Atom Free IT
for true business agility

MuDForM Definition

Metamodel and method flow

Version:1-6-2022 13:31:01
Author: Robert Deckers

Distribution and usage limited to: Atom Free IT

Table of Contents

1 MuDForM **4**

2 Method flow **4**

2.1 Main flow and sub flows diagram 4
2.2 Main flow with objects diagram 5
2.3 Scoping 6
2.3.1 Define purpose 7
2.3.2 Demarcate area 7
2.3.3 Select input text 8
2.4 Grammatical analysis 9
2.4.1 Extract phrases 9
2.4.2 Determine relevance 10
2.4.3 Eliminate homonyms and synonyms 11
2.4.4 List the final phrases 11
2.5 Text-to-model transformation 11
2.5.1 Identify candidates 12
2.5.2 Classify candidates 12
2.5.3 Identify specification spaces 13
2.5.4 Create initial specification spaces view 13
2.5.5 Declare and position model elements 14
2.5.6 Create initial models 14
2.5.6.1 Create initial context models 14
2.5.6.2 Create initial domain models 15
2.5.6.3 Create initial feature models 15
2.6 Model engineering 15
2.6.1 Engineer context 18
2.6.1.1 Make actors view 18
2.6.1.2 Make context structure 18
2.6.2 Engineer domain 19
2.6.2.1 Make object lifecycle 20
2.6.2.2 Make interaction view 21
2.6.2.3 Make activity model 21
2.6.2.4 Make class structure 22
2.6.2.5 Make attribute view 22
2.6.2.6 Specify domain constraints 23
2.6.3 Engineer feature 23
2.6.3.3 Specify function signature 25
2.6.4 Manage specification space dependencies 26

3 Discovery domain **26**

3.1 From text-to-model (interaction view) diagram 26
3.2 From text to model (static view) diagram 27
3.3 Knowledge containers (static view) diagram 28
3.4 Analysis item (interaction view) diagram 28

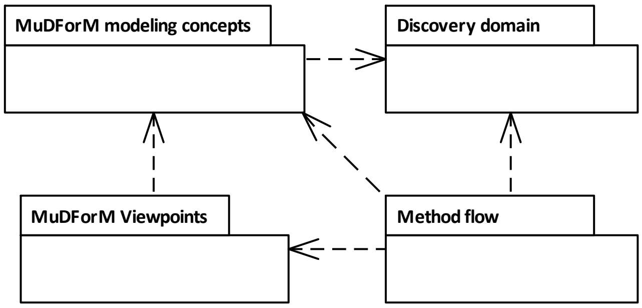
4 MuDForM modeling concepts **34**

4.1 Specification Space diagram 34
4.2 Context definition diagram 35
4.3 Domain definition diagram 35

4.4 Feature Definition diagram 36
4.5 Attributes diagram 37
4.6 Conditions diagram 37
4.7 Classifier structures diagram 38
4.8 Domain class definition diagram 39
4.9 Domain activity definition diagram 40
4.10 Function definition diagram 41
4.11 Class relations diagram 42
5 MuDForM Viewpoints 50
5.1 Viewpoints pattern diagram 50
5.2 For a MuDForM Model 51
5.2.1 Declarations view: 51
5.2.2 Dependencies view 51
5.3 For a context 52
5.3.1 Declarations view 52
5.3.2 Context structure 52
5.3.3 Actors view 53
5.4 For domains 53
5.4.1 Declarations view 53
5.4.2 Interaction view 53
5.4.3 Class view 54
5.4.4 Attribute view 55
5.4.5 Object lifecycle view 55
5.4.6 Activity view 56
5.5 For features 56
5.5.1 Declarations view 56
5.5.2 Feature structure 56
1.1.1 Function lifecycle 57
5.5.3 Function signature 58

1 MuDForM

The MuDForM metamodel is defined in four packages. The core is formed by the MuDForM modeling concepts the Method flow. The Discovery domain contains the concepts for elicitation of knowledge from experts and text. The viewpoints package describes the different viewpoints, which are used in the method flow.

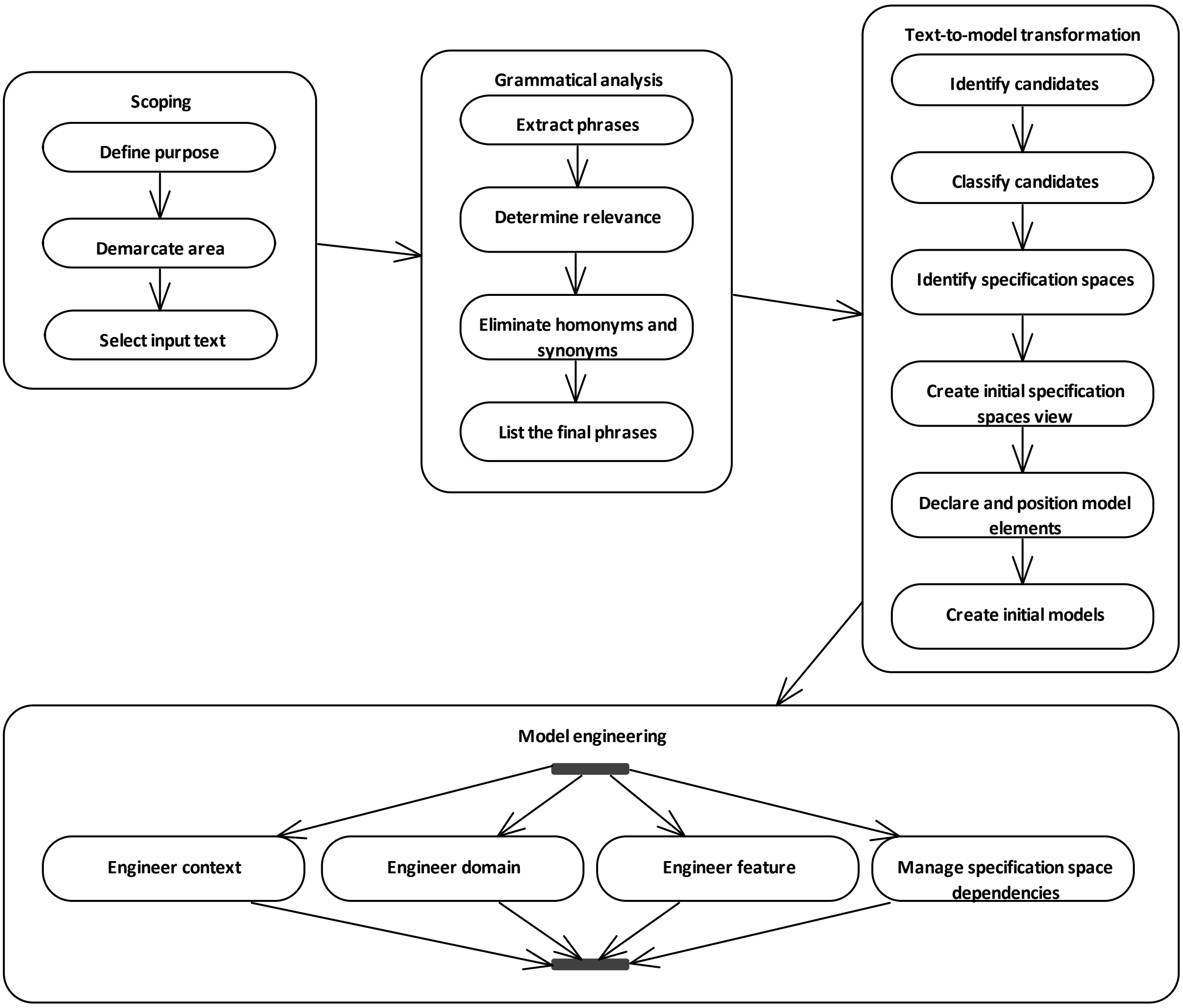


MuDForM Definition

2 Method flow

This package describes the steps and guidelines of the MuDForM method. it builds upon the concepts defined in the Specification structure package and the Discovery package.
Each step is described, and per step preconditions, postconditions and guidelines are given. Preconditions describe what must be valid before the step can be performed successfully. Postconditions define what must be valid at the end of the step, which means that the step is not finished until the postcondition is true. Guidelines give help in achieving the postconditions or how to perform the step in practice.
An experienced modeler may be inclined to skip steps or to follow guidelines of a step further in the process, for example by already "knowing" how a concept will end up in future modeling steps. This may save work in the short run, but the risk is that less experienced modelers, and especially involved domain experts, lose track of the reasoning behind the modeling step and perceive the modeling method as a very difficult and opaque activity. The advice is to stick to the method steps, unless the domain experts agree to apply “look ahead” insights in earlier steps.

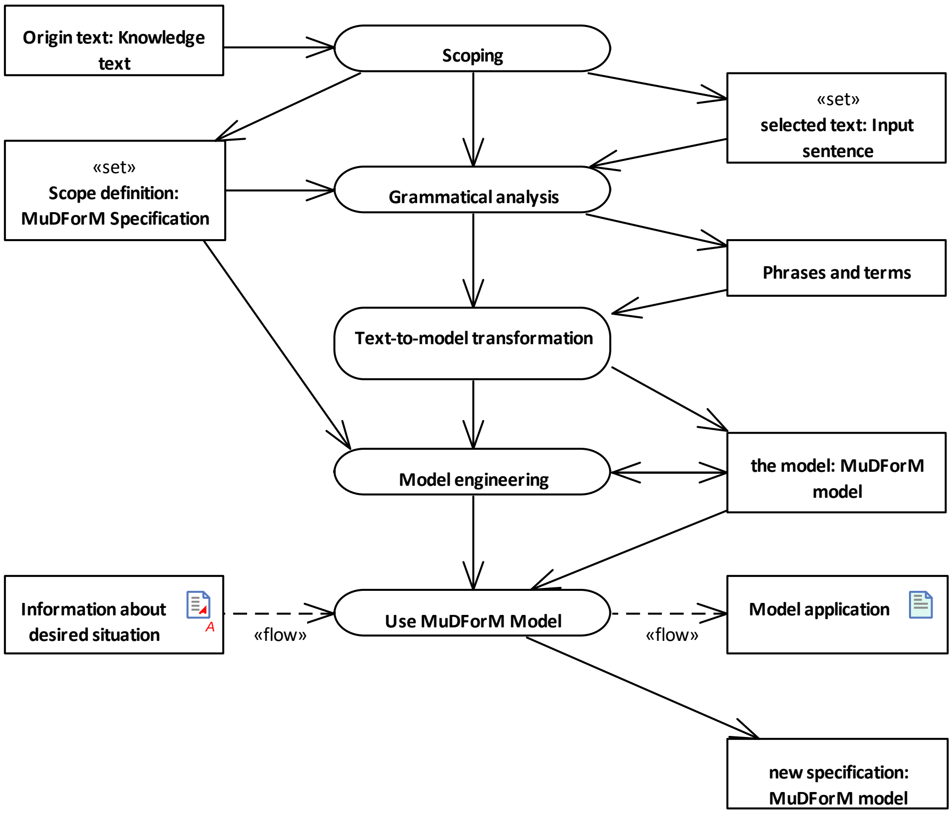
2.1 Main flow and sub flows diagram



Main flow and sub flows

2.2 Main flow with objects diagram

MuDForM consists of five main activities that typically happen sequentially, but also may overlap in practices. It starts with setting the scope where the input text is selected and people are involved. Then, knowledge from these people and text is extracted, grammatically analyzed, and transformed into a format that makes it suitable for modeling. After that, a first model structure is defined, and the analysis results are transformed into model elements. The core of the process is the model engineering phase in which all the modeling rules and guidelines are applied when iterating over the different model views. The process ends with applying the made MuDForM model in some context. This can be making another MuDForM model or any other usage.



Main flow with objects

2.3 Scoping

The scope of the targeted model is specified by defining the purpose, the boundaries, and the input text that is selected from the knowledge source. The knowledge source is often an existing document, or a document that is created from interviews with (domain) experts. For each piece of text, a domain expert is appointed to provide missing information and assist with inconsistencies. The goal of scoping is to have the proper input for the modeling process, in order to (i) prevent unnecessary modeling work, (ii) detect other relevant input, and (iii) keep the model and the modeling process manageable.

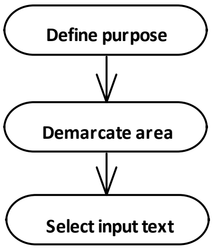


Figure 1: Scoping

Precondition: Have relevant text
Assure that you have text that you can select from. This can be an existing document or notes from interviews for example.
In the case that there is no explicit starting text, you can make an initial model by putting sentences in a tool together with a group of domain experts. Such a tool can be a whiteboard, a modeling tool like Enterprise Architect, or like KISS Domino.

Precondition: Stakeholders involved
A set of stakeholders must be involved, either directly or via representatives. There should be at least one expert for each of the targeted domains, and one customer (user) for each of the targeted specifications (domains and/or features). They do not have to be different people. Examples of stakeholders are the people that must use a targeted system, implement

the specification in a system, specify tests for a system, or are responsible for the delivery of the system and thus the correctness of its specification.

Postcondition: Sentences that can be analyzed
A set of selected sentences in correct natural language or formatted according one of the analyzable phrase types.

Postcondition: Specifications with a purpose
Write a clear purpose specification for each (expected) specification space.

2.3.1 Define purpose

Define who the customer/user of the specification is and what they want to do with the specification that you are going to make. What kind of specifications do you want to make with the specification? What applications/systems do you want to build from the targeted specification? One could define the purposes as use cases of the model.
Guideline: A purpose expresses an activity
A purpose description explains what happens with the specification, and what goal that activity has. It should be clear what the value and role of the specification is for that activity.

Guideline: Start with default domain model purposes
Default purposes for domain models are:

- Provide the terminology for specifying a specific feature.
- Provide terminology for the integration with other domains, i.e., to compose the domain model into another domain model.
- Derive specifications in another domain, typically a software domain. For example. in a code generation for a specific target platform.
- Provide terminology for specifying requirements for a system that operates in or controls the domain, e.g., specify the requirements for a fuel saving system in terms of the car driving domain.
- Provide terminology for specifying tests to check if a domain behaves according to specification.
- Align terminology across texts (in any kind of document) about the domain.

Guideline: Start with default context model purposes
Default purposes for context models are:

- Provide the terminology that is needed to specify a specific domain or feature. Think about terms that have meaning outside the targeted domain or feature, and that are needed to define behavior and structure of domain classes, domain activities, functions, and their attributes.
- Provide the terminology to specify the interaction of a feature with this context. Think about external actors, and their capabilities, or events that features must react to or generate.

Guideline: Start with default feature model purposes
When in doubt, start to check if these default purposes for feature models are applicable:

- Provide the terminology for specifying other features.
- Provide the terminology for specifying requirements for a system that implements the feature, like a software application, work process, or hardware.
- Derive specifications in another domain, typically a software domain. In other words, generate code (or models) for a specific target platform.
- Provide terminology for specifying tests to verify if a system works according to the feature specification.
- Provide actors with work instructions. Actors can also be (software) systems.

Guideline: Stakeholder per purpose
Have at least one stakeholder involved in the modeling process for each purpose. Any stakeholder that intends to use the targeted specification should have a purpose for it.

Guideline: Define different purposes for different specification spaces
Separate the purpose of a domain model from the purpose of a feature model. A domain model has typically a wider applicability than a feature model.

2.3.2 Demarcate area

Give an indication of the concepts that are in scope and the concepts that are out of scope. If you already think in modeling concepts, then you can name classes and activities for domains, and functions and actors for features. Otherwise, you can name nouns, verbs, and phrases.

Guideline: Keep revisiting the demarcation

Demarcation is an ongoing activity. After every step throughout the modeling process, you have more information available to discriminate between in "in scope" and "out of scope". This means that the demarcation typically becomes more accurate throughout the modeling process. Instead of doing the demarcation once:

- Make the demarcation a regular discussion point during the rest of the modeling process.
- Do not spend much time on it in the beginning of the modeling process. 15 minutes is a maximum.

Guideline: Explicit inclusion and exclusion of concepts

Make a list of concepts that are in scope and a list of concepts that are out of scope. In practice, involved (domain) experts already have an idea about these.

Guideline: Start with the top-of-mind concepts

Do a five-minute brainstorm with a domain expert, or a short model storming session with a group.

Guideline: Mention adjacent specification spaces

Mention specifications spaces (domains features) that are related in some way. For example, name other perspectives on the same concept, like sitting on a chair vs. crafting a chair vs. selling a chair. Or, functionality that your features interacts with, like selling goods interacts with buying goods and delivering goods.

2.3.3 Select input text

Select sentences from the text, which form the input for the grammatical analysis. The starting document can be a specific report, article, and/or set of interviews with domain experts. Examples documents are a project requirements document, a specification of a process in the domain, an application specification, use case scenarios, or an official standard that is applicable to the scope of the targeted model.

Guideline: Avoid long relevancy discussions

Do not try to select the "perfect" text in the beginning. The later modeling steps will filter out irrelevant information better than one can achieve by selecting and analyzing the right pieces of natural language text in the beginning. When choosing text is difficult, choose quickly and start working with the choice. This way, you get relevant feedback quickly. Don't be afraid to drop the choice and choose again.

Guideline: Start with the foundation and the core concepts

When a text is too large to take in at once, then the selection can be narrowed (initially) by detecting the parts of the text that are needed for understanding other parts, and by picking the part that is the core of the whole modeling activity.

Guideline: Start with concepts from the demarcation

If you cannot easily select a piece of text, because the document is too large and it is unclear where the relevant sentences are, then search for sentences with the most important terms according to the demarcation.

Guideline: Involve the expert

Involve the person who is responsible for the content of the selected input text, like the author or an expert on the content. The modeler might have his own ideas, but the domain experts have the knowledge and, more important, must feel they are the owner of the specification. Trust their hunch and use their input as direct as possible.

Guideline: Focus on the topic

Skip text that does not directly address the targeted topic, like an overview of the document structure, or a section about future work.

Guideline: Start small

Limit to 50 sentences for a first iteration. This helps to get an initial model very fast. After the transformation from text to an initial model, one can choose to start the model engineering, or to add more sentences.

Guideline: Format your interviews

In case you interview experts to obtain text, try to format the sentences from the interview in one of the analyzable phrase types. Also, you can direct the interview separating questions for the domain model from questions for the feature model, i.e., asking what is possible vs. asking what should happen. It is advisable to only do this if you have done the modeling process before. If not, then just stick to plain natural language.

2.4 Grammatical analysis

To analyze the input text, collect and transform it into a set of phrases that can be used to make an initial model.
The first step is to extract phrases from the selected input text. One could acquire phrases directly from the involved stakeholders, but then there should be a log of the stated phrases, which as such forms a piece of input text. For each of the extracted phrases the relevance is determined, it is checked for homonyms and synonyms. This results in a final set of phrases and candidates for the model.

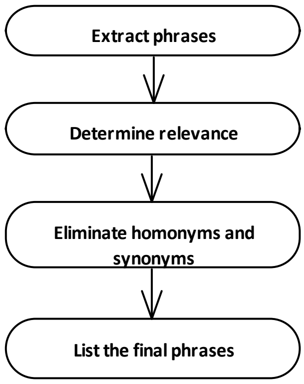


Figure 1: Grammatical analysis

Guideline: Combine steps
Experienced modelers may skip steps for efficiency of the process. But be aware, if involved people have to follow the steps of the process, you may lose them if the skipping is not understood.
For example, you may already discard a phrase of which the parts will be discarded due to guidelines in later modeling phases. This prevents unnecessary work. Explain this and only do it if the involved people agree. In case of doubt, do not skip or combine steps.

Guideline: Postpone long analysis discussions
When a discussion about a term or phrase takes too long (e.g., more than two minutes), or when involved domain experts disagree, then keep the information and postpone the discussion to the model engineering phase. Namely, the model engineering provides more overview and multiple viewpoints, which puts modeling questions in a clearer perspective.

Guideline: Raise issues
If you cannot make a clear decision about a phrase or candidate during grammatical analysis, then raise an issue for it. Then discuss it with the involved expert.
Whenever an issue is raised and you cannot resolve it quickly, write it down as “Open Issue” and move on. In some tools you can enter an issue at any place and moment, and you can query for them later when you want to discuss them.

Guideline: First do the domain model, then the feature model.
Do at least two iterations with a text when you target at both a domain model and a feature model. The first iteration focuses on the extraction of HAS and ISA phrases, and interaction phrases that have no actor, i.e, most phrases starting with "TO". Then do the model engineering until the domain model is stable. The second iteration is about the extraction of interaction phrases with actors and constraint phrases, which can immediately be rewritten to match the created domain model. This second iteration is also a validation of the created domain model. Namely, all the constraints should be expressed in terms of the domain model. If not, then either the constraint phrase is unclear or incorrect, or the domain model must to be adapted.

