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A Pattern-based Approach for Initial Diagram Layout

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Abstract: In a diagram editor, one can distinguish initial from incremental diagram layout. The former computes a diagram layout from scratch, whereas the latter adjusts an existing layout after diagram modifications.

In previous work, we have proposed a pattern-based approach as a solution for incremental diagram layout in visual language editors. Each LP encapsulates certain layout behavior. A diagram's layout is then defined by simultaneously applying several LPs to the diagram. This solution has been designed for an interactive environment where the user may select and alter the layout behavior at runtime. This paper describes an extension of this approach that now supports initial diagram layout, too. While the old version only enabled freehand editing, the extended version now supports diagram import and structured editing as well.

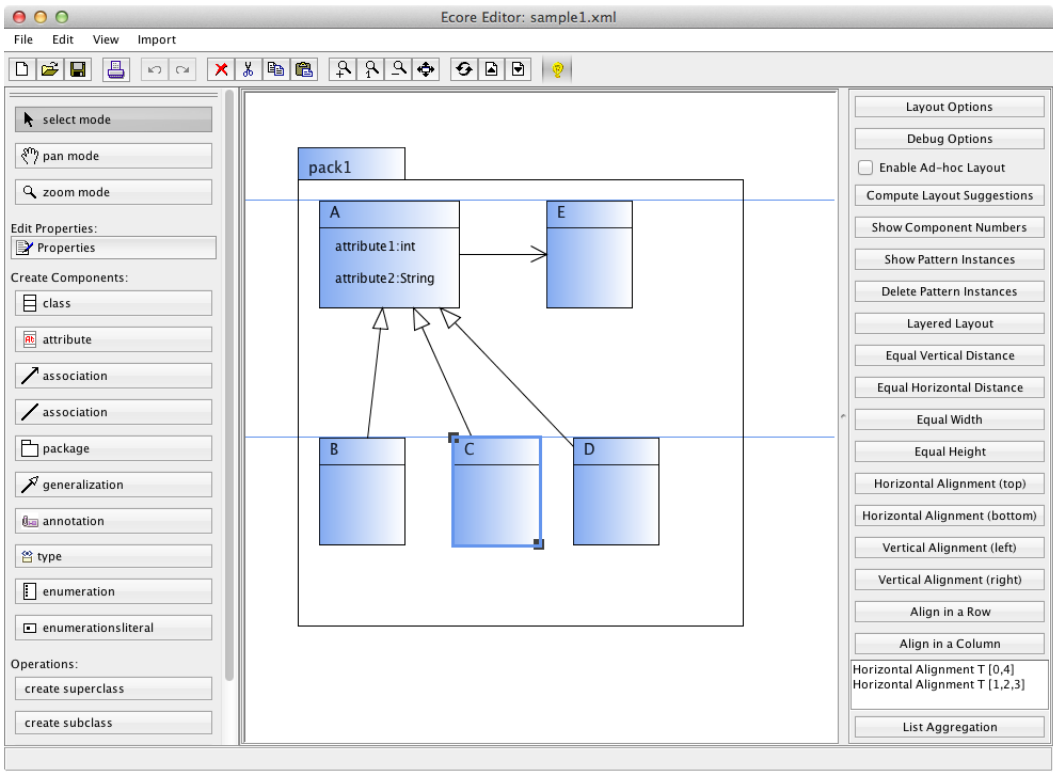
Keywords: layout, diagram editor, freehand & structured editing, diagram import

1 Introduction

A layout engine usually runs continuously within diagram editors and improves the layout in response to user interaction in real-time. Layout improvement includes all sorts of changes concerning the position or shape of diagram components. A powerful and flexible layout engine is needed in order to enable or to improve the usability of different modes of operation, such as freehand editing, structured editing or diagram import. We have developed a *pattern-based approach* [MM12, Mai12], which is tailored to such an interactive environment. *Layout patterns (LPs)* allow to encapsulate different kinds of layout algorithms and make them easily reusable for many different types of diagrams. The approach depends on a *control algorithm* for computing a diagram layout that is determined by different LP instances. With the help of the approach, the complex task of layout computation can be split up into rather small pieces.

The layout of a diagram is defined by applying LPs to selected sub-diagrams. Applying an LP to a sub-diagram means creating an LP instance and binding it to this sub-diagram. The LP instance then contributes to automatic layout, i.e., its layout algorithm adjusts component variables according to the pattern's specification. We distinguish two modes of operation which can be used simultaneously in the same diagram: *Automatic application* selects LPs and sub-diagrams automatically, controlled by the specification of the diagram syntax. For *user-controlled application*, the editor user selects diagram components that he would like to be arranged according to an LP and applies the corresponding LP to the sub-diagram consisting of this set of components.

