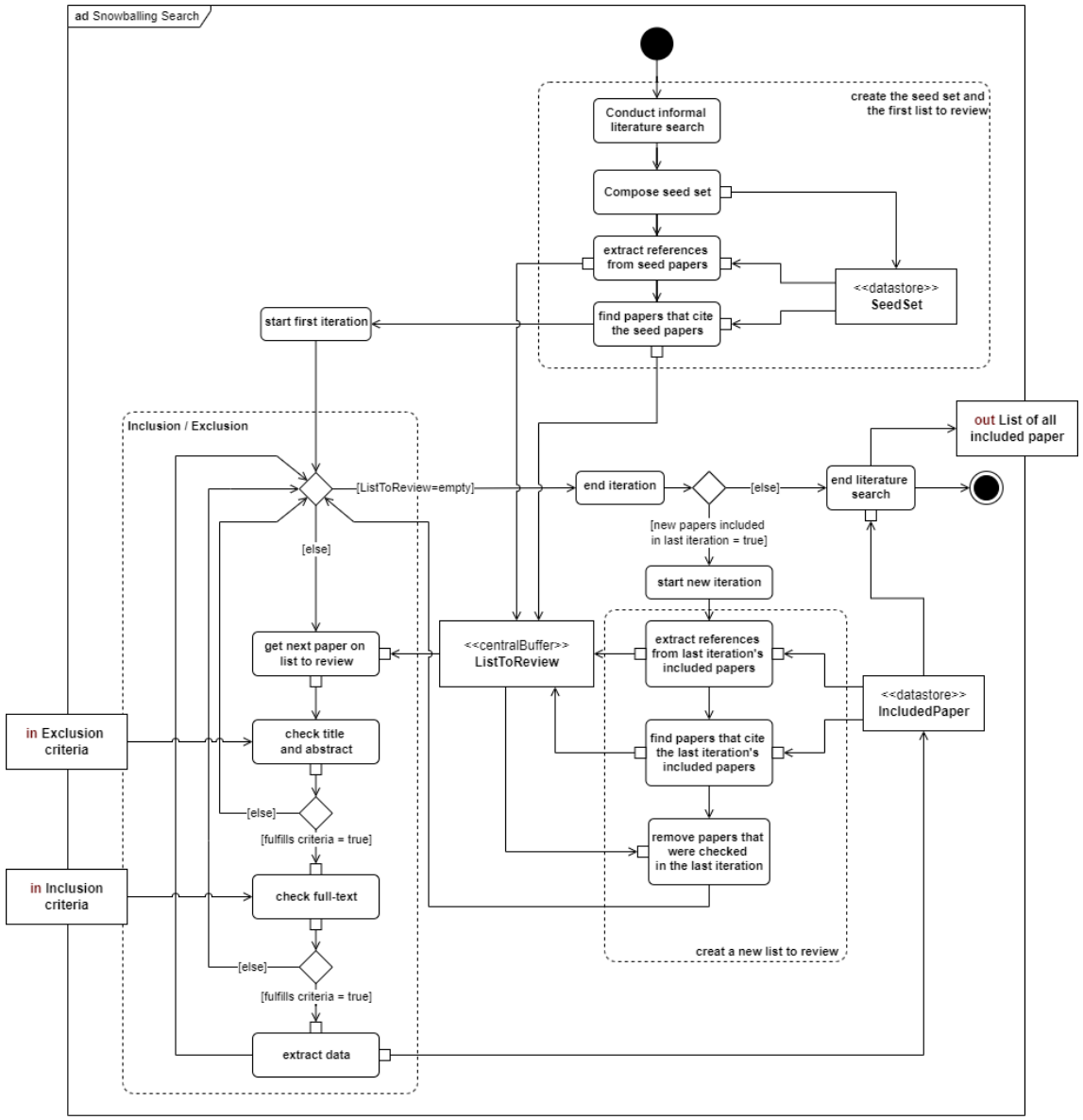


Thank You for listening

Appendix I

Literature Search

Search Process



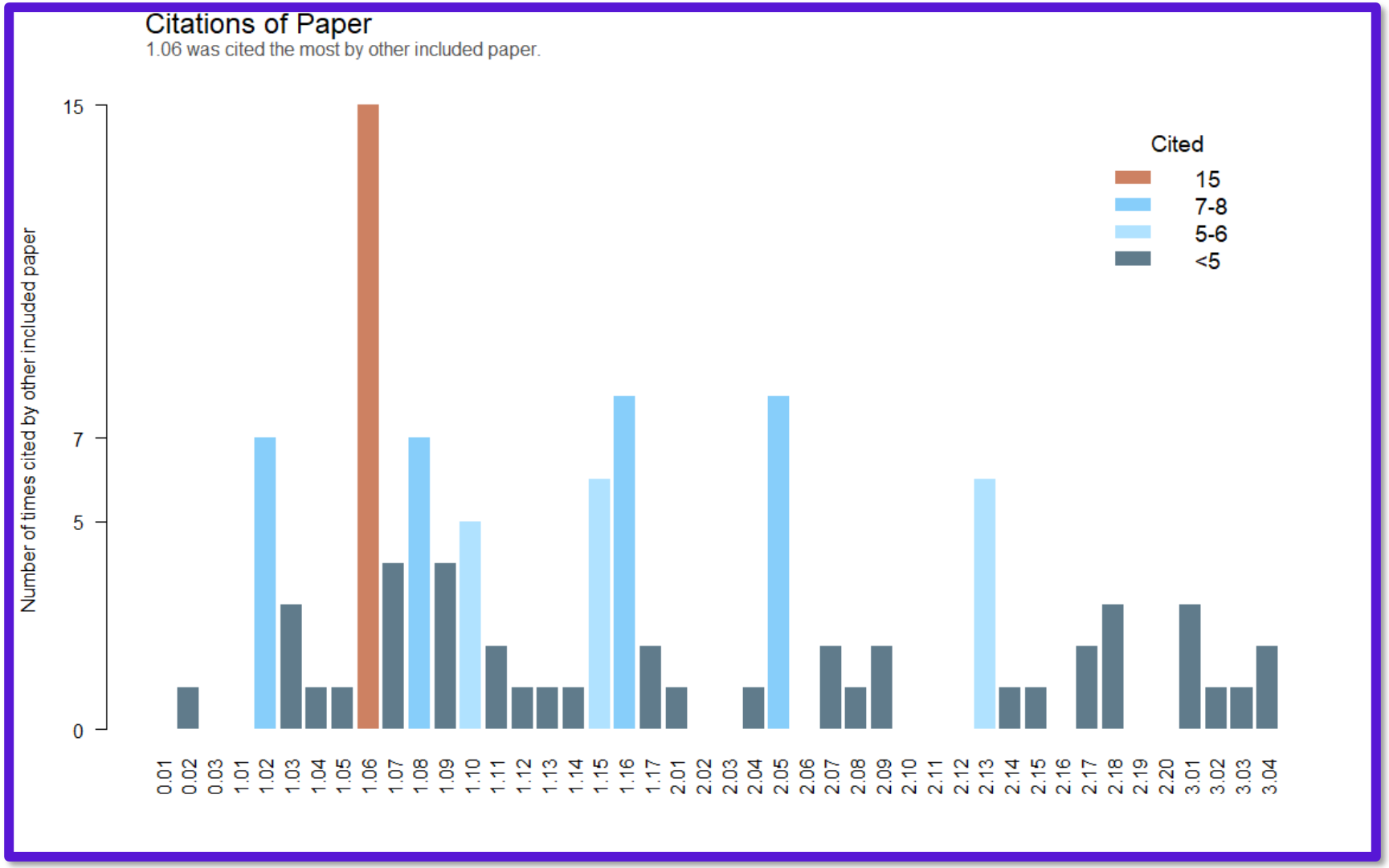
Search Criteria

ID	Criteria
E.1	Exclude tables of contents, editorials, commentaries, extended abstracts, communications, books, SLRs and tutorials.
E.2	Exclude papers that were already checked in a previous iteration.
E.3	Exclude papers that are not written in English.
E.4	Exclude papers where the natural language used for the transformation was not English.
I.1	Include papers that investigate at least one of the following topics: • Fully automatic transformations from only natural language into a UML class model. • Fully automatic transformations from a single UML class model into natural language.
I.2	Include papers that describe the implementation of the tool.
I.3	Include papers that evaluated their transformation tool.