2.4.1 Extract phrases

Extract phrases from each sentence in the selected input text. Format each phrase according to one of the phrase types.
Guideline: Investigate what behavior constitutes a verb
Investigate what behavior makes up the behavior denoted by a verb. These might be candidate operations for an activity model, or activities for a function lifecycle. Though, do not overload the grammatical analysis with phrases about data transformation, transfer, or simple calculus.

Guideline: Replace verb clauses with a preposition object

Sentences with a clause that expresses a means or reason to the main verb, can be replaced with a preposition and an object. For example, "He uses the key to open the door." can be replaced by "He opens the door with the key.". The verb in the clause is often a generic verb like "to use" or "to apply".

Guideline: Use a structure to separate input sentences
Make a table where each sentence gets its own row. Put the initial sentence in the first column. Put all the extracted phrases in the second column. Add a third column for open issues and decisions.
Of course, other structures besides a table could be used, possibly supported by a dedicated grammatical analysis tool.

Guideline: Ignore actors in domain models
When you are (only) modeling a domain model, then the subject of a structured active sentence is often not relevant. You can avoid a specific subject by using the term “Someone” for the subject or by using the infinitive form of the verb, like “to order”.
The subject can be relevant if you can make the verb reflexive, like in “The customer identifies himself with a passport.”.

Guideline: Check if subject is also an object in other phrases
Check if the subject of an active sentence occurs as object in other sentences. In this case, the sentence often means “The actual subject observes that…”. One can maintain the original sentence structure, but the subject will not become a candidate actor, but most likely a candidate domain class. Example: In a toll registration system “The vehicle passes the toll booth” could be rewritten as “The system observes the vehicle passing the toll booth”. But the original sentence is more natural and can be kept. And the subject "vehicle" will most likely occur as an object in other sentences, causing it to be a candidate domain class.

Guideline: Leave out indefinite articles
Leave out indefinite articles ("a" and "an") from extracted sentences. This way the extracted sentences contain only words that can go directly into the models.

Guideline: A genitive case indicates a static structure.
Genitive cases in noun phrases indicate a static structure.
For example, "the color of the car" indicates "car HAS color".

Guideline: Containment indicates a static structure
If a noun phrase has the preposition "in" between two nouns, a verb that expresses containment, indicate a static structure. For example, "the basket contains apples , or "the basket has apples in it", indicate "basket HAS apple".

Guideline: A possesive indicates a static structure
A possessive apostrophe indicate a static structure. For example, "the car's color" indicates "car HAS color".

Guideline: Detect type of adjectives and adverbs
First check the relevance of an adjective or adverb in a nominal predicate. For example, given "the car is blue", then ask if there are also non-blue cars. If not, then ignore the adjevtive or adverb. If yes, then replace nominal predicates of the kind <noun/verb is adjective> with a static structure sentence of the kind <noun/verb has aspect>. The replacement is a noun that expresses the aspect that the adjective is about. In the example: “car is blue” is replaced by “car has color”. Clearly, this only makes sense if cars can have other colors besides blue.

2.4.2 Determine relevance

Determine the relevance of each of the extracted phrases. Ignore phrases that do not fit the scope definition, or that are (partial) duplicates. Terms in a phrase can be replaced with a verbalization of an already existing model element.
Guideline: Ignore phrases about the document itself.
Ignore phrases that are about the document itself, like an explanation of the document structure, or sentences that "glue" paragraphs together.

Guideline: Ignore intention phrases.
Ignore sentences that are about the intention of the text content. Think of generic statements like "... is used to", "... is meant to", "the purpose of ...", or "it is the intention that ...". Unless those are domain terms of course.

Guideline: Find a verb that expresses the change.
Verbs that express a result or an effect can be ignored. For example, from the phrase "the list grows by adding items to it" the phrase "to add item to list" can be extracted becuase it expresses a change. But the verb "to grow" can be ignored, because it express an effect. For example, in the phrase "the items finally end up in the trash bin" the verb "to end up"

expresses an effect. One can ask what activity leads to that effect. The answer can be "to delete an item into the trash bin".

2.4.3 Eliminate homonyms and synonyms

Avoid that one term has more than one distinct meaning and avoid that one meaning is represented by more than one term. So, replace terms that are a homonym or synonym in phrases, with the chosen term. The chosen terms may also come from already existing models.
Guideline: The term must be recognized by the expert.
Let the domain expert choose the term in case of synonyms. Let the domain expert choose a new term in case of homonyms.

Guideline: Standardize logical constructs
Logical constructs are not always formatted uniformly. Sometimes punctuation is used to construct sentences containing “if”, “else”, “and” and “or”. By adding a clarifying keyword like “then” or parentheses it becomes clear which interpretation is meant. It also holds for operations like “is equal to” or “has the same value as”. Use a uniform syntax to express conditions and operators in sentences.

Guideline: Verbs with multiple sets of related nouns indicate a homonym
A verb is probably a homonym if it occurs in multiple phrases and the verb has different objects or prepositions related to it in those phrases. For example, in the sentences "I pay attention to the waiter" and "I pay the bill", "pay"is probably a homonym.

Guideline: Avoid generic verbs
Be aware of homonyms for generic, typically data-oriented verb terms. Examples of these verbs are:

- Create, identify, enter, define, describe, register, select, add.
- Update, adapt, change, modify.
- Delete, terminate, erase, remove, end.

These verbs are typical for administrative and conceptual objects. Preferably use a more semantical term from the actual domain. For example, “change address of a person” is actually “person moves to a new address” or “enter an order” becomes “place an order” or simply “to order”, or “change the color of the wall in blue” is really “paint the wall blue”. The verb term may be overloaded, when there is no good alternative available according to the domain experts. For example, to describe a person could be seen the same as the same activity as to describe a dog. But in case you consider it to be different, you can postfix the general verb with the direct object, resulting in "to describe person” and "to describe dog".

2.4.4 List the final phrases

Form the set of phrases for the initial model via:

- All extracted phrases that are marked as relevant and not discarded.
- All newly added and rewritten phrases.
- Replace the possible homonyms and synonyms in those phrases with the proper term.

2.5 Text-to-model transformation

To create an initial model from the results of grammatical analysis, i.e., assign a model element type to a candidate, and identify and relate the specification spaces of the model, and position the model elements and phrases in those spText-to-model traces.

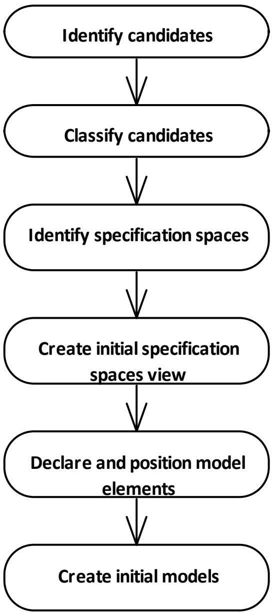


Figure 1: Transform text to model

2.5.1 Identify candidates

To select which terms (subjects, nouns, verbs, adjectives, adverbs) from the phrases are a potential element for the targeted model. Some phrases might be a candidate themselves as a whole, in the case of a condition.
Guideline: Keep a term if you are not sure
When in doubt, make it a candidate. The modeling engineering process will solve the uncertainty.

Guideline: Check if a verb has more objects related to it
Check (with the experts) if a verb has more objects related to it that are relevant for the outcome of the verb. You can just ask, or use a list of prepositions and check if any of the prepositions should be present in the phrases that involve the verb.

Guideline: Elicit more phrases for important nouns
Ask the involved stakeholders to come up with more sentences (phrases) for an identified noun. This is a way to be more complete and depend less on the completeness of the initial text. You typically do this for nouns that are important, but for which you only have a few phrases.

2.5.2 Classify candidates

Select which type of modeling element each identified noun (phrase), adjective, verb (phrase), and adverb is. The possible types are given by the metamodel class Model candidate type.
Guideline: Check if a candidate indicates a class
When it is not clear that a candidate indicates a class, ask if there are more instances possible that fall under that candidate's term and if they fit the scope. The candidate can be a noun, pronoun, or verb.

Guideline: Identify features and functions from text headers
Text headers often indicate the name of a function or feature, because texts are typically written as a coherent chronological series of events.

Guideline: Identify functions from use case interactions
If use cases, user stories, system (interaction) scenarios, are used as input source, then the steps that describe system behavior are often calls of system functions.

Guideline: Focus on the core concepts
Focus the classification on the domain classes, domain activities, and functions. Spend less time on attributes, and on candidate classes and operations that go into contexts.

Guideline: Classify changes by default as activities

If it is not clear if a verb must be classified as an activity, a function, or an operation, then classify it as a domain activity. Then begin with searching for domain model concepts by building the interaction view of the domain model. Then it will become clear if some verb is a combination of other activities, and most likely is a function. If it is not a function because it is not a behavioral unit in a feature, nor a unit of change in a domain, then it is part of a context, and thus an operation.

Guideline: Check if a noun is related to more verbs
When a noun occurs in only one sentence with a verb that indicates a change, ask if there are more sentences with other verbs in which that noun occurs. If the answer is yes, then classify it as a domain class. if not, then it is either a context class or no class at all.

Guideline: Value setting verbs indicate operations
Verbs that are about setting a value to object properties indicate an operation. Think of verbs like assign, copy, inherit, instantiate, add, and set. They indicate that object attributes get a value inside a certain activity, which makes them candidates for operations.

Guideline: The candidate type may differ in different phrases
If you cannot determine the type of a candidate, then just keep the phrases that have the candidate and decide the type per phrase.

Guideline: Not all subjects are candidate actors
Subjects that not actually perform or control behavior are not an actor. They are probably a domain class, or sometimes a function.

Guideline: Domain activities must change objects
Verbs that indicate an action in which derived information is generated, and that are not changing the state of one or more objects, are not a domain activity. They are so called inspections, i.e., queries. So, they are either a candidate function, operation, or a function step.

Guideline: Definite articles indicate a function attribute
A definite article, i.e., "the", might point to a role an object plays in a function. Classify it as a function attribute with a (domain) class as a type.

Guideline: The types of attributes are classes from a context
The type of a domain class attribute or a domain activity attribute is probably a class in a context model. These types occur as direct object in a static structure sentence.

2.5.3 Identify specification spaces

Identify the specification spaces and classify each of them as context, domains, or features. Of course, the existing specification spaces must be taken into account.
Guideline: Begin with one context, one domain, and one feature
In case there are no existing specifications spaces, and there are no obvious boundaries, start with one context, one domain, and one feature.

Guideline: Separate incoherent contexts
Separate contexts if a group of context candidates is clearly not related to another group of context candidates.

Guideline: Separate specification spaces for different owners
Identify separate specification spaces for pieces of model that are the responsibility of different people. This way the ownership of a piece of model is clear. Also the link between the responsibilities has to be made explicit through the dependencies between the separate specification spaces.

Guideline: Separate contexts for domain definition from contexts for feature interaction.
Separate concepts for defining domain class attributes, domain activity attributes, and operations in activity models, from concepts that are needed to specify the interaction of features with their environment. Examples of the latter are external actors and operations that are the type of function events.

2.5.4 Create initial specification spaces view

Define a view (e.g., a diagram) with all the specification spaces. Create a dependency between two spaces if you think that one will use concepts from the other. Typically, domains depend on contexts and possibly other domains, and features depend on features, domains, and contexts. A context may also depend on a feature when an actor in such a context can call functions from the feature.
Guideline: Begin with one context, one domain, and one feature.
In case there are not already existing specifications spaces, and there are no obvious borders, it is best to start with one context, one domain, and one feature.

2.5.5 Declare and position model elements

Create a model element per candidate in the right specification space.
Guideline: Auxiliary verbs indicate the specification space type
Auxiliary verbs can be an indication if a sentence belongs to a feature or to a domain. Verbs like "will, can, be able" indicate that it is content for a domain model. Verbs like "must, shall, should, ought to" indicate that it is content for a feature model.

Guideline: In case of doubt, position it in the domain model
When it is difficult to determine to which specification space an element belongs, one should add it to a domain model. The model engineering step will reposition the element if needed.

Postcondition: All candidates have a corresponding model element.
Per candidate at least one model element is created. A candidate that had multiple types has a corresponding number of model elements. For example, a grammatical subject might become a domain class and an actor, or a verb might become a domain activity and a function.

2.5.6 Create initial models

Create a first version of the views in the specification spaces from the list of final phrases, based on the candidate types and the positioning of the candidates in the specification spaces. All interaction phrases become a relation between a behavioral element (activity, operation, function) and a class, all static phrases become an attribute of the subject with as type the object of the phrase. All nominal predicates become a generalization. For the constraints it depends; they can become invariants, preconditions, postconditions, or a temporal ordering in a object lifecycle, or function lifecycle.

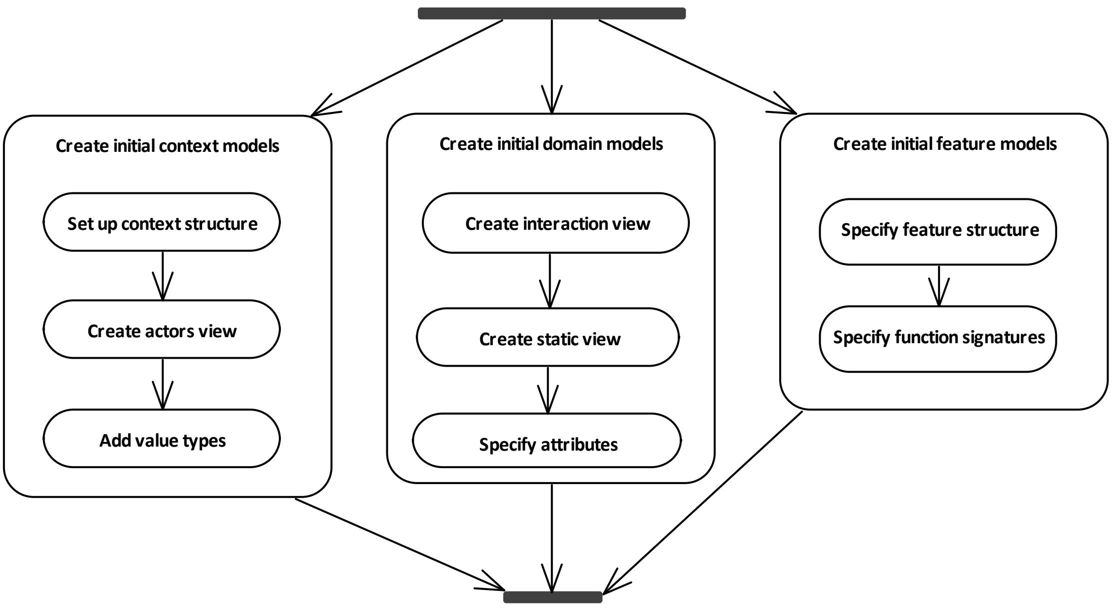


Figure 1: Create initial models

2.5.6.1 Create initial context models

Make the initial views per identified context.

Set up context structure

Make a view containing the classes, operations, and their relations (class relations, attributes, and generalizations).

Create actors view

Define function events for each actor that is not a domain class candidate, from the sentences where the actor is the subject.

Add value types

All the classes that have no attributes or are not a specialization of another class, can be a value type. Add a reference to a value (data) type from a formalism for each value type.

2.5.6.2 Create initial domain models

Make the initial views per identified domain.

Create interaction view

Put all the active structure sentences in a view (e.g., a diagram). Leave out the subjects if they are not a candidate domain class.
Guideline: Only connect the most abstract class to an activity role.
If two interaction phrases have different classes connected to them for the same activity role, and those classes also have an ISA-relation, then only draw a relation between the activity and the parent of the ISA-relation. For example, given "to drive a vehicle", "to drive a car", and "car ISA vehicle" then do not model "to drive a car", but only "to drive a vehicle" and "car ISA vehicle".

Create static view

Draw all the sentences that are a static structure sentence or a nominal predicate, but only if the relation is between two or more candidate domain classes from the same domain.
Guideline: Just use a class fro adjectives and adverbs in nominal predicate
If you do not know the type of an adjective or adverb yet, and it is used in a nominal predicate (IS-prhase), just draw a generalization relation between the corresponding class or activity and the adjective or adverb. For example, "Car is blue" is modeled as a class "Car", class "blue", and a generalization from Car to blue.

Specify attributes

For all the static structure sentences, add attributes to domain activities and domain classes, and a reference to the classes from the contexts for the type of an attribute.

2.5.6.3 Create initial feature models

Make the initial views per identified feature.

- **Specify feature structure**

For all the functions, define a function event for all the behavioral elements that can happen in the life of that function.

- **Specify function signatures**

Define function attributes for static structure sentences in which the function is a subject.
Guideline: Introduce feature attributes for sets of existing objects
A feature is often activated in an environment of sets of (independent) objects. Such sets of objects often serve as the pool of objects to select from for participation in function steps. Introduce set attributes for those objects in the feature or in the top-level functions.

Guideline: Introduce feature wide attributes for the central objects
Features, and sometimes top-level functions in the feature, often center around one or more central objects, which are referred to via a function attribute. Such an attribute can be global in the feature (or the top level function) to prevent that other functions must define it separately as a function attribute.

2.6 Model engineering

During model engineering, the initial models are iteratively transformed into engineered domain models, context models, and feature models. This means making the models comply with the set of rules that MuDForM prescribes. These rules address completeness, consistency among views, and restrictions on the metamodel.
The main principles that guide the modeling are 1) keeping the views consistent, and 2) acquire information from experts or documents to achieve a complete specification.

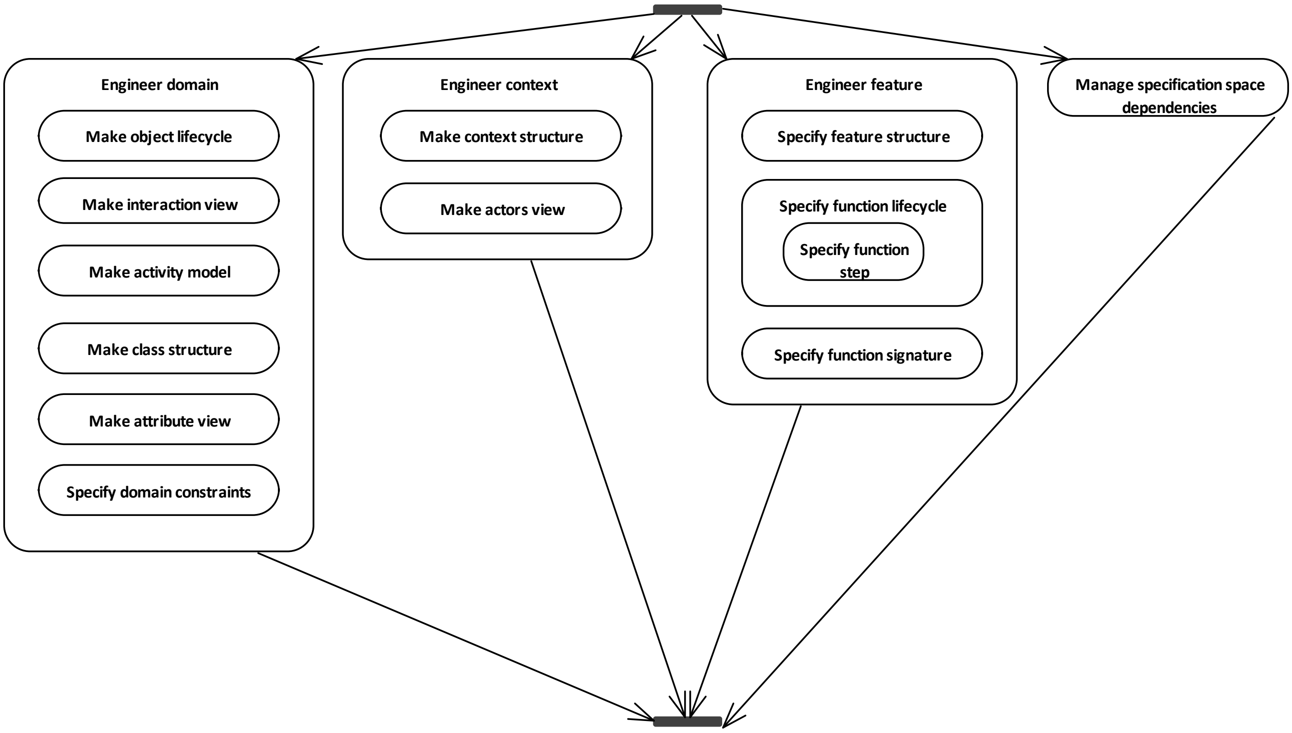
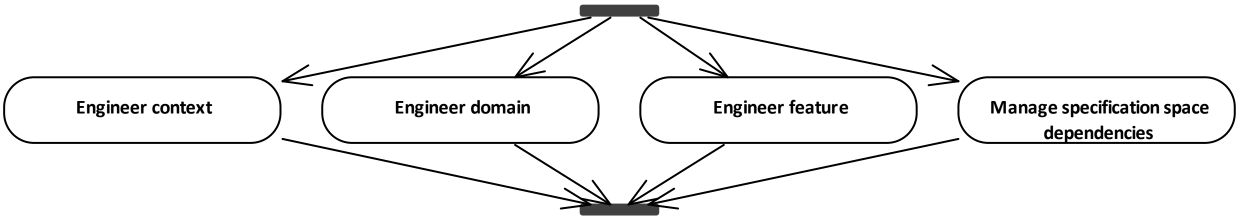


Figure 1: Model engineering



MBT feature engineering:
het selecteren van een object niet een aparte operation (step) hoeft te zijn. Het is gewoon een conditie op de relatie tussen function attribute die gekoppeld is aan de step participant. Kijken of dat object bestaat is denk ik de guard van een selection omdat je ook iets moet als die niet bestaat.
Ik snap natuurlijk de behoefte dat je een soort van default beslissing wilt als een step niet uitgevoerd kan worden omdat niet aan alle precondities voldaan kan worden. Mijn voorstel is dat je dan niks expliciet specificeert, maar het in vertaling naar een werkend systeem stopt. We moeten een soort van default semantiek afspreken dan wat het betekent voor de functie. Bijvoorbeeld: abort.
Even sparrend over wat je allemaal moet checken om een functiestep te kunnen uitvoeren:

- Mag het van het functiemodel:
  - Is dit een mogelijke step, d.w.z. een step is afgelopen en dit is een van de mogelijke volgende steps.
  - Mag het van de vorige step? In het geval van een disrupting step die vorige step beëindigt.

