

DIPLOMA THESIS

**A Graphical Editor for Structural Screen Models**

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## Kurzfassung

Die Usability von vollautomatisch generierten Graphical User Interfaces (**GUIs**) ist im allgemeinen nicht befriedigend. Semi-automatisches Generieren von **GUIs** bedeutet, dass der Designer manuelle Anpassungen vornehmen muss, um die Usability des generierten **GUI** zu verbessern. Um den Aufwand dafür gering zu halten, sind entsprechende Tools Voraussetzung. Die Unified Communication Platform (**UCP**) unterstützt semi-automatische Generierung eines **GUI** anhand eines Diskurs-basierten Kommunikationsmodells. **UCP** transformiert dieses in ein Screen-basiertes **GUI**-Modell – das Structural Screen Model. Dieses Modell ist am Concrete User Interface (**CUI**) level und **UCP** stellt einen Baum-Editor zur Verfügung, welcher zwar die **Widget**-Hierarchie des Strukturellen Screen Modells darstellt, jedoch Layout- und Style-Informationen nicht graphisch visualisiert.

Der Graphical Screen Model Editor (**GSME**) ermöglicht das Visualisieren und Anpassen des automatisch generierten **GUI** auch von nicht-Programmierern (z.B., Designern). Insbesondere visualisiert der **GSME** das Structural Screen Model (i.e., im **CUI** level) mit dem angegebenen Layout und mit dem Style von einer definierten CSS-Datei. Zusätzlich ermöglicht der **GSME** Verbesserungen des **GUI** durch direkte Layout und Style-Anpassungen am Structural Screen Model, sowie spezielle Layout-Anpassungen, welche notwendige Zwischenschritte automatisieren.

Wir entwickelten den **GSME** mit Hilfe des Eclipse Modeling Projects (**EMPs**). Das **Structural UI Meta-Model** ist das zugrundeliegende Meta-Modell des graphischen Editors. Erweitert und angepasst haben wir diesen Editor, mittels Templates und zusätzlichen Java-Klassen um eine vollständige Neugenerierung zu ermöglichen.

## Abstract

The usability of fully-automatically generated Graphical User Interfaces ([GUIs](#)) is typically in need of improvement. Semi-automatic [GUI](#)-generation, i.e, keeping the designer in the loop, allows for improving the usability through manual customizations and requires adequate tool support to keep the development effort low. The Unified Communication Platform ([UCP](#)) supports semi-automatic [GUI](#) generation from high-level interaction models. In particular, [UCP](#) automatically transforms Discourse-based Communication Models into a screen-based [GUI](#) model – the Structural Screen Model. This model is on the Concrete User Interface ([CUI](#)) level and [UCP](#) provides a Tree Editor that does not graphically visualize layout and style information, but displays the widget-hierarchy of the Structural Screen Model.

The Graphical Screen Model Editor ([GSME](#)) facilitates [GUI](#) customization for non-programming experts (e.g., designers) through visualizing the automatically generated [GUI](#). In particular, the [GSME](#) visualizes the Structural Screen Model (i.e., on [CUI](#) level) with its layout information and with the style information from the specified Cascading Style Sheet ([CSS](#))-file. Furthermore, it supports layout and style customizations through direct manipulation of the Structural Screen Model and advanced layout features that facilitate customization through partly automating moving and resizing a widget.

We developed the [GSME](#) based on the Eclipse Modeling Project ([EMP](#)). The [Structural UI meta-model](#) is the underlying model for the generation of the graphical editor. Adaptations and extensions of the [GSME](#) are persisted in templates and additional Java-classes, to support the re-generation of the graphical editor.

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Nicht das Beginnen wird belohnt, sondern einzig und allein das Durchhalten. Schlussendlich diese Worte zu schreiben ist die wahre Belohnung meines Weges durch das Studium.

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# Abbreviations

<b>ANM</b>	Action-Notification Model
<b>CRF</b>	CAMELEON Reference Framework
<b>CSS</b>	Cascading Style Sheet
<b>CUI</b>	Concrete User Interface
<b>DoD</b>	Domain-of-Discourse Model
<b>EMF</b>	Eclipse Modeling Framework
<b>EMP</b>	Eclipse Modeling Project
<b>GEF</b>	Graphical Editing Framework
<b>GMF</b>	Graphical Modeling Framework
<b>GSME</b>	Graphical Screen Model Editor
<b>GUI</b>	Graphical User Interface
<b>HTML</b>	Hypertext Markup Language
<b>IDE</b>	Integrated Development Environment
<b>MVC</b>	Model View Controller
<b>OCL</b>	Object Constraint Language
<b>RCP</b>	Rich Client Platform
<b>RST</b>	Rhetorical Structure Theory
<b>SWT</b>	Standard Widget Toolkit
<b>UCP:UI</b>	Unified Communication Platform UI Generation Framework
<b>UCP</b>	Unified Communication Platform
<b>UI</b>	User Interface
<b>UML</b>	Unified Modeling Language

# 1 Introduction and Motivation

## 1.1 Motivation

Graphical User Interface ([GUI](#)) development is time-consuming and error prone, so automating this process is desirable. Model-driven software development provides the means to automatically generate [GUIs](#). Generating [GUIs](#) from high-level models potentially saves time and effort, but currently has the drawback that the usability of such automatically generated User Interface ([UI](#))s is typically rather low [MPV11]. A major reason for the low usability is that high-level interaction models do not specify any details on layout and style of the final [GUI](#). This information is completed based on heuristics during the transformation process, which does typically not lead to the result desired by the designer.

One way to remedy this problem is semi-automated [GUI](#) generation, which keeps the designer in the loop and allows her to customize the resulting [GUI](#) through additional manual input. Inclusion of the human designer requires adequate tool support, to keep the development effort low.

The Unified Communication Platform ([UCP](#)) supports fully automated [GUI](#) generation for different devices [PRK13], but the usability of the fully automatically generated [GUIs](#) is still not satisfying [RWP<sup>+</sup>13]. Its transformation process allows for customizing a screen-based [GUI](#) model (i.e., the Screen Model) before the final source code is generated. However, [UCP](#) only provides a tree editor for the Screen Model, which makes layout and style customizations a rather tedious task [Ran14].

## 1.2 Approach

The proposed approach, to include the human designer, is to provide a Graphical Screen Model Editor ([GSME](#)) that supports layout and style customizations through direct manipulation. Such an editor has the additional benefit that it also supports “perfect fidelity prototyping” [FPR<sup>+</sup>07] through providing a graphical visualization of each application screen without requiring the corresponding application logic (i.e., application back-end).

[UCP](#) is based on the Eclipse Modeling Project ([EMP](#)), therefore we decided to use the Graphical Modeling Framework ([GMF](#)) which is part of the [EMP](#). Development of the [GSME](#) has been separated in two major steps.

The first step was the visualization of the Screen Model in a diagram. This was designed to show a graphical representation of the Screens using further information from device-dependent and application-specific Cascading Style Sheet ([CSS](#)).

For the second step, we extended the [GSME](#) with a set of layout- and style-manipulations which are an intersection of the Screen Model with [CSS](#) possibilities and the possibilities provided by [GMF](#). Additionally, we introduced a set of useful manipulations which partly automate previously required manual adaptations and allow the designer to achieve the desired result with less effort.

Layout manipulations update the model-file directly, so the tree editor can show them immediately. Style-manipulations are stored in a separate [CSS](#)-file, this enables their re-usability.

### 1.3 Outline

Chapter [2](#) presents background information on the Unified Unified Communication Platform UI Generation Framework ([UCP:UI](#)) whose Structural Screen Model provides the basis for the [GSME](#). It introduces a bike rental scenario as a running example, which is used to illustrate the approach and the capabilities of the [GSME](#) in the subsequent chapters. Finally, it presents background information on the Eclipse Graphical Modeling Framework<sup>[1](#)</sup>, which was used to implement the [GSME](#).

Chapter [3](#) lists the requirements for the [GSME](#). This chapter also introduces the [GSME](#) Work-bench GUI, providing detailed information about the supported layout and style customizations and their initiation. Subsequently we present the [GSME](#) features that were implemented to support these customizations, including interesting aspects about the implementation. The satisfaction of each requirement is presented at the end of this chapter.

Chapter [4](#) presents the results of this work, by comparing visualization and customization of the Structural Screen Model using the [GSME](#) and using the Tree Editor. Furthermore, we provide the results of computational performance measurements of two aspects, the loading time of a [Screen](#) and the execution time of certain features.

Chapter [5](#) discusses the limitations and alternative possibilities. Additionally, it presents ideas and improvements for future work.

Chapter [6](#) provides the conclusion of this work.

Appendix Chapter [A](#) provides a “getting started document” for facilitating the application of the [GSME](#).

Appendix Chapter [B](#) depicts the [Structural UI Meta-model](#), which is the base-model of this work.

Appendix Chapter [C](#) shows the detailed command-execution of an [AutoSize Request](#), which belongs to an example in Section [3.3](#) (i.e., Resizing by use of the [GSME](#) Pop-up bar)

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<sup>1</sup><http://www.eclipse.org/modeling/gmp/>

## 2 Background

This chapter provides background information on the [UCP](#) GUI Generation Framework and the Eclipse [GMF](#) which is relevant for subsequent chapters. Section [2.1](#) focuses on the process of [GUI](#)-generation as supported by the [UCP](#) and its models and tasks. Section [2.2](#) provides an overview about the [GMF](#), its dependency to the Eclipse Modeling Framework ([EMF](#)) and the Graphical Editing Framework ([GEF](#)), and details about the architecture which are relevant for this work.

### 2.1 The Unified Communication Platform User Interface Generation

The [UCP](#) supports automated generation of a [GUI](#) based on a Discourse-based Communication Model.

We use a simple Bike Rental Application<sup>1</sup> as a running example throughout this diploma thesis. This application supports the following use cases: Register, Login, Rent a bike, Return a bike.

This section presents an overview about the [GUI](#)-generation process in Subsection [2.1.1](#) focusing on details of its input, the Discourse-based Communication Model (Subsection [2.1.2](#)), and on the Screen Model presented in Subsection [2.1.3](#).

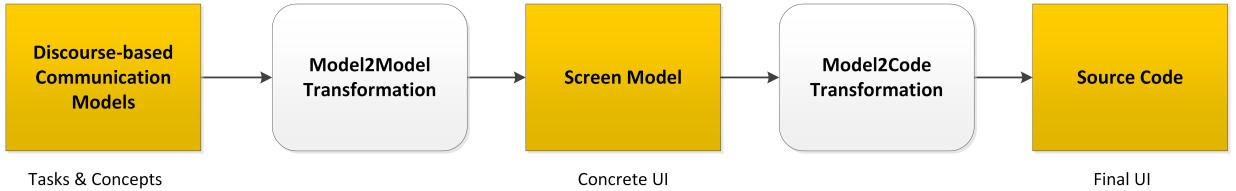
#### 2.1.1 The GUI Generation Process

The GUI Generation Process supports the (semi-) automatic transformation of a Discourse-based Communication Model to Source Code. Figure [2.1](#) shows a simplified version of this process, where the tasks (rounded rectangles) perform transformations between the models/artifacts (colored rectangles), which are on different levels of abstractions. Input is the [Discourse-based Communication Model](#), which is on the Tasks and Concepts level of the CAMELEON Reference Framework ([CRF](#)) [[CCT<sup>+</sup>03](#)]. The task [Model2Model Transformation](#) includes automated device tailoring, which considers device characteristics (e.g., screen-size). It transforms the [Discourse-based Communication Model](#) into the [Screen Model](#), which is device dependent but still independent from the target-toolkit. The abstraction level of the [Screen Model](#) is [Concrete UI](#). The task [Model2Code transformation](#) transforms the [Screen Model](#) into the [Source](#)

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<sup>1</sup><http://ucp.ict.tuwien.ac.at/UI/BikeRental>

Code (e.g., Hypertext Markup Language ([HTML](#))), which is on the Final **UI** level. For a more detailed description of the GUI generation process, see [[RPK<sup>+</sup>11](#), [Ran14](#)].



**Figure 2.1:** Simplified GUI Generation Process

### 2.1.2 Discourse-based Communication Model

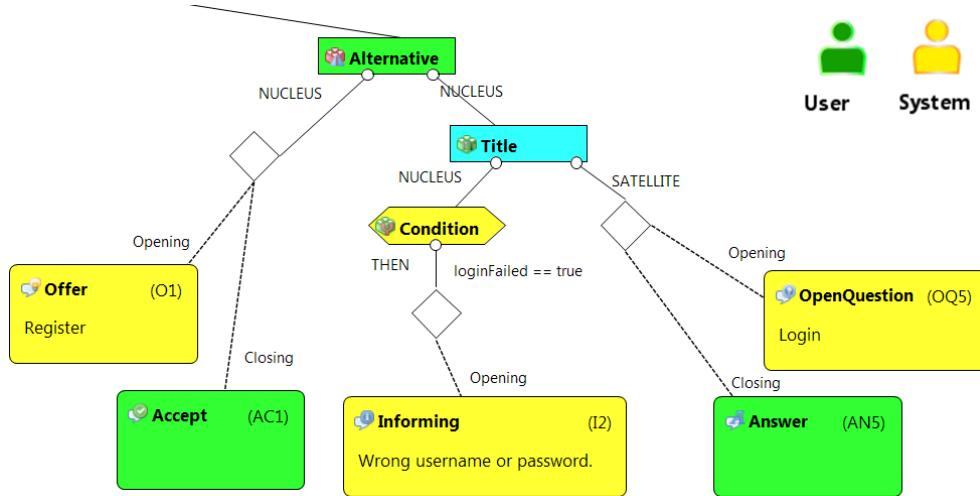
The Discourse-based Communication Model represents the communicative interaction between two parties and consists of three models [[Pop12](#)].

The first one is the **Domain-of-Discourse Model** ([DoD](#)), which specifies the objects of conversation (i.e., the objects that the two communicating parties can “talk about”) and their relations.

The second one is the **Action-Notification Model** ([ANM](#)), which specifies the operations that can be performed by a communication party [[Pop12](#)].

The third one is the **Discourse Model**, which defines classes of possible discourses using **Communicative Acts** as basic units. **Communicative Acts** specify the information exchanged between the communication parties, based on [DoD](#) and [ANM](#). **Adjacency Pairs** model typical turn-takings (e.g., question-answer) and consist of an opening **Communicative Act** (e.g., a Request) and up to two optional closing **Communicative Acts** (e.g., Accept or Reject). **Adjacency Pairs** are linked through Discourse Relations, which are partly based on the Rhetorical Structure Theory ([RST](#)) [[MT88](#)]. In addition, there are Procedural Constructs like **Condition** or the more complex **IfUntil**, which specify the flow of interaction.