In a diagram editor, we distinguish different ways, a user can create and modify a diagram. *Structured editing* means that the user uses editing operations that transform correct diagrams



```
Horizontal Alignment T [0,4]
Horizontal Alignment T [1,2,3]
```

Figure 1: Class Diagram Editor

into other correct diagrams. *Freehand editing*, on the other side, means that the editor user may arrange diagram components on the screen without any restrictions. The third way a user can create a diagram, is importing a diagram from an abstract representation. This mode of operation is called *diagram import* in the following. We further distinguish *initial* from *incremental (diagram) layout*. The former computes a diagram layout from scratch, i.e., without any previous layout information available, whereas the latter adjusts an existing layout after diagram modifications. Freehand editing requires incremental layout, whereas diagram import requires initial layout. Structured editing requires both initial as well as incremental layout.

Up to now, the layout approach was used in the context of freehand editing only, and hence it solely supported incremental layout. In order to support initial layout, we extended the approach, mainly by generalizing the control algorithm. In this paper, we show that the slightly adapted approach is useful in the context of diagram import. We further present a small case study, which gives evidence that the approach works well in the context of model refactoring, and, hence, in the context of structured editing. As we will see, although the approach was primarily designed for incremental layout, the adapted version is also useful in the context of initial layout, and even can be utilized for a combination of both.

Class diagrams (cf. Figure 1) are the visual language that serves as a running example in this paper. This visual language is a “real-world” example: The abstract syntax of the visual language is described by a predefined meta-model, the UML2 Ecore model [SBPM09]. This meta-model is more or less aligned with OMG's EMOF (Essential MOF), which comprises the essential parts of OMG's MOF. MOF is a so-called closed meta-modeling architecture, which defines the UML. Since class diagrams may contain a huge variety of different components, their Ecore model is quite complex. To keep the example simple, only a subset of components is considered in this paper, namely packages, classes, attributes, generalizations and associations. As can be seen in Figure 1, these components are visualized as usual.

The paper is structured as follows: Section 2 discusses related work. The extended pattern-based approach is sketched in Section 3. Section 4 gives details of how to utilize our approach in the context of diagram import as well as in the context of structured editing. Section 5 finally concludes the paper.

2 Related Work

Design patterns [GHJV95] serve as the formal basis of our pattern-based approach. In VL-Eli [Sch06], an editor generation framework, patterns are also used as a formal basis. In their approach, tree grammars are used as the basis for specifying visual languages and layout, whereas we use meta-models instead. This design decision was made, because nowadays, meta-models are more widely used than grammars. In contrast to our approach, their approach does not support freehand editing, and provides completely automatic layout only.

Dunnart [Wyb08] is an interactive system for drawing graph-based diagrams. Similar to our approach, their approach also has its strengths in the area of incremental layout, and also supports some sort of automatic and user-controlled layout.

A variety of layout algorithms exist that are tailored to one specific visual language. Most of these special-purpose layout algorithms are designed for completely automatic diagram layout only. In [Eig03], for instance, a topology-shapes-metrics approach for the automatic layout of UML class diagrams is presented. In [FSMH10], for instance, automatic layout and structure-based editing of UML diagrams is described.

Code refactorings are well known in software engineering. In case of class diagrams, the concepts can easily be lifted to models, which leads to model smells as well as model refactorings [Lan07]. Tools, such as EMF Refactor [Ecl12], enable, amongst others, the application of model refactoring operations. One weakness of such tools is often the integrated layout engine.

3 Pattern-based Layout Approach

In the following, an overview of the extended pattern-based approach is given. The approach was described in detail in [Mai12]. A brief overview of the approach and its integration into an editor is given in [MM12]. The cornerstones of the approach are the concept of LPs and an algorithm that controls the combination of different LPs. As shown in Figure 2, a diagram is internally represented by a language-specific model (LM), which is an instance of a language-specific meta-model (LMM). The LMM defines the abstract syntax and aspects of the concrete syntax of the visual language. The current layout of a diagram is represented by the LM, whereas the layout behavior of a diagram editor is defined by a set of LP instances. Each LP, in turn, encapsulates certain layout behavior.

After the user has edited a diagram, the diagram's LM is automatically created (updated). Furthermore, several LP instances are created (updated). Based on the LM and the LP instances, the new layout of the diagram is automatically computed, and the diagram is updated accordingly.

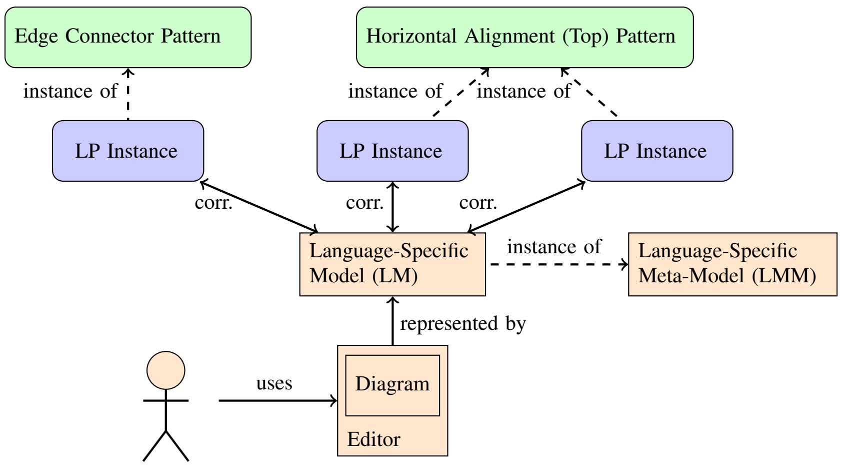


Figure 2: Overview of the Approach

3.1 Concept of Layout Patterns (LPs)

A LP encapsulates certain layout behavior. An example is the *edge connector pattern*, which ensures that "edges" are correctly connected to "nodes". Another example is the *horizontal alignment (top) pattern*, which makes sure that a set of "nodes" is horizontally aligned at the top.

