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Pattern-Based Layout Specifications for Visual Language Editors

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Abstract: When creating an editor for a visual language, a challenging task is the layout specification. Many visual languages, e.g., Ecore diagrams or Petri nets, show similar layout characteristics, and hence reuse of layout behavior should be enabled. For that purpose, we introduce the concept of layout patterns, which encapsulates certain layout behavior. With the approach, it is possible to combine different layout algorithms, e.g., standard graph drawing algorithms and constraint-based algorithms. In addition, rule-based layout algorithms may be used that are specifically tailored to the interactive nature of visual language editors.

Keywords: layout specification, meta models, patterns, reuse

1 Introduction

Examples of visual languages are Ecore diagrams [BBM03], Petri nets, Nassi-Shneiderman diagrams or VEX diagrams [CHZ95]. Many visual languages show similar layout characteristics, e.g., Ecore diagrams and Petri nets both have a graph-like structure and allow for nesting of nodes, and hence reuse of layout behavior should be enabled. For different layout characteristics, different layout algorithms should be used. E.g., for the graph-like structure of a language, standard graph drawing algorithms, such as force-directed layout or tree layout, should be applied. For other characteristics, constraint-based algorithms are more appropriate. Many layout characteristics require a layout algorithm that is specifically tailored to the interactive nature of diagram editors. Therefore, we added a rule-based layout algorithm, which may be used, too.

In this paper, we introduce layout patterns, which encapsulate certain layout behavior. The idea is to define layout behavior on top of a language-independent, but pattern-specific meta model. The behavior of a layout pattern may either be defined by our rule-based layout algorithm or by any other layout algorithm. This way, a layout pattern provides a reusable and language-independent “solution” for common layout characteristics.

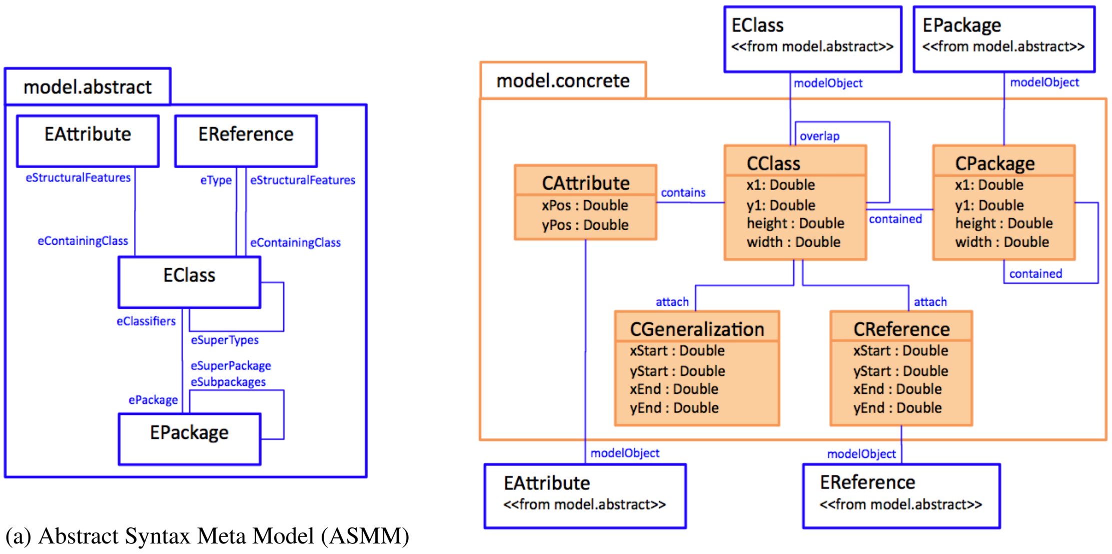
Our approach is used in the context of diagram editors. Here, the layout engine runs continuously and improves the layout in response to user interaction in real-time. The approach supports structured editing as well as freehand editing, which means that diagram components may be freely positioned on the screen. This way, also (temporarily) incorrect diagrams are allowed, and the editor user is more flexible.

Section 2 introduces Ecore diagrams, the running example used in this paper. The different layout algorithms are presented in Section 3. The concept of layout patterns is presented in Section 4, and related work is discussed in Section 5. Section 6 concludes the paper.