Figure 2.2 shows the Discourse Model of the Login use case of our **BikeRental** example. The diamond-shapes represent the **Adjacency Pairs**. Rounded rectangles represent the **Communicative Acts**, their fill-color shows the associated uttering communication party (**System** or **User**). **Alternative** is a Discourse Relation that allows for all branches to be executed concurrently (if assigned to the **User**), in this case register and login. Its left **Nucleus** consists of an **Adjacency Pair** with the opening **Offer Communicative Act** 01, where the **System** offers the **User** to register. The right **Nucleus** consists of a **Title Relation**, which also allows for all sub-branches to be executed concurrently. In this case, the left sub-branch is conditional due to the **Condition Relation**. The **Adjacency Pair** in the condition’s **Then**-branch, has just an opening **Informing Communicative Act** I2, which conditionally informs the **User** about a failed login. The right sub-branch of the **Title** (i.e., its **Satellite**) consists of an **Adjacency Pair**, where the **System** asks for the login-credentials, modeled through the **OpenQuestion (0Q5)-Answer (AN5) Adjacency-Pair**. The opening **Communicative Acts** specify the so-called **propositional content**, which references concepts from the [ANM](#) and the [DoD](#) and defines the interface between **User** and **System**, for more details see [[Pop12](#)].



**Figure 2.2:** Discourse Model: Login of our running example (Example: BikeRentalExtended [Ran14])

### 2.1.3 The Screen Model

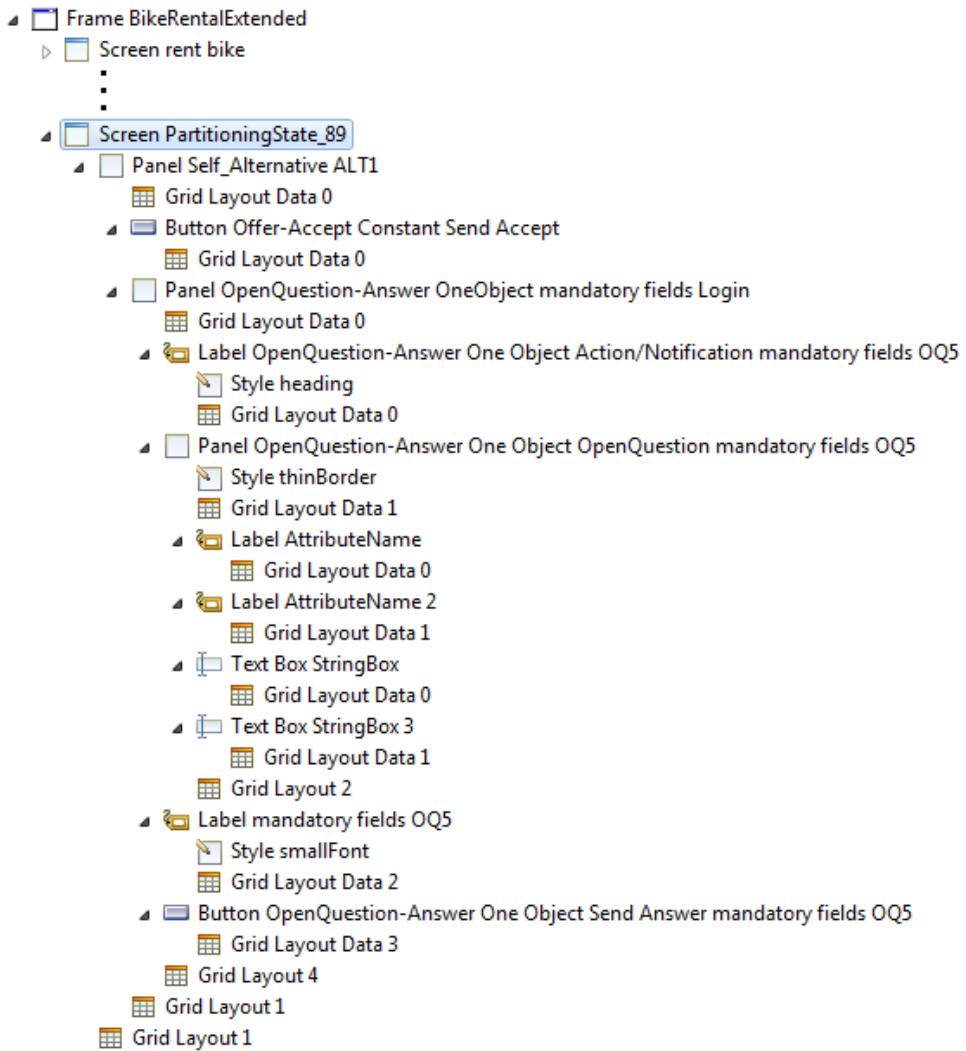
The Screen Model provides a screen-based GUI specification on [CUI](#) level [Ran14]. It consists of two parts, the **Behavior Screen Model** and the **Structural Screen Model**. The Behavior Screen Model is represented as a Unified Modeling Language ([UML](#)) state-machine, which defines all possible sequences of the Screens. The Structural Screen Model provides the basis for this work. It defines the concrete Screens with all the graphical as well as additional meta-information (e.g., reference to the corresponding element in the [DoD](#), reference to the rule which created a specific [Widget](#)).

The **Structural UI meta-model** defines all the graphical Elements (i.e., [Widgets](#)) with their properties and associations, which are available for creating the Screen Model. One specialization of [Widget](#) is [Container](#) like [Screen](#), [Panel](#), [List](#), etc., which can contain other [Widgets](#). [Buttons](#), [Labels](#), [TextBoxes](#), etc. cannot contain other [Widgets](#), they are the leaves of the model-tree.

Figure 2.3 shows the Structural Screen Model of the login use case in a tree view. The root of a Structural Screen Model is a [Frame](#) containing information about the screen-size (i.e., resolution). [Screens](#) are the direct children of a [Frame](#), and are optimized for the given resolution [Ran14].

An important attribute of [Widget](#) is [Layout Data](#), which defines the position within its parent (i.e., [Container](#)). There are different specializations of [LayoutData](#), the [XYLayoutData](#) and [GridLayoutData](#). This work concentrates on the [GridLayoutData](#), because it was the only one used in the examples and references when this work started. [Containers](#) need the additional attribute [Layout Manager](#), which must fit with the kind of [LayoutData](#) of its children (i.e., containing [Widgets](#)). The [FlowLayout](#), as an exception, does not need additional layout-information from the children. Their width and height, which are properties of the [Widget](#), are sufficient for this trivial layout.

Figure 2.3 also shows optional [Style](#)-properties (e.g., heading). The value is an ID which references a predefined style in a separate [CSS](#)-file. The path of corresponding [CSS](#)-files is also specified in the Structural Screen Model.



**Figure 2.3:** Example of a Structural Screen Model

This simple example allows identifying the references between the Structural Screen Model in Figure 2.3 and the Discourse Model in Figure 2.2. For example, the **Button Offer-Accept Constant Send Accept** in the Screen Model represents the **left Nucleus** in the Discourse Model. The **Panel OpenQuestion-Answer OneObject mandatory fields login** represents the **right Nucleus** of the **Alternative**.

#### 2.1.4 UCP-Tool Support

The **UCP**-tools are packed in a Rich Client Platform (**RCP**)-Application, which is based on the Eclipse Integrated Development Environment (**IDE**). Eclipse is mostly written in Java. It consists of a small Runtime-Kernel and a configurable amount of plug-ins, like build-tools, compilers, text editor, resource explorer, problems view, console etc.

The **EMF** is the most important plug-in for **UCP**. **EMF** supports model-based software development. It provides an **Ecore-metamodel** and a graphical editor to create a custom model. The **EMF** also supports the automated generation of a simple tree editor.

In particular, **UCP** provides a wizard that facilitates the creation of new projects [Š14], graphical editors for the Discourse Model [FKP<sup>+</sup>09] and the **ANM**, tree-based editors for the transformation rules and the Structural Screen Model [PRK13]. The **DoD** is an **Ecore Model**. So, the graphical editor provided by **EMF** is sufficient. **UCP** applies model-to-model transformations in the context of automated **GUI**-tailoring [Ran14] and model-to-code transformations for automated source code generation (see Figure 2.1). **UCP** supports generating the **GUI** source code fully automatically [Ran08]. **UCP** also generates parts of the source-code for the back-end, which runs on a Web Server as the other interaction party, the **System** [PKR13]. Further details about tool support can be found in [PRK13].

## 2.2 Eclipse Graphical Modeling Framework

This section introduces the architecture of Graphical Modeling Framework (**GMF**)/Graphical Editing Framework (**GEF**) and provides information about the generation<sup>2</sup> process of the graphical editor in Subsection 2.2.1. In Subsection 2.2.2, we provide an overview of the Eclipse Workbench, which provides the basis for the **GSME** Workbench.

### 2.2.1 GMF/GEF Architecture

**GMF** is part of the Eclipse Graphical Modeling Project<sup>3</sup>, which consists of the parts **GMF-Tooling** and **GMF-Runtime**. While **GMF-Tooling** provides a model-driven approach to generate standardized Eclipse graphical editors, **GMF-Runtime** is an application framework for creating graphical editors using Eclipse Modeling Framework (**EMF**) and **GEF**. **GEF** provides a set of libraries to develop graphical representations of a given meta-model<sup>4</sup>.

Figure 2.4 illustrates the Model View Controller (**MVC**)-architecture of **GMF**, where the **Controller**, as well as the user-interaction-interface with **Events**, **Requests** and **Commands** can be considered as part of the **GEF**. Changes to the instantiation of a specific meta-model concept can only be done via the **Controller**. There is exactly one **Controller**, the so-called **EditPart**, per instantiation. Such an **EditPart** is responsible for synchronizing the **View** (i.e., notation model) and its model (instantiation).

Persistence of the **Meta-Model** is done by **EMF**. **GMF** produces a separate diagram-file in addition to the model-file for persisting the **Notation Model** with properties like position, size, format, annotations and a reference to the corresponding model.

Figure 2.5 depicts the prerequisites for generating a graphical editor, provided as **Diagram Plug-in**. The **Meta-Model** must be provided as an **Ecore Model**. This can be created with the graphical **Ecore-Editor**, which is part of the **EMF**. The **Graphical Definition Model** (.gmfgraph) defines the notational representation (i.e., **Figures**) for the concepts specified in the meta-model. A textual **Tree Editor** with the **Eclipse Properties-View** is provided for its creation by **EMF**. The **Tooling Definition Model** defines the tools in the **Palette-View**, which supports creating new **Nodes** (i.e., a **Figure** with a corresponding **EditPart** and the meta-model) and **Links** between **Nodes**, see [Gro09]. For creating this model, the **EMF** provides another **Tree-Editor** with the **Eclipse Properties-View**. The **Mapping Model** defines the mapping between the

<sup>2</sup>In this section, the term *generation* means generation of the source-code for the graphical editor.

<sup>3</sup><http://www.eclipse.org/modeling/gmf/>

<sup>4</sup>This model is denoted as *domain* or *semantic* model in publications on GMF.

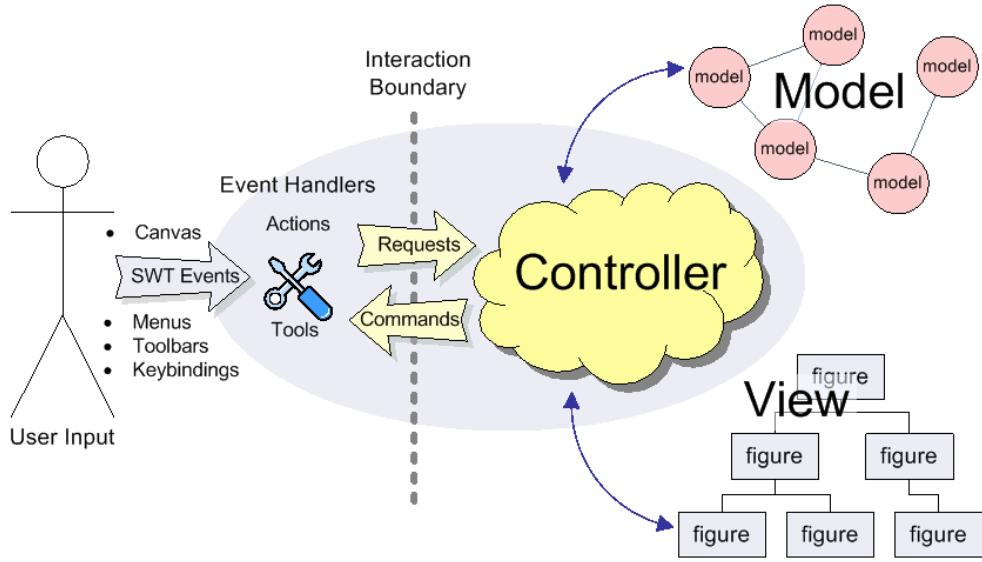


Figure 2.4: Architecture of GMF/GEF[Fou]

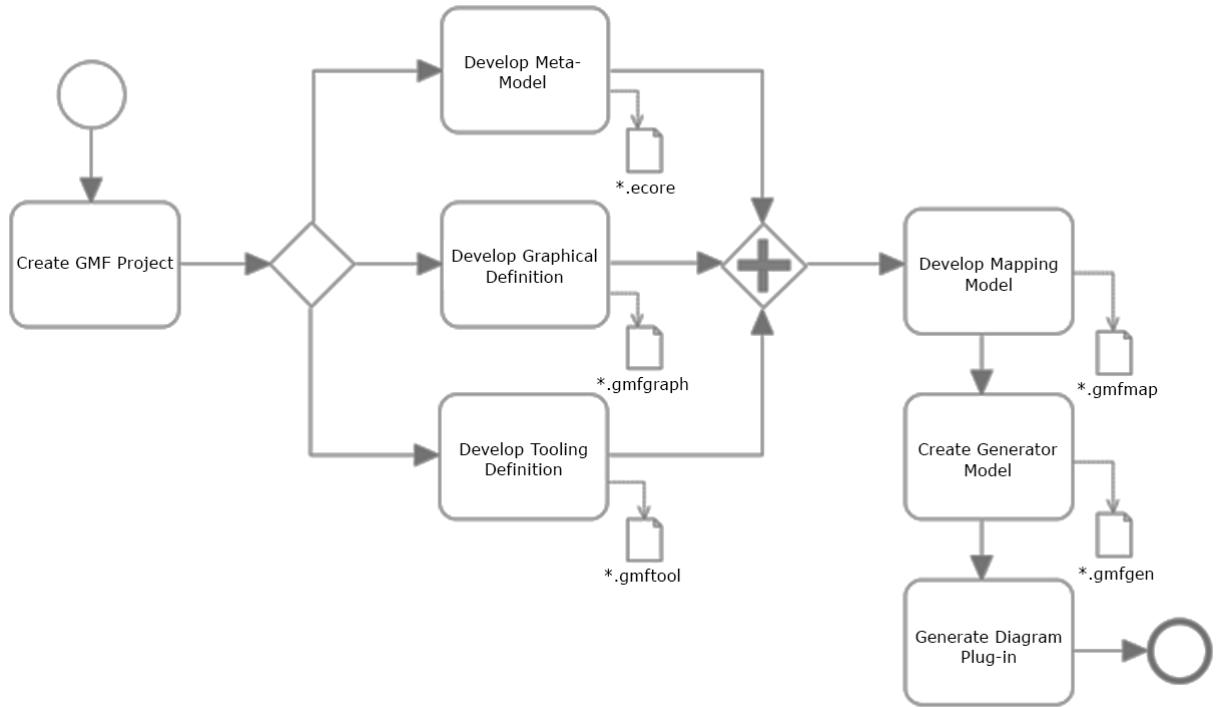
meta-model and the notation model, as well as the structure. [EMF](#) provides a wizard, which helps creating the [Mapping Model](#) using these three models. After all four models are provided, the [Generator Model](#) can be created automatically. Some adjustments on this model influence the final diagram plug-in (e.g., diagram root-element, package-prefix). Creating this plug-in, is also an automated step providing the option to build an [RCP](#)-application.