As can be seen in Figure 2, after the user has edited a diagram, several LP instances are created, and a correspondence between the LM and each of these LP instances is established. A LP may be instantiated one or more times for the same diagram. Its instantiation is either performed automatically, or it is triggered by the user. For instance, the *edge connector pattern* is instantiated automatically. For the diagram shown in Figure 1, one pattern instance is created for the classes A, B, C, D and E together with the three generalizations and the association. In contrast, the instantiation of the *horizontal alignment (top) pattern* is triggered by the user. For the diagram shown in Figure 1, for instance, two pattern instances could be created - one for the classes A and E, and one for the classes B, C and D.

We distinguish two different types of LPs, namely *continuously-applied LPs (CA-LPs)* and *temporarily-applied LPs (TA-LP)*. The difference is that CA-LPs are continuously applied, whereas TA-LPs are applied for a certain time interval. The instantiation of CA-LPs is always performed automatically, whereas the instantiation of TA-LPs is either performed automatically or it is triggered by the user. In the course of LP instantiation, pattern matching is performed in order to determine the parts of the (sub-)diagram, for which the LP is instantiated. In case of CA-LP and TA-LP instantiation, pattern matching is either performed on the whole diagram or on a sub-diagram. More precisely, pattern matching is performed on the LM that represents the diagram - either the whole LM or the part of the LM that corresponds to the sub-diagram.

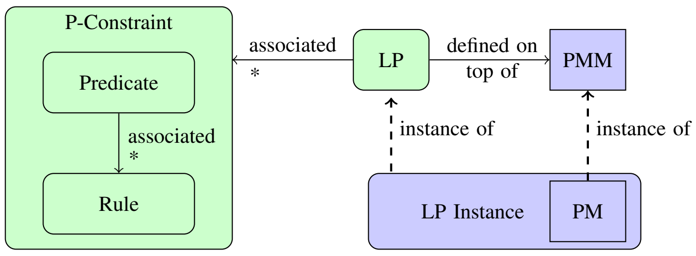


Figure 3: Layout Pattern (LP)

A LP (cf. Figure 3) is defined on top of a pattern-specific meta-model (PMM). It has one or more associated p-constraints (pattern-constraints), and each p-constraint consists of one predicate, which in turn has one or more associated rules. The predicates of all LP instances present in a diagram assure layout properties of the diagram. The layout of a diagram is correct if all predicates hold. The layout of a diagram is incorrect and needs to be updated if one or more predicates are broken. Each rule describes how the layout can be adjusted such that the broken predicate is repaired. The most commonly used types of rules are graph drawing algorithms, constraint-based (layout) algorithms and rule-based (layout) algorithms. Rule-based (layout) algorithms were introduced in [Mai12], and are specifically tailored to the interactive nature of diagram editors.

For instance, the *horizontal alignment (top) pattern* has the associated predicate $c_1.y = c_2.y$. c_1 and c_2 are two components to be aligned. $c_1.y$ is the y-position of the first component, and $c_2.y$ is the y-position of the second component. The predicate has the two associated rules $c_1.y := c_2.y$ and $c_2.y := c_1.y$, which are rather trivial. For the example mentioned above, the predicate as well as the associated rules are "instantiated" several times: For the alignment of the classes A and E, they are instantiated for the pair of components $\{A,E\}$. For the alignment of the classes B, C and D, they are instantiated for the pairs of components $\{B,C\}$ and $\{C,D\}$.

3.2 Control Algorithm for Pattern Combination

The control algorithm for pattern combination is essentially a local propagation-based constraint solver that uses backtracking. The idea is that modifications made by the user, i.e., attribute changes because of user activity - e.g. moving a class - are "propagated" in the diagram. Its purpose is to find a valid layout after user modification, and hence, to compute a variable assignment for which all p-constraints (i.e. all predicates) are satisfied.

The control algorithm allows for the computation of the layout in the context of freehand editing. The generalized version of the control algorithm now enables the computation in the context of diagram import and structured editing as well. In the generalized version, the markings *toCheck* and *frozen* are introduced, which have the following meaning: All p-constraints that involve at least one variable marked as *toCheck* are potentially violated, and need to be checked by the control algorithm. Once a variable is marked as *frozen*, it may not be changed by the control algorithm anymore. The marking *frozen* avoids a cyclic behavior, and assures that the control algorithm terminates. Backtracking makes sure that the rules are applied in an order that leads to a valid layout, if existent.