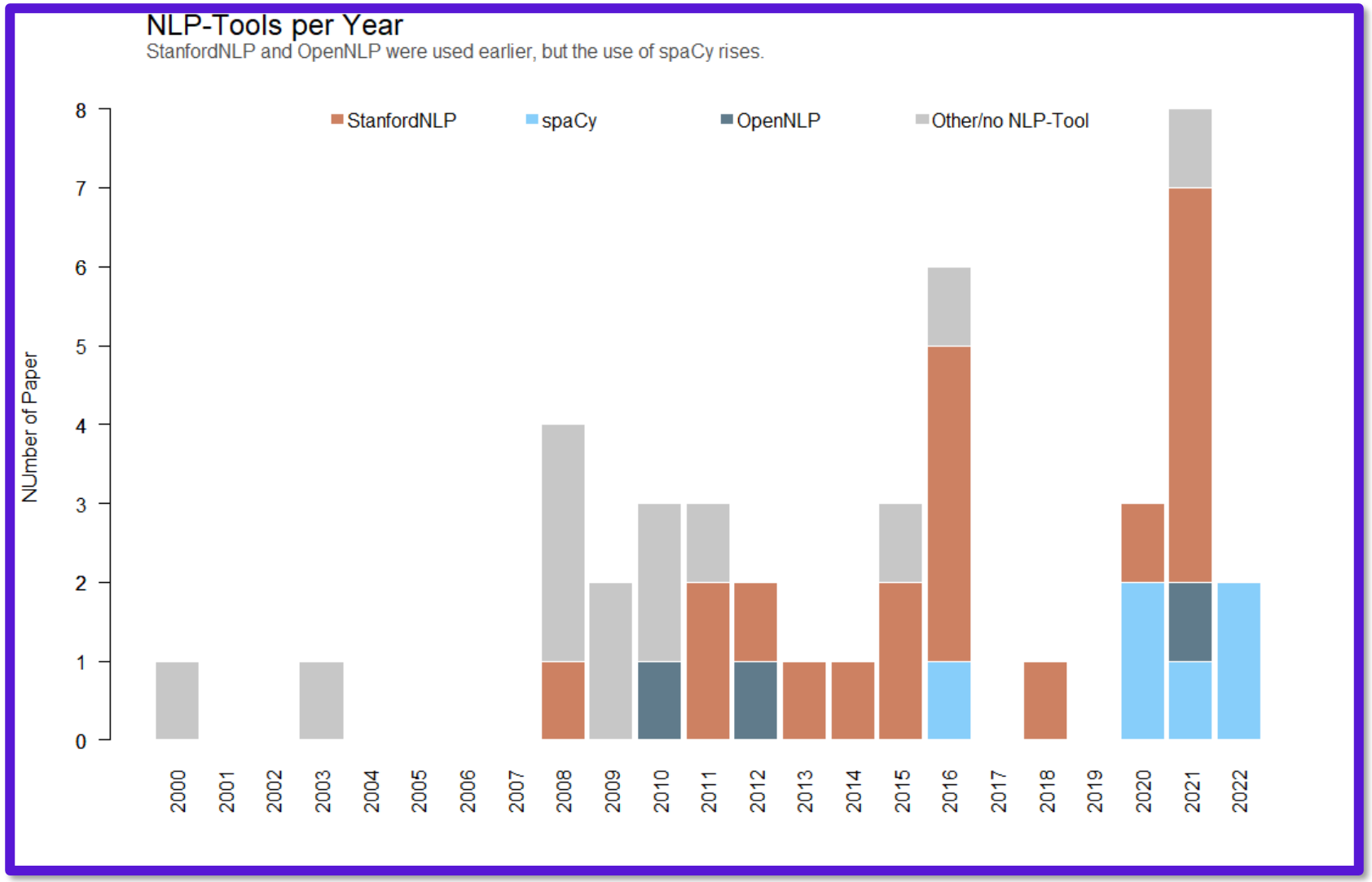
Appendix II

SLR Findings

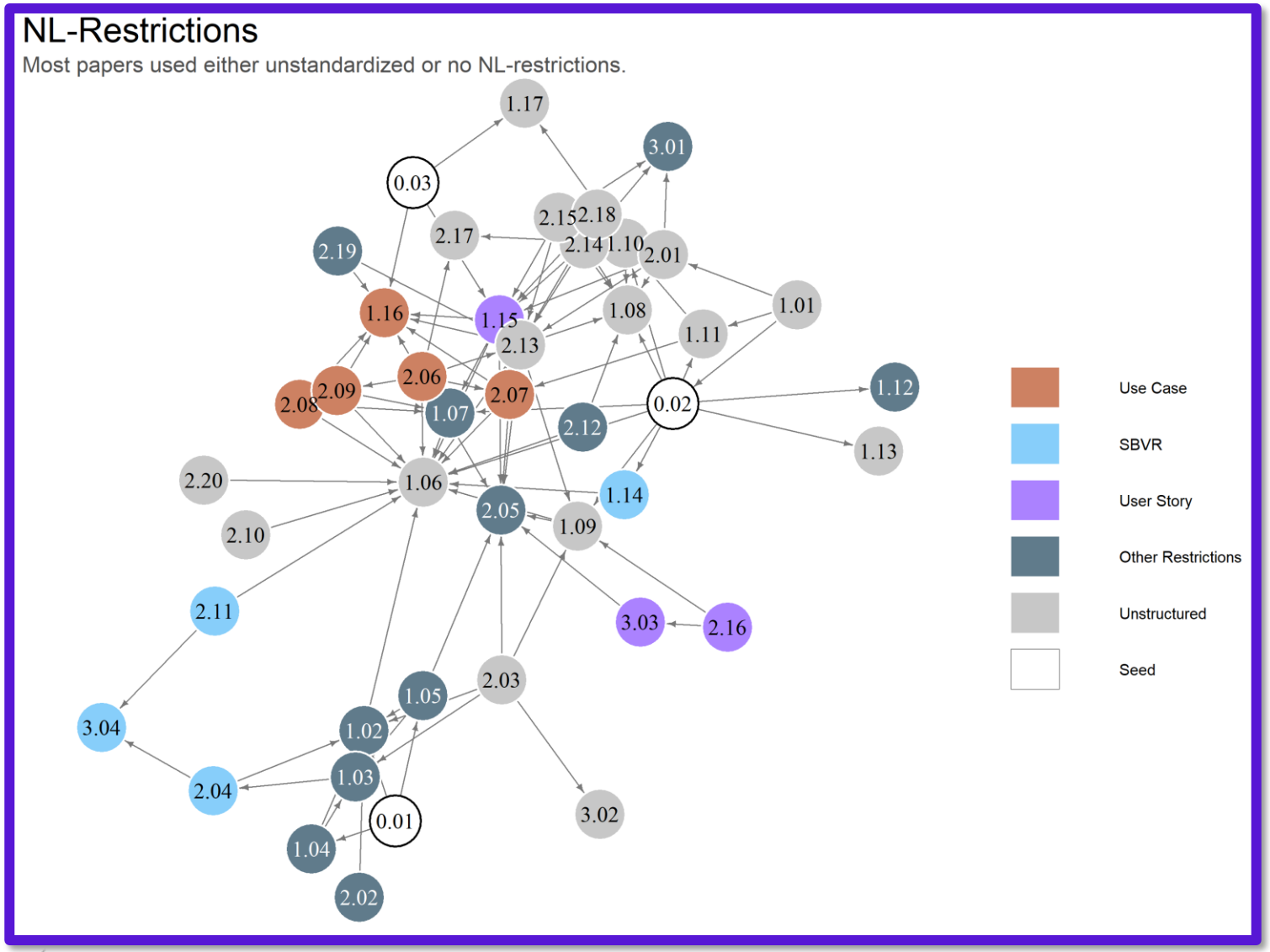
Citations per Paper



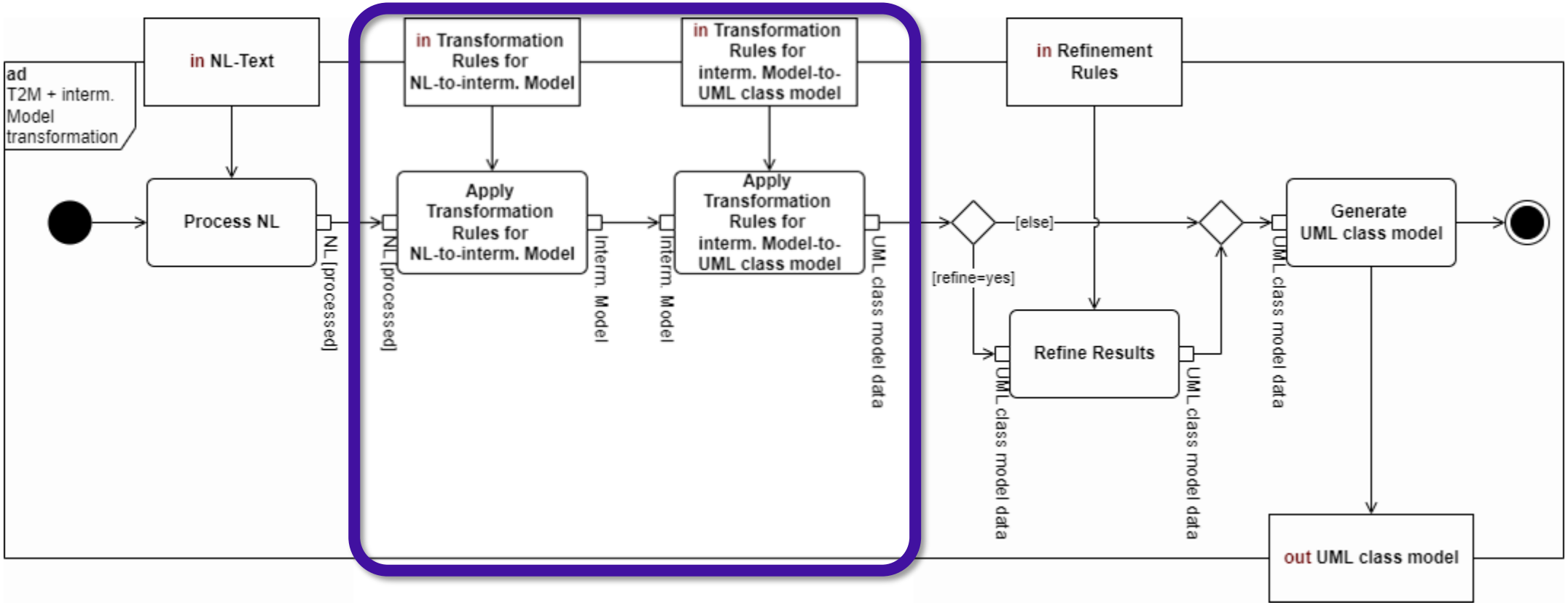
NLP Tools per year



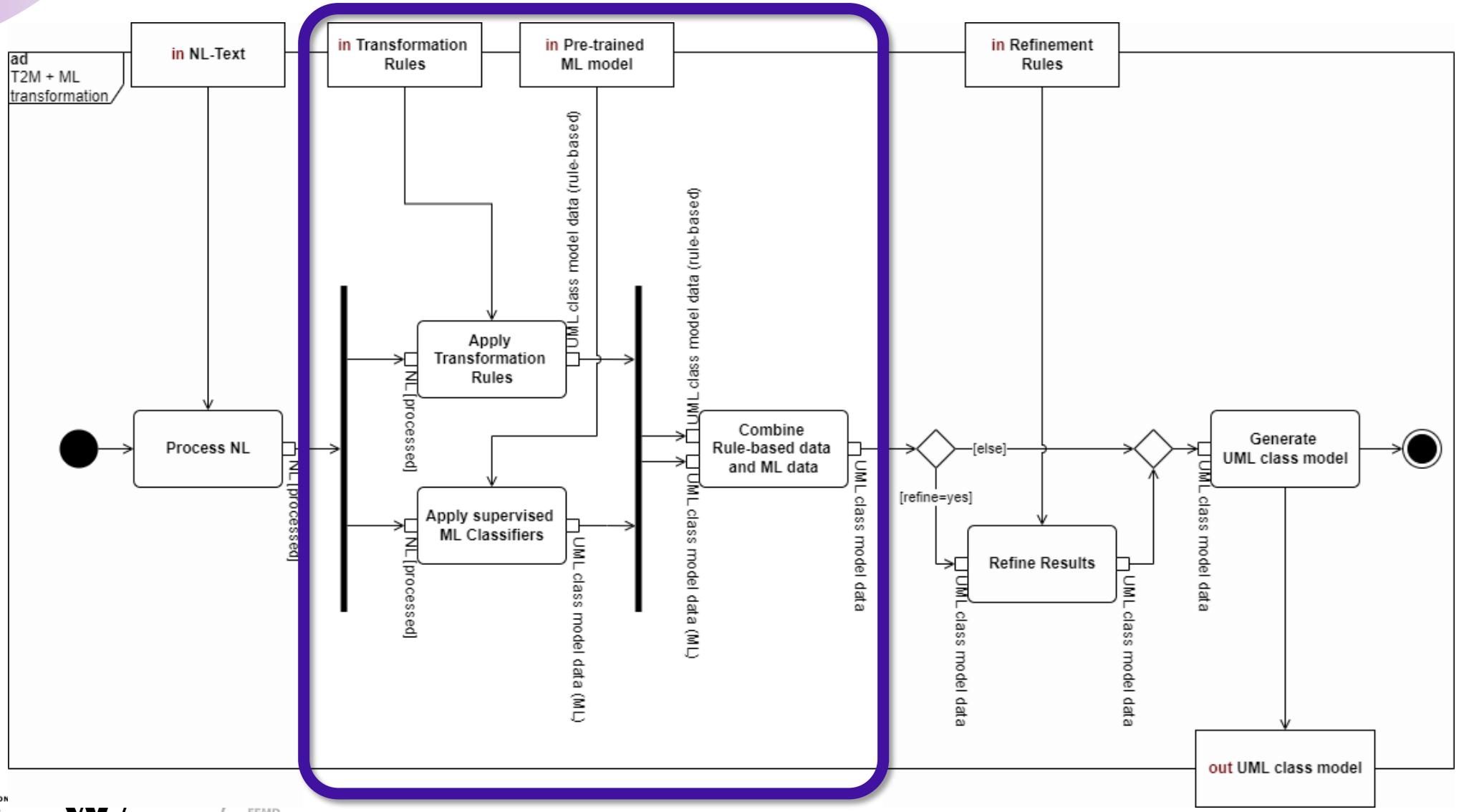
NL Restrictions



T2M - Intermediate



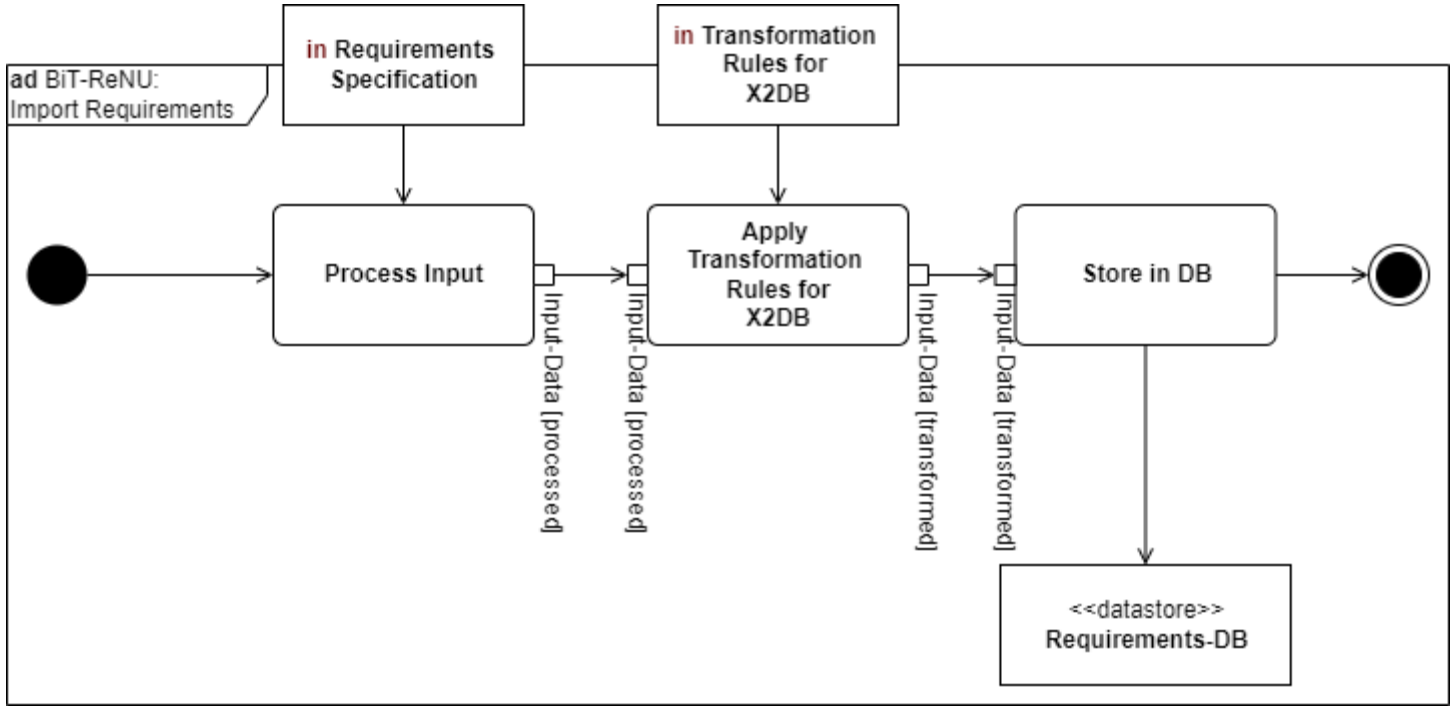
T2M – Machine Learning



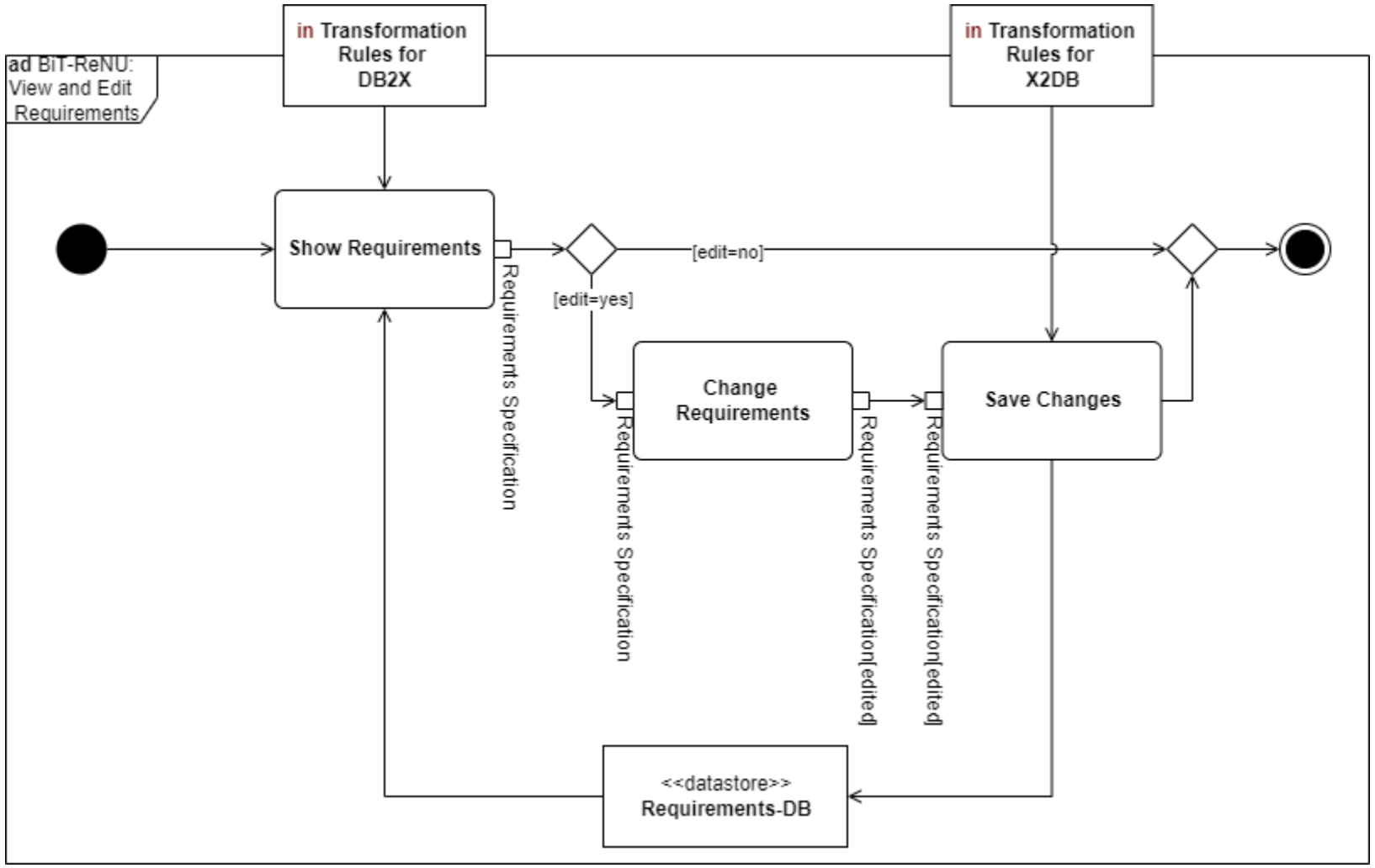
Appendix III

BiT-ReNU Design

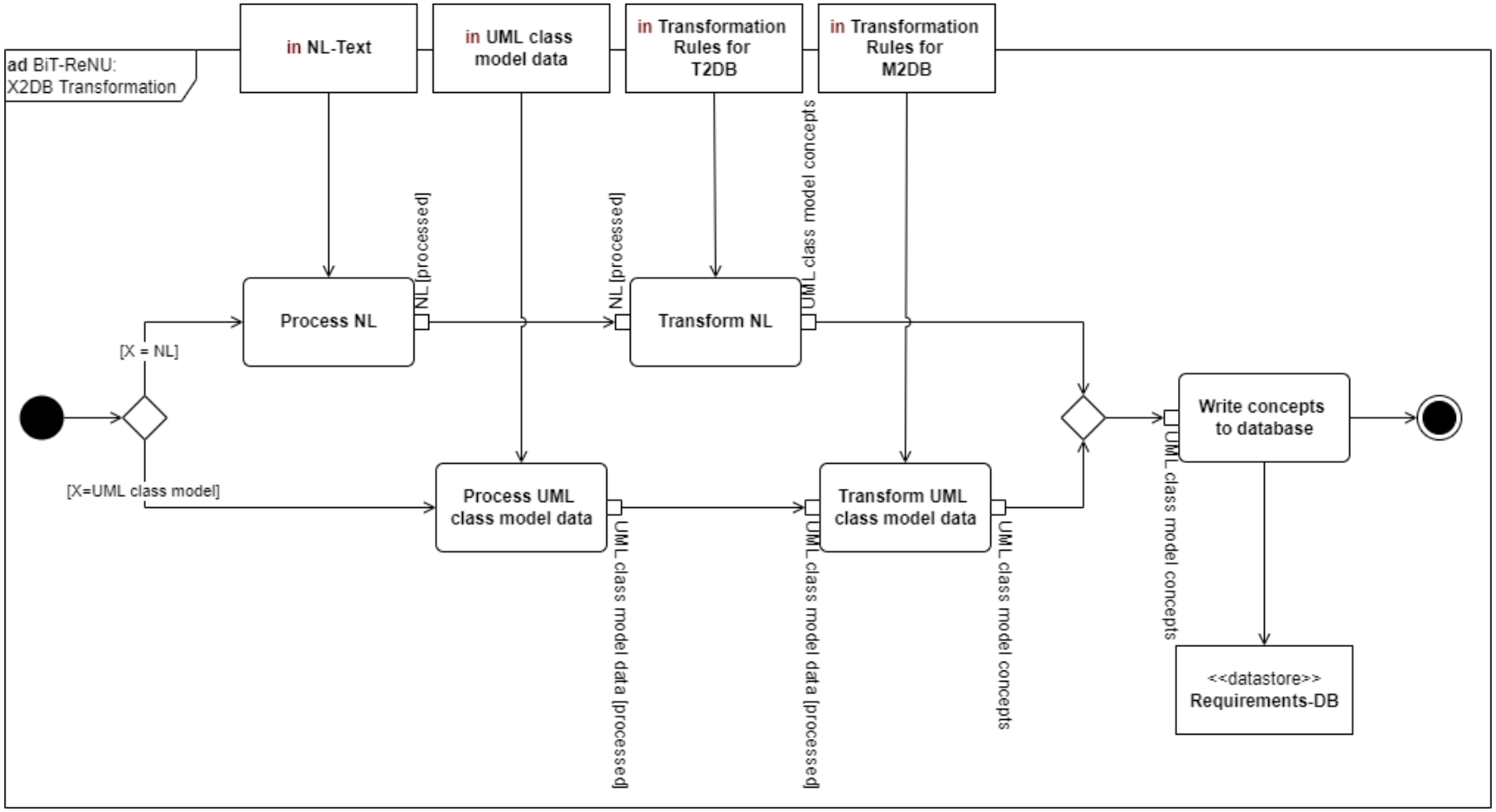
Import Requirements