The created Diagram Plug-in (i.e., such an automatically generated graphical editor) provides common features as a basis:

- Selection and Zooming of all objects in the diagram-view
- Displaying a grid in the diagram-view
- A Diagram-Assistant providing Popup-Bars for creating new **nodes** and Connection-Handles to create **links**
- Core- and Appearance-Properties-View (e.g., to edit style-properties like font-size)
- An Appearance Toolbar to edit appearance properties (e.g., font-size)
- A Menu, providing Preview, Print and Export as an image

The [GMF](#) is built on top of [EMF](#), it supports automated generation of the source-code for a basic graphical editor, which can be easily adapted or extended. At this point, we define the terms *adaptation* and *extension*, which are used for adapting the editor with templates and extending the editor via Extension Points. The term *customization* is reserved for manual changes during the semi-automatic generation of [GUIs](#) from the Discourse-based Communication Models.

The basic diagram plug-in does not support the consideration of explicitly specified layout data, because such editors are typically used for visualizing models with no information about the layout (e.g., [UML](#) class-diagram). Visualizing layout information is a core-task of the [GSME](#), which means that the automatically generated editor needs to be adapted. Such adaptations are



**Figure 2.5:** Generating a Diagram Plug-in with GMF, copied from [Com]

typically performed on source-code level. The problem is that they are lost in case of re-generation of the graphical editor, after altering the meta-model.

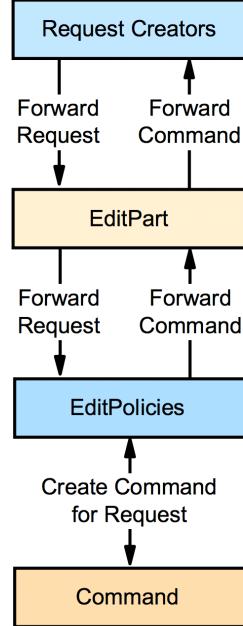
There are several ways to adapt the graphical editor in a persistent way. The simplest possibility is adaptation of the generated source-files. If the sources are regenerated, all manual changes are overwritten, unless the altered methods are annotated with `@generated not`.

Another way for making adaptations persistent, is offered through templates (e.g., Xtend, Xpand2). **GMF** uses templates for the generation of the source-files and supports using template-files. This adaption is applied at generation-time and allows for changing many similar classes/source-files (e.g., `EditParts` of `Widgets`).

Eclipse supports Extensions and Extension-Points, which can be defined by plug-ins and contributed by plug-ins. Extension-Points provide a loosely coupled way for a modular extension of a plug-in (e.g., adding menu-entries). An extending plug-in is typically an additional Eclipse-project, which the **GMF** generation-process does not alter.

In order to change the behavior of a `Widget` when the user interacts with it (e.g., hover, select, double-click), the **GEF**-architecture provides a pluggable contribution with so-called `EditPolicies` [Van04]. An existing `EditPolicy` can be assigned to a specific *role* (e.g., `PRIMARY_DRAG_ROLE`) and installed to an `EditPart`. Figure 2.6 shows the typical communication chain in **GEF**. A `Request Creator` (e.g., a drag-drop handler) creates a `Request`, which is forwarded to the corresponding `EditPart`. The `EditPart` delegates the `Request` to all installed `EditPolicies`. If an `EditPolicy` supports the `Request`, an appropriate `Command` is returned, otherwise `null`. Different `EditPolicies` can support the same `Request`. All returned `Commands` are chained together and executed sequentially. If no `EditPolicy` of a given `EditPart` supports the `Request`, the resulting `Command` is `null`, which means the `EditPart` does not support it and

the mouse-pointer shows a “not-allowed” icon to the user. A **Command**, which alters the model, can be interpreted as the upper blue arrow from the **Controller** to the **Model** in Figure 2.4.



**Figure 2.6:** Communication Chain, copied from [Van04]

The **EditParts** (i.e., **Controller** of the [MVC](#)-architecture) implement a *NotificationListener*, from which the method *notifyChanged(Notification notification)* is called, when the **EditPart** must update its **View** due to a corresponding *semantic change within the model*, which is visualized by the blue arrow in Figure 2.4 pointing from the **Model** to the **Controller**. A notification is also fired, when an **EditPart** must update its model due to a *notational change in the diagram*. This notification is depicted as the upper blue arrow pointing from the **View** to the **Controller**.

### 2.2.2 Eclipse Workbench

The Eclipse Workbench provides many perspectives and views to facilitate different kinds of software development. This subsection introduces the most common visual parts. Figure 2.7 depicts an overview of the Eclipse [IDE](#). The green-framed Views, referenced by the number in the box, are:

- 1 – **The Toolbar Menu**, which provides shortcuts for often used actions (e.g., New, Run, Debug, Search).
- 2 – **The Project Explorer**, which lets the user navigate through the projects, create/open files and folders. Alternatively, a Resource Explorer can be used, which provides similar navigation.
- 3 – **The Editor**, which visualizes the corresponding content. There are different Editors for different kinds of Data.

- 4 – The Outline View**, which shows an outline of the Editor content (e.g., overview). This can also be a graphical representation.
- 5 – The Properties View**, which provides details of the item that is selected in the Editor or in the Project Explorer.

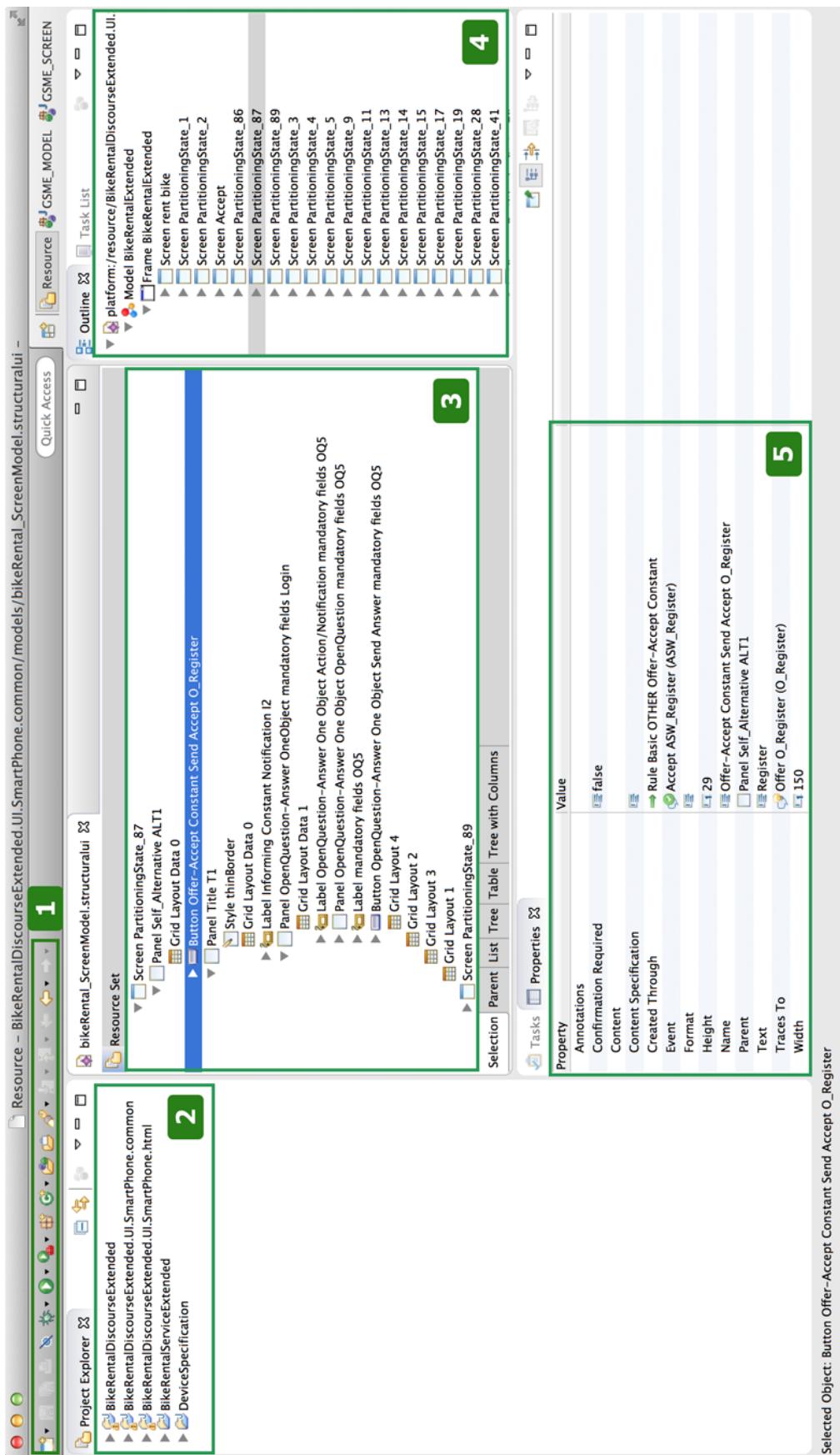


Figure 2.7: Eclipse Workbench

## 3 Graphical Screen Model Editor

The Graphical Screen Model Editor (**GSME**) visualizes the **Structural Screen Model** and supports its customization. The **GSME** consists of two diagram plug-ins and an additional plug-in that implements a custom toolbar (i.e., the **GSME** Toolbar) and handles its actions. The first diagram plug-in provides an overview of all Screens specified in a given **Structural Screen Model** and the second diagram plug-in provides a **Screen**-based visualization of the automatically generated **GUI**. Furthermore, the **GSME** supports several customizations.

Section 3.1 presents the requirements for the **GSME**, followed by argumentations about the choice of the used architecture. Section 3.2 presents an overview of the **GSME** Workbench, which hosts the diagram plug-ins, and details about the initiation of the supported customizations. Section 3.3 presents the software design and illustrates the implementation of the customizations (i.e., features) supported by the **GSME**.

### 3.1 Requirements for the GSME

Following, we itemize the requirements and present the rationale for the used architecture in the **GSME**.

**RQT1** – The **GSME** shall generate a graphical representation of **Widgets** (i.e., a diagram) for \*.structuralui files.

**RQT2** – The **GSME** shall use the layout information specified in the Screen Model for the graphical representation.

**RQT3** – The **GSME** shall use the style information specified in referenced **CSS**-files for the graphical representation.

**RQT4** – The **GSME** shall use only information specified in the Structural Screen Model, including referenced information (e.g., style-references), for the graphical representation (i.e., without information from an application back-end).

**RQT5** – The **GSME** shall make manipulations (e.g., layout, size, text, color, etc.) in the diagram persistent in either the \*.structuralui file or an additional **CSS**-file.

**RQT6** – The **GSME** shall provide support for restricting/constraining the allowed manipulations (e.g., a **Widget** can only be laid out anew within its **Container**).

**RQT7** – The **GSME** shall be compatible with Eclipse Validation Framework Live Constraints.

**RQT8** – The **GSME** shall be regenerate-able (i.e., all code modifications shall be persistent, for new generation).

**RQT9** – The **GSME** should support realistic figures for displaying the **Widgets** to make the diagrams more intuitive.

**RQT10** – The **GSME** should provide an interface for reporting layout customizations.

Based on these requirements, we compared three different alternatives for implementing the **GSME**. The first alternative was to build the **GSME** from scratch. This would have been the most flexible way, but also the most expensive one. The second alternative was to extend an existing tool (e.g., the Eclipse WindowBuilder<sup>1</sup>) and use it as a basis for the **GSME**. For that, intensive research of the specific tool and its output would have been necessary. A remaining uncertainty, about the extent of the changes on the tool, keeps the expense difficult to estimate. The third alternative was to use the Eclipse **GMF** to create the graphical diagrams. **GMF** supports visualizing **EMF**-models (e.g., the Screen Model) and provides basic editor functionality. The **GMF** is known to have a steep learning curve, but compared with the other alternatives, it potentially allows for an efficient implementation.

The rationale for using the Eclipse Modeling Project with the **EMF** and the **GMF**, was also driven by the already existing **UCP**, which hosts the **GSME** as a collection of plug-ins. The **UCP** already contained other graphical editors (e.g., the Discourse Model Editor), which are based on the **EMF/GMF** [FKP<sup>+</sup>09]. So, the **EMF** and **GMF** plug-ins were already part of **UCP** and the know-how was already available in the development team and in the project.

### 3.2 GSME Workbench GUI

The **GSME** Workbench provides the **GUI** for the **GSME**. Figure 3.1 depicts an overview of the **GSME** Workbench. The green rectangles are described next, referenced by their numbers in the boxes:

**1 – The Appearance Toolbar** provides a standard set of style modifications (e.g., fonts and colors).

**2 – The Package Explorer** shows the file-structure of all projects (i.e., plug-ins).

Figure 3.1 shows the project-structure of our Bike Rental Application running example. The **BikeRentalDiscourseExtended** plug-in contains the **Discourse-Based Communication Model**, automatically generated launch-configurations and optional custom data like images, rules and style-sheets.

The **BikeRentalDiscourseExtended.UI.SmartPhone.common** plug-in is an automatically generated plug-in, which contains the Screen Model. It is used by the **GSME** as a basis and for persisting changes. The files in the **models** folder are described next. The **bikeRental\_ScreenModel\_gsme.css** is a Cascading Style Sheet (**CSS**), created by the **GSME**, which is used to persist the style-changes of the widgets. The **bikeRental\_ScreenModel.pstm** is a device-independent behavior Model, which is not to be modified and only provided for debugging reasons.