Prior to the execution of the control algorithm, some variables are marked as *toCheck*, and some are marked as *toCheck* and *frozen*. The marking depends on the user interaction that triggers the execution of the control algorithm, and will be described in Section 4. During the execution of the control algorithm, some additional variables are marked as *toCheck* and *frozen*.

Starting with the variables that were marked as *toCheck*, all p-constraints are checked that involve these variables. For each violated p-constraint, meaning that the associated predicate is not satisfied, one of the corresponding rules is executed. These rules change one or more variables. All variables that are involved in the layout computation are marked as *toCheck* and *frozen*. Again, all p-constraints are checked that involve the variables marked as *toCheck*. This procedure is continued until all p-constraints that need to be checked are satisfied. Backtracking is used if necessary. The first result found is chosen and the control algorithm stops immediately. If no solution can be found, the control algorithm signals a failure.

In one step, it might be the case that more than one p-constraint needs to be repaired, and hence, more than one rule needs to be executed. For that purpose, the control algorithm determines an ordered list of these p-constraints based on a prioritization scheme, which is defined by the editor developer. Furthermore, if a p-constraint is violated, there might be several rules available to “repair” this violation. To do so, the control algorithm determines an ordered list of these rules based on a prioritization scheme, which is also defined by the LP creator. Starting with the ordered list of p-constraints and the ordered lists of rules, the rules are tried out by backtracking until the control algorithm terminates either by finding a new assignment satisfying all p-constraints, or by signaling a failure.

3.3 Layout in the Class Diagram Editor

In the class diagram editor, several LPs are available. The application of the following ones is automatically performed: The *node overlap removal pattern* makes sure that components do not overlap. It is automatically applied to classes and packages on the same level, i.e. inside the same package. The *edge connector pattern* makes sure that edges are correctly connected. It is automatically applied to classes, together with generalizations and associations. The *minimal size component pattern* makes sure that components are larger than a minimal size. It is automatically applied to classes as well as packages. The *list pattern* makes sure that components inside a container are arranged as a list and that they are correctly contained in the container. It is automatically applied to the attributes inside a class. The *rectangular containment pattern* makes sure that components are correctly nested. It is automatically applied to classes and packages.

The application of the following LPs is controlled by the user: The *layered layout pattern* arranges components by the help of a layered layout algorithm. It may be applied to classes together with generalizations. The *equal horizontal distance pattern* as well as the *equal vertical distance pattern* make sure that components are placed equally distant to each other. They may be applied to packages and classes. The *equal height pattern* as well as the *equal width pattern* make sure that components have the same width or height. They may be applied to classes and packages. The *align in a row pattern* and the *align in a column pattern* make sure that components are aligned in a row or in a column. They may be applied to classes and packages. The *horizontal alignment pattern* and the *vertical alignment pattern* make sure that components are aligned horizontally or vertically. They may be applied to classes and packages.

4 Diagram Import, Structured Editing & Model Refactoring

As mentioned in Section 3, user interactions trigger the execution of the control algorithm. Before extending our approach, the control algorithm was executed after the user had performed freehand editing, i.e. after he had created, modified or deleted one or more components. It was also executed after the user had applied a TA-LP to a user-selected set of components. After extending our approach, the control algorithm is now also executed after the user has imported a diagram from an abstract representation, or after the user has performed a structured editing operation. Prior to the execution of the control algorithm, some variables are marked as *toCheck*, and some as *toCheck* and *frozen*, depending on one of the following situations:

- Freehand editing: All variables of all components that are modified by the user are marked as *toCheck* and *frozen*.
- User applies a TA-LP: All variables of *one of the components*, the TA-LP is applied to, are marked as *toCheck* and *frozen*. This component is (usually) the component that was selected first by the user. All variables of the other components, the TA-LP is applied to, are marked as *toCheck*.
- Diagram import: The imported diagram consists of several components. All variables of all these components are marked as *toCheck*.
- Structured editing: Several components take part in the structured editing operation. All variables of all these components are marked as *toCheck*. Some of them are (optionally) marked as *frozen* as well.

During the execution of the control algorithm, usually only a small subset of p-constraints that are present in the diagram needs to be checked. In case of diagram import, all p-constraints need to be checked, and hence, performance seems to be an issue. But this is only a minor issue, as the control algorithm only needs to be executed once after diagram import.

4.1 DiaMeta Architecture

The class diagram editor, our running example, was built by the help of DiaMeta [Min06], an editor generation framework. An overview of the architecture of a DiaMeta editor is shown in Figure 4. The abstract syntax and some aspects of the concrete syntax of the diagram are represented by the graph model. The graph model is internally transformed into the LM, which forms the basis for layout computation. Freehand editing operates on the diagram itself, whereas diagram import as well as structured editing both operate on the graph model.

After the editor user draws a diagram, the graph model is created on the basis of the diagram. An LMM instance LM is created on the basis of this graph model. Based on the LM, all LP instances are created. Some of these instances are automatically created, whereas others are created by the editor user. The layout engine gets the LM as well as all LP instances as input and computes the layout. After layout computation, all variable changes are collected, and the diagram is updated. Based on the changed diagram, the graph model, and the LM are updated automatically.