2 Running Example

In the following, we briefly revisit Ecore diagrams. Ecore diagrams are similar to UML class diagrams. The simplified version considered in this paper consists of *packages*, *classes*, *attributes*, *generalizations* and *associations*. In Figure 2, an Ecore diagram editor, which was created with the editor generation framework DiaMeta [Min06], is shown.

For each visual language editor, a layout meta model (LMM) is specified, on which the layout specification is based on. When a diagram is drawn, the editor instantiates the LMM, obtaining the layout model (LM). The LMM consists of two parts: the abstract syntax meta model (ASMM), representing the languages abstract syntax, and the concrete syntax meta model (CSMM), representing the languages concrete syntax (see Figure 1). Both meta models are connected via the associations named `modelObject`, as denoted in Figure 1b. The CSMM resembles all visual components and their spatial relationships, whereas the ASMM is an instance of the diagram language's meta model that defines the language's abstract syntax.



(a) Abstract Syntax Meta Model (ASMM)

(b) Concrete Syntax Meta Model (CSMM) together with the connection to the ASMM

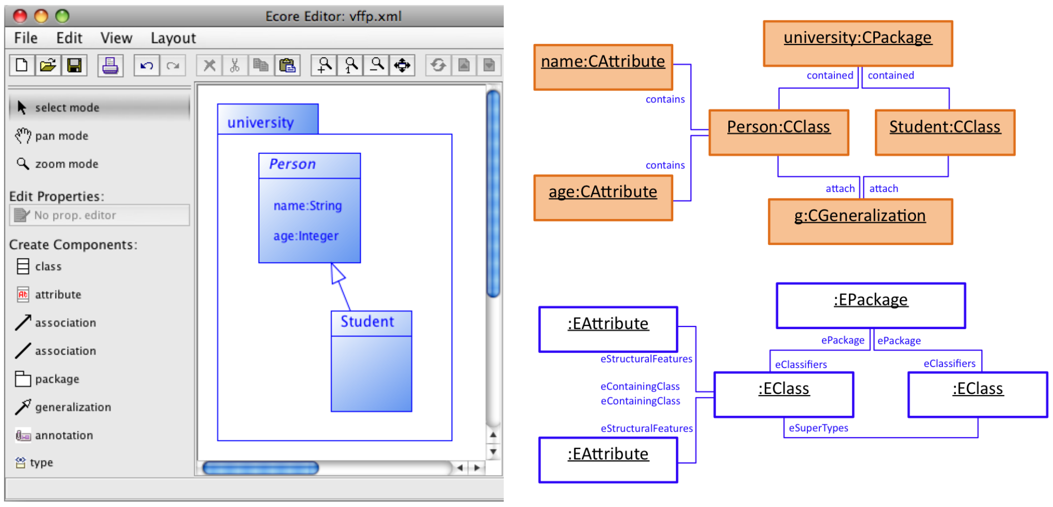
Figure 1: Layout Meta Model (LMM)

In the CSMM, each component type is represented by a class, which is connected with its abstract syntax counterpart, if available.[1] In addition, in the CSMM, each meaningful relationship between component types is represented by an association. For Ecore diagrams, the components

[1] There is no correspondence available for the class CGeneralization in the Ecore meta model.

package, *class*, *attribute*, *generalization* and *association* are represented by classes. The relationships *contains*, *contained*, *overlap* and *attach* are represented by associations. In our example, the ASMM exactly is the Ecore specification [BBM03] and hence is unmodifiable.

Figure 2 shows an Ecore diagram (Figure 2a) together with its CSM and ASM (Figure 2b), where `modelObject` links are omitted. The diagram consists of the following components: the package *university*, the two classes *Person* and *Student*, the two attributes *name* of type *String* and *age* of type *Integer* and the generalization *g*. The CSM is an instance of the concrete syntax meta model (CSMM), and shows the diagram components together with their spatial relationships. The ASM is an instance of the abstract syntax meta model (ASMM), which conforms to the Ecore specification.