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<sup>1</sup><http://www.eclipse.org/windowbuilder/>

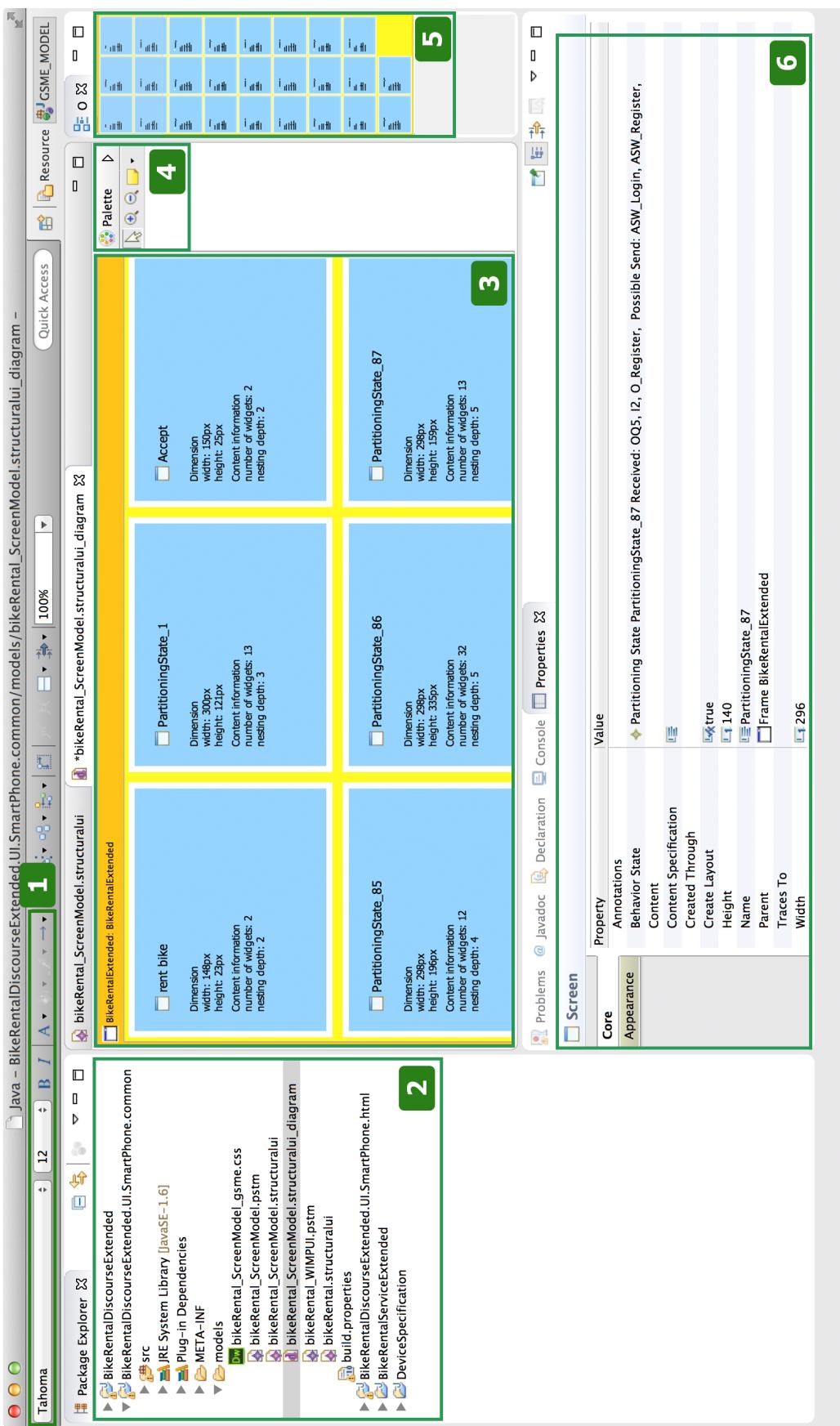


Figure 3.1: GSME Workbench showing the overview diagram (3)

The `bikeRental_ScreenModel.structuralui` is the **Structural Screen Model**, which is described in detail in 2.1.3 above. The file `bikeRental_ScreenModel.structuralui_diagram` was generated by the [GSME](#).

This generation must be triggered manually, with “initialize diagram file” from the context-menu of the **Structural Screen Model**-file (accessible through a right-button mouse click on the corresponding Screen Model file). The `bikeRental_WIMPUI.pstm` represents the **Behavior Screen Model**. The model `bikeRental.structuralui` and the `bikeRental_ScreenModel.pstm` are intermediate models, which are weaved together resulting in the Screen Model, see [RPK<sup>+11</sup>].

The `BikeRentalDiscourseExtended.UI.SmartPhone.html` plug-in is created automatically, using the Screen Model. The task **Model2Code transformation** (Figure 2.1) generates the source-code of the [GUI](#), which is persisted in this plug-in. The source code consists of [HTML](#)-, [CSS](#)- and [JavaScript](#)-files.

The `BikeRentalServiceExtended` plug-in contains the application back-end.

The `DeviceSpecification` plug-in contains default Application-Tailored Device Specifications [KRF<sup>+09</sup>] with the corresponding [CSS](#), which are used by [UCP](#) for tailoring the [GUI](#) automatically.

- 3 – **The Editor View** is presented by an Editor plug-in, which visualizes the corresponding content (e.g., a Screen Model or a Screen). Figure 3.1 shows the [GSME](#) diagram plug-in, presenting an overview of the **Frame** (shown orange) with its **Screens** (shown blue), arranged in a matrix with three columns and as many rows as necessary to display all **Screens**. If there is more than one **Frame**, the **Frames** are displayed below each other. The purpose of this plug-in is to allow for opening a particular **Screen** using the second diagram plug-in, by double-clicking the corresponding **Screen** representation. The **Screens** have automatically generated screen-names, which are difficult to assign to a dedicated **Screen** for the designer. So, we show additional **Screen**-information (i.e., dimensions, number and nesting-depth of contained **Widgets**) in the overview diagram.
- 4 – **The Palette** presents elementary tools, e.g., Selection, Zooming and Annotation.
- 5 – **The Outline View** provides an overview of the editor view’s content. The actually visible content of the editor view is a highlighted segment, which is indicated by the blue semitransparent rectangle. This can also be moved, to change the visible content of the editor.
- 6 – **The Tabbed Property View** in Figure 3.1 shows the **Core Properties**-tab, which represents the properties of the **Widget** that is selected in the Editor-View – in our case, the **Login-Screen** (PartitioningState\_87) of our running example. Let us introduce the properties of the **Login-Screen**. **Annotations** are supported by every Ecore-Object (the Ecore-class is the very super-type of the **Widget** class). **Annotations** are used, for example, to pass information to the [UCP-Layouter](#) [RPV12]. The **Behavior State** links to the **Behavior Screen Model**. The **Content** defines information about dynamic data to display, unknown at design-time (e.g., a specification of a [DoD](#)-Model concept). The **Content Specification** is an Object Constraint Language ([OCL](#)) expression, evaluated on the object in the **Traces To**-property (which references to a **Communicative Act** of the **Discourse Model**). The result is stored in the **Content**-property. **Created Through** shows the id of the transformation rule that created a specific **Widget**. **Height** and **Width** define the dimension

of a **Widget**. The property **Name** presents a generated string that identifies the **Widget**. The **Parent** shows the type and the name of the **Widget**'s parent (i.e., **Container**).

GMF supports tabbed Property Views, the **Appearance** Property Sheet can be selected by clicking on its caption. It contains the same properties as the **Appearance** Toolbar.

Figure 3.2 depicts the **GSME**-toolbar and the **Screen**-based diagram.

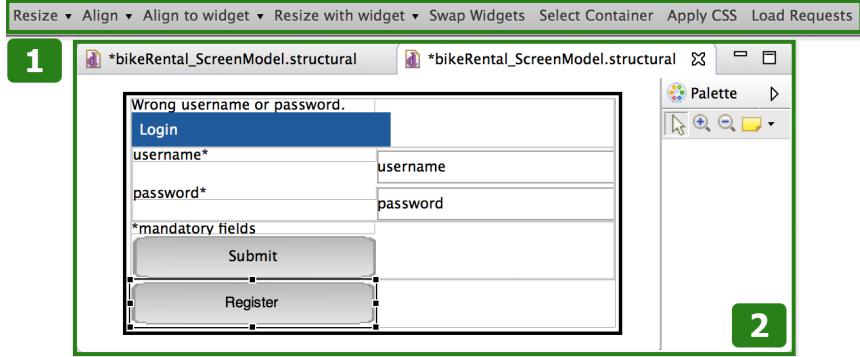


Figure 3.2: The **GSME**-Toolbar and the **Screen**-based diagram of our running example

- 1 – **The GSME-toolbar** lets the user initiate features for customizing the size and position of a **Widget** (depending on other **Widgets**). Furthermore, it allows for selecting the **Container** of a **Widget**, applying the **CSS**-styles on the selected **Widget** and all containing **Widgets** recursively. It also supports loading of previously initiated Changes (i.e., **Requests**) [Ran14]. A detailed description of the menu-items is presented below.
- 2 – **The Screen-based diagram** presents the detailed preview of our running example's login-screen (in the black box). It is the same screen as shown in the tree-view in Figure 2.3. This preview already visualizes the layout as well as the graphical style (e.g., font, font-size, font-color, background-color) from the given **CSS** and allows the designer to get a good idea of what the final **UI** will look like.

### 3.2.1 Layout Customizations

Layout customizations change the *size* or *position* of **Widgets**, constrained by the **Layout** of the **Container** (i.e., parent), by other **Widgets**, having the same parent (i.e., siblings) and by contained **Widgets** (i.e., children). Table 3.1 summarizes these constraints.

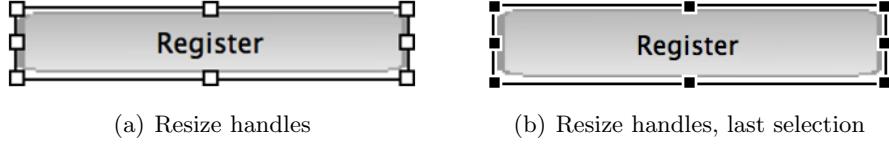
Table 3.1: Layout constraints

1	<b>Containers</b>	must wrap their children
2	<b>Widgets</b>	must be within their parents
3	<b>Widgets</b>	must not overlap with siblings

Layout customizations can be initiated in several ways, the most intuitive are direct manipulations on the **Widget**. Before a customization can be applied on a **Widget**, it must be selected (with the exception of using the **GSME**-Toolbar). Following, a short description of every customization and their initiation is presented. They are split in resize and move customizations.

### Selection of a Widget

A **Widget** can be selected by a single left mouse-click, which is reflected by a surrounding thin rectangle with so-called *resize-handles*, see Figure 3.3 (a).



**Figure 3.3:** Resize handles

### Selection of multiple Widgets

Multiple selection is possible by pressing *CMD* on a MAC (or *CTRL* on a PC) while selecting the **Widgets**. The last selected **Widget** shows a small difference in its resize handles (Figure 3.3 (b)). Some **Resize with Widget** and **Align to Widget** customizations support changes on multiple **Widgets** in one step, using the last selected **Widget** as a **reference Widget**.

### Selection of invisible Containers

Some **Widgets** have a **Container** with a size equal to the **Widgets**-size. Moving or Resizing such a **Widget**, may show the *unsupported operation icon* (Figure 3.4) decorating the mouse-pointer because of a violated constraint from Table 3.1 with this *invisible Container*. Preceding manipulation on this **Container** is necessary, which requires its selection. Direct selection of such an invisible **Container** is not feasible, so the **GSME** Toolbar offers the menu-entry **Select Container** (Figure 3.2 (1)).



**Figure 3.4:** The *unsupported operation icon*

#### 3.2.1.1 Resize Customizations

Resize customizations include changing width and height of a **Widget**.

##### Directly Resizing

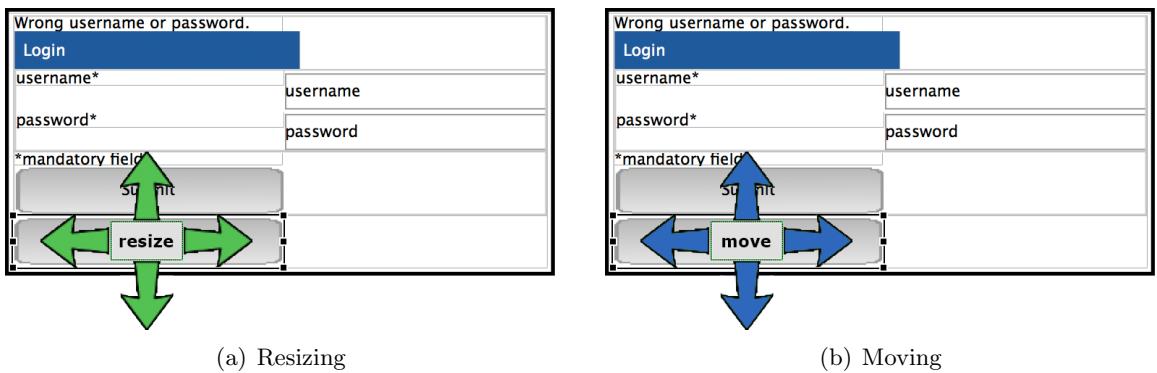
Direct resizing means to grab the **Widget** on a *resize-handle* and drag it to the desired size. This change of size is represented graphically with a gray rectangle, as well as numerically, showing the actual *width* and *height* during the operation. Figure 3.5 (a) shows the feedback during the resize-operation. If the designer tries to resize the **Widget** exceeding the available space, an *unsupported operation icon* decorates the mouse-pointer. The designer is responsible to free the space by moving or resizing other **Widgets** or **Containers**, which can be a tedious task if the **Widgets** are deeply nested.



**Figure 3.5:** Feedback during a direct manipulation

### Resizing by use of the **GSME** Pop-up bar

This feature automates the tedious task of moving or resizing other **Widgets** or **Containers** described above. The designer just selects the **Widget** and the direction in which to resize (i.e., extend the **Widget** by 10 pixels), the **GSME** automatically frees the required space, by moving siblings and resizing parents recursively. This **GSME** Pop-up bar can be accessed by pressing *Shift* while hovering the **Widget** (i.e., moving the mouse-pointer over the corresponding **Widget**). The appearing pop-up bar shows the name of the operation (i.e., “resize”) in the center, surrounded by green arrows in each direction (Figure 3.6 (a)). By clicking on an arrow, the **GSME** stretches the **Widget** by 10 pixels in the selected direction. Resizing to the left or top direction, performs a move and resize operation concurrently, because changing the left-top corner position of a **Widget** means a move operation.



**Figure 3.6:** Customizations through the **GSME** Pop-up bar

### Resizing by use of the Core Properties View

Resizing a **Widget** can be done by changing the **width** and/or **height** values of the corresponding properties in the Properties View. After applying a new value, it is immediately verified by the Validation Framework [Sch10], regarding the constraints from Table 3.1. Figure 3.7 shows the result of changing the height of a **Button** from the Properties View. The new height of the **Widget** is invalid, because of a violated constraint from Table 3.1 (e.g., the **Widget** would overlap a sibling).

### Resizing by use of the Toolbar Menu

Figure 3.2 (1) depicts the **GSME** Toolbar, which provides two advanced *resize-features*.