- Mogen alle deelnemende objecten het van hun OLC.
- Zijn de precondities van de het type van de step geldig? (type kan zijn operation, domain activity, function) Denk aan condities voor attributen en involvements (=objecttype in actierol).
- Gelden alle extra condities die op stepnivo gedefinieerd zijn?
- En.... Is de actor er klaar voor?

mbt life existence dependency:

1. De potentiele bestaansafhankelijke ouders zijn de objecten die mee doen aan de instantierende actie van een kind. De vraag die je moet stellen is: betekent het kind nog iets als de ouder niets meer betekent? (guideline in domain model engineering)
2. Sommige deelnemende objecten worden ene ouder en sommigen niet.
3. Met mudform komen daar nog complexiteiten bij door het expliciet onderkennen van een context.
4. Wat doe je met objecten uit de context die deelnemen aan de instantierende actie, maar die geen leven hebben in het model.
5. Mijn antwoord: als die een leven hebben in de context dan moet de actie ook voorkomen in de OLC van de ouder. Daarmee komt er een nieuwe issue: namelijk binnen welk domein(en) wordt die actie geplaatst?
6. Mijn antwoord: er is blijkbaar een overkoepelend domein waarin die actie geplaatst moet worden.
   Voorbeeld: als een imposition “verwijderd” wordt, dan zit natuurlijk de content nog steeds op de imprint, en ook verwijst de imprint naar een impositionID. Ahaaa. Hier hebben we het verschil: als een domainobject een “foreign key” heeft, dan zijn er twee opties: het foreign object kan verwijderd worden en het is dus gewoon een verwijzingsattribuut. Of het foreign object mag niet verwijderd worden. De laatste optie levert een probeel op, want dan moet een functie/domain restricties opleggen aan de context. Ik kan opereren met een context die zich aan mijn restricties houdt.
   Hetzelfde vraagstuk treedt niet alleen op bij het verwijderen van het context object, maar gewoon met wijzigen ook al.

KISS was niet helemaal compleet en “natuurlijk/logisch”: wat doe je als een kind tijdens zijn leven ouder kan verwisselen? In KISS moest je dan het kind end-of-life actie geven en vervolgens een nieuw kind instantieren. Voorbeeld uit bankvoorbeeld: rekening een andere rekeninghouder geven. Dit soort acties wil je kunnen doen. Daarmee zou de bestaansafhankelijke ouder veranderd worden. In mudform wil ik dat zeker toestaan. (in het metamodel: het gaat via domain operations in het actiemodel). Daarmee is er een loskoppeling van semantisch bestaansafhankelijk (typenivo) en objectafhankelijkheid (instantienivo).
Overigens vraagt het verwisselen van ouder wel veel checks” namelijk al die condities die in het leven van een ouder geschonden kunnen worden door acties op een kind. Bijvoorbeeld: een persoon mag maximaal 3 rekeningen hebben. Dit mpet een guideline worden voor acties waar een kind van ouder verwisseld.

Figure 1: Model engineering black box

Guideline: Start with the domains
Although the sub activities of model engineering can de done in parallel, it is probably efficient to start with he domain model(s). During domain model engineering elements will typically be "pushed out" into contexts and features.

Guideline: Describe a view with a story
A view description is a story that talks the reader through the view. It should say something about all the elements that are visible in the view.

Guideline: Ensure commitment of stakeholders
Make sure stakeholders, and especially domain experts are “on board”. They spend time and share their costly knowledge. They must see the model as the representation of their language and knowledge.

Guideline: The definition of a specification space should help to position elements

A specification space definition should help to decide if a specification element belongs to that specification space. The definition contains a purpose and a demarcation of concepts that are in scope and concepts that are out of scope.

Postcondition: Attributes have a type
All elements in an attribute structure are either a substructure with at least one element, or are a reference to a class, i.e., the type of the attribute.

Postcondition: Classifier types of a generalization must match
The metamodel type of the referred classifier in a generalization must be the same as the type of the referring classifier in the case they are declared in the same specification space. (With classifier we mean class, domain class, activity, operation, or actor.)
If they are not declared in the same specification space, then:

- Domain class may refer to context class
- Domain activity may refer to context operation
- Feature actor may refer to context actor
- Feature actor may refer to context class
- Feature actor may refer to domain class

Postcondition: Conditions must operate within scope
All the Condition operands of a Condition may only be bound to specification elements in the specification space of its container. This is to prevent that conditions are defined in terms of elements that are not in the scope of the condition.

Postcondition: Every substructure should have at least two elements
It makes no sense to coordinate (AND, OR, XOR) over one element.

Postcondition: References and specializations may not violate the type/parent
If an element p refers to an element q, i.e., q is the type of p or p is a specialization of q, then the reference p may only change the properties (like attributes, and constraints), if those properties are compliant to q. So, a typed element must always fit the definition of its type. In logic terms: p may not be weaker than q.
This does not only hold for properties that are defined in a structure of q, but also for constraints that are defined upon q, like invariants and preconditions.

Postcondition: Unique names
All specification elements in a specification space must have a unique name.

- Context: classes, class relations, actors, and operations.
- Domain: domain classes, domain class relations, domain activities, and domain invariants.
- Features: functions, and actors.

2.6.1 Engineer context

Make a context model by defining the context structure and actor specifications, cross checking with domain models and features, and using the formalisms for value types and specifications of operations.

2.6.1.1 Make actors view

Specify the actors, their attributes, and their generalizations. Specify the events that the actors can call and react to.

2.6.1.2 Make context structure

Specify the operations and classes, and their attributes. Specify the class relations, the class relation roles, and the role connections. Specify the generalizations between classes and between operations.
Guideline: Define operators
The meaning of a generic operator might be ambiguous for a used value type (class). Ensure that such operators are defined in a context model. For example, a phone number is a number. But the meaning of "my phone number is larger than yours" is not obvious. Make sure that the meaning of the "larger" operator on phone numbers is defined explicitly.

Guideline: A class description positions the class in its context
A class definition spends one sentence on the class, and then one or more on the parents of the class and on the other associations of the class. Preferably, give an example instance of the class.

Postcondition: All value types have a default value
The default value should of course match with the datatype of the value type, which is defined by its formalism.

2.6.2 Engineer domain

Make a complete domain model by iterating over the sub activities and following the guidelines and assuring the postconditions.

Guideline: The Intention of a domain model

- A domain model clarifies what can be managed and controlled in the domain.
- A domain model defines what can happen and what can exist in the domain. “Can happen” excludes should (not) happen, does happen, is likely to happen, has always happened, how can it happen. For example, the functional specification of any system in the domain is not in the domain model; it typically belongs to one of the sytem's features.
- The domain model does not contain elements that are a result of the current way of working in the domain.
- The domain model serves as a shared lexicon. People that are active in the domain should recognize its terms and agree to their definition.
- In the case that a system is analyzed to make a domain model of the functionality domain, the domain model should not contain technologies and elements that are used to make the system work. The domain model should focus on the changes that the execution of the functionality establishes.
- In the case that a system is analyzed to make a domain model of the solution technology, the domain model should not contain information about the targeted application, or about the why the technology is suitable for the application.

Guideline: Do not freeze the domain model too soon.

Stopping the domain modeling too soon may give a false sense of clarity and stability, and may lead to unnecessary complex feature specifications. One can time box the domain engineering activity, but if discussions with domain experts still cause major changes, then it is better to continue with the domain model before applying it in another specification, e.g., a feature specification. If discussions with domain experts lead to reoccurring changes, then applying the domain model in a feature specification must be considered, in order to validate it first and get new insights for the domain model due to feature modeling. Only freeze and release the stable part, and keep the immature part open for change.

Guideline: Analyse if managing and maintaining a domain model will pay off

It costs significant time of several people to make a good domain model and to maintain it. This is time to structure and understand knowledge. It will save coding time, but it is not programming an executable. Consider if domain modeling pays off by asking the following questions:

- Are there multiple applications/systems that involve the domain model?
- Is the domain model used in multiple stages of the development process?
- Must several people understand it? Is the shared terminology essential?
- Are the developers (and others) new to the domain?

If not, one could just do context and feature modeling. Though, in those cases it could still pay off to do a little domain modeling to get the essential concepts clear and to discuss them separately from their usage in different applications. Be aware that most modeling methods, e.g., FODA, OPM, do not separate a domain model from a feature specification (in the same way that MuDForM does).

Guideline: Criterion for distinguishing a domain class

Introduce a different domain class if and only if:

- It has “different” domain activities on it then on another class, .i.e., you do something different with it.
- It has “significant” different attributes.
- It has an interesting life in the considered scope, i.e., it undergoes multiple domain activities in the considered scope. If this is not the case, then it is probably just a class in a context.

One could define domain classes with any kind of granularity. This may lead to two extremes:

- A very generic and reusable model, without enough semantics. The extreme form is a small generic model, namely something has a relation with something.
- A very detailed and large (in the number of elements) model, which leads to an unmanageable and unreadable model. The extreme form is that every object is a class.

Guideline: Criterion for specializations

Only introduce a specialization if:

- Two or more classes share the same relation to another class or action.
- Two ore more classes share attribute definitions. In this case they probably also share a (possible implicit) relation/activity

- A clear case for the above in the future of the model. (This is obviously a vaguer criterion).

Guideline: Criterion for compositions in domain models
A composition (a domain class having another domain class as an attribute type) of a whole and a part is only interesting if:

- The part is reused in other compositions.
- Several parts are instances of the same type (like your left and right eye, or the wheels of a car).
- There is a need to communicate about the part independently from the whole, i.e., the part has a life outside the composition.

It is often said that a domain models should resemble the real-world domain. But this does not help in making a useful model. Especially physical decompositions of a real-world object may not be needed in a model, because it may lead to unnecessary complex structures, i.e., not normalized structures.

Postcondition: Activity attributes refer to classes outside the domain
Attributes of an activity, activity role, or involvement, may not refer to a domain class from their own domain. In those cases, it would not be an Attribute, but an Involvement (of a domain class).

Postcondition: Activities must have at least one domain class involved.
Each domain activity must have at least one role, and that role must be an involvement of at least one domain class.

Postcondition: Life dependencies are set in the instantiating action
The parents that are specified in the life dependencies of a domain class, must have involvements in roles of the instantiating activities of that domain class, or must be types of attributes of the instantiating activities of that domain class.

Postcondition: No derived information
A domain model may not have derived information in the elements. For example, no derived attributes, relations, or classes. This implies that the domain model is in the third normal form.

2.6.2.1 Make object lifecycle

Define the object lifecycle of a domain class, in which involvements of the domain class in activity roles are placed in the OLC, and become an OLC step.
Guideline: Split up a non-atomic domain activity
If a domain activity is not atomic, i.e., the domain class can undergo other activities during the activity, then introduce an explicit begin-activity, and end-activity.
If the activity can be active multiple times for the same object at the same time, then introduce a (weak) domain class to identify an instance of the non-atomic activity. The latter is called normalization.

Guideline: An object can leave a role
A role class should have at least one reverse transformation activity, i.e., an activity which cause the object to exit its role. This is just a guideline, because it can be the case that once a role is entered, the object always keeps it.

Guideline: Split non-atomic activities
Determine for an activity (verb) if it is non-atomic, i.e., it is a composition of other activities, or if just other activities can happen during the activity. If it is non-atomic, then split it into sub-activities; at least a begin and end moment. Ask if there are specific verbs that indicate the beginning and ending of an activity. if not, then just use "begin/start" <activity> and "end/stop" <activity> as names.

Postcondition: An OLC has steps for all involvements.
If a domain class has an OLC, then each of its involvements are at least referred to once by an OLC step.

Postcondition: An OLC must describe a life
Each Object lifecycle must have at least two actions that follow each other. Otherwise, the objects of that class don't have a life, i.e., don't have changeable state.

Postcondition: Each domain class must have at least one instantiating domain activity
A domain class should at least have one involvement in an instantiating activity role. That involvement should be the referred item of the first step in the object lifecycle. There can be more instantiating involvements for a domain class. In that case, the OLC starts with a selection between those involvements.

Postcondition: An OLC includes the OLC of abstract parents and abstract children
If an abstract class that has one or more concrete parent classes (such an abstract class is called role class), then each of the parent classes must specify how the role fits into that parent class. This means that the object lifecycle view of the parent class must clarify how it incorporates the object lifecycle of the role class.

Postcondition: Only proper involvements are the type of an OLC step
An Object Lifecycle may only contain references to Involvements of the Domain class of the Object Lifecycle, or involvements of abstract classes that are a superclass or sub class of the domain class.

2.6.2.2 Make interaction view

Define the domain activities, their roles, and their involvements. Define the generalizations between domain activities.
Guideline: Define a domain activity
An activity definition contains the involved classes and the roles they have in the activity. Preferably an example instance is given.

Guideline: Define a domain class
A domain class definition spends one sentence on the class and then one or more on the parents of the class, and on the other associations of the class. Preferably an example instance is given.

Guideline: Use an abstract class for reoccurring involvements
If a group of domain classes is referred to from multiple activity roles (from the same or different activities, then introduce an abstract domain class. Make a generalization from each of the domain classes in the group to the introduced abstract class.

Postcondition: The roles of a domain activity must have a unique name within the scope of that activity
Default names are:

- <No name> or “d.o.” to indicate the direct object of the verb that the activity denotes.
- “w.r.i.” for “which results in”. This is often used when an activity is objectified into a domain class.
- “subj” for “subject” to indicate the grammatical subject of the verb that the activity denotes.
- <preposition> in the sentence to indicate an indirect (prepositional) object.

Postcondition: A class without activities is not a domain class
Each domain class (including abstract domain classes) must have at least one action in which it has an involvement.

Postcondition: Objects enter a role via an action
An abstract child class (=role class) must be associated to at least one activity that transforms an object into that role. Such an activity is called a transformation activity of that role class. This may be the instantiating activity of the domain class to which the role class belongs.

Postcondition: Objects from the domain must be instantiated in the domain
Each domain class must have at least one instantiating domain activity that is declared in the same domain.

Postcondition: Activities change only objects from the same domain
A domain activity may only change the status of objects of domain classes that are in the same domain as the activity. If an activity involves domain classes from different domains, then an extra domain must be introduced, which contains the activity, to ensure than the OLCs of those involved classes have the activity in their scope.

2.6.2.3 Make activity model

Define the order of operations in the activity model. Operations can be a local operation defined with some formalism, or invocations of operations defined in a context.
Guideline: Ensure the realizability of an activity
Sometimes activity models are skipped. Often this is not a problem for the rest of the specification, because the activity model is a structure of a single activity. But when implementing the activity in software, one might discover that it cannot be implemented with the available activity attributes, or object attributes. In this case making the activity model will make clear what attributes or domain classes are missing from the scope of the activity.

Guideline: Activity attributes lead to changes in domain class attributes

All input attributes should be used in an operation in the activity model. Activity operations change either local activity attributes, object attributes, or are a domain operation (like creating or deleting a link between two objects).

Postcondition: Activities attributes are not output attributes.
Each activity attribute is either an input attribute or is an internal local activity attribute. An activity attribute is not an output attribute in the sense that the activity sets its value.

Postcondition: An activity model may only refer to related objects
An activity model may only change attributes of involved objects, and it may only refer to attributes or inspect attributes of the action itself, of involved objects, or of parents or those objects. This means that all the actual parameters of the actual parameter structure of the Operation invocations in the Activity model, may only be parameterized by such attributes (and of its roles and involvements).
The activity model may also refer to the history of the involved objects, i.e., refer to a previous object state past. Of course, it cannot change the past state of an object.

2.6.2.4 Make class structure

Define the class relations, generalizations, and life dependencies between domain classes.
Guideline: Names of life dependency relations
By default, life dependency relations are named the same as the role in which the parent is involved in the instantiating action. In the case that role is "direct object", the life dependency relation is named "of".

Guideline: Domain class relations are deleted via a domain activity
All domain class relations (except compositions) should refer to at least one action in which the instance of that association is broken (via a "delete link" operation in the activity model). This is a guideline and not a rule, because it is not necessary that a link can be deleted within the domain. But typically, all things that can be created in a domain, can also be eliminated in that domain.

Postcondition: Life dependency starts at instantiation
All life dependencies of a domain class must be linked in the instantiating activity. The parents of domain class, as defined in the life dependencies, must be involved in the instantiating activity of the class.
qqq check if this is covered in the metamodel qqq

Postcondition: Domain class relations are instantiated via a domain activity
All class relations between domain classes must refer to at least one domain activity in which the relation is instantiated. This activity must have involvements for all the domain classes that are in the relation. In the case that one class is associated to two or more roles of the activity, the association must refer to the roles that result in the link of two objects. That activity must have a domain operation of the type “Link objects” in its activity model.

Postcondition: Domain class relations are instantiated in the domain
All domain class relations between domain classes (including compositions) must be created in at least one activity in which those classes are involved or must be part of a composition and the composition has an instantiating activity.

Postcondition: A domain object is an instance of precisely one concrete domain class
An object cannot be instance of just an abstract class. Each abstract domain class must have at least one non-abstract subclass or superclass in the same domain.

2.6.2.5 Make attribute view

Define the attributes of domain activities and domain classes.
Guideline: Each domain activity should have input attributes
Activities most likely change objects depending on properties of the activity itself. This is just a guideline, because participating in an action with another object, without explicit attribute changes, could also be a state change.

Guideline: Domain classes have attributes
Each domain class should have at least one attribute. If it doesn’t have an attribute it might be a domain class relation.

Postcondition: A strong domain class must have identifying attributes

A domain class is strong if its objects do not depend on the existence of another object (from another domain class in the same domain). As a result, a strong domain class must have identifying attributes, because an object from a strong class cannot be identified via other domain objects, because it has no parents in the domain.

Postcondition: Attribute types are classes from a context
Referred classes of all attributes must be an element of a context. The classes must belong to the same domain in case it is a composition between domain classes. Otherwise, it is a class in a context.

Postcondition: All object attributes get a value in an action
All domain class attributes must have at least one operation in at least one activity model that sets its value. If an attribute does not explicitly get a value in the instantiating activity of the class, then it has a default value, possibly defined by the attribute, but at least by its value type.

2.6.2.6 Specify domain constraints

Add invariants to domain classes, domain class relations and attributes. This step is typically done at the end of domain engineering.
Guideline: Only use invariants if other concepts cannot cover it
Use the modeling concepts (other than the constraints) as intended, and only apply an invariant if another modeling concept cannot or should not be used to specify something. For example, do not use a constraint to restrict the possible order of actions on an object, when it can be modeled in the object lifecycle. Or, do not use a constraint to separate a path from other paths in the object lifecycle of a domain class, if that domain class should be split in two domain classes.

Guideline: Do not skip the invariants
The modeling language part that is formed by the metamodel structure, i.e., the modeling concepts and their relations, does not cover every possibly relevant aspect of a domain. It is very likely that you have to model some domain properties in the form of a domain invariant.

2.6.3 Engineer feature

A feature is engineered by working in parallel on the feature structure, function lifecycles, and function signatures.