In the graph model, arrangements of diagram components are described by spatial relationships between them: Each diagram component has several attachment areas at which it can be

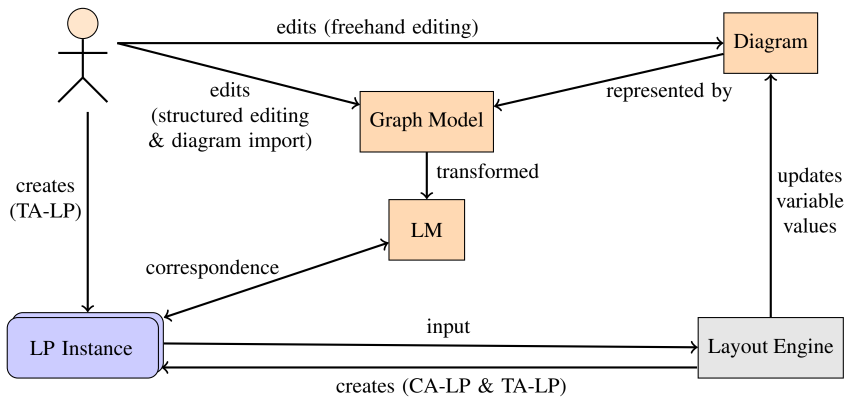
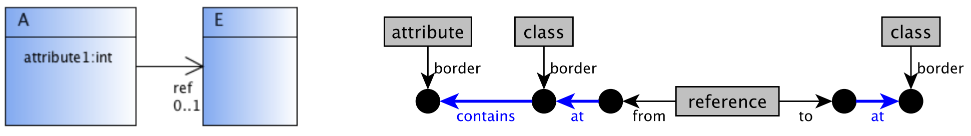


Figure 4: Integration into DiaMeta



(a) Diagram (b) Graph Model

Figure 5: Internal Representation of a Class Diagram

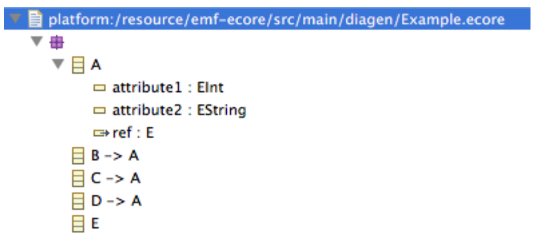
connected to other diagram components. In class diagrams, a class, for instance, has its border as attachment area, and an association has its start point and its end point as attachment areas. Connections can be established by spatially related attachment areas. In class diagrams, for instance, an association has to start or end at the border of a class in order to be connected to this class. In the graph model, each component is modeled by a node (component node). Each attachment area is also modeled by a node (attachment node). Edges (attachment edges) connect component nodes with all attachment nodes that belong to this component node. Furthermore, edges (relationship edges) connect attachment nodes that are in relationship with each other. Figure 5(b) shows the graph model of the diagram shown in Figure 5(a). Attachment nodes are drawn as black circles, component nodes as gray rectangles, attachment edges as thin black arrows and relationship edges as thick blue arrows.

4.2 Diagram Import

The pattern-based approach was designed for a context in which previous layout information is available. In case of *diagram import*, no previous layout information is available, which means that an initial layout has to be computed. In order to create an initial layout, the following procedure turned out to be reasonable: All variables are initialized with the value 0, and all instances of all CA-LPs are automatically created. In addition, one or more instances of one or more TA-LPs are also automatically created. Based on the initial values of the variables and all LP instances, the layout engine computes the initial layout as usual.

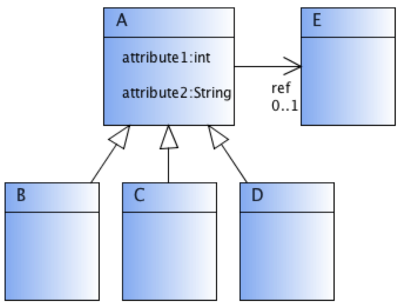
The diagram import module is specified by the editor developer. The specification consists of two parts: It is defined how the graph model is created from an abstract representation. Besides, it is specified which TA-LPs are applied to which parts of the diagram.

For the diagram that is represented in Figure 6(a), all variables are initialized with the value 0. The following instances of CA-LPs are automatically created: Instances of the *minimal size component pattern* are created for the sets $\{A\}$, $\{B\}$, $\{C\}$, $\{D\}$ and $\{E\}$ of components. An instance of the *edge connector pattern* is created for the set $\{A,B,C,D,E,g1,g2,g3,a1\}$ of components. $g1$ is the generalization between A and B, $g2$ the one between A and C, $g3$ the one between A and D, and $a1$ the association between A and E. An instance of the *list pattern* is created for the set $\{A,attribute1,attribute2\}$ of components. In addition, an instance of a TA-LP is also automatically created, namely an instance of the *layered layout pattern* for the set $\{A,B,C,D,E,g1,g2,g3\}$ of components. The diagram is arranged as can be seen in Figure 6(b).