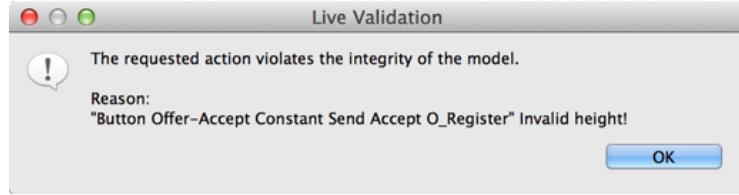


Figure 3.7: Feedback from the Validation Framework

**Resize** is the first *resize-feature*, which extends the selected **Widget** in a specified direction. The **Resize** menu-entry hides a sub-menu for MAX, TOP, RIGHT, BOTTOM and LEFT. These are the directions in which the selected **Widget** can be extended, until it touches a sibling or its container. MAX extends the **Widget** in all four directions.

Figure 3.8 presents an example, where the designer wants to extend the title “Login” (i.e., a styled **Label**) to grab the whole width of its **Container**. The designer selects the **Label** to resize Figure 3.8 (a), then she opens the **Resize** sub-menu and selects the entry **Right** to extend the **Label** to the most right valid position. Figure 3.8 (b) shows the resulting **Screen** with the extended **Label**.

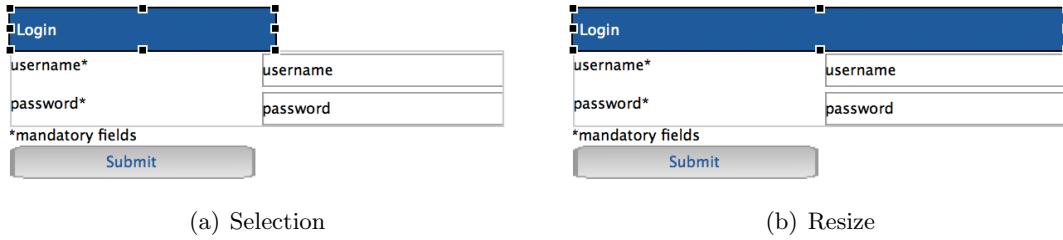


Figure 3.8: Example: Resize via the GSME-Toolbar

**Resize with Widget** is the second *resize-feature*, which changes the size of a **Widget** in a specified plane (HORIZONTAL, VERTICAL or ALL), depending on the size of a **reference Widget**. This menu-entry hides a sub-menu for selecting one of these planes. To use this feature, it is necessary to select two or more **Widgets**. The last selected **Widget** is used as the **reference Widget**, whereas all previously selected **Widgets** are resized according to the size of the **reference Widget** in the respective plane(s). If there is not enough empty space for the resize operation, the **GSME** tries to free the space by moving and resizing other **Widgets** (i.e., obstacles). The **GSME** does not handle the case, if a **Widget** to resize is an obstacle for other **Widgets**. Figure 3.9 shows the corresponding error.



Figure 3.9: Error if an obstacle is a **Widget** to resize

Figure 3.10 (a) shows an example, where the designer wants the three **TextBoxes** to have equal widths, the same as the one in the middle. The corresponding multiple selection is depicted in Figure 3.10 (b), where the **reference TextBox** can be identified through the black *resize-handles*. After folding out the sub-menu of **Resize with Widget**, the designer selects the **HORIZONTAL** plane. Figure 3.10 (c) shows the result of this example, where all three **Widgets** have the same width.

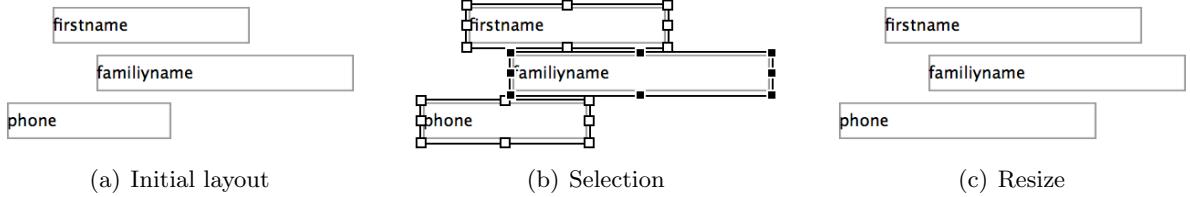


Figure 3.10: Example: **Resize with Widget** via the **GSME**-Toolbar

### 3.2.1.2 Move Customizations

Move customizations include changing the position of a **Widget** (specified through the *x* and *y* coordinates of the **Widget**'s upper left corner).

#### Directly Moving

Moving a **Widget** can be done directly, by grabbing the whole **Widget** (not the *resize-handles*) and dragging it to the desired position. Another possibility to move the **Widget**, is to use the *cursor buttons* on the keyboard to move it by 1 pixel with each click. The visual feedback for moving is shown in Figure 3.5 (b), where the numerical values reflect the top-left coordinates *x* and *y*, relative to the **Widget**'s **Container**. The designer is not allowed to move the **Widget** overlapping another one or outside its **Container**. This is displayed by the *Unsupported Operation Icon*, which decorates the mouse-pointer. The designer is responsible to free the space manually in advance.

#### Moving by use of the GSME Pop-up bar

This feature moves a **Widget** by 10 pixels in the selected direction, freeing the required space for the movement automatically. The **GSME** Pop-up bar for moving can be accessed by pressing **CTRL** while hovering the **Widget**, see Figure 3.6 (b).

#### Moving by use of the Toolbar Menu

Figure 3.2 (1) depicts the **GSME** Toolbar, which provides two advanced *align-features* and the feature **Swap Widgets**, which is related to the move features.

**Align** is the first one, which moves the selected part as far as possible (until it touches a sibling or the border of the parent) in the selected direction. The sub-menu provides the directions TOP, RIGHT, BOTTOM and LEFT.

Figure 3.11 presents an example, where the designer wants to align the **Button** “Submit” to the right of its **Container**. She selects the **Button** to align (Figure 3.11 (a)) then she opens the **Align** sub-menu and selects the entry **Right** to move the **Button** to the right most position. Figure 3.11 (b) shows the result.

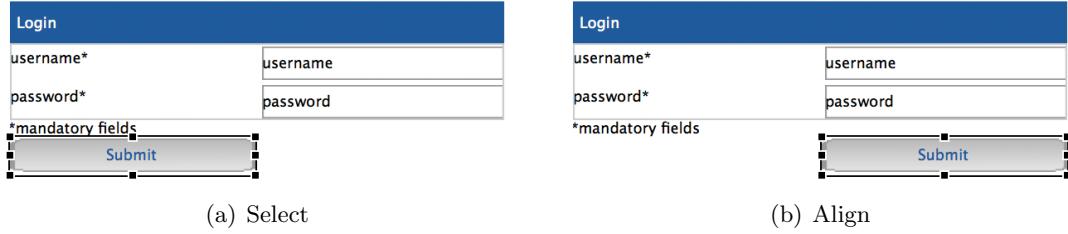


Figure 3.11: Example: Align via the GSME-Toolbar

**Align to Widget** is the second *align-feature*, which automatically aligns a specified edge of the selected **Widget** to that of a **reference Widget**. This feature frees the space if necessary. The menu-item of this feature offers the edges TOP, RIGHT, BOTTOM and LEFT. The last selected **Widget** is the **reference Widget**.

Figure 3.12 (a) shows an example, where the designer wants the three **Text Boxes** to be aligned to the left edge of the bottom **Text Box**. The corresponding selection is depicted in Figure 3.12 (b), where the **reference TextBox** can be identified through the black *resize-handles*. After folding out the sub-menu of **Align to Widget**, the designer selects the **LEFT** edge. Figure 3.12 (c) shows the result of this example, where all three **Widgets** are aligned.

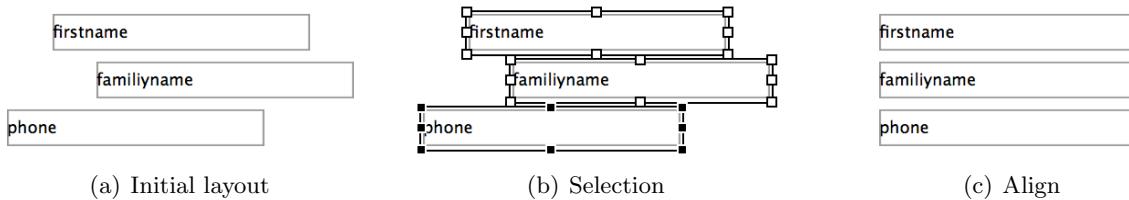


Figure 3.12: Example: Align to Widget via the GSME-Toolbar

**Swap Widgets** is a useful feature, which changes the position of two selected **Widgets**. This feature requires the selection of exactly two **Widgets**, which must have the same **Container**. The best result can be achieved, if the **Widgets** have the same size, so that no automated move or resize operations are necessary to free required space. This would result in a, maybe undesired, change of the layout. The size of the **Widgets** to swap is not changed.

### 3.2.2 Style Customizations

Style-customizations change the appearance of a **Widget** (e.g., border, color, font). Supported style-customizations are a subset of the styles specified in [CSS 2.1](#), but not all of them can be reflected by the graphical editor, see Table 3.2. For example, if the selected border-style is *inset*, the [GSME](#) shows a solid bordered **Widget**. if the selected value for vertical text alignment (*vertical-align*), is *baseline*, the [GSME](#) shows the text bottom-aligned. The supported values of *vertical-align* is just a subset of its [CSS](#) specification. The values *sub*, *percentage* and *length* are not available.

**Table 3.2:** Style properties that can not be displayed correctly by the **Screen**-based diagram

Style-Property	Value	displayed
border-style	inset	solid
	groove	solid
	outset	solid
	double	solid
	ridge	solid
Text: vertical-align	baseline	bottom
	sub	n.a.
	text-top	top
	text-bottom	bottom
	percentage	n.a.
	length	n.a.

The following is divided in the initiation of the change from our custom [CSS](#)-Property-page, the standard appearance property-page and the appearance toolbar.

#### 3.2.2.1 CSS Property-Page

The [CSS](#) Property-Page in Figure 3.13 shows the supported style-customizations. In addition to the standard appearance styles, the [GSME](#) supports [CSS](#)-styles like text-alignment (horizontal and vertical), margin, and padding.

Some widget-style combinations are not supported by Web-Browsers, so they are also prohibited by the [GSME](#). Table 3.3 shows these combinations, e.g., a **TextBox** has a defined border and a background-color, which cannot be changed. A **ComboBox** does not even show styles like font-size or font-color.

#### 3.2.2.2 Appearance Property-Page and Toolbar

Figure 3.14 shows the appearance property-page, which is a standard Eclipse plug-in. It supports common style changes like fonts, colors and the border-style. The **Appearance Toolbar** (Figure 3.1(1)) provides the same possibilities to change the styles. Prohibited styles are grayed out.

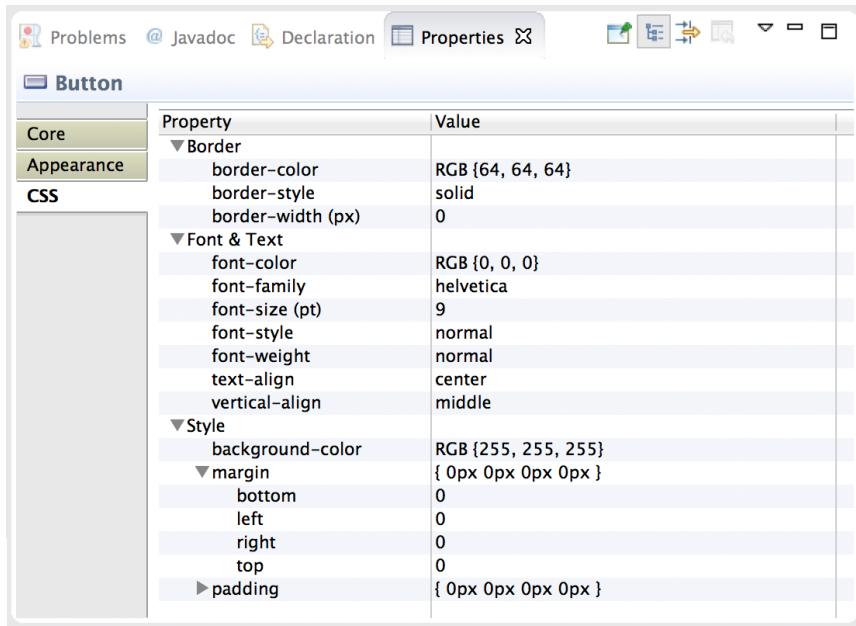


Figure 3.13: Property-Page CSS

Table 3.3: Widget-Style combinations not supported by Web-Browsers

Widget	Style
TextBox	border background-color dimension
ComboBox	border background-color dimension font-size font-style font-weight font-color
Button	border background-color

### 3.2.2.3 “Apply CSS” on the GSME-Toolbar

The [GSME](#)-Toolbar offers the menu-entry **Apply CSS**, which updates the actual styles of the selected **Widget** and its children recursively. In the development phase, it was an important menu-entry for testing and debugging purposes.

## 3.3 Software Design

The software design of the [GSME](#) is based on the design of [EMF](#) and [GMF](#) projects. The [GSME](#) consists of several plug-ins, containing the sources of the domain-model, the tree-view, the diagrams as well as a custom plug-in.

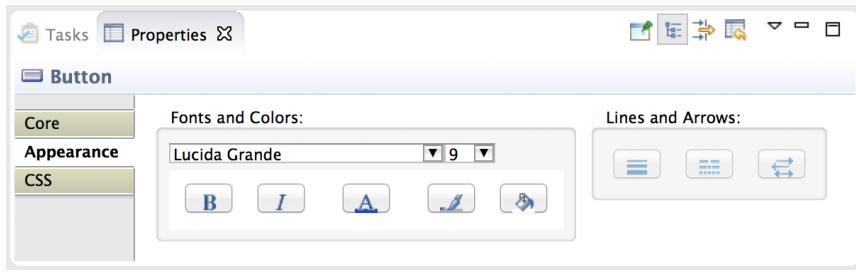


Figure 3.14: Property-Page Appearance

**E1** – The `org.ontoucp.structuralui.model` plug-in contains the automatically generated sources of the Structural UI Meta-model (see Chapter B) as well as manually added helper-classes.

**E2** – The `org.ontoucp.structuralui.edit` plug-in contains an `ItemProvider` for every Structural UI Meta-model element. `ItemProviders` are adapters, used to support the presentation of the model objects in the viewers.

**E3** – The `org.ontoucp.structuralui.editor` plug-in consists of the sources of a fully functional Eclipse Editor (i.e., Tree-View) and a wizard for creating a new model-file (i.e., graphical Screen Model).

**G1** – The `org.ontoucp.structuralui.digest.diagram` plug-in contains the sources of the overview-diagram depicted in Figure 3.1.