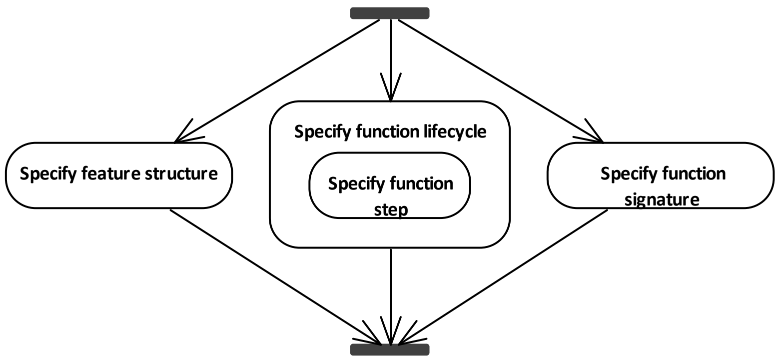


Figure 1: Engineer feature

Guideline: Find functions via reoccurring behavior
Like normal functional decomposition used in programming or a function-oriented modeling method, a functional decomposition is handy when several higher-level functions embody the same sub-behavior. Such sub-behavior may be captured in a function.

Guideline: Define a function for behavior that will be assigned to an actor.
Define functions for units of behavior that will be assigned to and performed by an actor.

Guideline: Check if atomic object manipulations are domain activities
During feature specification, one may find functions that manipulate a single object. Take into consideration if such a function should be defined as a domain activity. If so, it should be positioned into the domain model. It might be a domain activity if it is about what can happen and not about what must happen or how it happens, and if it is independent from any actor that performs the function.

Guideline: Find functions from system specifications
System functions can be found from three perspectives:

- System use cases indicate a system function, and steps in the use case scenario indicate lower-level functions.
- Sub-systems in a system architecture indicate often a high-level function.
- A decomposition of the system requirements may indicate functions and sub functions.
- Chapters or aspects in a requirements document indicate features or high-level functions.

2.6.3.1 Specify feature structure

During this step, the behavioral composition of the feature is managed. This means specifying the decomposition of the feature into functions, and possibly of each function into sub functions. Additionally, the use of behavioral elements (operations, activities, functions) from outside the feature is specified. The resulting tree structure has the feature as a root.

Guideline: Find functions via reoccurring behavior

Like normal functional decomposition used in programming or a function-oriented modeling method, a functional decomposition is handy when several higher-level functions contain the same sub-behavior. This common sub-behavior may be captured in a function.

Guideline: Define a function for coherent behavior that will be assigned to one actor

Define functions for units of behavior, often called tasks, that will be assigned to and performed by one actor.

Guideline: Find functions from system specifications

System functions can be found from several perspectives:

- System use cases indicate a system function, and steps in the use case scenario indicate lower-level functions.
- Sub-systems in a system architecture often indicate a high-level function.
- A decomposition of the system requirements may indicate functions and sub functions.
- Chapters or aspects in a requirements document indicate features or high-level functions,

Guideline: Check the domain models for unused activities

Go through the domain activities of the relevant domain models and check if they should be used in the feature. It is not that all activities must be used, because a feature might only cover a domain partially. But if activities are not used at all, they might be forgotten in the feature model, or might not be a domain activity at all.

Guideline: Check if atomic object manipulations are domain activities

During feature specification, one may find functions that manipulate a single object. Take into consideration if such a function should be defined as a domain activity. If so, it should be positioned into the domain model. It might be a domain activity if it is about what can happen and not about what must happen or how it happens, and if it is independent from the feature, and any actor that performs the function.

2.6.3.2 Specify function lifecycle

During this step, the control flow of each function is specified. This means describing the order of the steps in the function. The function steps refer to sub-behaviors of the function. The sub-behaviors are references to domain activities, operations, or functions of a specification space that the function's feature depends on. A lifecycle view typically has arrows for the control flow, as well as for specifying which function attributes participate in each function step. When these arrows cross each other too much, the view may get messy and the lifecycle view could be split into two views: 1) a view just the order of the steps and without any function attributes related to them, i.e., just the control flow, and 2) a view in which is specified which function attributes are participating in which step.

Another option is to use a textual notation for the function step, like with a regular programming language, where a function call contains the link between variables and the actual parameters of the function call.

Guideline: Check for temporal words in the input text

Temporal words in the input text are a hint about the passage of time or the position of an event in time, usually indicated with a transitional preposition (e.g., after, before, during, until). Other temporal words can also be a hint, e.g., now, eventually, suddenly, initially.

Guideline: Go with the flow

Begin with the major function steps:

- The activities and functions that must be executed in the function.
- Their temporal ordering: sequence, selection, parallel, iteration.

Initially skip:

- Constraints of steps (enter criteria and exit criteria)
- Decision logic of coordinators (guards of selections, forks, iterators)
- Decision logic of step participants, i.e., constraints on the attributes that are participating in a function steps.

Postcondition: Check if all function events are occurring as a step in a function lifecycle
All the function sub-behaviors should occur at least once as a step in the function lifecycle. It means that the type of the function step is the same as the type of the function sub-behavior.

Postcondition: Function flow consistent with domain model
For all actions in a function lifecycle, i.e., function steps that are an instance of a domain activity:

- The objects linked to the action, must be an instance of an involved domain class.
- The input attributes of the action must be parameterized by a function attribute.
- The function flow must not violate the OLC of an involved object.

Specify function step

During this modeling step, each function step is related to the context with respect to the objects (parameters) that play a role in the step. The following aspects have to be specified:

- The function attributes, which must belong to the same function or a container function, have to be allocated to (the actual parameters of) the function steps.
- The preconditions for this step, i.e., the constraints on the step participants. A condition is typically expressed in a logic language and may only use terms that are elements within the scope of the function. (Step preconditions are also called enter conditions.)
- The postconditions for this step, i.e., the conditions that have to be true for this step to end. (Step postconditions are also called exit conditions.)

A specified function lifecycle must be consistent with the domains that the function uses, which means that for function steps that are an instance of a domain activity, holds that:

- The objects allocated to the action, are an instance of a domain class that is involved in the domain activity.
- Function attributes are allocated to each input attribute of the action, and their types match.
- The function lifecycle does not violate the object lifecycle of an involved object.

Guideline: Default allocation
Often one domain class will only occur just once as the type of an attribute in a function. That means that such an attribute is probably the attribute that will be allocated to all function step participants that have that domain class as type. In practice, this guideline can imply that those step participants don't need to be allocated manually.

Guideline: Check the used activities with the domain model
For each domain activity that is used (invoked) in a function step, immediately cross-check the domain activity with the domain model. Is the domain activity also present in the interaction view? Does it have the same objects associated with it (using the same prepositions)?
Postpone other cross checks with the domain model until the function lifecycle is completed.
By doing the domain model check immediately, the domain model is validated as well, and it is assured that all the domain activities usages conform to the domain model.

2.6.3.3 Specify function signature

A function signature describes the interface of each function in terms of attributes and events, and frames the behavior of the function. Attributes are typed by a (domain) class, and events are typed by a behavioral element.

All function signatures can be put in a single diagram, or a separate diagram is created for important and complex functions. Each attribute can be an input, output, or local attribute. Local attributes, which are used to pass on data between function steps, could be omitted from the signatures, because they are not visible outside the function. But then, a different view would have be created for the declaration of the local attributes. So normally, we put them in the same view.

The function signatures also specify the preconditions, and invariants that hold for the function attributes, i.e., things that must be true in order to guarantee the proper outcome of the function. It is possible to specify postconditions, but this is superfluous because MuDForM follows a whitebox perspective on function specifications. Though, a postcondition could help to guide the design of the function lifecycle.
Guideline: Begin and end with function signature

Make a preliminary signature of the function before specifying the function lifecycle, but do not spend too much time on it. Finalize the signature after the function body is complete (lifecycle complete, constraints & decisions complete).
Check for any “free attribute”, i.e., an attribute that is not a property of an object that participates in one of the function steps, nor is computed from such properties. A free attribute can only come from the outside and must be an input attribute of the function.

2.6.4 Manage specification space dependencies

Define the dependencies between the different specification spaces. Define a dependency from P to Q (the dependency structure of P has a reference to Q) if P has elements that refer to elements of Q.
Guideline: Only define dependencies that are used
Do not define a dependency from specification space P to specification space Q, if nowhere in P a reference to an element of Q is set.

Postcondition: No cyclic dependencies
The graph of all dependencies between specification spaces may not contain cycles. If a cycle appears, it is most likely that a specification space must be split, because it contains parts that differ in abstraction or aggregation level.

Postcondition: Only refer to elements of specification spaces that you depend on
Specification elements in the specification declarations of the specification space may only refer to specification elements in the specification spaces that this specification space is dependent on.
If an element in specification space P refers to an element from specification space Q, then P must be dependent on Q. If the dependency is not intended, then the element form Q may not be used in P.

3 Discovery domain

The Discovery domain contains the concepts that are used to gather input (text) and perform a grammatical analysis in order to acquire an initial MuDForM compliant model. It also contains concepts to record analysis decisions.

3.1 From text-to-model (interaction view) diagram

This diagram presents the activities and related classes that are needed to follow the method flow from the steps Scoping to text-to-model transformation. A set of source sentences is Selected from a Knowledge source. Phrases are Extracted from other Phrases, which can be Source sentences. Phrases can be Extracted or Rewritten according to one of the Phrase types.
A Phrase can be Parsed into Phrase elements, in which each Phrase element is typed with a Term. If a Term did not exist yet, it is first Detected in the scope of the Knowledge source. Later, due to new insights, a Phrase element can be (re)Typed with another Term, typically, because of a detected homonym or synonym. Terms can also be Renamed. A new Term can be Split off from an existing Term, mostly when an existing Term has two different meanings and a new Term is needed to separate two meanings. During analysis, it is also possible to add new Analysis items, which can be a Term or Phrase. One Analysis Items can be Merged into another Analysis Item.
To go from text to model, Terms will be classified with one or more model term types, and all (relevant) Analysis items will be located in a MuDForM specification (context, domain, or feature).

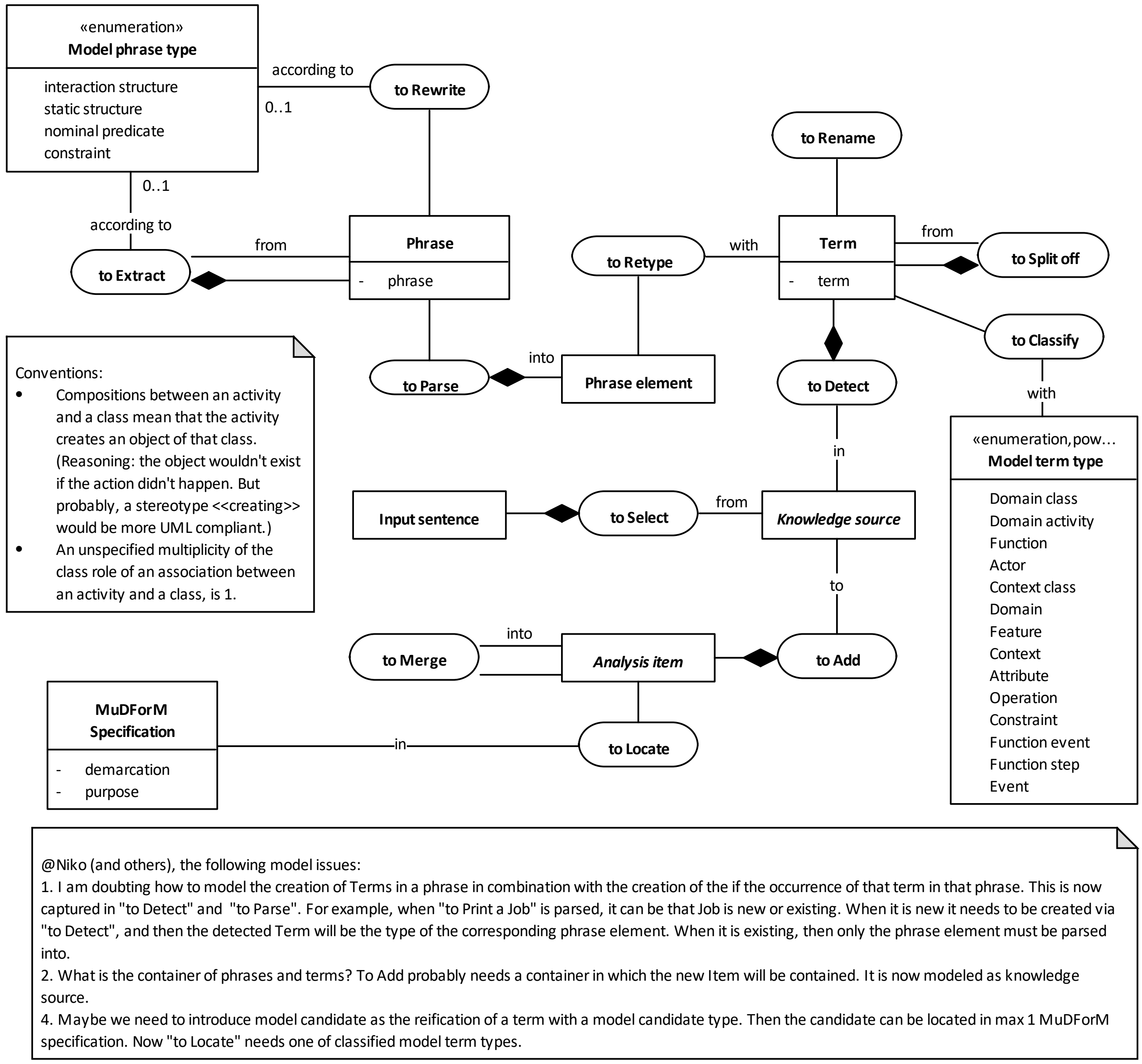


Figure 1: From text-to-model (interaction view)

3.2 From text to model (static view) diagram

The phase of grammatical analysis starts with a text source with relevant knowledge. In practice, this can be a publication or an interview with a domain expert. The Knowledge text contains Source sentences. After that, phrases are extracted from the Source sentences. An alternative approach is not to have an initial text, but to acquire knowledge more interactively. This could take place in a brainstorming session with a group domain experts. In such a session, one could already format the sentences according to the phrase types.

Due to discussions with the domain experts or other knowledgeable people, Phrases may be discarded and new Phrases may be introduced. After a set of phrases is obtained, Model candidates are identified. Per candidate a first indication of its type is determined. Phrases and Model candidates are analysis items.

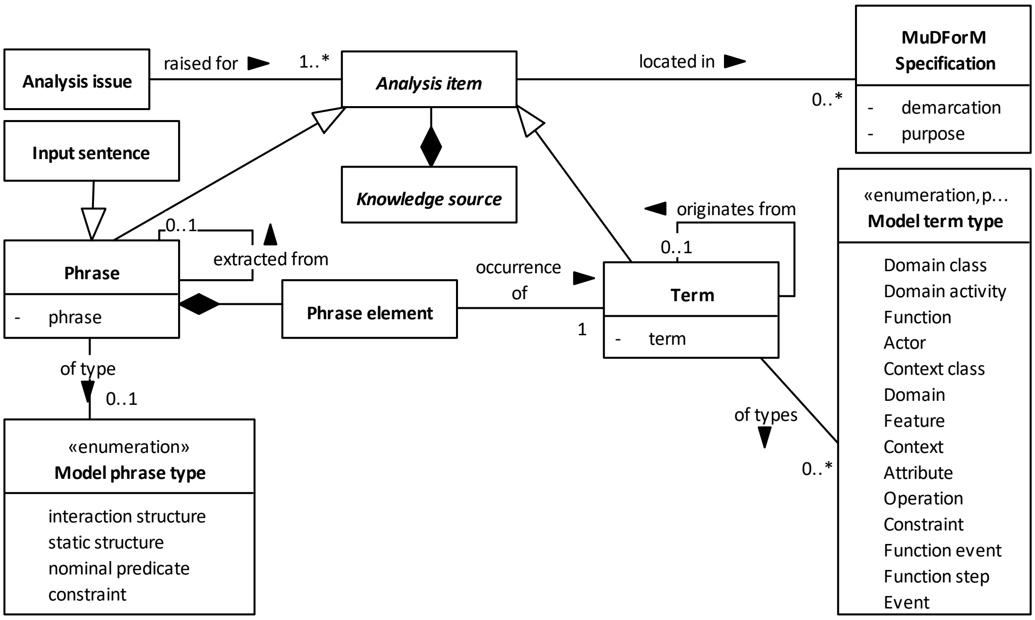


Figure 2: From text to model (static view)

3.3 Knowledge containers (static view) diagram

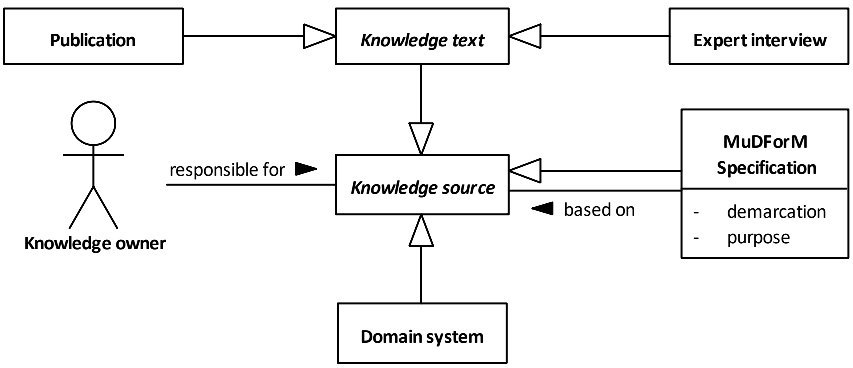


Figure 3: Knowledge containers (static view)

3.4 Analysis item (interaction view) diagram

Analysis issues can be Raised for Analysis items. Analysis actions act upon analysis items and can be based on Analysis guidelines. Analysis actions can be performed to solve zero or more Analysis issues. Analysis issues can be Closed.

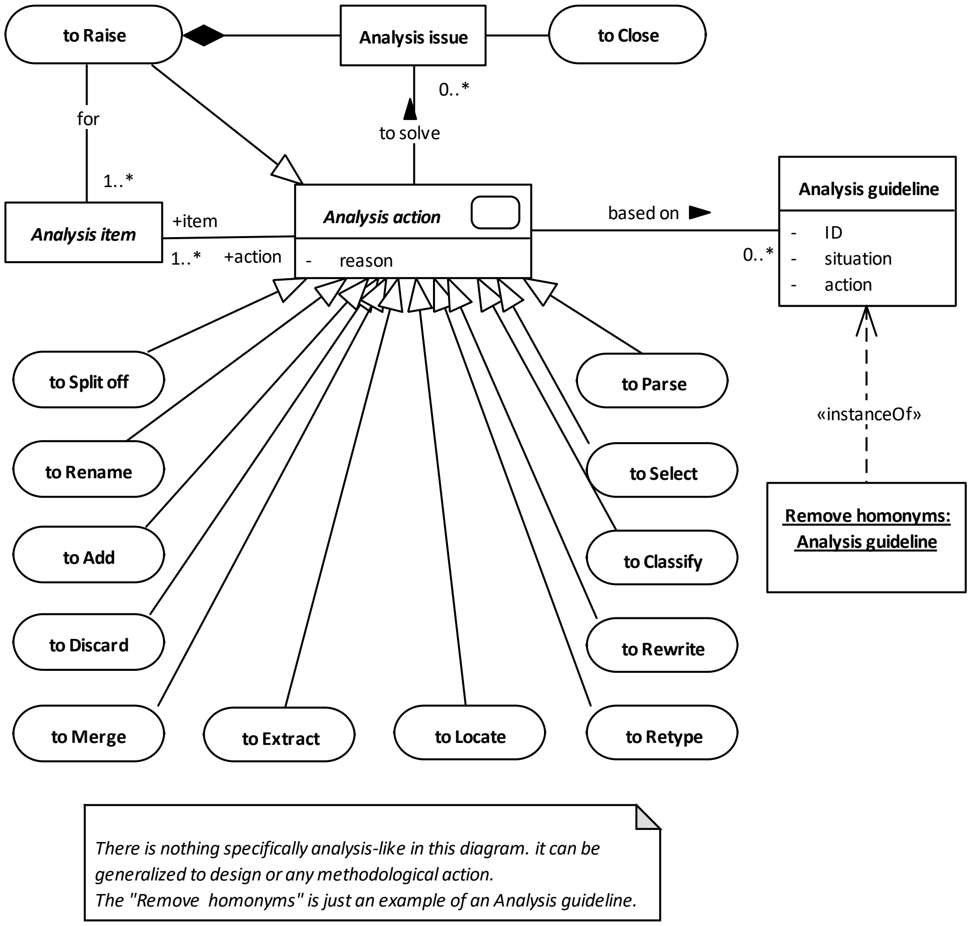


Figure 4: Analysis item (interaction view)

Name	Definition
Knowledge owner	Person or organizational unit that is responsible for the contents of one or more knowledge sources.
Analysis issue	Issue raised for one or more Analysis items.
Domain system	(Software) system that applies and exposes relevant knowledge about a domain or feature. This typically is visible by the use of domain terms in the design, (user) interface, code, or database of the application.
Expert interview	Documentation of the interview with an expert. Typically, the interviewed expert is the Knowledge owner of the interview.
Input sentence	Sentence that is contained in a source text and selected as input for the grammatical analysis. Most likely, an input sentence is not formatted according to one of the phrase types.