(a) Example Ecore Diagram

(b) CSM and ASM (modelObject links are omitted)

Figure 2: Ecore Diagram Editor

3 Layout Algorithms

In the context of diagram editors, usually one of the following layout concepts is chosen: the layouter is written by hand, a standard graph drawing algorithm is applied, or a constraint-based layout algorithm is used. To better support the interactive nature of diagram editors, we extended this list with rule-based layout algorithms. The underlying concept is already known, e.g., interaction dynamics are defined via rules in [BGL06].

With the approach presented in this paper, it is possible to reuse the layout behavior. More details are given in Section 4. Furthermore, all these layout algorithms may be combined. This way, a powerful layouter may be created. Different layout algorithms are combined via the *application control*, a language-specific control program. If two algorithms are in conflict, a prioritization of the algorithms resolves this conflict.

3.1 Graph Drawing Algorithms

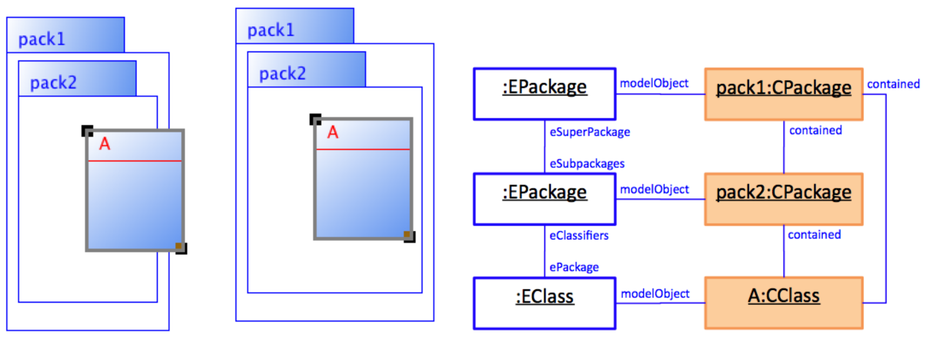
Examples for standard graph drawing algorithms are force-directed layout or layered layout. As graph drawing algorithms tend to be quite complex, it is reasonable to implement them, not to define them on an abstract level. To support interactive diagram drawing, we added several graph drawing algorithms to DiaMeta, following the descriptions of [TDET98, DK08]. The meaningful implementation of these algorithms enables reuse for different visual language editors.

3.2 Constraint-Based Layout Algorithms

A constraint-based algorithm is defined by providing a set of declarative constraints. Many tools that deal with dynamic graph drawing are based on declarative constraints, e.g., [DMW09]. In our approach, the constraints are attached to the LM. A standard constraint solver then computes a solution to this constraint satisfaction problem. As constraints are defined on top of the language-specific LM, they need to be redefined for every visual language.

3.3 Rule-Based Layout Algorithms

The layout algorithm outlined in this section was introduced in [MMM08a, MMM08b]. To give an overview of the algorithm, we use the simple example shown in Figure 3. When the editor user moves a class, or more generally, changes the diagram, the layout engine is called, and the diagram is updated. In our example, the user has moved class A right (Figure 3a). As classes are not correctly nested after movement, the sizes of both packages (Figure 3b) are updated by the layout engine. This requires the layout engine to run continuously, and to provide immediate feedback about the effect of user changes.