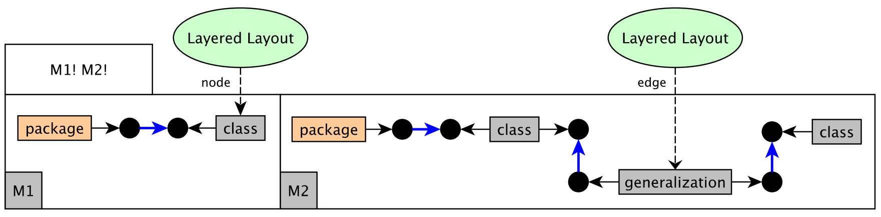


```
platform:/resource/emf-ecore/src/main/diagen/Example.ecore
  
    A
      attribute1 : EInt
      attribute2 : EString
      ref : E
    B -> A
    C -> A
    D -> A
    E
```

(a) Abstract Representation



(b) Initial Layout



(c) Specification

Figure 6: Diagram Import

Discussion In the example presented, the described procedure leads to an acceptable layout. But this may not be the case for other examples. In general, the quality of the produced layout depends on the set of LPs that is included in the editor and the specification of the diagram import module, i.e., which TA-LPs are additionally applied. The existence of cases in which an unacceptable layout is produced gives evidence that the layout specification is incomplete, and that it should be extended. For instance, in class diagrams, the nesting of packages and classes presents a challenge. An acceptable layout is produced as follows: For each package, one *layered layout pattern* instance is created. The pattern is applied to all classes and generalizations that are contained in this package. Pattern matching and LP instantiation is performed as shown in Figure 6(c): For each package, all contained classes (match of M1) and all contained generalizations (match of M2) are collected. For this set of components, one *layered layout pattern* instance is created, where classes play the role *node* and generalizations the role *edge*.

There might be cases in which it is not possible to compute a valid layout after diagram import. In such a scenario, in the worst case, a diagram import results in a diagram whose layout is incorrect. Whether or not such cases exist, again, depends on the set of LPs that is included in the editor, and the specification of the diagram import module, i.e., which TA-LPs are additionally applied. The existence of cases in which it is impossible to compute a valid layout gives evidence that the layout specification is inconsistent, and should be revised.

Up to now, we specified a diagram import module for a graph editor as well as a class diagram editor. In both cases, the import of an arbitrary diagram leads to a valid and acceptable layout. This result is promising, but does not give us a guarantee that the described proceeding suffices for other diagram editors as well. A more detailed evaluation is up to future work.

4.3 Structured Editing & Model Refactoring

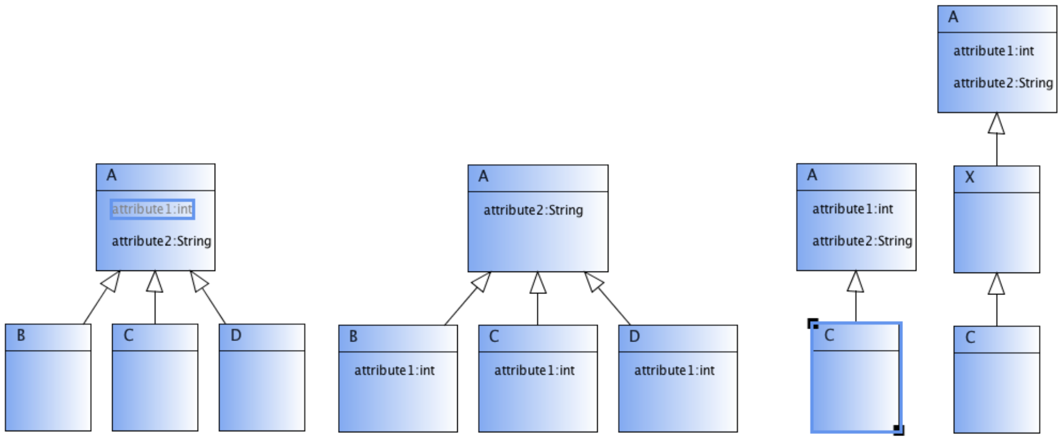
Structured editing is quite interesting in terms of layout as it requires a combination of initial and incremental layout. In the context of structured editing, in most cases, the application of CA-LPs results in a valid and acceptable layout. In some cases, it makes sense to also automatically apply one or more TA-LPs to the sub-diagram, the structured editing operation is applied to.

Structured editing operations are defined by the editor developer. The specification consists of three parts: The structured editing operation itself is defined. Besides, it is specified which TA-LPs are applied to the sub-diagram, the structured editing operation is applied to. Finally, it is defined which variables are marked as *frozen* prior to the execution of the control algorithm.

Model refactoring can be considered as structured editing with sophisticated editing operations. In a small case study, several model refactoring operations were defined and integrated into the class diagram editor. The model refactoring operations *remove (inline) associated class*, *remove (inline) superclass*, *remove (inline) subclass*, *push up (pull down) attribute*, or *push up (pull down) method* required CA-LPs only. In contrast, the model refactoring operations *create (extract) associated class*, *create (extract) superclass*, or *create (extract) subclass* required the automatic application of TA-LPs in addition to the application of CA-LPs. These were the ones that incorporated the creation of classes and (or) packages.