**G2** – The `org.ontoucp.structuralui.diagram` plug-in contains the core part of this work, the Screen-based diagram. It contains the generated diagram-basis, templates to adapt this basis and further source-files for extending the generated diagram-view.

**C1** – The `org.ontoucp.structuralui.diagram.custom` plug-in contains the toolbar-menu and the corresponding event-handling.

The Plug-ins E1 to E3 are generated by the `EMF`. Adaptations of these plug-ins, have been done directly in the files by adding the annotation `@generated not` and in separate files. If the Structural UI meta-model is changed (e.g., by adding a new type of `Widget`), these plug-ins must be re-generated, whereas the adaptations are kept.

The Plug-ins G1 and G2 are generated by the `GMF`. Adaptations have been done by adding templates, which define super-classes (e.g., for all the `EditParts` of `Containers`) and `Widget`-specific methods. These templates are used at diagram-generation-time, to create the source-code of the `EditParts`. Additional adaptations have been done by adding files. After changing the Structural UI meta-model and re-generating the plug-ins E1 to E3, the latter described plug-ins G1 and G2 must also be re-generated to reflect the changes in the diagrams. All adaptations are kept, but in case of adding a `Widget`, adaptations in a template-file to show an individual diagram-figure is necessary.

The plug-in C1 is created manually, it is not touched by a diagram-generation process.

### 3.3.1 Layout Features

This subsection shows details about the implementation of customizations, which are supported by the **Screen**-based graphical editor. The separation between *layout* and *style* continues in this section, although it cannot be split strictly, because layout-relevant data is not only persisted in the model, but also in the [CSS](#)-file. This is necessary to provide sufficient information for reflecting the layout-customizations in the final [GUI](#). In [3.3.1](#) we describe details about supported layout-features and their implementation. In [3.3.2](#) we provide information about the style-features and how they are implemented.

#### 3.3.1.1 Supported LayoutManagers

A **Layout** consists of a **LayoutManager** as a property of a container and **LayoutData** as a property of its children (e.g., **Widgets** in the domain of our Structural Screen Model).

The Screen Model uses a **GridLayout** to define position and size of the **Widgets**. The **GridLayoutManager** consists of the number of *columns* and *rows* and the lists *colWidth* and *rowHeight*, describing the size of the cells in pixels. **GridLayoutData** contains *column* and *row*, which reflect the position of the child. The values in *colSpan* and *rowSpan* reflect the used space in the granularity of a column or a row, which provide information to calculate the **Widget**'s size. There are a few additional parameters in the **GridLayoutData**, which are omitted in this work, because they were not used [\[Ran14\]](#).

An **XYLayout** consists of an **XYLayoutManager** as a property of the container and **XYLayoutData** as a property of its children. **XYLayoutData** consists of the *x* and *y* values, which reflect the coordinates of the position in pixels, relative to its parent (i.e., container).

The [GSME](#) diagram uses an **XYLayout** with one pixel as the smallest unit to create the layout for a given **Screen** (i.e., to draw the figures, which represent the **Widgets** of the Structural UI model). Using the **XYLayout** in the [GSME](#) instead of, a grid-based layout, was driven by the following rationale:

- The position of a specific figure (i.e., **Widget**) can be determined directly without the need of additional calculations.
- The **XYLayoutData** allows for easy layout verification.
- The **Structural UI meta-model** (see [Appendix B](#)) also supports an **XYLayout** to layout the **Widgets** within their **Containers**.
- The **XYLayout** is a common denominator, where all other layouts of the **Structural UI meta-model** can directly be calculated and vice versa.
- The diagram-canvas uses *draw2d* to visualize figures. *Draw2d* also supports a **GridLayout**, but this is not compliant with the more powerful **GridLayout** specified in the **Structural UI meta-model**.

For visualizing the **Widgets** (i.e., drawing the corresponding figures) in the **Screen**-based diagram, it is necessary to calculate the positions (i.e., the **XYLayoutData**) from the **GridLayout**.

To persist a layout customization from the **Screen**-based diagram into the Structural Screen Model, the new **GridLayout** of the **Widgets** must be recalculated from the **XYLayoutData** and the size of the corresponding figures (and the size of their parent-figures) from the diagram. This calculation is described below:

- Store all  $x$ -values ( $x$  and  $x + w$ ) of all direct children in a **List** (*colWidths*), avoiding duplicates.
- Add the values 0 and the **Container**.*width*, if not existing.
- Sort the values in ascending order.
- Calculate the *column* and *colSpan* values as follows. Iterate over the *colWidths* and compare with the left-bounds of the children. On a match, store the *column* and compare the next values of *colWidths* with the right bound of that child, incrementing the *colSpan* for every non-match. If the  $x$ -value from the *colWidths* equals the right bound ( $x + w$ ) of the **Widget**, the *colSpan* is determined. Store the values in the **GridLayoutData** of the corresponding **Widget**.
- Calculate the distances between the values in the *colWidths* and store them in the **GridLayoutManager**.*colWidths*.
- Store the number of columns in the **GridLayoutManager**.*columns*.

The row-values can be determined analogously from the  $y$ -values, which result in the complete **GridLayout**.

An example is depicted in Figure 3.15, where the left side depicts the laid out **Widgets** including information about both layouts. The green grid visualizes the granularity of the **GridLayout**, but we use the same grid for the **XYLayout** and show the corresponding  $x$  and  $y$  values in red. The blue values enumerate the columns and rows of the **GridLayout**. The tables in Figure 3.15 present the corresponding **LayoutManagers** and **LayoutDatas** of this simple example.

**XYLayoutManager** (Container)

	width	80
	height	50

**XYLayoutData** (Container)

	Label	Button	TextBox
X	10	50	20
Y	20	10	30
width	20	20	40
height	10	10	10

**GridLayoutManager** (Container)

cols	7
rows	5
colWidths	10 10 10 20 10 10 10
rowHeights	10 10 10 10 10

**GridLayoutData** (Container)

	Label	Button	TextBox
column	1	4	2
row	1	1	3
colSpan	2	2	3
rowSpan	1	1	1

Figure 3.15: The relation between XYLayout and GridLayout

The Structural UI Meta-model also specifies an **XYLayout**, which can be used by the Structural Screen Model. The **GSME** is not prepared for that, because it was not implemented in the **UCP**, but it could be a trivial extension to implement support for it.

### 3.3.1.2 Resize Features

Following, the implementation of the resize-features is presented. They are structured according to their types of initiation. Details about the initiation are shown in [3.2.1.1](#).

#### Direct Resizing

This feature implements resizing a **Widget** through direct manipulation. The implementation of this feature is based on the communication chain in Figure [2.6](#) above, in this case the **Request Creator** is the drag-handler, which creates a **ChangeBoundsRequest**. It is a standard Request from **GMF**, which is used to alter size and position. We extended the **XYLayoutEditPolicy** to check the constraints from Table [3.1](#), calculate the resulting layout and return the appropriate Commands. The **ContainerXYLayoutEditPolicy** of the **Widget**'s parent accepts this **ChangeBoundsRequest** and the new **LayoutManager** and the **LayoutData** of its children are calculated. These new values are stored in the corresponding Commands (**SetWidgetBounds** and **SetContainerBounds**), which are returned and executed on the **Command Stack**. After execution, the corresponding **EditParts** get notified about the changes, which initiate refreshing the visuals with the new values.

A second part of this feature is the resize feedback, which is shown during direct resizing (Figure [3.5](#) (a)). For that, we created the **FeedbackEditPolicy**, which receives the **ChangeBoundsRequests** and shows a rectangle with the new size and position, overlaying the **Widget** on a so called *FeedbackLayer*. To show the corresponding feedback above the **Widget**, a coordinate transformations to absolute and calculations to translate and resize the shape according to the **Request**, are necessary.

#### Resizing by use of the **GSME** Pop-up bar

This advanced feature implements the customization Paragraph [Resizing by use of the GSME Pop-up bar](#) including many automatic steps involved. Let us illustrate this feature using a simple example.

The initial layout in Figure [3.16](#) (a) shows a **Panel** with the size of 120x120 pixels and its children, a **Button** and a **Label**. In this example, the designer wants to increase the height of the **Button** by 10 pixels, but there is no space between this **Button** and the **Label** below. Also the **Container** is not big enough for the new size.

If the designer did it by direct resizing, she would start with extending the **Panel** (b), moving the **Label** (c) and finally stretching the **Button** (d). The **GSME** starts with trying to stretch the **Button** by creating an **AutoSize-Request**, detects a violated constraint before execution, and solves the issue by creating the next **Request**, and so forth. The execution of the **Commands** is done in the opposite sequence (i.e., the same sequence as the designers').

The green arrow “down” of the **GSME** Pop-up bar sends the **Autosize-Request RQ1 extend the height by 10** to the **EditPart** of the **Button**. The **EditPart** queries all its **EditPolicies**, until the **AutoSizeEditPolicy** accepts the **Request** and constructs the **Command** (compare Figure [2.6](#)) for updating the model of this **Button**.

First of all, the **AutoSizeEditPolicy** determines the validity of the **Request**. On success, the requested changes are checked against the constraints defined in Table [3.1](#):

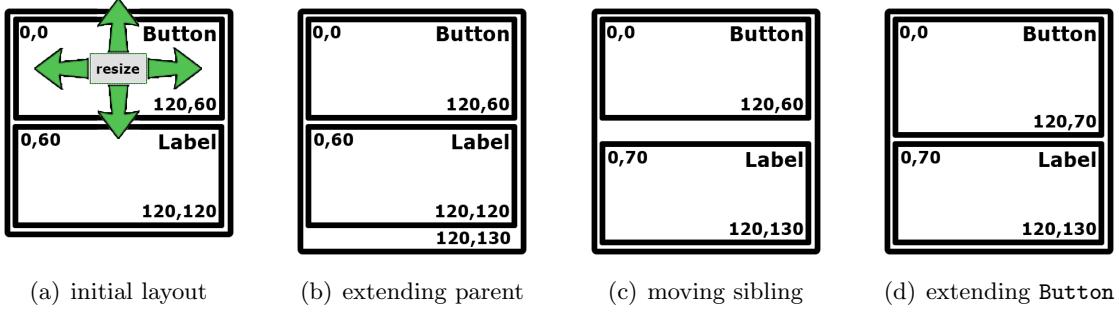


Figure 3.16: Resizing a Widget using the GSME Pop-up bar

- 1 – **A Container must wrap its children:** if the `Widget` is a `Container`, its size must not be smaller than the space required by its children with the given layout. If this constraint is not satisfied, the `Request` cannot be handled at all. In our case, the `Widget` is a `Button`, which cannot contain other `Widgets`.
- 2 – **A Widget must be within its parent:** the new bounds (i.e., a rectangle with the upper left edge on `x`, `y` and the width and height of the `Widget`) must not exceed the size of its `Container`. If this is not fulfilled, the `Container` must be resized to satisfy `constraint 1`. For that, a new `AutoSize-Request` must be created and handled by the `EditPart` of the `Container`. The execution of the previous `Request` must wait, until this is executed and the models have been updated. In our example, the new bounds of the `Button` and the bounds of the `Label` do not exceed the size of the `Panel`, so no additional `AutoSize-Request` is necessary.
- 3 – **A Widget must not overlap with siblings:** this constraint determines, if the layout changes would lead to an overlapping of `Widgets` within the `Container`, which compromises the Screen Model. In that case, the siblings of the `Widget` being resized, are expected to free the space by moving in the direction with the smallest necessary movement. A new `AutoSize-Request` is created to achieve this. In our example, the `Request` `RQ2 increment the y-value by 10` is created for the `Label`. The initial `Request` must wait until the models are updated, and is stored in the `HashMap` `extendedData` with the key “`nextRequest`” of the newly created `Request`.

The `AutoSize-Request` `RQ2` for moving the `Label` by 10 pixels down, must also go through the procedure described above. It would violate `constraint 2`, because the new bounds of the `Label` exceed the size of the `Panel`. Another `AutoSize-Request` `RQ3` (i.e., *extend the height by 10*) is created with the previous one stored in its `HashMap`. This `Request` is successfully checked against the presented constraints, i.e., all necessary `Requests` for resizing the `Button` have been created.

Before we continue with the description of creating the corresponding `Commands`, we explain a small difference in the communication chain, shown in Figure 2.6. It matches exactly with the first `Request`, created by the `GSME` Pop-up bar until it is forwarded to the `EditPolicy`. Subsequent `Requests` are created directly within our `AutoSizeEditPolicy`, while checking the constraints in a recursive manner. The sequence of the `Requests` is inverted, because the necessary change resulting from a constraint, is a prerequisite for the previous `Request`. The returned `Command` (Figure 2.6) corresponds to the most recently created `Request`. Figure 3.17 depicts the created `AutoSize-Requests` in the execution order, containing the next `Request` as described above.



Figure 3.17: Inverted order of the chained Requests

In the next step, the **GSME** has to recalculate the **LayoutData** of the **Widget** to alter the **LayoutData** of its siblings and the **LayoutManager** of their **Container**. Our example does not show a **Container** for the **Panel**, we define it now as the **Screen**, to describe the following steps. Figure 3.18 depicts the **Commands** (e.g., **SetWidgetBounds**) resulting from the previously created **Requests**. Every solid-lined box represents a **Command**, the **Commands** in a dashed-lined rectangle (e.g., RQ3) are chained together and put on the **Command-Stack** at once. The left column of Figure 3.18, labeled as RQ3, shows the **Commands** to update the **LayoutData** (blue) of the **Panel**, the **LayoutManager** (green) of the **Screen** and the **ScheduleNextCommand**, which carries the **Request** RQ2 and the parameter *waitingFor* from the type **EditPart**. This is the **EditPart** (i.e., **Screen**), whose model must have been updated with the layout changes before RQ2 is allowed to be handled. We usually use the **Container**, where we update the **LayoutManager** as the *waitingFor* part.