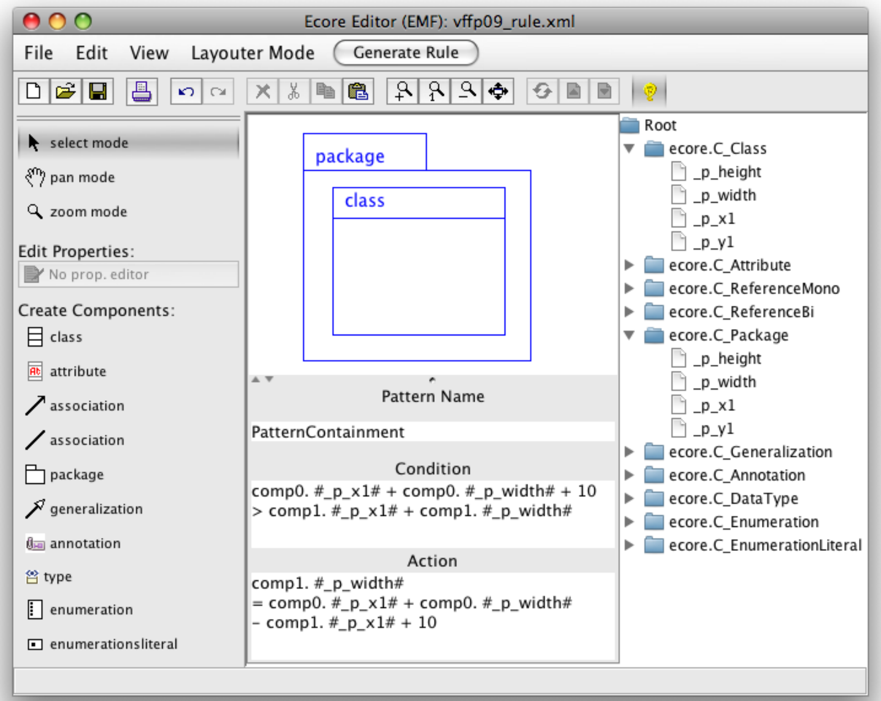
(a) Before (b) After (c) Instance of LMM

Figure 3: Example User Interaction

The layout engine gets an instance of the LMM and the component(s) changed by the user as input. The LM of our example is shown in Figure 3c and the component changed is class A. When the layout engine is called, roughly speaking, layout rules, that are based on this LM, are applied to the diagram. The order in which *a single* layout rule is applied to different parts of the diagram, and the order in which *several* layout rules are applied follows an exact plan.

Layout Rule A layout rule operates on the LM. An example for a layout rule is the rule *containment*, which takes care of the correct nesting of classes and packages. For each rule, one diagram component is given as input. This usually is a component changed by the user, or a component changed by the layout engine. In the example of Figure 3, this is class `A`. Then, other components that are necessary for the layout rule are identified by the layout engine. Here, this is package `pack2`. Afterwards, if a rule-specific condition is fulfilled, a rule-specific action is applied. For the rule *containment*, the condition checks if the “package is not large enough”. If this is the case, the action “enlarges the package”.

Specification of a Layout Rule Layout rules are defined on the LMM, and hence they need to be re-specified for every visual language. To define a layout rule, the developer needs to proceed as follows: he has to provide a left-hand side[2], a condition (which is optional) and an action. The left-hand side identifies a component, which has been changed previously, together with the local context needed for layout computation. The condition describes the circumstances, in which an action is applied (e.g., “package is not large enough” as described earlier). The action defines the changes that are actually performed if the condition is fulfilled (e.g., “enlarge the package”).



Pattern Name

PatternContainment

Condition

```
comp0. #_p_x1# + comp0. #_p_width# + 10
> comp1. #_p_x1# + comp1. #_p_width#
```

Action

```
comp1. #_p_width#
= comp0. #_p_x1# + comp0. #_p_width#
- comp1. #_p_x1# + 10
```

Figure 4: Layout Editor

[2] In previous work, the left-hand side has been called pattern. We changed the name to avoid a mix up with the other use of the term pattern in this paper.

To allow a more intuitive description, we provide a visual language for layout rule definition. In Figure 4, a screenshot of such an editor for Ecore diagrams is shown. In order to create a layout rule, the editor developer draws a left-hand side using the language's concrete syntax. In the example, he uses the components *class* and *package*. The name of the layout rule, a condition and an action are specified below. For specifying conditions and actions, he may access the attributes shown on the right side of the editor, here attributes `x1` and `width` of the components `C_Class` and `C_Package`.

Strategy The order in which each layout rule is applied to different parts of the diagram usually follows an exact plan, called strategy. In our example the strategy *containment* is used: Starting with the class changed by the user, internal packages are moved and resized first, and surrounding packages are updated afterwards. Besides, the order in which different strategies (and hence their corresponding layout rules) are applied to the diagram has to be specified, too.

Specification of Strategies The definition of strategies is also based on the LMM of the diagram language, and hence they need to be redefined for every visual language. For each strategy, a traversal strategy is specified, which is based on the LMM. For the strategy *containment* described earlier, the following is defined: If a class is moved, follow the link `ePackage`, and retrieve the surrounding package. Apply the rule *containment* to this package, and resize the package accordingly. If the package is changed, follow the link `eSuperPackage`, retrieve the surrounding package, and apply the rule *containment* to the surrounding package. Besides, it needs to be defined how strategies interact with each other.