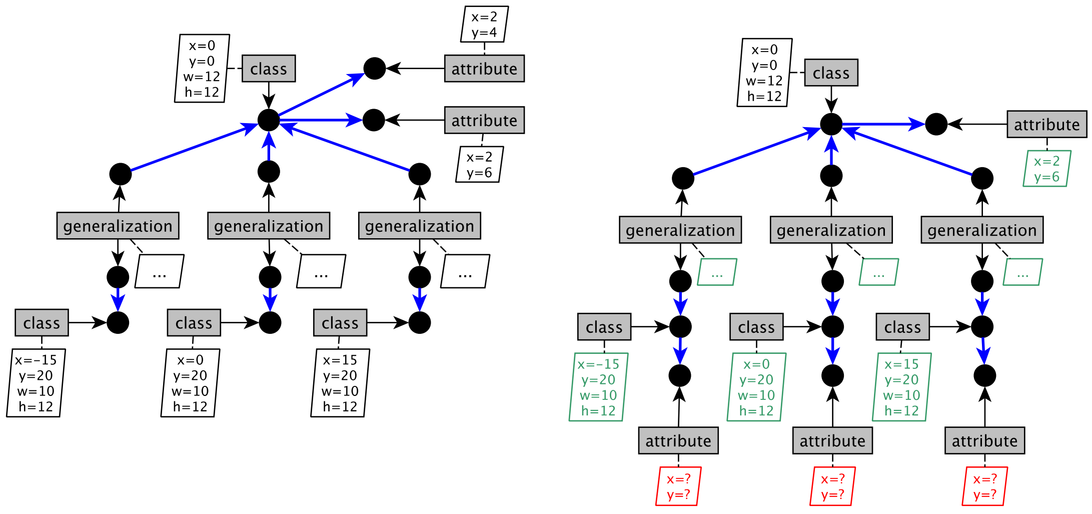
CA-LPs only For most model refactoring operations, the automatic creation of all instances of all CA-LPs turned out to be sufficient. An example is shown in Figure 7(a): The user has selected attribute $attribute1$ of type *int* and has chosen the operation *pull down attribute*. As a consequence, the attribute $attribute1$ is deleted. Three new attributes are added to the classes B, C, and D, all of them with the name $attribute1$ and the type *int*, and all of them located at the position $(0,0)$. During layout computation, several instances of several CA-LPs are automatically created. Amongst others, three instances of the *list pattern* are created. These instances make sure that the three attributes are located at the “correct” position within their containing classes after layout computation, as shown in Figure 7(b).

Figure 8(a) shows the graph model of the diagram before the model refactoring operation is performed, and Figure 8(b) afterwards, but before the layout is updated. Before layout computation, all variables that are shown in the right figure are marked as *toCheck*. During layout computation, the variables colored in red will be initialized by the layout engine, the variables colored in green will be updated by the layout engine, and the variables colored in black remain unchanged.



(a) Before (b) After (c) Before (d) After

Figure 7: Model Refactorings: Pull Down Attribute & Create Superclass



(a) Before Refactoring (b) After Refactoring, Before Layout Computation

Figure 8: Pull Down Attribute - Graph Model

CA-LPs & TA-LPs In certain situations, the automatic creation of all instances of all CA-LPs may lead to an unacceptable or invalid layout. To improve this situation, the editor developer, who specifies the structured editing operation, has the possibility to define which TA-LP instances are automatically created. An example is shown in Figure 7(c) and Figure 7(d): The user has selected class C and has chosen the operation *create superclass*. That is why the generalization between the classes C and A gets deleted. Furthermore, the class X, and the generalizations $g1$ between X and A and $g2$ between C and X get created. After creation, the class X is located at the position $(0,0)$ and has the width and height 0. Both generalizations start and end at the position $(0,0)$. During layout computation, amongst others, instances of the *minimal size component pattern* and the *edge connector pattern* are automatically created. In addition, an instance of a TA-LP is also automatically created, namely an instance of the *layered layout pattern* for the set $\{A,X,C,g1,g2\}$ of components. The model refactoring operation together with the LP instantiation is shown in Figure 9: The user-selected class is colored orange. One of the rules (R1 or R2) is applied, depending on whether or not a superclass exists. In both cases, one *layered layout pattern* instance is created.