View and Edit Requirements



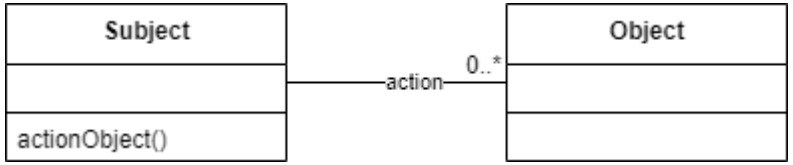
Transform X-to-DB



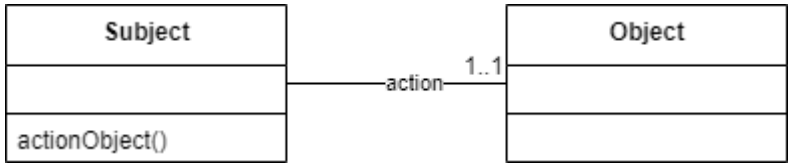
T.1 Active Association

<Subject> CAN | MUST <Action> <Object>

CAN



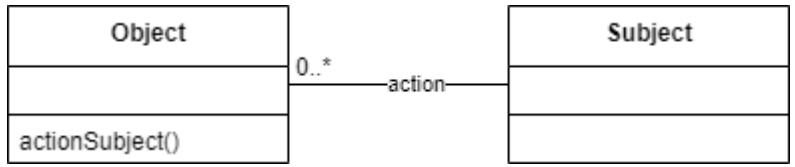
MUST



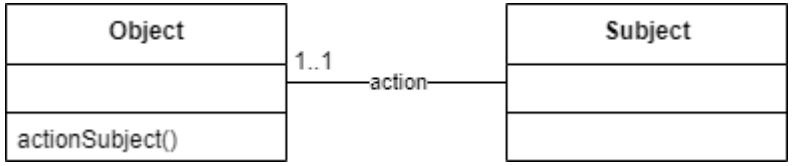
T.2 Passive Association

<Subject> CAN | MUST <Passive Action> <Object>

CAN

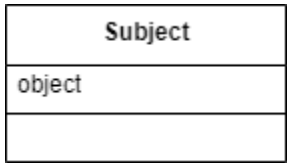


MUST



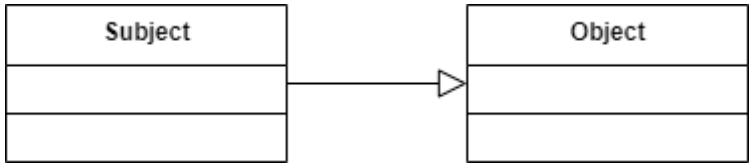
T.3 Attributes