3.4 Ecore Editor

The Ecore Editor example uses several layout algorithms. The following rule-based layout algorithms are used:

- An algorithm that keeps the minimal *size* of classes and packages.
- An algorithm that takes care of the *containment* of classes and packages. The algorithm is applied from inside-out.
- An algorithm that aligns attributes as a *list*. The algorithm is applied from top-to-bottom.

The following graph drawing algorithms are used:

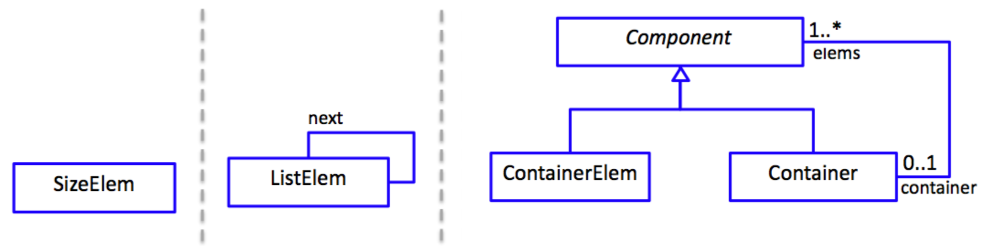
- An algorithm that performs *force-directed layout*, which avoids overlapping of classes.
- An algorithm that executes an *edge follower*. The edge follower makes sure that associations and generalizations stay attached to components.
- An algorithm that performs an *edge router*, which is responsible for routing associations and generalizations.
- An algorithm that executes a *tree layouter* or an algorithm that creates a *layered layout*.

4 Pattern-Based Layout Specification

It is reasonable to reuse parts of the layout specification. To enable reuse, we introduce layout patterns that encapsulate certain layout behavior. The term *pattern* is already known in the context of layout specification [SK03] where the specification of a visual language editor is based on a tree grammar instead of a meta model. In our approach, each layout pattern is based on a language-independant, but pattern-specific meta model. Layout algorithms, graph drawing algorithms and constraint-based algorithms are defined on top of these pattern-specific meta models. In order to apply a layout pattern to a certain visual language, i.e., in order to instantiate the pattern, a mapping between the pattern-specific meta model and the language-specific LMM needs to be defined.

4.1 Meta Models

Layout behavior that belongs to a certain layout pattern is defined on top of the corresponding pattern-specific meta model. The meta models SizeLMM, ListLMM and ContainmentLMM, on which the patterns *Size*, *List* and *Containment* are based, are shown in Figure 5. The meta model SizeLMM consists of a class `SizeElem`, which stands for the resizable component. The meta model ListLMM describes a list in terms of many instances of class `ListElem`. The meta model ContainmentLMM consists of a class `Container`. Each instance may contain one or more `Component` objects. A `Component` object is either a `ContainerElem` instance or a `Container` instance.



(a) SizeLMM (b) ListLMM (c) ContainmentLMM

Figure 5: LMM for Size, List, and Containment

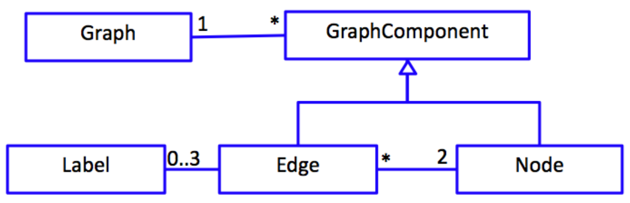


Figure 6: LMM for Graphs (GLMM)

A pattern-specific meta model is an abstraction of the situation in the LMM, meaning that concrete classes in the pattern-specific meta model, that are named roles in the following, correspond to classes in the LMM. E.g., the pattern *Containment* has the two roles *ContainerElem* and *Container*. The mapping defines the occurrences of these roles in the LMM.

Meta Model for Graph Drawing Algorithms As we saw in the Ecore Editor example, it is necessary to integrate graph drawing algorithms. To allow for reuse, graph drawing algorithms are integrated as certain patterns, and hence, are based on a pattern-specific meta model. The layout meta model for graphs (GLMM) is shown in Figure 6: A graph consists of several components. A component is either an edge or a node. An edge has up to three labels and connects two nodes.