Knowledge source	A source with relevant knowledge. A knowledge source can have one or more actors (organization or person) that are responsible for the knowledge that is contained in the source.
Knowledge text	A piece of text with relevant knowledge, which can be used for grammatical analysis.
Model phrase type	Predefined format for a phrase which can be transformed into a piece of model. **attribute:** interaction structure Phrase expressing a change to one or more objects, and or subject. The format is: Subject **TO** verb object (preposition/indirect object)* or **TO** verb object (preposition/indirect object)* **Interaction structures** will end up in the model as relations between acclivities/operations/functions and classes. They define which objects can participate in which actions. Objects change state when participating in an action. All domain classes have an object lifecycle that expresses the order in which its objects may participate in specific actions. **attribute:** static structure Phrase that expresses a static relation. The format is: noun **HAS** noun OR verb **HAS** noun OR verb **HAS** verb Static structures typically end up in the model as attributes. **attribute:** nominal predicate Phrase that expresses a property or type of a term. The format is: noun "IS" adjective OR verb "IS" adverb OR noun "ISA" noun OR verb "ISA" verb Nominal predicates typically end up in the model as specializations or as possible values for the type of an attribute. An example of the latter is that the nominal predicate "the car is blue" leads to an attribute "color" of the class "car", and that "blue is a possible value for "color". **attribute:** constraint Phrase that expresses some condition, typically written with operators of propositional or predicate logic, like a "if A then B", or a "for all A: B". Also temporal constraints are possible like "after- A then B"or before X seconds after B".
Model term type	Modeling concepts that are used in a MuDForM specification., MuDForM offers different types of specification elements. The type of specification space, i.e., domain, feature, or context, determines which types of specification elements are allowed, and what is their semantics. The three different specification spaces all have concepts to specify state, concepts to specify change, and concepts to specify the relation between state and change. Besides the concepts that are specific for a type of specification space, almost all specification elements can have **attributes** and **specializations**, and have **constraints** attached to them. We now list the specification elements that can be the input of the model engineering step, and thus the output of the grammatical and text-to-model transformation. Each of the specification elements occurs as a possible phrase type or a possible term type in the grammatical analysis. **Domain** models contain the following types of concepts:

	Domain activities define what can happen in a domain. They are elements for the creation of composite behavioral specifications, e.g., processes, scenarios, and system functions. Instances of domain activities are actions, which represent atomic (state) changes in the domain. **Domain classes** define what objects can exist in a domain. They are elements for the creation of compositions and serves as the types of function attributes. Instances of domain classes are objects with an interesting life. **Attributes** define properties of Domain Classes or Domain Activities. Each attribute refers to a class form a context of the domain. **Feature** models can contain the following concepts: **Functions** are behavior elements. They specify what must happen when the function is active. %A feature is a function, \ie the top-level function of a feature model. A function can use other behavioral elements, which can be other functions, domain activities, and operations. The usage of a behavioral element in a function structure is called a **Function event**}. Some function events are not performed by the function, but are interactions with behavior outside the function. Such events are generated by the function or the function can react to it. Typically, one tree view is created with all the sub-behaviors of all functions of the feature. It has the feature as the root and is called the feature structure. Function lifecycles describe the control flow of the function's behavior in a process algebra style, i.e., in terms of sequence, selection, parallelism, and iterations of **Function steps**, which are typed by a function event. **Context** models contain specification elements that do not belong to the scopes of the targeted domains and features, but that are needed to specify the elements in those domains and features. %The correctness of a context model is often not the responsibility of the experts that are responsible for the domains and features. There are typically two kinds of context elements: **Context classes** represent either physical quantities like length, time, or speed, or concepts whose definition is not determined by the owners of the domains and features of interest, like Name, Address, Phone number. **Operations** to inspect and change instances of context classes, like an operation to determine the postal code of an address, or converting inches to centimeters, or just to divided distances by time. Concepts related to the interaction of features, such as external **actors** or **events**. **attribute:** Domain class **attribute:** Domain activity **attribute:** Function **attribute:** Actor **attribute:** Context class **attribute:** Domain **attribute:** Feature **attribute:** Context **attribute:** Attribute **attribute:** Operation **attribute:** Constraint **attribute:** Function event **attribute:** Function step

	attribute: Event
MuDForM Specification	A MuDForM compliant specification. The scope of a specification is addressed in the demarcation and the purpose. The demarcation lists what are the targeted concepts in the specification, and what concepts are out of scope. The purpose explains what the targeted application of the specification is. A MuDForM specification itself can also serve as a knowledge source. **attribute:** demarcation Demarcation is done from two perspectives: • Intrinsic: a set of terms that are expected to be in scope, or to be out scope. • Application: a list a set of uses cases, features, functions that the domain specification should be usable for. **attribute:** purpose What is the purpose of the specification? What is it used for?
Phrase	Phrase in natural language or according to a Phrase type. A Phrase is an Analysis item. A Phrase can be rewritten in one or more other Phrases. **attribute:** phrase
Phrase element	The occurrence of a term in a phrase.
Publication	A (part of) a document, or document set, that contains text. Typically, one of the authors is the knowledge owner of the publication. But, it can also be someone who is acceptably knowledgeable about it.
Term	A single word that is used in the analyzed text. This can be a noun (phrase), verb, proper name, adjective, adverb. A Term can be instantiated when parsing a phrase, or introduced in another analysis action. In the latter case, an introduced term can be based on an original term, in which case the originates-from association has an instantiated link. A term can be typed with Model candidate types, which makes the term a candidate for the targeted model. **attribute:** term
Analysis guideline	Guideline for analysis actions. **attribute:** ID **attribute:** situation A description of the situation in which the guideline is applicable. **attribute:** action A description of the analysis (or design) action that should be done on the involved items.
Analysis item	Item that is the subject of grammatical analysis. An Analysis item can undergo Analysis actions. An item can be located in a MuDForM specification, when it has a proper type, i.e., it has a phrase type of a Term type.

Remove homonyms	When one term occurs has different meanings in different phrases, a new term should be split off and get a different name.
to Add	To introduce a new Analysis Item. This might happen because of new insights of the domain expert, possibly triggered by an open issue.
to Classify	To assign a Model candidate type to a Term. A Term can have more types.
to Close	To state that an issue is solved.
to Detect	To find a new Term in the analyzed Knowledge Source.
to Discard	To state that an Item is not of interest anymore.
to Extract	The state a new phrase based on an existing phrase that has more phrases in it. The extracted phrase is part of the same knowledge source that the original phrase is part of.
to Locate	To position an Analysis item in a MudForM specification. This means that you determine in which domain, context, or feature the item will be put. Only Terms that are classified with at least one term type can be located. Only phrases that are formatted according to a (model) phrase type can be modeled.
to Merge	To unite two Analysis items into one. Typically it gets the name of one of the merged items, for example when two Terms are considered to be synonyms, or when two active phrases are considered the same, but they do not have all the same Terms as Phrase elements.
to Parse	to Identify the terms in a phrase, which results in one or more phrase elements that have
to Raise	To open an issue for one or more analysis items.
to Rename	To rewrite the term of an analysis item. Term.term gets a new value.
to Retype	To replace the existing term of a phrase element with another term.
to Rewrite	To rewrite a phrase such that it matches one of the Phrase types.

to Select	To indicate that a sentence form a knowledge source will be analyzed.
to Split off	To create a new term from an existing term, most likely because the existing term was a homonym. Typically, this is followed by retyping some of the phrase elements from the existing term to the new term. New term.origninates from.Term := from.Term New term.term is given a value
Analysis action	Activity that is the placeholder for all actions that change the set of of analysis items in some way. The reason explains why the action is done. An analysis decision might be taken based on a guideline and/or to address some issue. **attribute:** reason A justification for the action.

4 MuDForM modeling concepts

Modeling concepts are the concepts for defining a model. The major modeling concepts (like value type, domain class, function) are the specification elements that can be declared in a specification space. Each major modeling concept is defined by a set of cognitive aspects that are modeled via one of the modeling constructs. The sub concepts are the ones that are created in a structure of a major concept (like attribute, involvement, function event).

4.1 Specification Space diagram

A specification space contains declarations, which is a static structure of specification elements. A Specification space also contains dependencies, which is a static structure of references to other specification spaces. The specification elements in the declarations of a specification space may only refer to specification elements in specification spaces that this specification space depends on (similar to the include-construction in many programming language).
There are four types of specification spaces:

- MuDForM models contain contexts, domains, and features. A MuDForM model forms the root of a specification. It doesn't contain other elements besides specification spaces.
- Context models contain concepts that have a clear meaning without defining their internal properties. A context model typically contains two types of concepts. Firstly, physical concepts like length, time, power, speed, and their relations. Secondly, concepts from a domain that you do not want to model, but that you want to refer to. In this category you define classifiers and constraints for their identifying terms. Think of Name, Address, Phone number. You need these type of concepts to define specification elements in domains and features, but you are not interested in the life of their instances. For example, you are typically not interested how an address changes over time. Modeling concepts for the specification of a context domain: Classes, Attributes, Operations, Events, Value types, Conditions, and Class relations, Classification structures.
  Besides these, a context model may also define external actors and their interfaces.
- Domain models contain classifiers that define what lives (objects with state), called domain classes, can exist, and in which changes (actions), called domain activities, those lives may be involved. Modeling concepts for the specification of domain models: Domain classes, Object lifecycles, Attributes, Classification structures, Activities, Roles of activities, Involvements of domain classes in roles, Activity behavior specifications (precondition, and activity model, or post-condition), Domain class relations (associations between domain classes, which are not a composition).
  - Feature models which depend on one or more domain models, other features, or contexts. A feature defines what instances shall exist and what changes shall take place in the domains that the feature depends on. Modeling concepts for features: Functions, Function signatures (attributes, input events, output events), Functional composition, Function lifecycle (of functions, events, activities), and Actors.

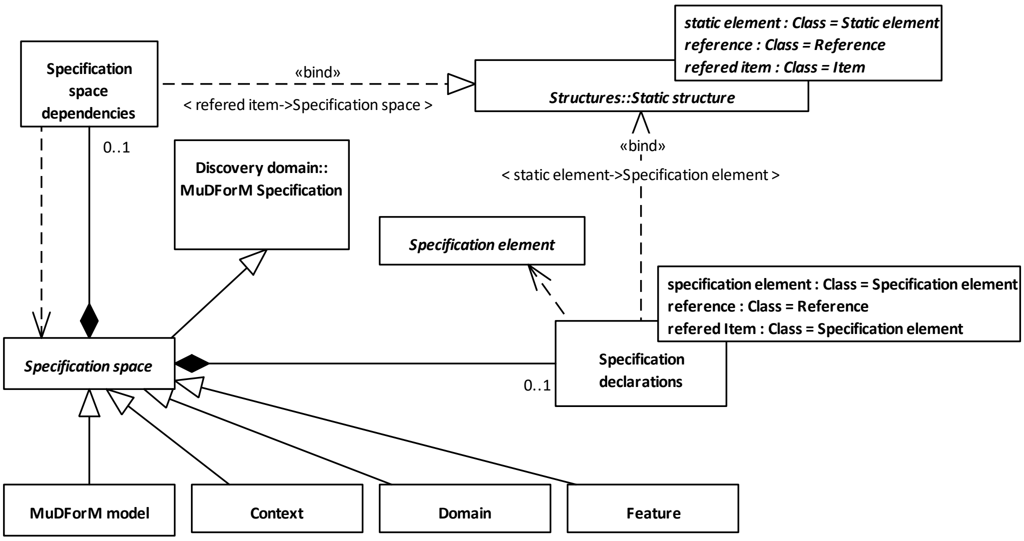


Figure 5: Specification Space

4.2 Context definition diagram

A context is a specification space in which the elements are actors, classes, value types, class relations, and operations. The elements may be referred to in the definition a specification elements of dependent specification spaces, domains and features in particular.

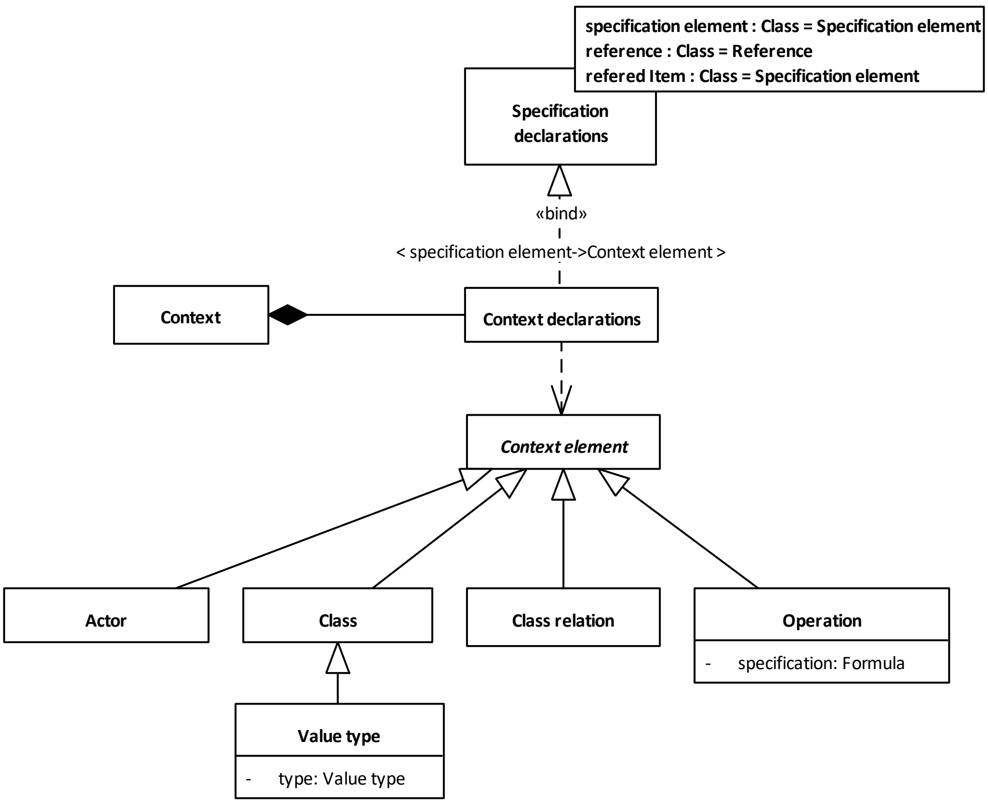


Figure 6: Context definition

4.3 Domain definition diagram

A Domain contains Domain elements, declared in the Domain declarations. Domain Class, Domain activity, and Domain class relation are Domain elements. A domain contains a dependencies specification in which the specification spaces are defined that this domain depends on.
The root domain is not contained in an any domain. Mmm, what to do for this exception. Philosophy: as long as the universe is infinite, a domain is always part of another domain. But the latter domain might just not be modeled. So here we need to take the finiteness of a model into account. This means that syntactically: the Void is the root of all domains. It is the only domain that is a domain element of its own domain elements declarations itself. (Nice example of an infinite loop). Check: does this also hold for Context and Feature.

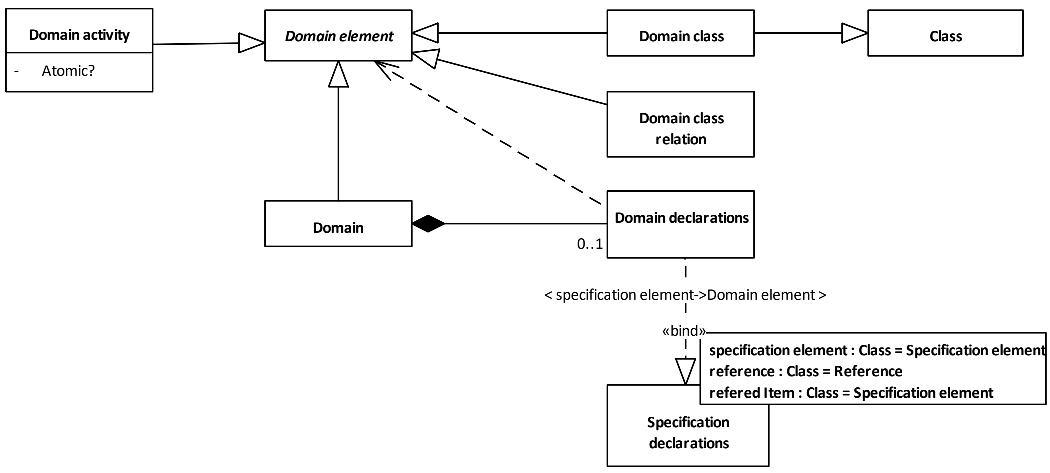


Figure 7: Domain definition

4.4 Feature Definition diagram

A feature is a specification space in which the specification elements are feature elements, i.e., functions and actors.

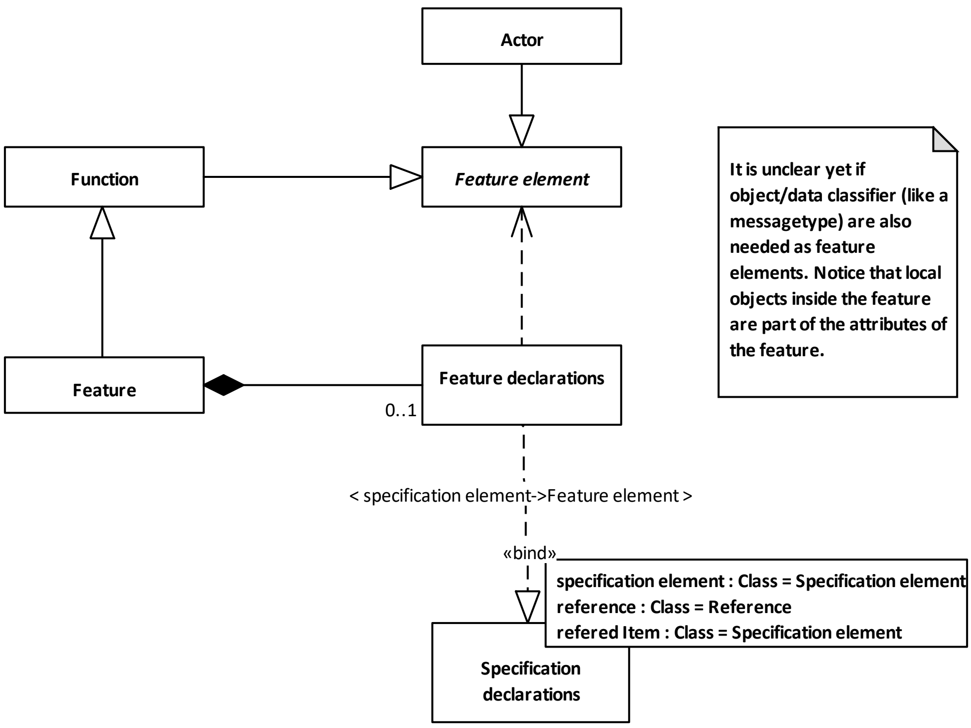


Figure 8: Feature Definition

4.5 Attributes diagram

An attribute container can have an Attribute structure. An attribute structure consists of attributes that may refer to a class. Some attributes are parameters. Only behavior elements can have parameters.

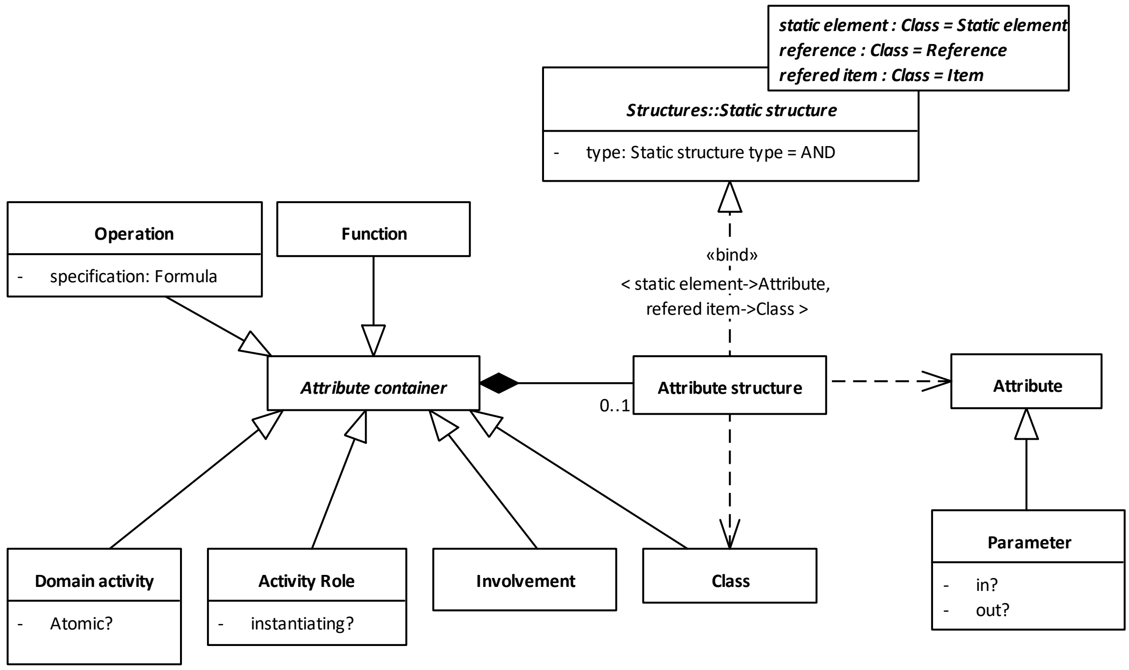


Figure 9: Attributes

4.6 Conditions diagram

Any identifiable element can have conditions. A condition is a structure where the elements are called Condition operands. A Condition operand is bound to an Identifiable Element. That Element must be part (possibly recursively) of the Identifiable element that the Condition holds for. Any Identifiable element can have invariants. Behavior elements can also have a precondition and a postcondition.