<Subject> HAS <Object>



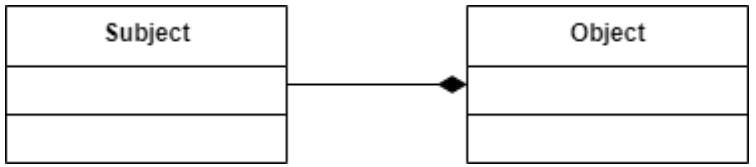
T.4 Generalization

<Subject> IS <Object>

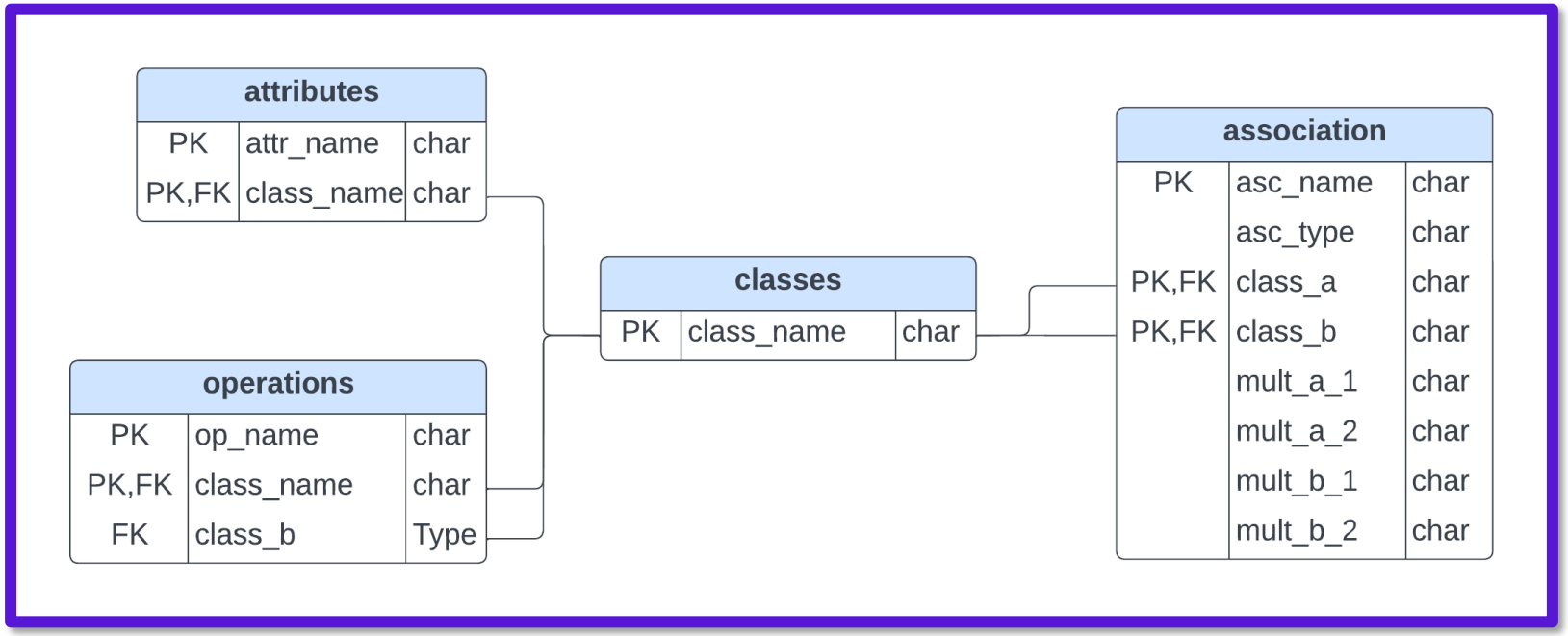


T.5 Composition

<Subject> IS PART OF <Object>

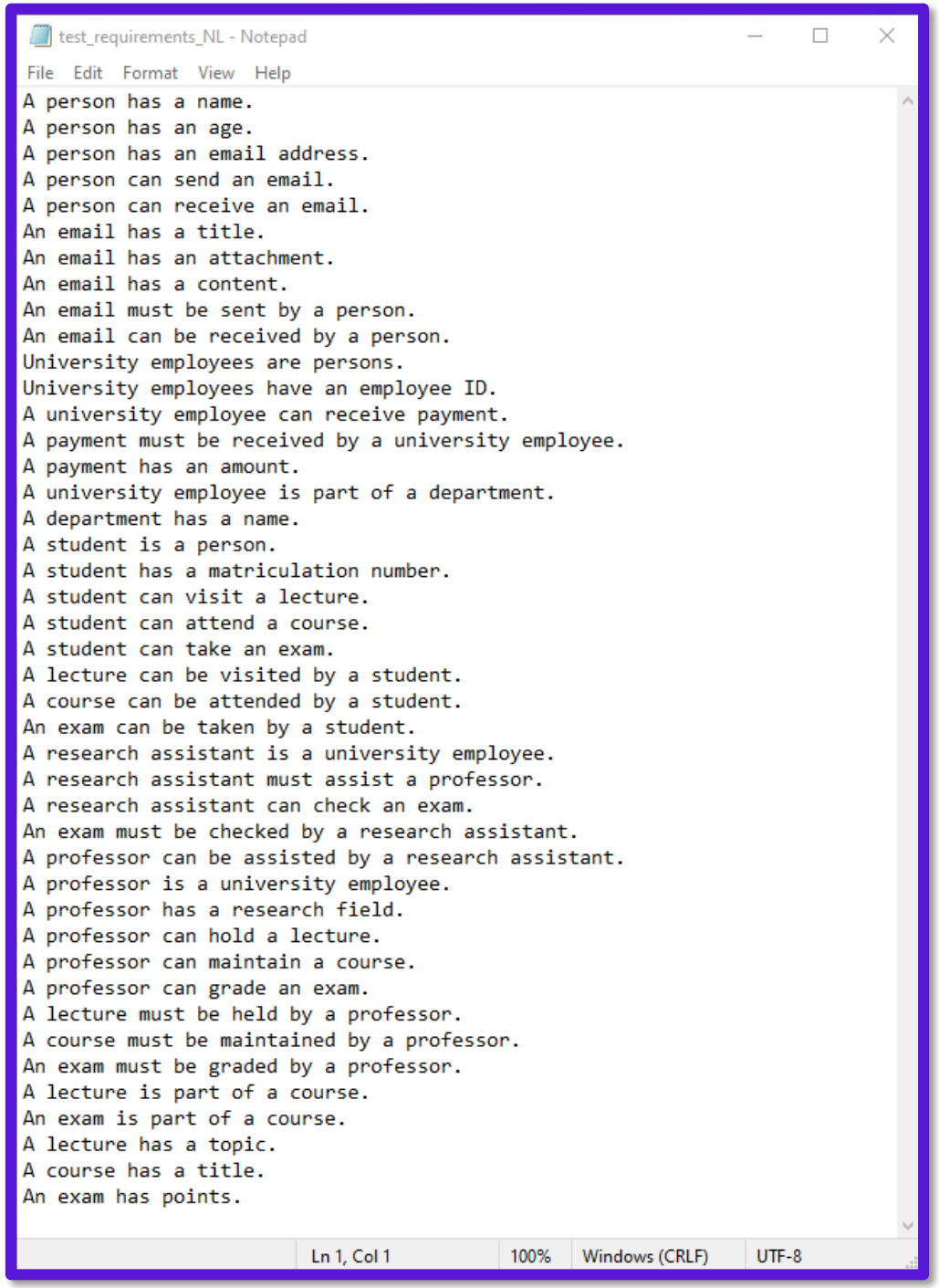


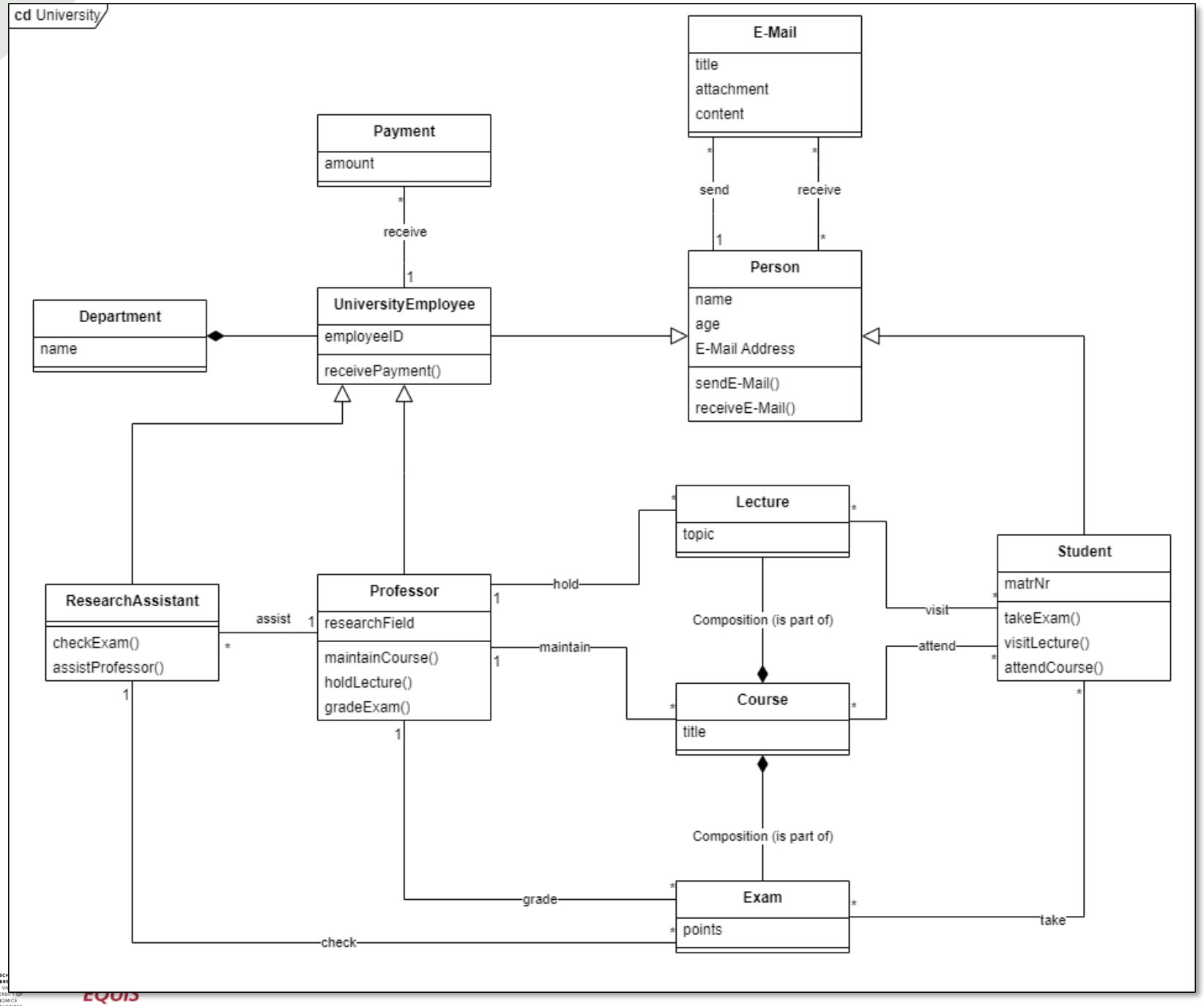
Database Schema



Appendix IV

Example Requirements


test_requirements_NL - Notepad
File Edit Format View Help
A person has a name.
A person has an age.
A person has an email address.
A person can send an email.