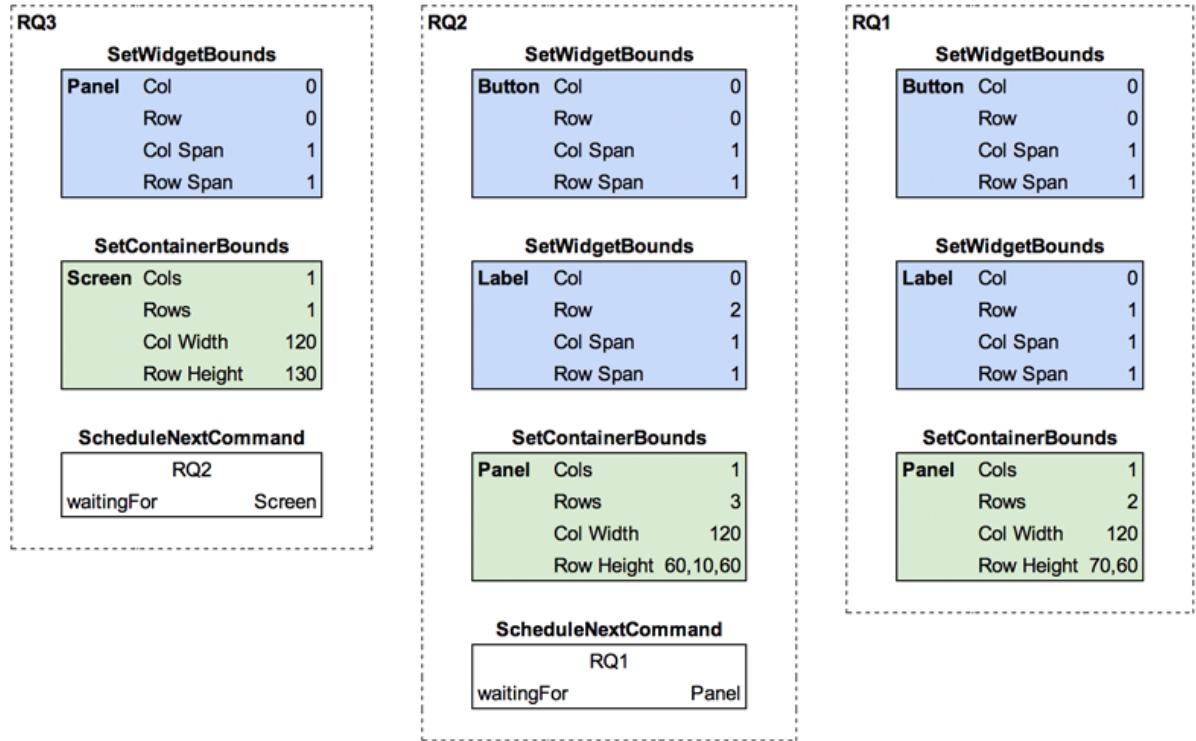


Figure 3.18: Commands resulting from the Requests

Figure 3.19 shows a **UML Sequence Diagram** executing the chained **Commands** from RQ3, which are returned from the **AutoSizeEditPolicy**. The **EditPart** puts them on the **CommandStack** for execution. The **SetWidgetBoundsCommand** and the **SetContainerBoundsCommand** update

the model directly, whereas the `ScheduleNextCommand` does not alter the model. It uses the method `addPendingRequest` of the `CommandScheduler` to store the *waitingFor* `EditPart` with the `Request`. The data is stored in the `HashMap<EditPart, Request>` *pendingRequests*, with the `EditPart` as the key and the `Request` as its value. Back to our example, after calling `addPendingRequest`, the `HashMap` contains the entry `<Screen, RQ2>`. When a model is altered by a `Command`, it notifies the `EditPart` about the changes. The `EditPart` of our `Panel` gets informed about changed `LayoutData` and its corresponding changes of the `Width` and `Height` attributes. This initiates an update of the `Panel`'s `View`, reflecting the new values. The `EditPart` of our `Screen` gets notified about changes in the `LayoutManager`, refreshes its visuals and notifies the `CommandScheduler` with `notifyEditPartFinished` about the update. The `CommandScheduler` requests the stored value for the key `Screen` from the *pendingRequests*, which returns the `Request` `RQ2`. The `Commands` of `RQ2` are retrieved from the `AutoSizeEditPolicy`, which returns the middle column of Figure 3.18. During the execution, a `ProgressMonitor` is shown with details about the `Command` being executed.

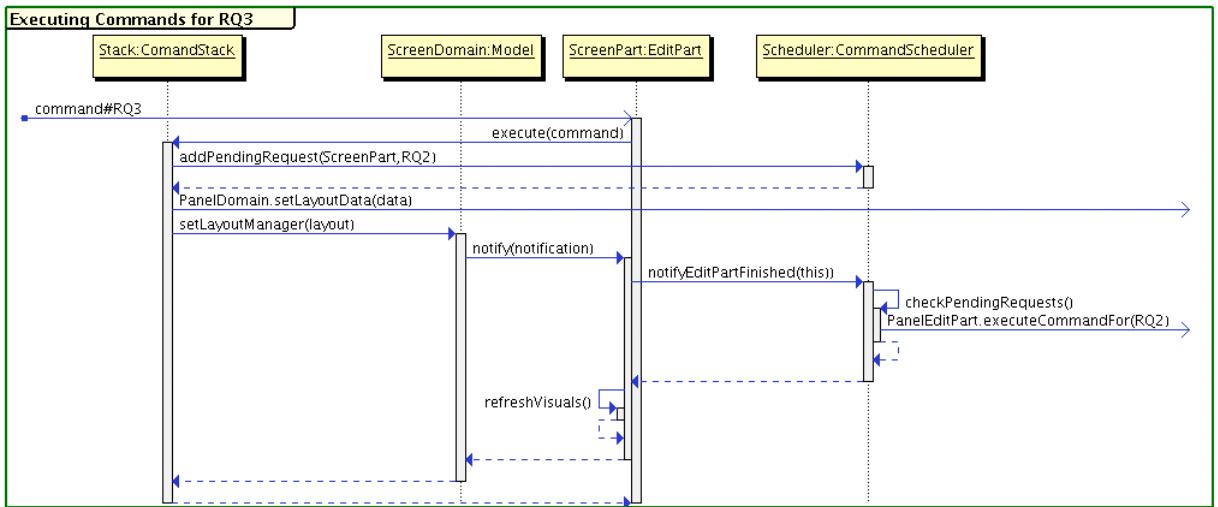


Figure 3.19: Executing the Commands of Request RQ3

**Termination Conditions.** The recursive creation of the `AutoSize-Requests` to free the required space is either terminated by the fact that there is enough space for the current `Request` or the conditions itemized below.

**The given fixed size of the Frame** is defined by the device-specification. If the required space of a given `Request` exceeds the size of the `Frame`, it is terminated by constraint 1 of Table 3.1.

**The SkipZone** is a rectangle, which is stored in an `AutoSize-Request`. With every move or resize, the `SkipZone` grows by calculating the bounds of a new rectangle that contains the `SkipZone` and the new bounds of the `Widget`. This new rectangle is the new `SkipZone`. In subsequent `Requests`, the `Widget` is not allowed to be placed overlapping its `SkipZone`. This avoids the potentially infinite swapping of two `Widgets` to free space for each other.

**An Obstacle** is a `Widget` blocking the `Request` and must, therefore, be moved or resized, to free space for the given `Request`. This `Obstacle` must not be a `Widget` being involved in the

given `Request`. This case would lead to layout-changes that require a different algorithm to calculate the necessary `AutoSize-Requests`.

These conditions are detected before executing the initial `Command`. Undoing the executed `Commands` is also supported, to go back to the initial layout.

### Resizing by use of the Core Properties View

Changes of the `Width` or `Height` from the `Core Properties View` are checked immediately after applying the new value. This check is performed by a so-called *validation provider*, which is based on the Eclipse Validation Framework. Strictly speaking, such a *validation provider* performs a verification. It contains the Adapter-class, extended from `AbstractModelConstraint`, which must override the abstract method `validate(IValidationContext ctx)`. This parameter contains information about the selected `Widget` and the changed property with the new value. With this information, the `GSME` checks the constraints from Table 3.1 by creating a new `AutoSize-Request` and checking the integrity of the Screen Model with the resulting layout. If it fails, the dialog presented in Figure 3.7 is shown and the values are reset to the previous ones.

If the integrity check is positive, the `EditParts` of the involved `Widgets` get notified to redraw their visual representation.

### Resizing by use of the Toolbar Menu

The result and so the implementation of the two following *resize-features* is quite different. The first one “Resize” uses the surrounding `Widgets` and bounds to calculate the resulting size (i.e., new size is defined by the first violated constraint), while the second one “Resize with Widget” creates a `Request` with a predefined size and frees the space if necessary.

**Resize** – The implementation of this feature is very simple. The `GSME` extends the bounds of the `Widget` by one pixel and checks the constraints from Table 3.1 in a loop, until a constraint-check fails. The last valid bounds are used to create a `ChangeBoundsRequest`. Our `ContainerXYLayoutEditPolicy` is used to check the constraints of the resulting layout and return the appropriate `Commands`. These are a `SetContainerBounds` for the parent and `SetWidgetBounds` for the `Widgets` (i.e., all children of the parent), similar to the ones presented above. This feature does not free space, it just fills empty space by extending the selected `Widget`. When the sub-menu `MAX` is selected, extending in the single directions follows a sequence (i.e., priority), which is *left, right, top and bottom*.

**Resize depending on a Reference Widget** – This feature requires a multiple selection of at least 2 `Widgets`. The initially created `Request` is an `AutoSize-Request` to resize the first to the  $n - 1$  selected `Widgets` to the size of the  $n^{\text{th}}$  selected (i.e., the `reference Widget`). If there is not enough available space for the resize operations, the `GSME` tries to free the space with subsequent `AutoSize-Requests` as described above. If there are many selected `Widgets` to resize (i.e., extend), they might mutually prevent a successful operation. The reason is the *Obstacle* presented in Subparagraph [Termination Conditions](#) on page 31.

### 3.3.1.3 Move Features

#### Moving with direct manipulation

The implementation of this feature is similar to the one presented in Paragraph [Direct Resizing](#). A minor difference is in the implementation of the `FeedbackEditPolicy`, where the coordinates  $x$  and  $y$  are displayed, i.e., the left top position relative to the moving `Widget`'s container.

#### Moving by use of the GSME Pop-up bar

A detailed description of the resizing-counterpart of this feature can be found in Paragraph [Resizing by use of the GSME Pop-up bar](#). We used a simple example with just a few `Widgets`. Following, we provide a very similar example, where just the initial `Request` differs.

**Example Moving by use of the GSME Pop-up bar** Figure 3.20 (a) shows the initial layout of our example, with the [GSME Pop-up bar](#). By clicking on the blue arrow “down”, the `AutoSize-Request move down by 10 pixels` is created, and delegated to the `EditPart` of the `Button`. The subsequently created `AutoSize-Requests` are equal to `RQ2` and `RQ3` of the example above.

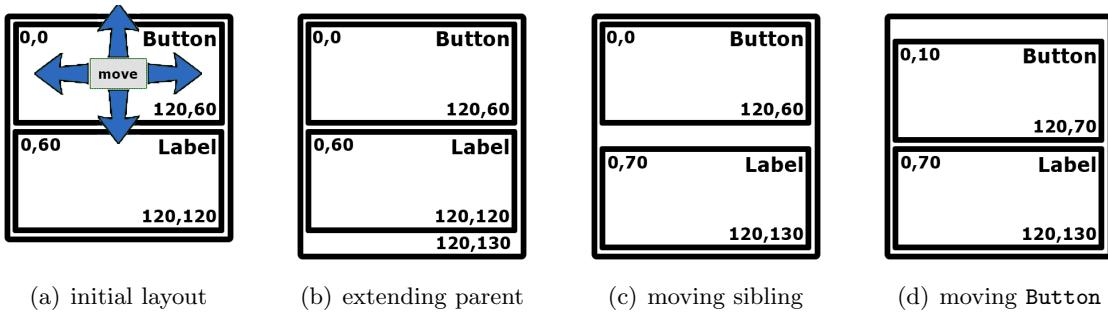


Figure 3.20: *Moving a Widget using the GSME Pop-up bar*

#### Moving by use of the Toolbar Menu

The [GSME Toolbar](#) (Figure 3.2)(1) consists of three `move-features`, where `Align` moves the `Widget` to the next obstacle in the specified direction, using the empty space. `Align to Widget` moves the `Widget`'s edge to that of a reference, freeing the space if necessary. `Swap Widgets` exchanges the position of two widgets.

**Align** – The implementation of this feature is very similar to its *Resize*-counterpart from Paragraph [Resizing by use of the Toolbar Menu](#). The `Widget`'s bounds are moved by 1 pixel in the specified direction in a loop, until a constraint from Table 3.1 fails. It is moved, until it “touches” another `Widget` or the `Container`.

**Align to Widget** – The counterpart of this feature is *Resize depending on a Reference Widget*. Multiple selection is necessary, to provide a moving `Widget` and the `reference Widget`. After selecting an edge to align to, an `AutoSize-Request` is created, which contains all

moving **Widgets** an their new bounds. The **GSME** checks the resulting layout against the constraints in Table 3.1 and tries to free the required space if necessary.

**Swap Widgets** – To use this feature, it is necessary to select exactly two **Widgets**, which must have a common container. **Widgets** are not allowed to be “reparented”, this would violate the integrity of the **Screen Model**. First of all, these prerequisites are checked. On success, the **AutoSize-Request** is created, containing the **Widgets** and their new bounds. By selecting two **Widgets**, the new bounds of each other are known. Depending on the position and size of the **Widgets**, it is possible that a termination condition, presented in Subparagraph [Termination Conditions](#) on page 31, cancels the execution in advance.

### 3.3.2 Style Features

The implementations of the different style features have individual sources (i.e., **Request Creators**, see Figure 2.6). Some features, i.e., *font-color*, can be changed on three places: via the **CSS Property-Page**, via the **appearance Property-Page**, and via the **appearance Toolbar**. The created **PropertyChangeRequests** to retrieve the **Commands** are equal. **NotationalListeners** notify the corresponding **EditPart** about the changed property, which persists the new value and updates the **Views**.

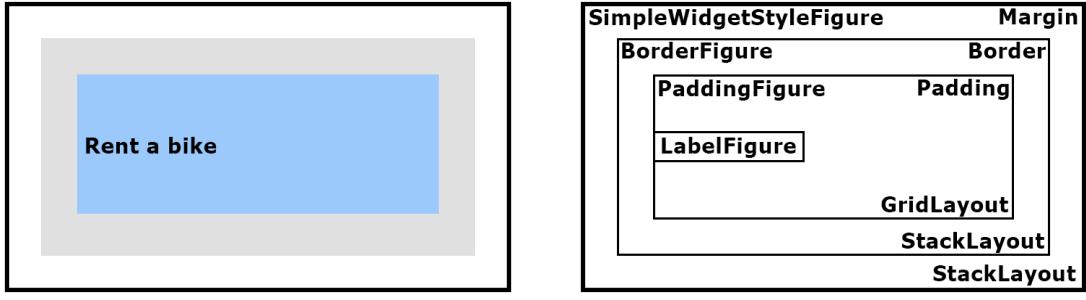
#### 3.3.2.1 The Views

In the **GMF** diagram, the **Widgets** are represented through **Figures** (see Figure 2.4), which visualize the **Screen Model** with the supported **CSS-styles** (Figure 3.13).