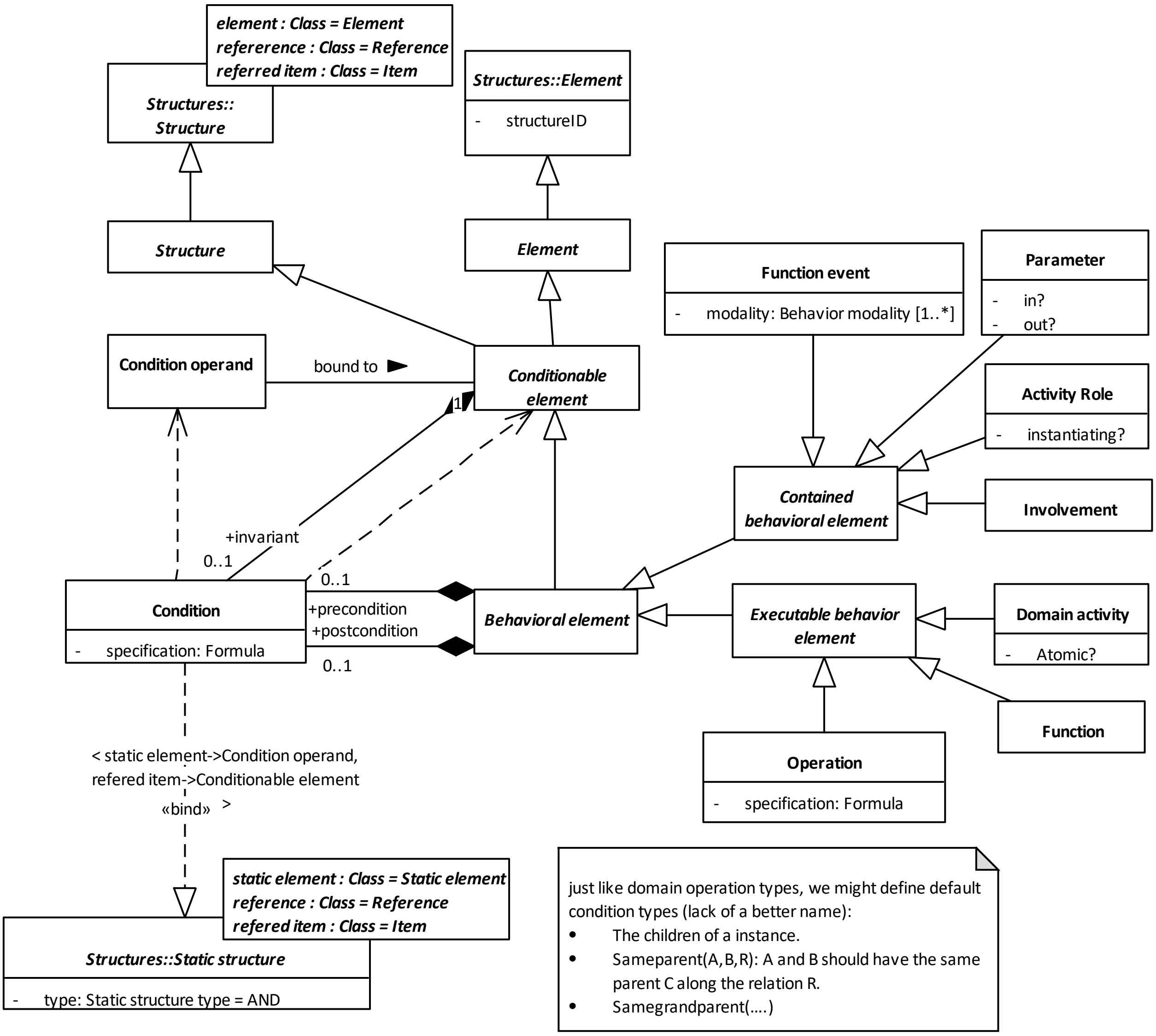


Figure 10: Conditions

4.7 Classifier structures diagram

A classifier can have a classifier structure that expresses what the super classes are of the classifier. The super classes occur as generalizations in the classifier structure. Note that, in contrary to UML and inheritance in programming languages, the concept of generalization is specified on type level, but does not imply that it is always exist on instance level. This is because the classifier structure type can be also a "selection". For example, an abstract class Thief with a classifier structure of type "selection" has generalizations towards domain classes Person and to Crow. This means that a Thief is either a Person or a Crow. This also expresses that some Persons and some Crows are Thieves (but not all Persons or Crows). If a Person is a Thief, might also vary over time.

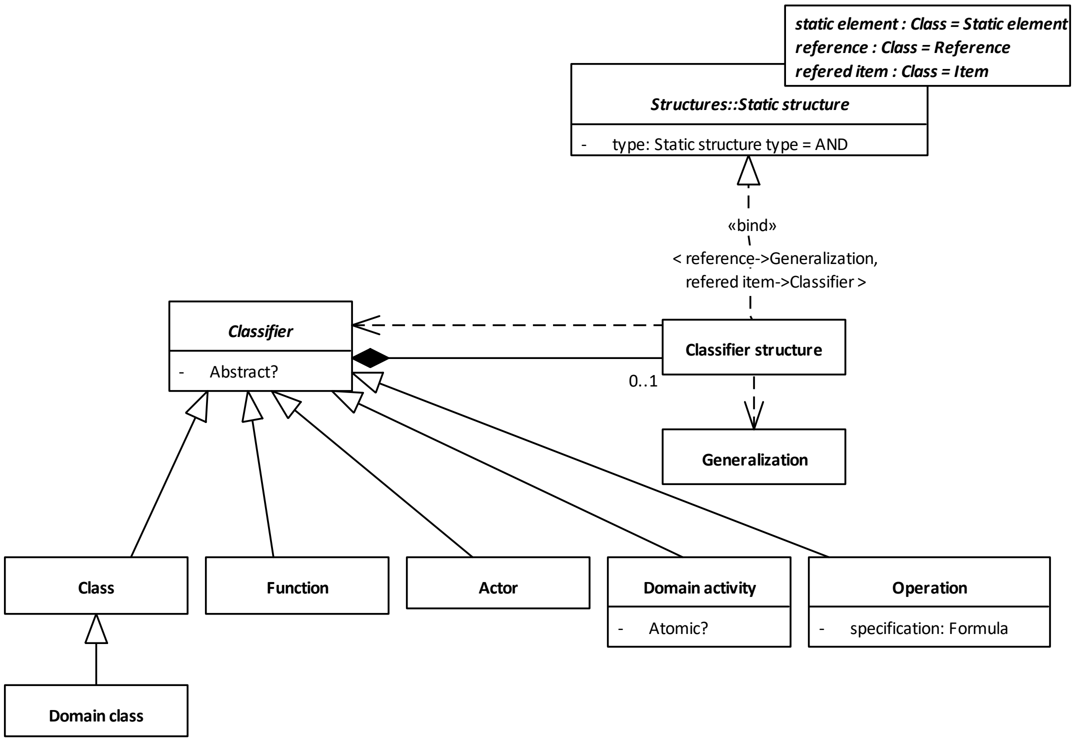


Figure 11: Classifier structures

4.8 Domain class definition diagram

A Domain class is a class of which the objects follow a defined Object lifecycle, which is a flow structure of involvements of the domain class. A Domain class can also contain a life dependency structures, which is a static structure with references to classes. Such a reference means that the instances of the domain class can not be alive without the referred objects in the life dependencies. This also means that a referred object cannot be deleted if it is a context object, or must be alive when it is a domain object.
We must consider if abstract classes have an OLC. But then it becomes an issue on how to integrate OLCs of multiple abstract classes. An idea could be to allow the role class appear as an involvement step. It could be that this way, parallel role classes or mainstream involvement steps need to be synchronized on an common involvement. (probably we need event synchronization anyway for parallel functions)
The answer involves that an activity role occurs only once as involvement in a specialization structure, e.g., eat an apple is the same role as eat a piece of fruit. This is also logical, because if it are to OLC steps, then they refer to the same involvement, i.e., the involvement of piece of fruit in eat-d.o..

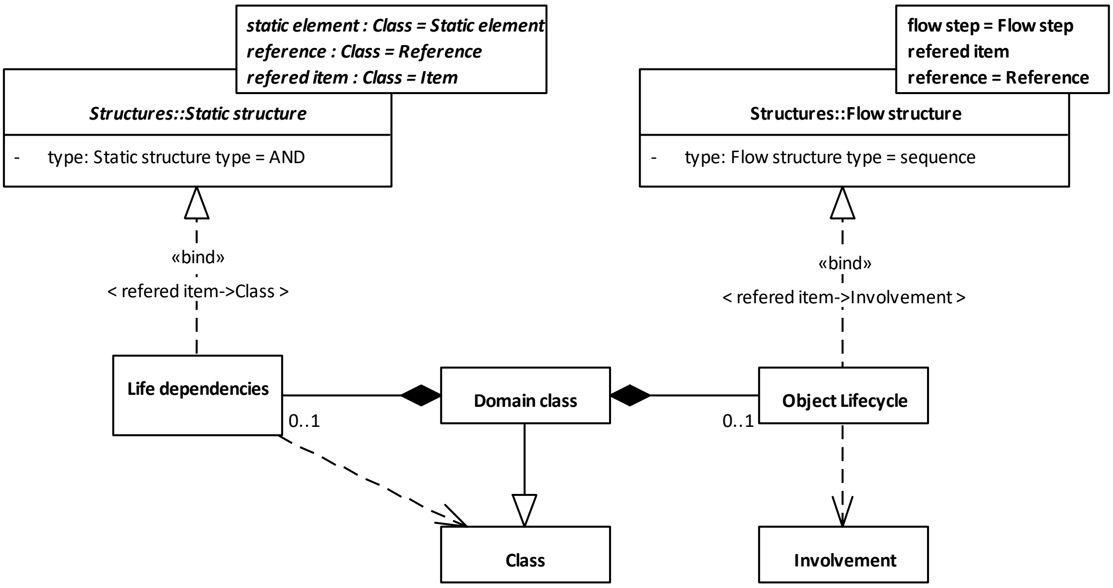


Figure 12: Domain class definition

4.9 Domain activity definition diagram

A domain activity has one or more Activity roles. Each activity role has one or more involvements of a Class.
A domain activity may have an activity model that expresses the behavior of the activity. The behavior consists of operations to set attributes, to initialize objects, and to create or break relations between involved domain classes of the activity. Operations can be locally defined in an Activity Operation or it can be an Operation invocation of an Operation from a Context.
An operation invocation has a Actual parameter structure, in which the actual parameters of the invocation are parameterized by Attributes. These attributes must be in the scope of the Domain activity.

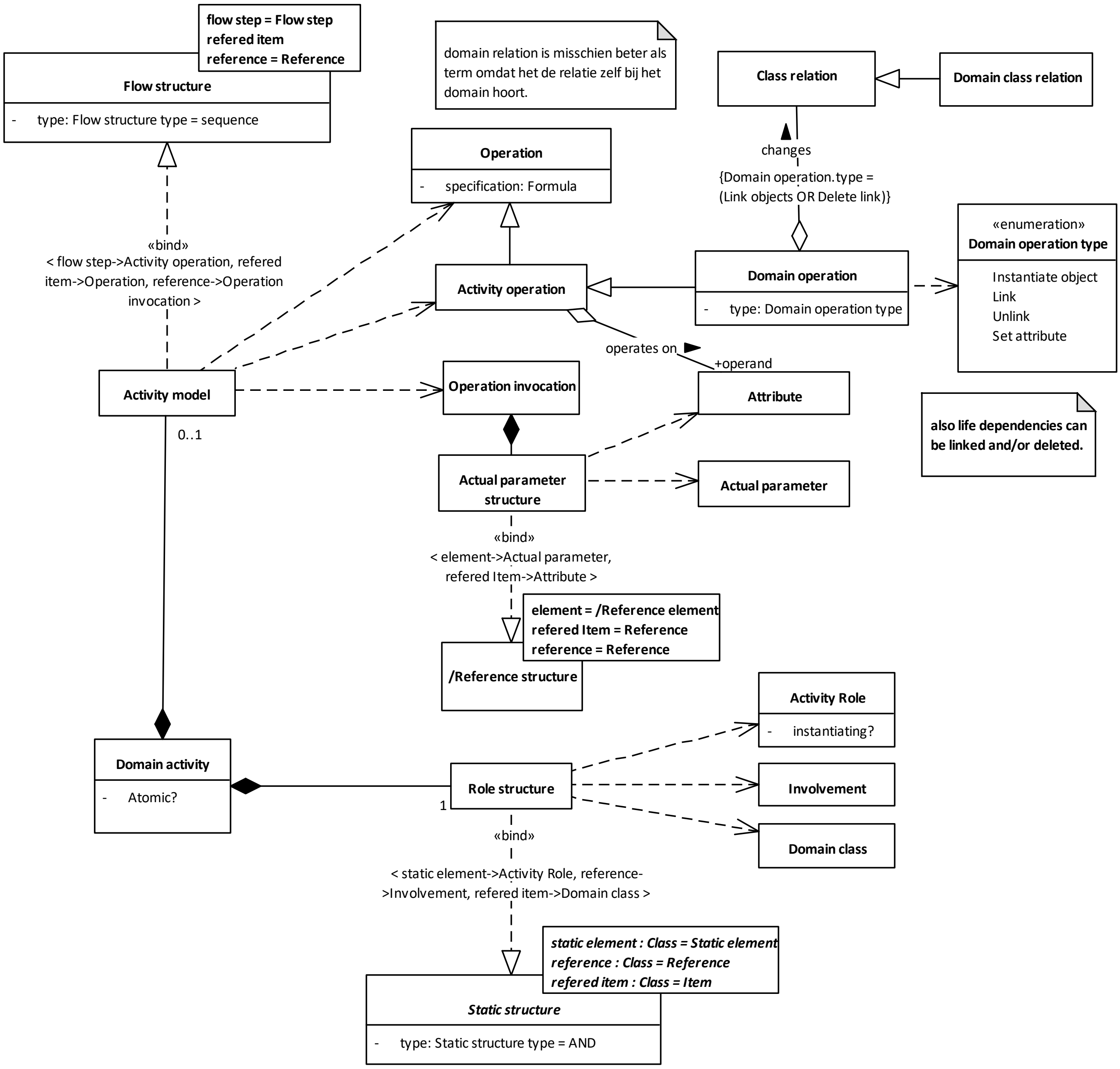


Figure 13: Domain activity definition

4.10 Function definition diagram

A function is a feature element, a classifier, a behavior element, and an attribute container. A Function expresses what shall happen when the function is instantiated. The flow steps refer to Behavior elements. The behavior elements can be:

- A domain activity in one of the domains that the feature of the function depends on.
- An operation in one of the contexts that the feature of the function depends on.
- A function from the same feature as the function or from one of the features the feature of the function depends on.

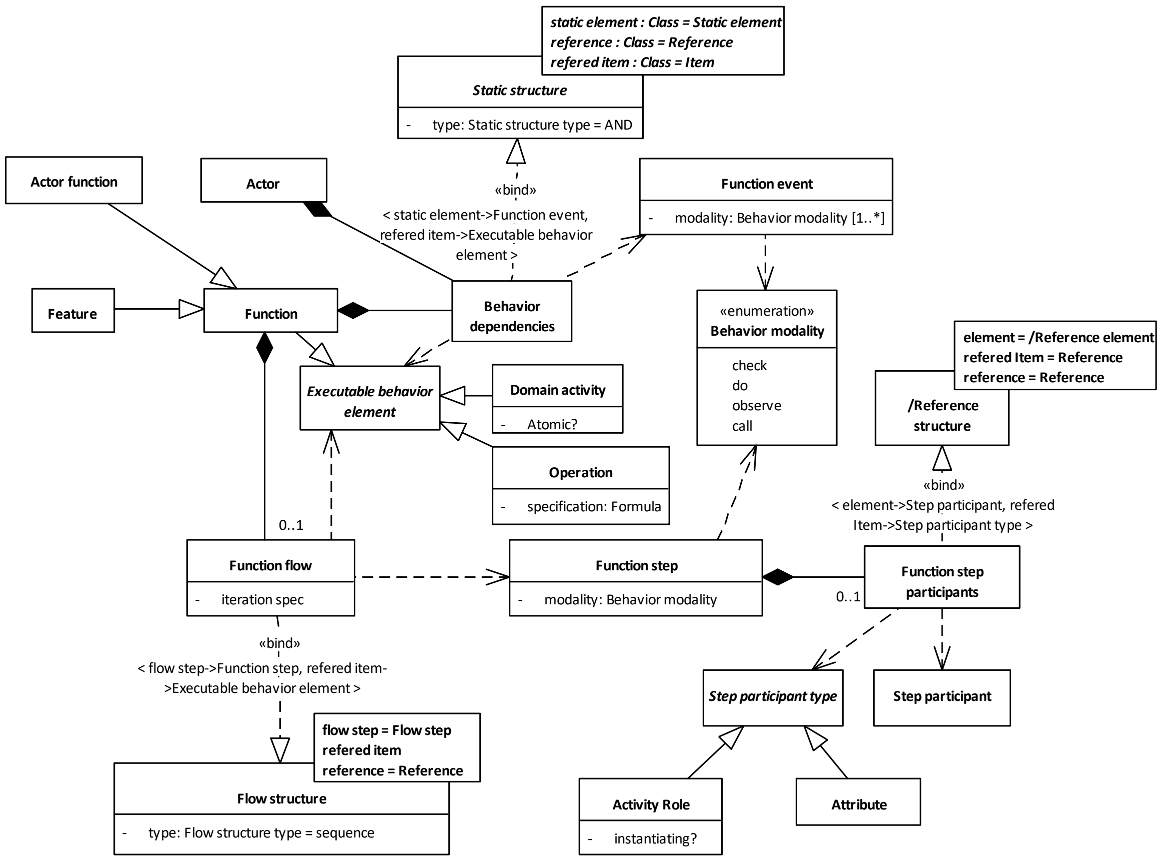


Figure 14: Function definition

4.11 Class relations diagram

A class relation has a class relation structure in which the static elements are Class relation roles, the references are Role connections, and the referred items are Classes. Class relations are used when there is not a clear containment/composition relation between two classes.

MudForM distinguishes different sorts of (domain) class relations:

- association: the result of a shared activity or coming into the domain as an aggregate. <u>This is the one we mean with Domain class relation.</u>
- lifecycle dependency: modeled via the life dependency structure of a domain class.
- composition: end of life of parent makes children inactive. This is the opposite of an object coming into scope with parts attached. E.g., you buy a car with wheels and you sell a car with wheels. This is very common in the physical world.