A person can receive an email.
An email has a title.
An email has an attachment.
An email has a content.
An email must be sent by a person.
An email can be received by a person.
University employees are persons.
University employees have an employee ID.
A university employee can receive payment.
A payment must be received by a university employee.
A payment has an amount.
A university employee is part of a department.
A department has a name.
A student is a person.
A student has a matriculation number.
A student can visit a lecture.
A student can attend a course.
A student can take an exam.
A lecture can be visited by a student.
A course can be attended by a student.
An exam can be taken by a student.
A research assistant is a university employee.
A research assistant must assist a professor.
A research assistant can check an exam.
An exam must be checked by a research assistant.
A professor can be assisted by a research assistant.
A professor is a university employee.
A professor has a research field.
A professor can hold a lecture.
A professor can maintain a course.
A professor can grade an exam.
A lecture must be held by a professor.
A course must be maintained by a professor.
An exam must be graded by a professor.
A lecture is part of a course.
An exam is part of a course.
A lecture has a topic.
A course has a title.
An exam has points.
Ln 1, Col 1
100%
Windows (CRLF)
UTF-8


cd University
E-Mail
title
attachment
content
Payment
amount
send
receive
receive
Person
name
age
E-Mail Address
sendE-Mail()
receiveE-Mail()
Department
name
UniversityEmployee
employeeID
receivePayment()
Lecture
topic
Student
matrNr
takeExam()
visitLecture()
attendCourse()
ResearchAssistant
checkExam()
assistProfessor()
assist
Professor
researchField
maintainCourse()
holdLecture()
gradeExam()
hold
maintain
Composition (is part of)
visit
attend
Course
title
Composition (is part of)
Exam
points
grade
check
take