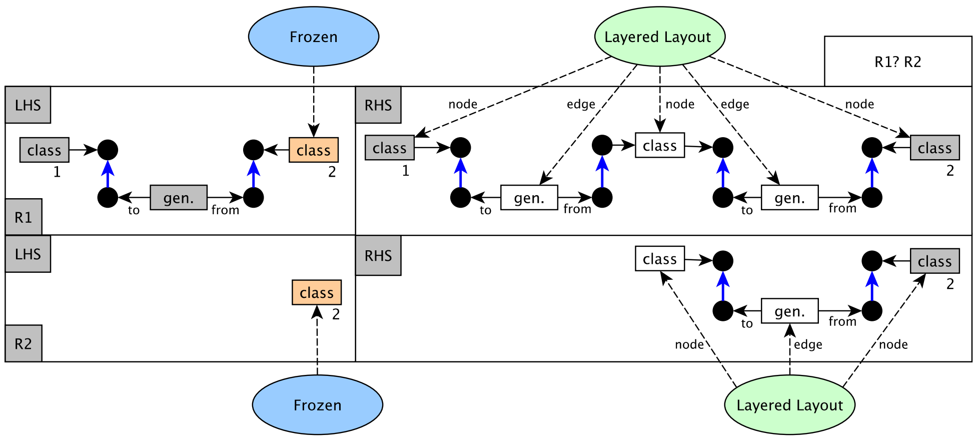


Figure 9: Create Superclass - Specification

To further improve the situation, the editor developer, who specifies a structured editing operation, has the possibility to define which variables are marked as *frozen* prior to the execution of the control algorithm. For instance, in case of the operation *create superclass*, all variables of the component that was selected by the user are marked as *frozen*. In the example, this is class C. As a consequence, this component remains unchanged during layout computation.

To improve the situation even more, the definition of the structured editing operation itself can be adapted: In the definition, the editor developer has the possibility to specify which layout information has to be provided by the editor user. For instance, in case of the operation *create superclass*, the structured editing operation is defined as follows: The user is required to select a class and then choose the operation *create superclass*. Thereafter, the layout engine updates the layout. As an alternative, the user could additionally have to choose the position, the newly created class should (approximately) be placed at. Thereafter, the layout engine updates the layout as usual.

Discussion In accordance to diagram import, there might be cases in which an unacceptable layout is produced after applying a structured editing operation. The existence of such cases gives evidence that the definition of the structured editing operation is incomplete, and that it should be extended. Also in accordance to diagram import, there might even be cases in which it is not possible to compute a valid layout afterwards. The existence of such cases gives evidence that the layout specification is inconsistent, and should be revised.

As already described, we specified several structured editing operations in the context of the small case study. The application of these structured editing operations to an arbitrary diagram leads to a valid and acceptable layout. This result is promising, but does not give us a guarantee that the described proceeding suffices for other structured editing operations as well. A more detailed evaluation is up to future work.

One interesting finding of the small case study was that the definition of the layout-part of the operations turned out to be straightforward. In contrast, the definition of the operations themselves turned out to be a bit more challenging: As DiaMeta does not focus on structured editing, the transformation language provides basic concepts only. Besides, it has some limitations concerning the possible user input. E.g., the selection of an arbitrarily-sized set of components is not supported. Another interesting finding was that model refactoring operations require a rather complex user input. E.g., the model refactoring operation *extract associated class* requires the user to select a class and an arbitrarily-sized set of attributes and methods of this class.

5 Future Work & Conclusions

In previous work, we have proposed a pattern-based approach as a solution for incremental layout in visual language editors. In this paper, an extension of this approach was described, which now supports initial layout, too. We showed that our pattern-based approach is also useful in the context of diagram import. Furthermore, the case study presented gives evidence that the approach works pretty well in the context of structured editing. With the approach, usually no "perfect" layout is achievable, but an acceptable one. Our general-purpose layout approach cannot compete with layout algorithms for diagram import or structured editing that are specifically designed for a visual language. But the nice thing is that layout support for diagram import and structured editing can be provided with very small effort.

The usability of our approach in the context of diagram import and structured editing heavily depends on the LPs that are integrated in the specific diagram editor. Hence, usability can be improved by defining additional LPs and including them in the diagram editor, or by slightly adapting one or more of the LPs that are already included in the diagram editor. But defining and including more and more LPs should not be exaggerated. More LPs means that the layout specification is more complex, and that it is more challenging to build a consistent one. Furthermore, performance issues potentially arise.

Our pattern-based approach produces a "nicer" layout in the context of structured editing than in the context of diagram import. One reason for that is that some previous layout information is available in the context of structured editing, while it is not in the context of diagram import. Another reason is that the interactivity of a diagram editor can be utilized in the context of structured editing: The user can provide some layout information himself, if required.

We have included the layout approach in several DiaMeta- and GEF-editors, and already use it for diagram import as well as structured editing in three of them. Besides the authors of this paper, several students helped creating these editors, and experimented with them. This paper reported on the findings of this informal evaluation. A more formal evaluation is up to future work. It would include the creation of several editors, the integration of the layout approach into these editors, and the use of these editors for carefully selected tasks.

At the moment, we plan to extend the approach in two different ways: Up to now, the layout engine signals a failure if it is not able to compute a valid layout. As an alternative, the layout engine could also compute a partial layout. The choice, which p-constraints are satisfied after layout computation, and which ones are not, is a challenging task. We further plan to create diagram editors that are specifically intended to run on multi-touch enabled devices: Multi-touch gestures in combination with our layout approach opens up a variety of new possibilities.

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