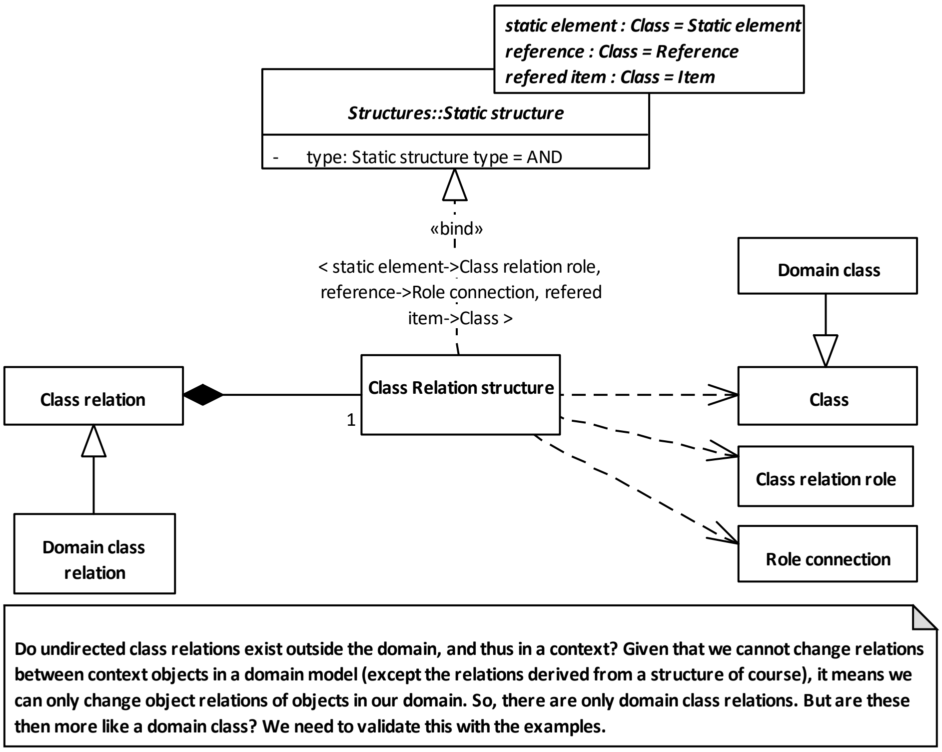


Figure 15: Class relations

Name	Definition
Activity model	A flow structure belonging to an activity, in which the flow steps are activity operations, references are operation invocations, and the referred items are operations. An activity model express the internal behavior of an activity, i.e., what happens when the activity is executed.
Activity operation	An operation that is defined in the scope of an activity model. The behavior of Activity operation is specified in terms of the supported formalisms.
Activity Role	Role within an activity in which domain classes can be involved. An activity role must be involved by at least one role class in the domain. An activity role can have also attributes. Sometimes it makes more sense to connect some attributes to a role instead of to the activity. **attribute:** instantiating? Is an object instantiated in this role?
Actor	Classifier that can check, execute, observe, and control (call) behavior elements, which is specified in the Behavior composition structure of the Actor. **Insight: Actor is not part of a feature specification. Actor is part of the context and has the above definition. We can allocate functions to actors, and actors must have capabilities. These capabilities can be specified in the context.**
Actor function	A function that can be assigned to an actor and can be invoked, canceled (devoked?), suspended, and resumed. **We need to consider concepts for invoke, devoke, suspend on actor level.**

Actual parameter	Placeholder for the objects that must be "fed" to an Operation invocation, aka the actual parameters of the Operation invocation. A step participant must be bound to a function attribute.
Actual parameter structure	Reference structure in which the elements are actual parameters, and the referred items are the attributes of the operation that is invoked. Derivation: the structure has an actual parameter for each attribute of the invoked operation, and the actual parameter refers to its attribute.
Attribute	Property definition for instances of attribute containers. An attribute refers to a Class that defines the type of the attribute.
Attribute container	Abstract class for model elements that can have attributes.
Attribute structure	A static structure belonging to an attribute container, in which the static elements are attributes, and the referred items are classes.
Behavior dependencies	Static structure in which the static elements are function events and the referred items are behavior elements.
Behavior modality	The modalities that are possible for a function event. **attribute:** check Check if the behavior element instance can happen, according to all constraints that apply to this event. *(The usefulness of this one is doubtful)* **attribute:** do Execute the behavior. So, the actor that executes the function also executes the step. **attribute:** observe React to the execution of this behavior in the environment of the function. In this case the Function must have a Function event that refers to the same behavior element as the Function step. **attribute:** call Tell the environment to execute the behavior. In this case the Function must have a Function event that refers to the same behavior element as the Function step.
Behavioral element	Any classifier that defines a change. This can be defined via pre- and postconditions, or by an explicit operation that defines the body of the behavior element, or by an explicit flow of other behavior elements.
Class	A set of objects. A class is an attribute container and can be part of a class relation.
Class relation	A relation between two or more classes in which none of the class can be seen as the container of the relation. Namely, in that case the relation is an attribute in the attribute structure of the container class. Class relations are used when one wants to express and communicate a relation between a number of classes.

Class relation role	A role of a class relation to which classes can be connected.
Class Relation structure	A static structure of a class relation, in which that static elements are Class relation roles, references are Role connections, and referred items are classes.
Classifier	Classifier is an abstract class. A classifier is something that has instances. A classifier can have a classifier structure that expresses the generalizations of the classifier. A classifier can be abstract, which means that it cannot have instances on itself. Its instances must be of a class that is related via a generalization, either as a subclass or a superclass. **attribute:** Abstract? An abstract classifier doe not have elements that only belong to the classifier. They must always belong to at least one of its specializations or generalizations as specified by a classifier structure.
Classifier structure	A static structure of a classifier, in which the references are generalizations, and the referred items are classifiers.
Condition	A static structure in which the elements are Condition operands, and the referred items are Specification elements. A Condition states what must be true for its container. All specification elements can have invariants. Behavior elements can have a precondition and postcondition. A condition is specified by a formula. That formula is specified in a formalism that is not part of MuDForM. **attribute:** specification
Condition operand	The use of a specification element in a condition, i.e., the condition operand is bound to the specification element. Example: Invariant of person: person.age > 0. The Condition operand person.age in <u>this</u> condition is bound to the specification element person.age.
Conditionable element	Any element that is part of a structure can be identified, and as such can have invariants.
Contained behavioral element	Behavioral element that is part another behavioral element. It is not executable, but it can have an explicit precondition and postcondition.
Context	A specification space that contains elements that you need to define elements of other specification spaces, especially domains and features. Contexts form the boundaries of your feature and domain specifications. In a context you define the things that are either define somewhere else, or that you do not want to model in detail, i.e., the things that are not in your domain-of-interest or feature-of-interest. Typically these conext elements are either concepts that you assume trivial, like datatypes and their operators, or systems (actors) that you want to use because of their capabilities. In some cases the actors are just the things your feature has to interact with.

Context declarations	A specification declaration structure belonging to a context, in which the specification elements are context elements.
Context element	Element in a Context declarations.
Domain	Area of activity or knowledge, that is managed as one. A domain contains domain elements that define the domain. A domain should have a definition that helps to determine if a certain concept belongs to the domain.
Domain activity	Domain element that defines a unit of change in the domain. Domain activities have instances called actions. Actions are atomic by deault. A non-atomic activity has a start action and stop action at instance level. **attribute:** Atomic? Is the execution of an activity instance (action) indivisible? If not, the activity has two instances: a begin action and an end action.
Domain class	A class with instances that have an interesting life in the domain of the class. The life is described via the Object lifecycle.
Domain class relation	A class relation between domain classes. A domain class relation instance between two objects may be established by participation of those objects in one domain activity instance (action). And a domain class relation instance can be broken by participation in a domain activity instance. There is a strong similarity between non-atomic activity and domain class relation. Difference: an domain class relation be changed (created or deleted) by multiple activities, and thus has its own identity. Hence, we need in a domain model.
Domain declarations	A specification declarations structure belonging to a domain, in which the specification elements are domain elements.
Domain element	Specification element that is part of a specific domain. A domain element may be a reference to another specification element outside its domain. For example, a domain class may refer to a class from a context, which gets an interesting life in the domain, and thus must be a domain class.
Domain operation	An activity operation that is an invocation of a Domain operation type. **attribute:** type
Domain operation type	The possible types of Activity operations in an Activity model. **attribute:** Instantiate object The operation creates an object of the given type and sets its attributes to a default values and sets the initial relations for the object. **attribute:** Link Create a link between two or more objects given the Class relation. **attribute:** Unlink Delete an existing link between two or more objects. **attribute:** Set attribute Give one ore more attributes a value.

Element	
Executable behavior element	Any behavioral element that is executable, which means it can be a referred Item is an activity model or a function flow. **Every executable behavior element can be seen as an event (type). That is why there is no modeling concept called event type. Event can be seen as a "parameter" of a function (or actor) that refers to an executable behavior element. A function has input events to which it reacts and output events that it generates. A special event is the invocation/execution of a function (or the invocation of a action or operation).**
Feature	Specification that operates in one or more domains. A feature typically specifies a desired situation in those domains. A feature should be self-contained, i.e., has not implicit context dependencies, and hence, is reusable for other specifications.
Feature declarations	Specifications declarations in which the specification elements are feature elements. It is possible to declare feature-wide objects, i.e., “global” objects within the feature. These objects can be used within the functions of the feature. This prevents that these objects have to be passed on between the functions of the feature. Of course, this means that the functions of the feature are context-dependent, namely on the feature.
Feature element	Element in a Feature declarations.
Function	A specification element that is part of a feature. A function expresses what shall happen if the function is active.
Function event	Behavior that a function executes, reacts to, or calls. Events are declared in the same way as attributes. They are local within the scope they are declared and their type is a behavior element. (Note that this differs from most languages that use the event concept, in which events are global and can be defined without any restriction to their scope). Events are expressed in terms of behavior elements thus can be: • Function activation or de-activation. Every function has these two events. • Calling or executing an atomic domain activity. • Execution of a Operation. • A condition defined on some object attributes becomes true or false. This can be a timing condition. Notice that such a moment always takes place during the execution of a behavior element. **attribute:** modality
Function flow	The control flow of a function, specified by a flow structure of Function steps, in which the referred Behavior Items are Executable behavior elements. **attribute:** iteration spec

Function step	Step in the Function flow of a Function. A Function step is a reference to a behavior element. **attribute:** modality The modality indicates what the actor that executes the function should do with the behavior that is referred by the function step.
Function step participants	A reference structure in which the elements are Step participants, and the referred elements are Step participant types. The functions step structure must be bound to Function attributes. Derivation: The Function step participants structure has a Step participant for each Attribute and activity role (if applicable) of the Behavior element that the Function step refers to, and the Step participant refers to that Step participant type.
Generalization	Reference to a classifier in a classifier structure of a classifier. meaning that the classifier is a subclass of the referred classifier.
Involvement	An involvement states that instances of a domain class may be participating in a specific role of an action (instance of domain activity). An involvement may have attributes that are specific to the involvement.
Life dependencies	A static structure in which the referred items are classes. The life dependencies of a domain class express what type of parent objects an instance of the domain class must have. This can be classes from a context or domain that the containing domain is depending or from the containing domain itself. A Life dependency (a reference in the Life dependencies of a child domain class) means that the parent (referred item) cannot end its life if it has living children. The child object doesn't have meaning without the parent object. So, the parent life cannot be ended before its children's lives are ended. E.g., An order always belongs to a customer. You cannot end the life of a customer when there are still living orders. If you could, the order would become meaningless.
MuDForM model	This is the root of a complete MuDForM compliant specification. A MuDForM model contains contexts, domains, and features. Typically, it contains at least one of each type.
Object Lifecycle	Involvement flow that specifies in which order an object of a domain class may participate in related activity roles. Derived property: an object of a domain class is **Alive** when is still can do an involvement step according the OLC of the domain class.
Operation	An operation defines an atomic change expressed by a formula. An operation has operands which can be input for the operation and/or output of the operation. **attribute:** specification Specification of the formula in some Formalism.
Operation invocation	Invocation of an operation in an activity model. The operation must be defined in a context of the domain of the activity.
Parameter	A parameter is an attribute of the attribute structure of a behavior element. An input parameter must get a value when the behavior element in instantiated. An output parameter might get a value during the execution of the instantiated behavior element.

	Note: a "local" parameter is just an attribute. **attribute:** in? Does the parameter get a value form the environment of the behavior element? **attribute:** out? Does the behavior element give a value to the parameter?
Role connection	A role connection defines that instances of the referred class can be in the Class relation role of instances of the Class relation.
Role structure	Static structure belonging to an activity, in which the static elements are activity roles, the references are involvements, and the referred items are domain classes. The role structure expresses which domain classes can and must be involved in an activity instance (=action).
Specification declarations	Static structure belonging to a specification space, in which the static elements are specification element. The declarations contains all the specification elements that are declared in this specification space.
Specification element	Element declared in a specification space. Specification elements can be static elements and behavior elements. Which types are allowed depends on the concrete subclass of the Specification space. Specification element are things in a specification space, which have there own autonomous identity in that space, i.e. they are not contained like an attribute, parameter, or activity role.
Specification space	Container for specification elements. The specification elements will be in the declaration structures of the sub classes of specification space.
Specification space dependencies	A static structure belonging to a specification space, in which the referred items are specification spaces.
Step participant	Placeholder for the objects that must be "fed" to a Function step, i.e., the actual parameters of the function step. A step participant must be parametetrized with a function attribute.
Step participant type	Placeholder for the objects or attributes that are participating in a function step. In case the step refers to an Activity these can be Activity roles or activity attributes. In case the step refers to a function or an operation, these can be attributes.
Structure	
Value type	A value type is meant for objects that just represent a single value, like a name, a phone number, or a length. The type of the value should be defined by some formalism, like a string, a fixed length string of digits, or a positive real. **attribute:** type The type of the values of this value type. That type is typically from one of the used formalisms.

5 MuDForM Viewpoints

This package defines the viewpoints in a MuDForM specification. Each viewpoint is defined by a constraint in terms of the metamodel. i.e., in terms of the MuDForM concepts, and a notation. The constraint says which modeling concepts are allowed in a view of that viewpoint. The notation says which symbols and layout conventions hold for the viewpoint. We distinguish the following viewpoints.

For a MuDForM model:

- Declarations view
- Dependencies view

For contexts:

- Declarations view
- Context structure
- Actors view

For domains:

- Declarations view
- Interaction view
- Class Structure view
- Attribute view
- Object lifecycle view per domain class
- Activity view per domain activity

For features:

- Declarations view
- Functional composition
- Function life cycle per function
- Function signature per function
- Context integration model (**Maybe move this one to the context model or integration model)**

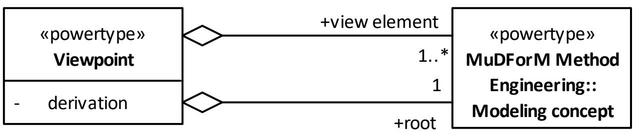
Integration model:

- TBD.
- Think of system use cases, where a system is (partially) defined by integrating a feature and a context.

The viewpoints are defined in a separate document called "MuDForM Viewpoints".

5.1 Viewpoints pattern diagram

A MuDForm viewpoint presents one or more view elements, which are modeling concepts. Each Viewpoint has one modeling concept as its root. The content of a view according to the viewpoint is specified by the derivation.



Viewpoints pattern

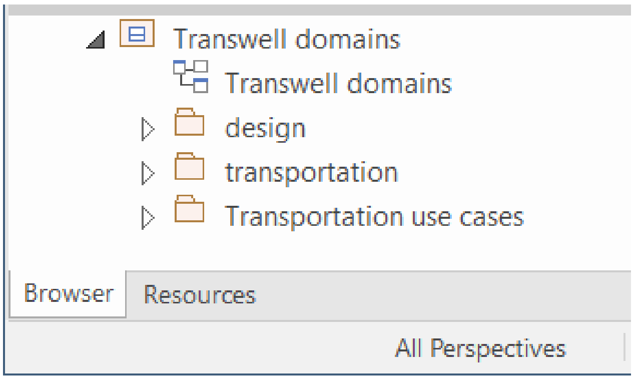
Name	Definition
Viewpoint	Type of view of a MuDForM compliant specification that shows a defined set of view elements. A viewpoint belongs to a root Modeling concept, and represents other modeling concepts (view elements). **attribute:** derivation Specification of the content of a view according to this viewpoint for a given

	root. The derivation explains which view concepts are visible in a view on the model for this viewpoint and the root.

5.2 For a MuDForM Model

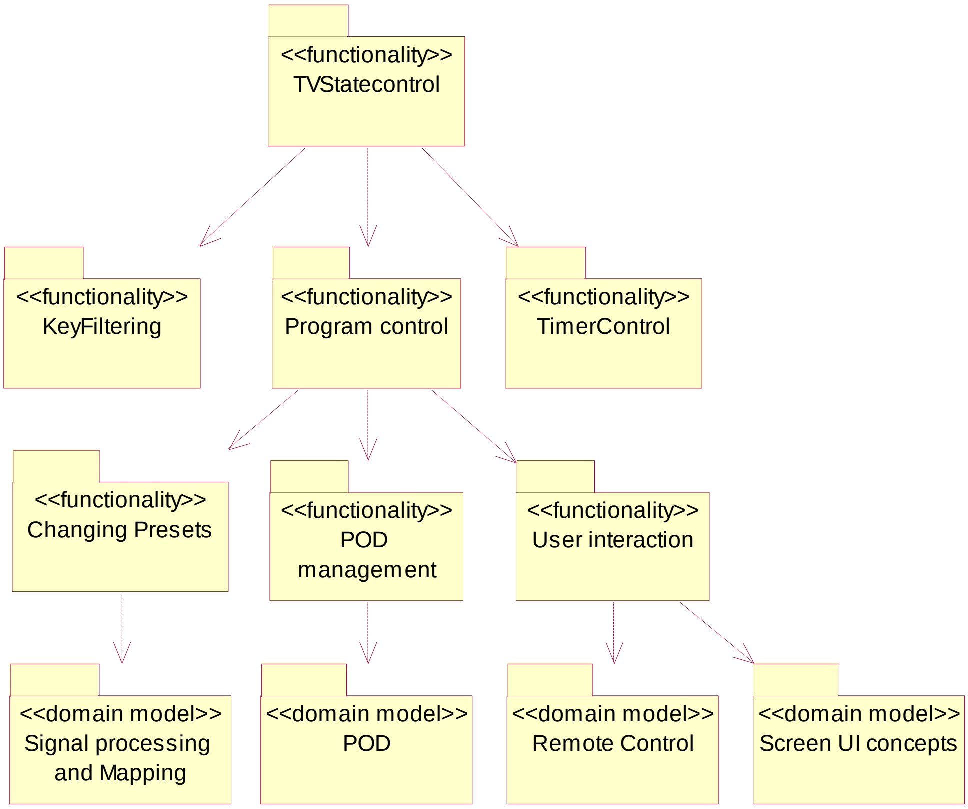
5.2.1 Declarations view:

- Root: MuDForM model
- Derivation: The specification elements in the specification declarations of the MuDForM model.



5.2.2 Dependencies view

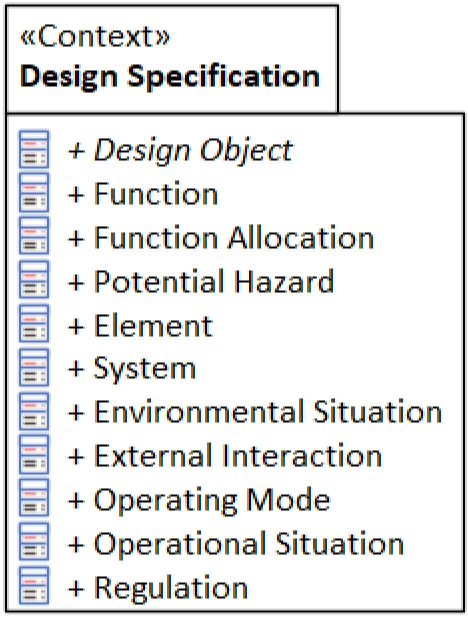
- Root: MudForM model
- Derivation: the references in the specification space dependencies of all the specification spaces in the specification declarations of the MuDForM model. So, show all the specification spaces contained in the MuDForM model, and show the dependencies between those spaces.



5.3 For a context

5.3.1 Declarations view

- Root: Context
- Derivation: The specification elements in the specification declarations of the context.



5.3.2 Context structure

- Root: context

- Derivation:
  - The context elements in the specification declarations of the context.
  - The attributes in the attribute structure of the context elements.
  - The class relations, the class relation roles, and role connections of the class relations.
  - The generalizations in the classifier structure of the context elements.

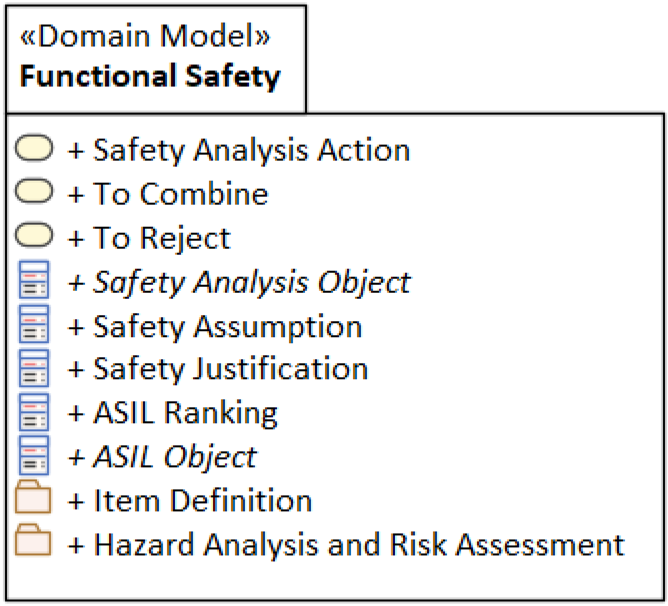
5.3.3 Actors view

- Root: context
- Derivation:
  - The actors in the specification declarations of the context.
  - Per actor the events it can react to or it can generate.