4.2 Mappings

Table 1 shows four patterns, and enumerates the components of the visual languages Ecore diagrams and Petri nets, these patterns are applied to. The different roles are identified in the LMM. For Ecore diagrams, the roles are visualized in Figure 7. E.g., for the pattern *Containment*, classes may have the role *ContainerElem*, and packages may have the role *Container*.

Pattern	Role	Ecore diagrams	Petri nets
Size	SizeElem	package & class	state & transition
List	ListElem	attribute	—
Containment	Container ContainerElem	package class	state token
Graph	Node Edge	class generalization	state & transition arrow

Table 1: Mappings of Ecore diagrams & Petri nets.

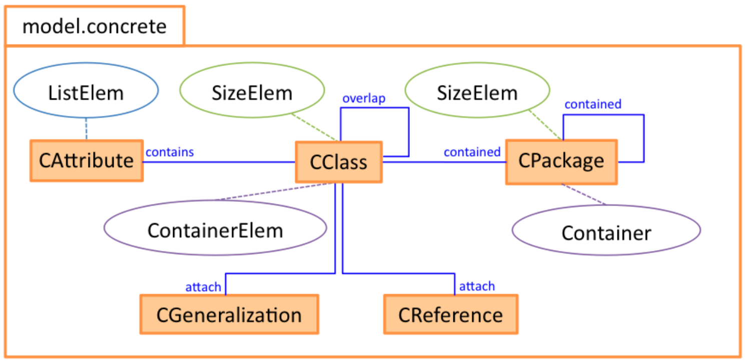


Figure 7: Roles Identified in the LMM

Usually a pattern is not exactly represented in the meta model of a diagram language. Instead, some variation can be found. E.g., in case of the pattern *List*, a *next* relationship is not explicitly contained in the Ecore meta model (Figure 1). The order of attributes is only implicitly defined by the values of the attribute `yPos` of the class `CAttribute`. To allow for pattern detection, the LMM must be mapped to a pattern-specific meta model. In case of the pattern *List*, the class `CAttribute` is mapped to the class *ListElem*. Furthermore, the attribute `yPos` of the class `CAttribute` is mapped to the association `next`.

In the Ecore example, for each pattern, a mapping to the corresponding meta model must be defined: the correspondence between the different models can be seen in Figure 8. Here, instances of the meta models of Figure 5 are ListLM, SizeLM, ContainmentLM, GLM 1 and GLM 2. The dashed arrows show the transformations between different models. Every ellipse connected with a rectangle forms a pattern instance, e.g., List together with ListLM, or Edge Router together with GLM 1. Each meta model is instantiated several times: once for each occurrence in the LM. E.g., the pattern *List* is instantiated for each `CClass` that contains one or more `CAttributes`.

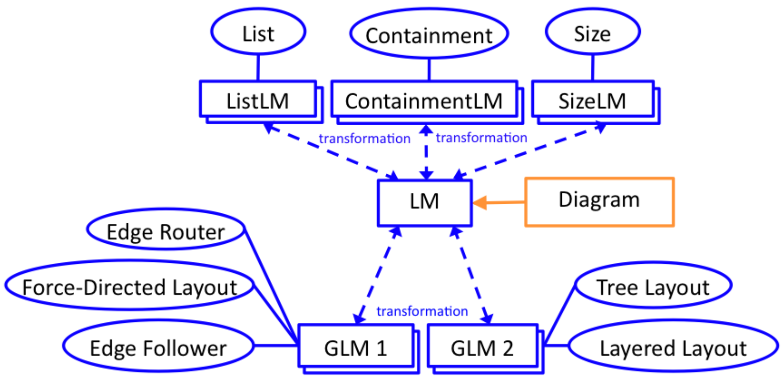
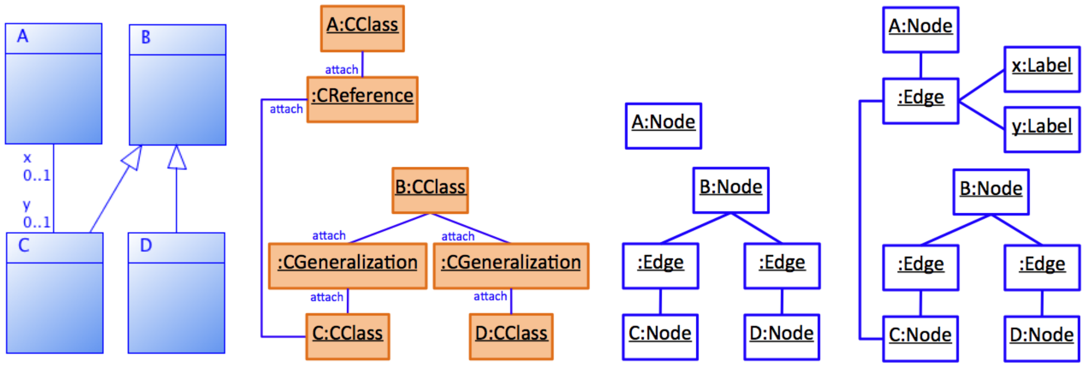