5.4 For domains

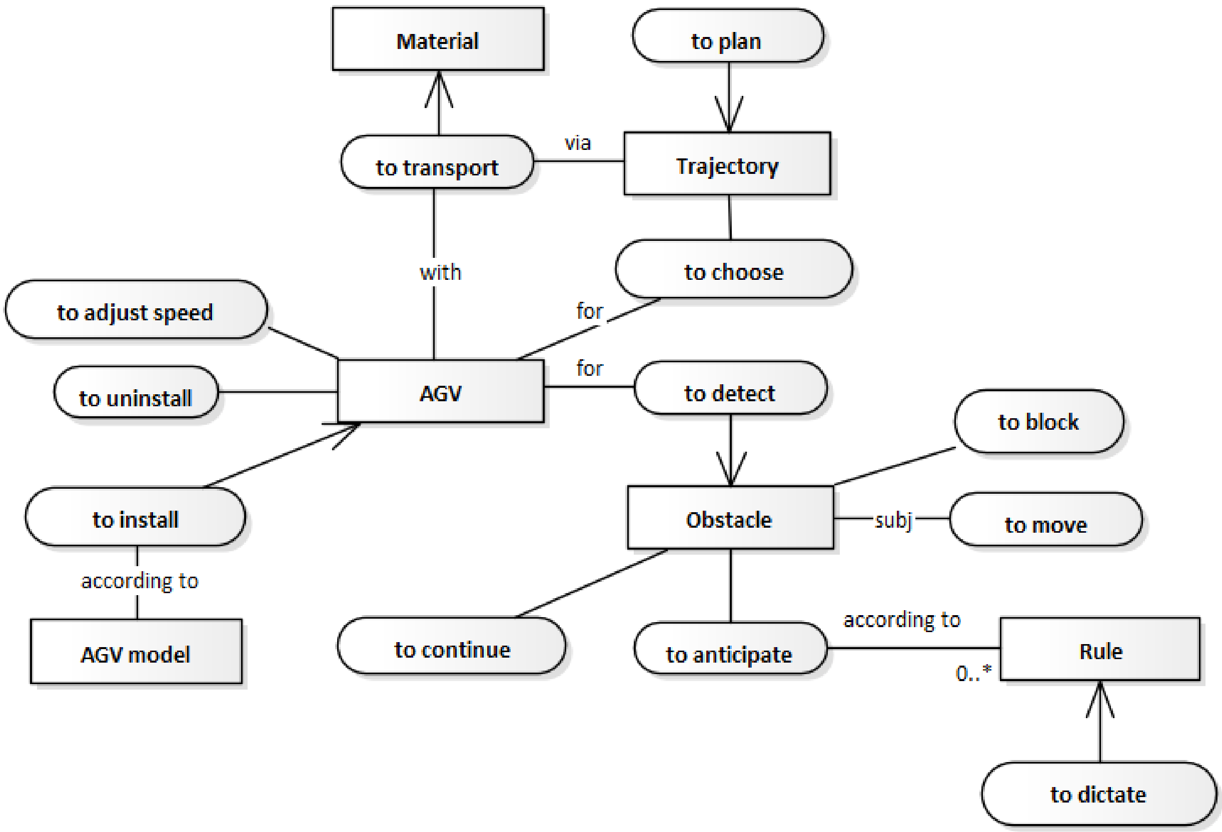
5.4.1 Declarations view

- Root: Context
- Derivation: The specification elements in the specification declarations of the domain.

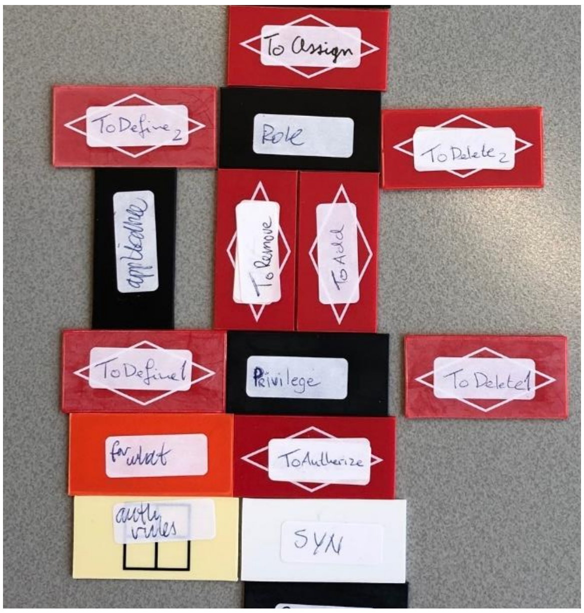


5.4.2 Interaction view

- Root: domain
- Derivation:
  - The domain activities of the domain, and the roles and involvements in their role structure.
  - The generalizations in the classifier structure of the domain activities.



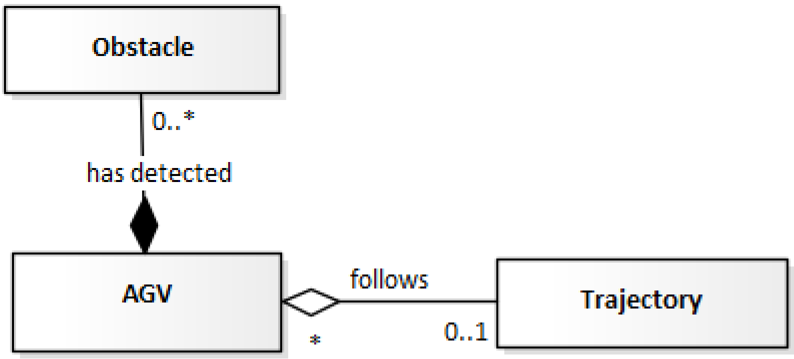
Example with KISS domino:



5.4.3 Class view

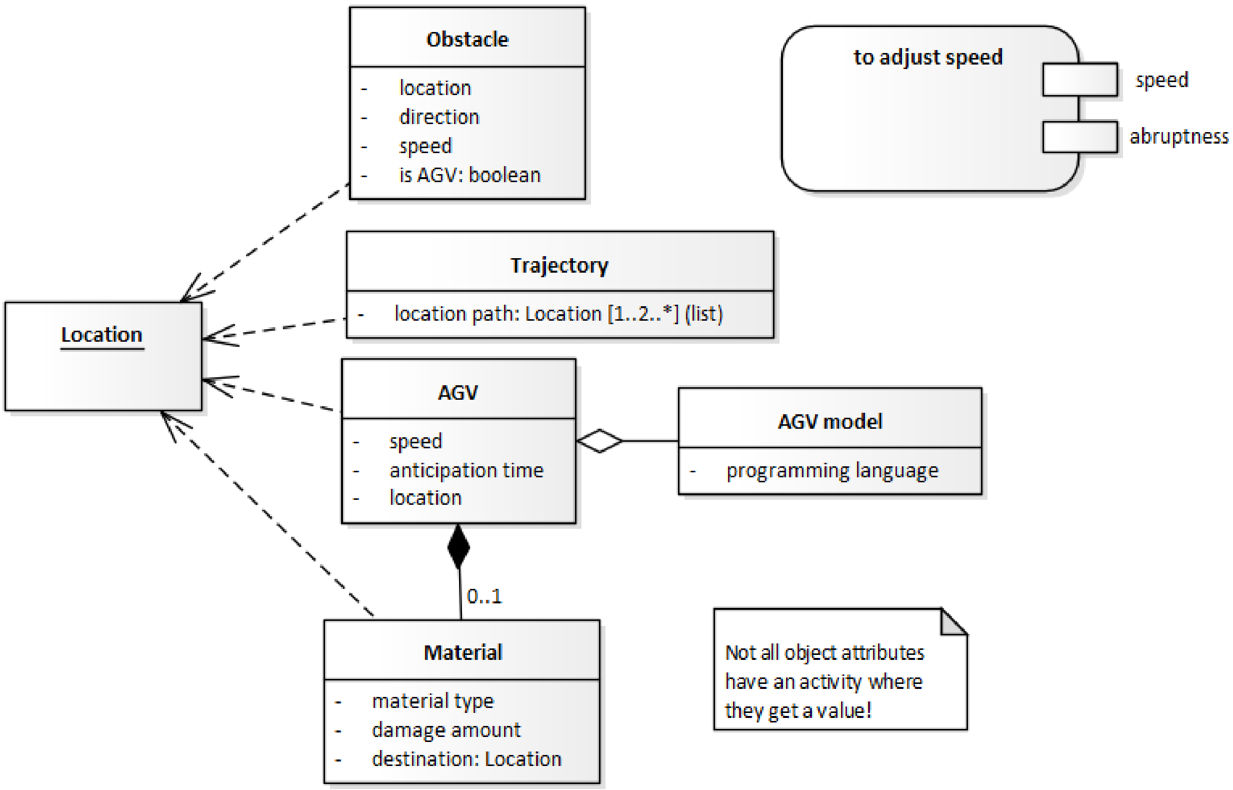
- Root: domain
- Derivation:
  - Domain classes in the domain.

- References in the Life dependencies of the domain classes.
- Domain class relations in the domain, and the class relation roles and their role connections, in the class relation structure of the domain class relations.



5.4.4 Attribute view

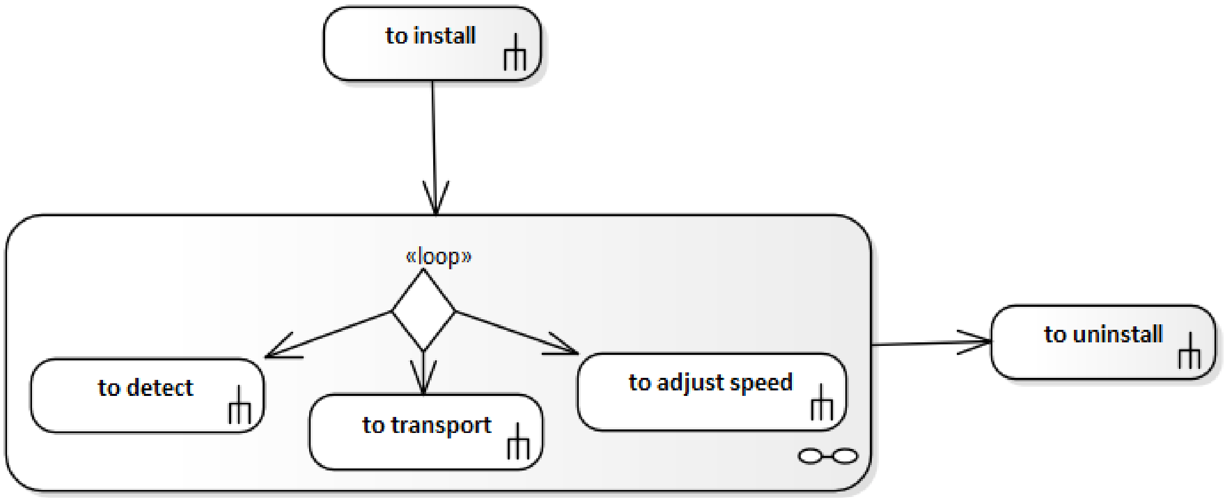
- Root: Domain
- Derivation: Attributes in the attribute structure of each of the:
  - domain classes,
  - domain activities,
  - the activity roles of those domain activities,
  - the involvements of those activity roles.



5.4.5 Object lifecycle view

- Root: domain class

- Derivation: the flows steps in the object lifecycle of the domain class.



5.4.6 Activity view

- Root: domain activity
- Derivation:
  - The activity operations and operation invocations in the activity model of the domain activity.
  - And the actual parameters in the actual parameter structure of the operation invocations, and the bound attributes of each actual parameter.

No example yet.

5.5 For features

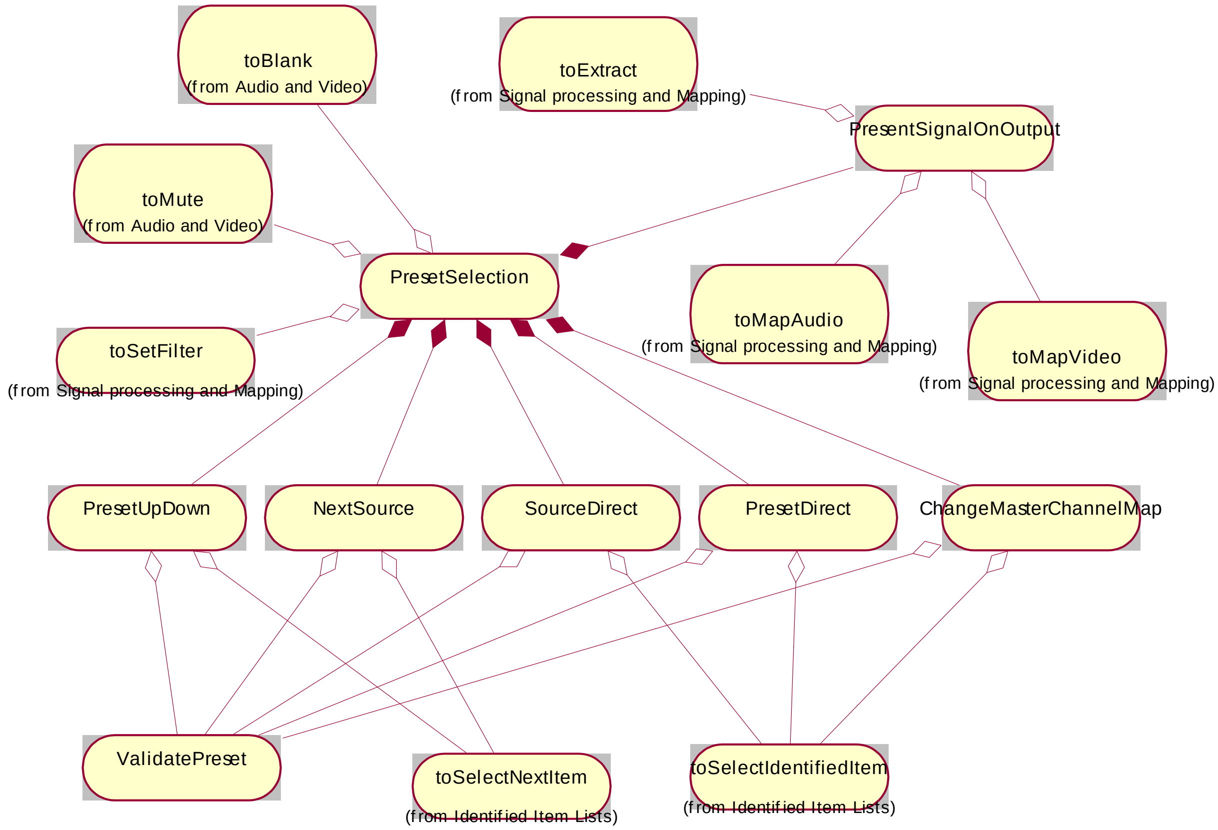
5.5.1 Declarations view

- Root: Feature
- Derivation: The specification elements in the specification declarations of the feature.

No example, but it looks the same as the other declaration views.

5.5.2 Feature structure

- Root: Feature
- Derivation: All the compositions in the functional composition structure of the functions of the feature (including the feature itself).



1.1.1 Function lifecycle

- Root: function
- Derivation: (similar to activity view)
  - The function steps in the function flow of the function.
  - The function step participants in the function step structure, and the bound Function attributes of each step participant.

Below an example that is a purely textual notation. The more logical choice is a notation based on the UML activity diagram.

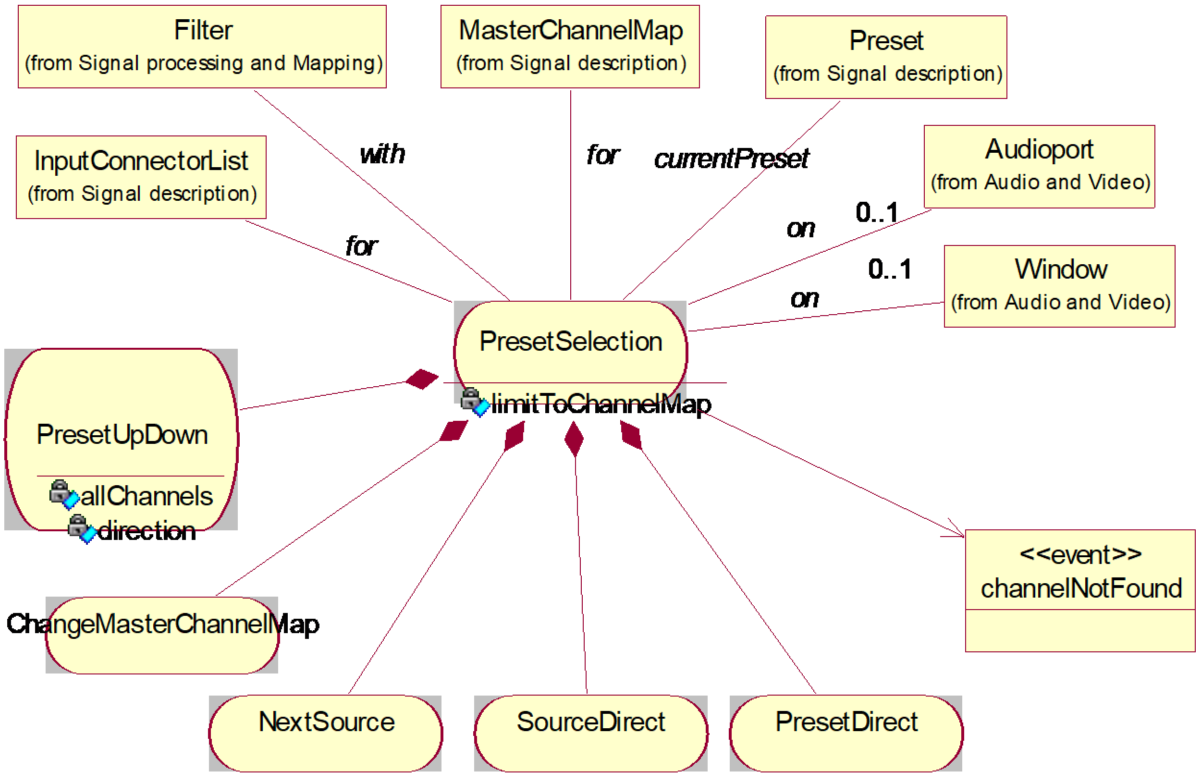
```
if      this event is equal to the n events before
        longPress = true;
        if      the table contains longPress for this event
                for all events in the selected column
                        generate the event as indicated in Table 1;
elif    this event is equal to the m events before
        extraLongPress = true;
        if      the table contains extraLongPress for this event
                for all events in the selected column
                        generate the event as indicated in Table 1;
elif    this event is not equal to the previous event
        generate the event as indicated in Table 1;
end if;
```

Table 1: KeyFiltering definition of code mapping

Code	Condition	if not HotelMode	if HotelMode
RC5 0,56 RC6 0,56		RCNextSource	RCNextSourceHM
RC5 0,32 RC6 0,32 RC6 0,30		RCChanStepUp	RCChanStepUp
RC5 0,3 RC6 0,3		RCDigit 3	RCDigit 3
RC5 0,4 RC6 0,4		RCDigit 4	RCDigit 4
RC5 0,5 RC6 0,5		RCDigit 5	RCDigit 5

5.5.3 Function signature

- Root: function
- Derivation:
  - All the attributes in the attribute structure of the function.
  - All the function event parameters of the function. *(This should be changed into an event structure where the static elements are events and the referred Items are behavior elements.)*



Other example:

Signature

Attribute	**Type**	**Scope**	**Description**
theWindow	Window	In, out	This instance of PresetSelection is applicable for this Window.
theAudioPort	Audioport	In, out	This instance of PresetSelection is applicable for this Audioport.
currentPreset	Preset	In, out	The preset that is shown.
masterChannelMap	MasterChannelMap	In	The map that is currently in use.
inputConnectorList	InputConnectorList	In	The list of Extensions in the TV.
theFilter	Filter	In, out	A reference to the filter (in most cases a tuner) that is used to extract the program signal from the Input connector.
limitToChannelMap	Boolean	In	If limitToChannelMap = true, then entering digits that identify a channel that is not in the masterChannelMap does not invoke a preset change. E.g. in case of authenticated POD.
when(theFilter.signalAvailable)	Event	In	
PresetUpDown (direction: UpDown, allChannels: Boolean)	Function	In	
NextSource()	Function	In	
PresetDirect(targetPresetID: IDString)	Function	In	
SourceDirect(targetPresetID: IDString)	Function	In	
ChangeMasterChannelMap(mcm: MasterChannelMap, limit: Boolean)	Function	In	
channelNotFound	Event	Out	
theAudio	AudioSignal	Local	

Attribute	Type	Scope	Description
theVideo	VideoSignal	Local	
newPreset	Preset	Local	
ChangePreset(newPreset: Preset)	Event	Local	
ValidatePreset(tmpPreset: Preset)	Function	Local	
PresentSignalOnOutput()	Function	Local	