Figure 8: Correlation of Diagram, LM, Pattern-Specific Models and Patterns

For different graph drawing algorithms, it may be the case that different mappings must be specified. In our example, two mappings between LMM and GLMM are defined. Figure 9 shows an example diagram (Figure 9a) together with its LM (Figure 9b). The corresponding instances of the GLMM can be seen in Figure 9c (GLM 1) and Figure 9d (GLM 2). In GLM 1 classes are mapped to nodes, and generalizations are mapped to edges. In GLM 2, classes are mapped to nodes, and generalizations as well as associations are mapped to edges.

The easiest mapping, the mapping between LM and SizeLM, is visualized in Figure 10. The visual language for the description of QVT transformations is used [OMG05] here. In the implementation, the mappings are currently written by hand. In the example, the classes `CClass` and `CPackage` are mapped to the class `SizeElem`. By the help of model transformation, it is now possible to create an instance of each pattern-specific meta model.



(a) Example Graph (b) LM (c) GLM 1 (d) GLM 2

Figure 9: Graph Drawing

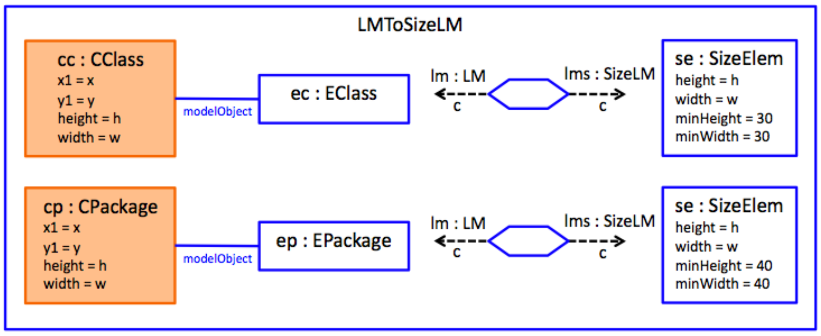


Figure 10: Mapping between LM and SizeLM

Mapping of Attributes In the transformation, attributes of classes in the LM are mapped to attributes of classes in the pattern-specific model. For the pattern *Size* (Figure 10), the class `SizeElem` has the two parameters `height` and `width`. Besides, the two options `minHeight` and `minWidth` can be set. For Ecore diagrams, the pattern *Size* is applied to packages and classes. For packages and classes, `height` is mapped to the attribute `height`, and `width` is mapped to the attribute `width`. For packages, the minimal height (`minHeight`) and the minimal width (`minWidth`) are set to 40. Analogously, for classes, they are both set to 30:

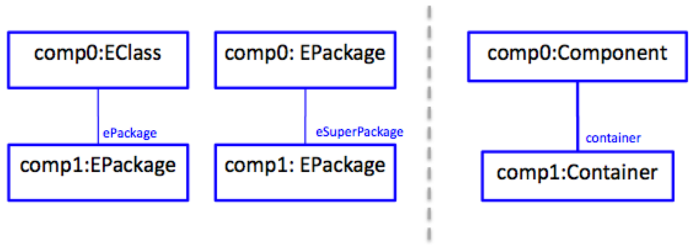
```
SizeElem
   height = CClass.height, width = CClass.width
   minHeight = 30, minWidth = 30

SizeElem
   height = CPackage.height, width = CPackage.width
   minHeight = 40, minWidth = 40
```

Here, also a more sophisticated mapping is imaginable, e.g., for places of Petri nets, `height` and `width` would be mapped to `2*radius`.

4.3 Rule-Based Layout Algorithms

The specification of rule-based layout algorithms is based on the pattern-specific meta model. Layout rules as well as strategies must be specified on this meta model.

Layout Rules E.g., the layout rules that belong to the layout pattern *Containment* are based on the meta model ContainmentLM. The "language-specific version" of this pattern consists of two layout rules, whereas the "generalized version" of this pattern consists of one rule. Figure 11 shows the left-hand sides of the layout rules that are based on the LM (Figure 11a) and the left-hand side of the layout rule that is based on the ContainmentLM (Figure 11b).



(a) LMM (b) Pattern-Specific MM

Figure 11: Left-hand side of Layout Rule

Strategies Strategies are also defined on top of the pattern-specific meta model. E.g., the strategy that belongs to the pattern *Containment* starts with the component changed, and then follows the link `container` (see Figure 5), until no more components are available.

4.4 Graph Drawing Algorithms

Graph drawing algorithms are defined on the (predefined) GLMM. The algorithm is either hand-coded or an external graph drawing algorithm. The graph drawing algorithms edge router, edge follower, force-directed layout, tree layout and layered layout all operate on the same GLMM (see Figure 8).

5 Related Work

We use the concept of layout patterns to encapsulate layout behavior. The term *pattern* is already known in the context of layout specification [SK03] where the specification of a visual language editor is based on a tree grammar instead of a meta model. We use layout patterns on the basis of meta-model-based visual language editors.

Rules are the underlying concept of our layout algorithm, as also done in [BGL06]. Here, interaction dynamics are defined via rules. In this work, the definition of interaction is based on one language-independent meta model for all diagram languages. To enable reuse, we introduce several language-independent meta models, one for each layout pattern.

In [Bra01], special aspects are discussed that should be considered when dealing with dynamic graph drawing. In this context, predictable results that preserve the mental map [PS08, MELS95] are favored, instead of high quality layout derived from a standard layout algorithm. As most diagram languages show a graph-like structure, these aspects also apply in our context and are considered in our approach.

Many tools that deal with dynamic graph drawing are based on declarative constraints, e.g., [DMW09]. In our layout algorithm, conditions are defined, which are similar to constraints. In addition, a solution is provided. This way, it is easier to define a target-oriented and, hence, a more pleasant layout behavior. In addition, performance is usually increased since no complicated constraint solver must be invoked. However, constraint-based layout algorithms can be combined with rule-based layout algorithms with our approach of layout patterns.

6 Future Work and Conclusions

In this paper, we introduced layout patterns, which encapsulate certain layout behavior. With the approach, it is possible to combine different layout algorithms: Rule-based layout algorithms that are specifically tailored to the interactive nature of visual language editors may be combined with standard graph drawing algorithms and constraint-based layout algorithms. Due to the language-independant nature of layout patterns, reuse of layout behavior is enabled. Layout patterns are defined on top of pattern-specific meta models. To allow for a seamless integration, transformations between the language-specific model and pattern-specific models were introduced. After an editor developer specifies one or more transformations, he may reuse one or more layout patterns. This way, he only needs to specify ”real” language-specific layout behavior.

Currently, transformations between models are written by hand. In future, they will be defined on an abstract level. For that purpose, we currently analyze QVT transformations [OMG05], which offer a visual language for model transformations. As a next step, an “automatic” model mapping would be imaginable, too, as done in [BSG$^+$04]. Besides, the application control is also written by hand. Here, a visual language similar to AGG, Fujaba or PROGRES [FMRS07] is under consideration.

At this point, the combination of different layout patterns is done via the application control, a language-specific control program. Currently, we are working on a more general and formal approach that replaces this part.

Our overall goal is to create a platform, on which new language-specific algorithms that are tailored to interactive diagram drawing may be rapidly created and tested.

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