Figure 3.21 (a) depicts the structure of a simple **Label**, where the outer frame represents its **Container**. The corresponding **Figure** is the **SimpleWidgetStyleFigure**, which implements the interface **IWidgetFigure** declaring a set of methods, used by their **EditParts**. The **SimpleWidgetStyleFigure** defines the **Margin** (i.e., the space outside the border) of the **Label**. It uses a **StackLayout**, which allows stacking a child on the parent (or on top of the previously added child). It adds the **BorderFigure** as its child, which reflects the **CSS-border** (i.e., **border-width**, **border-style** and **border-color**). The **BorderFigure** also uses the **StackLayout** to layout its child, the **PaddingFigure**. This figure keeps the specified space inside the border free (i.e., **padding**) and is filled with the **background-color** of the **Label**. Furthermore, it is responsible to layout the “real label” (i.e., the text) depending on the **text-alignment** in the horizontal and vertical direction. We use a **GridLayout** with the corresponding properties to achieve this. The **LabelFigure** extends the **WrappingLabel**, which automatically handles displaying of long text and supports **CSS-fon**ts (i.e., **font-color**, **font-family**, **font-size**, **font-style** and **font-weight**).

The example in Figure 3.21 (b) shows a **Label** with the text “Rent a bike”. The text is **horizontally aligned** to the left, and **vertically aligned** to the middle. There is no **padding** specified, the **background-color** is light blue. A thick, solid, light-gray **border** is visible and a **margin** in all directions is shown.

There are several **Figures** for the different **Widgets**, but their structure is very similar. E.g., the **Button** uses a **SVGFigure** instead of the **BorderFigure**, which shows the image of a typical button.



(a) Visualized Label including style-attributes

(b) Detailed layout of the Label

**Figure 3.21:** Visual representation of a Label through its Figure

### 3.3.2.2 CSS Property-Page

This property page (Figure 3.13) provides an overview about all supported style-customizations. It consists of several classes, where the *CSSPropertySource* implementing the *IPropertySource* does most of the work. It defines the property descriptors, which can be seen as the lines in the property page. Property descriptors can be instantiated from different specializations (e.g., *TextPropertyDescriptor*, *ComboBoxPropertyDescriptor*). For the properties **Margin** and **Padding**, a *PropertyDescriptor* containing a nested *PropertySource*, the *CSSArrayPropertySource* with a property descriptor for every direction (`bottom`, `left`, `right` and `top`), was created.

Changes of a style-property creates a *PropertyChangeRequest*, which notifies the corresponding *EditPart* to handle the update.

### 3.3.2.3 Appearance Property-Page and Toolbar

These two possibilities for changing the styles, create *PropertyChangeRequests* directly. The corresponding *EditPart* gets notified and handles the update.

## 3.4 Requirements Satisfaction

In the following, we evaluate the satisfaction of the Requirements that are presented in Section 3.1.

**RQT1** – The **GSME** shall generate a graphical representation of **Widgets** (i.e., a diagram) for `*.structuralui` files.

This Requirement is fulfilled through both diagrams of the **GSME**. The Overview diagram presents all the **Screens** and the Screen-based diagram presents the content of the **Screens** (i.e., all their **Widgets**). The information is used from the Screen Model (i.e., the `*.structuralui`-file).

**RQT2** – The **GSME** shall use the layout information specified in the Screen Model for the graphical representation.

This Requirement is fulfilled, because the Screen-based diagram of the **GSME** uses the **LayoutManager** of the **Container** and the **LayoutData** of all **Widgets** to provide a layout-correct graphical representation of the **Screens**.

**RQT3** – The **GSME** shall use the style information specified in referenced **CSS**-files for the graphical representation.

This Requirement is fulfilled, because the **GSME** decorates the **Widgets** using a referenced set of **CSS**-styles, where the id of the **CSS**-style is annotated in the model, and the definition of the style is specified in a **CSS**-file (its location and name is part of the Screen Models content).

**RQT4** – The **GSME** shall use only information specified in the Structural Screen Model, including referenced information (e.g., style-references), for the graphical representation (i.e., without information from an application back-end).

This Requirement is fulfilled, because the **GSME** visualizes the **Widgets** without the need of an application back-end. Static data that is defined in the Screen Model, is displayed in the **Widgets**. Dynamic data that is usually provided by the back-end in combination with previous user-input, is replaced with other information to help the designer identifying the **Widget**.

**RQT5** – The **GSME** shall make manipulations (e.g., layout, size, text, color, etc.) in the diagram persistent in either the \*.structuralui file or an additional **CSS**-file.

This Requirement is fulfilled, because using the features, presented in Section 3.3, may alter layout and style of the Structural Screen Model. Layout-changes are persisted directly in the Screen Model and style-changes are persisted in a newly created **CSS**-file.

**RQT6** – The **GSME** shall provide support for restricting/constraining the allowed manipulations (e.g., a **Widget** can only be laid out anew within its **Container**).

This Requirement is fulfilled, because the **GSME** restricts manipulations, layout-constraints are defined in Table 3.1. Style constraints depend on the type of **Widget**. They are specified in Table 3.3.

**RQT7** – The **GSME** shall be compatible with Eclipse Validation Framework Live Constraints.

This Requirement is fulfilled, because due to the choice of using **GEF/GMF**, the Eclipse Validation Framework is supported. the **GSME** uses its Live Validation when the designer alters the width or height value in the properties view.

**RQT8** – The **GSME** shall be regenerate-able (i.e., all code modifications shall be persistent, for new generation).

This Requirement is fulfilled, because adaptations on the **GSME** diagrams are persisted in severals ways, like described in Section 3.3. Therefore, the code of the **GSME** is robust against re-generation.

**RQT9** – The **GSME** should support custom figures for displaying the **Widgets** to make the diagrams more “fancy”.

This Requirement is fulfilled, because the **Widgets** have individual figures. **ComboBoxes** and **Buttons** are given a realistic representation, to get an immediate impression about the resulting **Screen**.

**RQT10** – The **GSME** should provide an interface for reporting layout customizations.

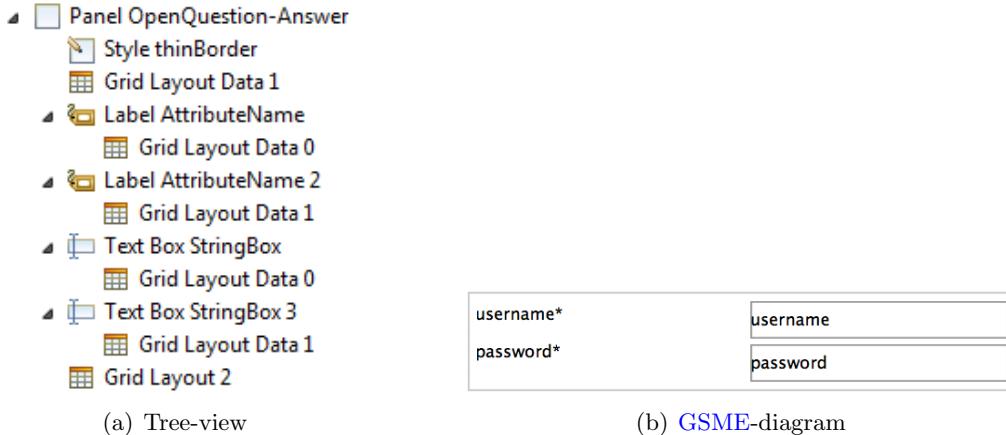
This Requirement is fulfilled, because an interface to persist model-changes was implemented, where the source of initiation (e.g., Pop-up bar, Toolbar), the trigger (manually or automatically) and the serialized Request-Object is stored in a **ChangeLog**.

## 4 Results

The main result of this diploma thesis is the prototypical implementation of the [GSME](#) in form of Eclipse plug-ins, which satisfies all requirements specified in Section 3.1. In particular, we present a visualization example and a customization example for a comparison between the [GSME](#) and the Tree Editor. Furthermore, we present the results of computational performance measurements of certain features of the [GSME](#).

### GUI visualization and customization: GSME vs. Tree Editor

Figure 4.1 shows the visualization of a Structural Screen Model excerpt using the [GSME](#) and the Tree Editor. This figure shows that the [GSME](#) visualizes the *Widgets* graphically with corresponding figures, the *Layout* and the *Style* in contrast to the Tree Editor. Thus, the [GSME](#) provides a visual impression of the final [GUI](#), even without an existing back-end.



**Figure 4.1:** Snippet of the Login-Screen of our running example

Visualizing the Structural Screen Model through the [GSME](#) means to visualize all the information the Tree Editor shows (the Structural Screen Model containing the *Widget*-hierarchy, layout information and style-ids). Additionally, the [GSME](#) visualizes the style-properties specified in a given [CSS](#)-file that are referenced through the style-ids. All visualized data is either static and specified in the Screen Model, or dynamic data, which will be provided by the application back-end at run-time. Such dynamic data is visualized based on information specified in the *Text*-attribute

of the **Widget** to visualize (e.g., the **TextBox** labeled “username” in Figure 4.1 (b)). If no such information is available, a place-holder (i.e., `<...>`) is inserted and the **Widget** can be identified through its properties, visualized by the Property-View. Visualization and Customization of this intermediate Structural Screen Model, allows for developing the **GUI** in iterations even without the need for an application back-end (see [RPK<sup>+</sup>14, RKP<sup>+</sup>14]). Furthermore, the **GSME** allows for decoupling the development of the **GUI** and the application back-end, which can in principle be developed in parallel.

In addition, the **GSME** facilitates *layout customizations*. Direct layout manipulations can be performed using the Tree Editor, too. Trivial manipulations that do not change the **LayoutManager** of the **Container** can be done in one step, even from the Tree Editor. An example is depicted in Figure 3.11, where a **Button** is laid out in the left column of its parent. It can be moved to the empty right column, which has the same size. From the Tree Editor, the **Button** can be moved by altering the *column*-attribute of the **Button**’s **GridLayoutData** from 0 to 1. Using the **GSME**, there are several ways to move the **Button**. It can be done by direct manipulation with the mouse or the cursor-keys, or by the **GSME** Pop-Up bar. The most convenient way is to use the **Align**-feature of the **GSME** Toolbar.

Usually, a layout-change requires recalculation of the **Container**’s **LayoutManager** and the **LayoutData** of all its children (see 3.3.1.1), because the empty target-space often differs from the required space. Using the Tree Editor, this layout-calculation has to be done manually and the resulting values have to be put in the corresponding fields of the **LayoutManager** and the **LayoutData**. This task is difficult and error-prone. The **GSME** facilitates such customizations through automating the recalculation of the layout.

*Style customizations* cannot be done by the Tree Editor at all, it just shows a reference-ID (e.g., `thinBorder` in Figure 4.1) for which the style is specified in one of the predefined **CSS**-files. The **GSME** reflects the specified style of the **Widgets** and supports their customization directly from the properties-view.

## Computational performance of the **GSME**

We measured two types of computational performance. First, we measure the loading time required for visualizing (i.e., rendering) a given **Screen**. Second, we measure the execution time of resize-features. These measurements have been performed with a MacBook Pro, 2.6 Ghz dual-core Intel Core i5, 8 GB 1600 MHz memory, 256 GB PCIe-based flash storage.

The overview-diagram of the **GSME** allows for the selection of a **Screen** for visualizing its content in the **Screen-based** diagram. This rendering of a **Screen** (i.e., the creation of the **Screen-based** diagram) takes a certain amount of *loading time*. We define this *loading time* from initiating the task “open the **Screen**” until the new diagram with the corresponding **Screen** is completely visible to the user.

Table 4.1 presents three examples of **Screens** with different content-properties (i.e., nesting-depth and number of **Widgets**) and their loading times. The nesting-depth reflects the number of hierarchy levels.

The **Screen** *PartitioningState\_1* (depicted in Figure 4.2 (a)) contains 13 **Widgets** in 3 hierarchy levels. *PartitioningState\_87* (depicted in Figure 4.3 (a)) also contains 13 **Widgets**, but the maximum nesting-depth of this **Screen** is 5. The loading time of both **Screens** takes 7 seconds each. The more complex **Screen** *PartitioningState\_13* visualized in Figure 4.4 (a) contains 36 **Widgets**.

Table 4.1: Screen loading time

Screen	Maximum nesting-depth	Number of Widgets	Loading time
PartitioningState_1 (Figure 4.2 (a))	3	13	7s
PartitioningState_87 (Figure 4.3 (a))	5	13	7s
PartitioningState_13 (Figure 4.4 (a))	5	36	11s

and a maximum nesting-depth of 5 (like *PartitioningState\_87*). This **Screen** needs 11 seconds to be rendered. These results indicate that the loading time depends more on the number of **Widgets** than on the maximum nesting-depth.

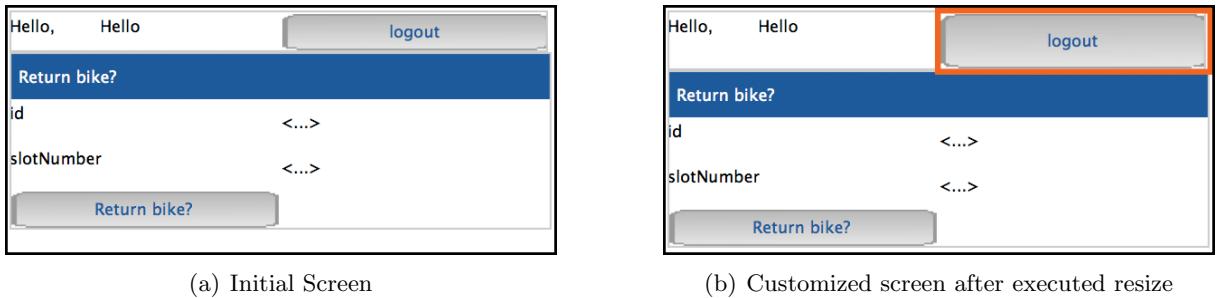


Figure 4.2: Screen PartitioningState\_1 of our running example

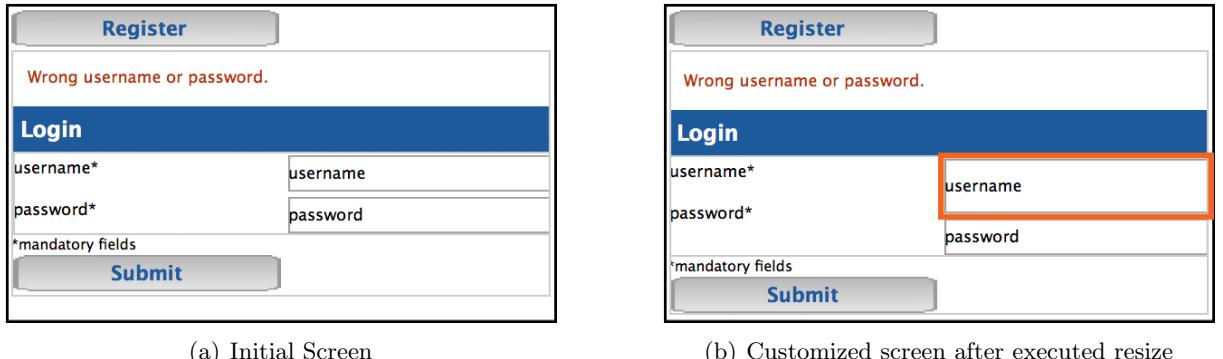
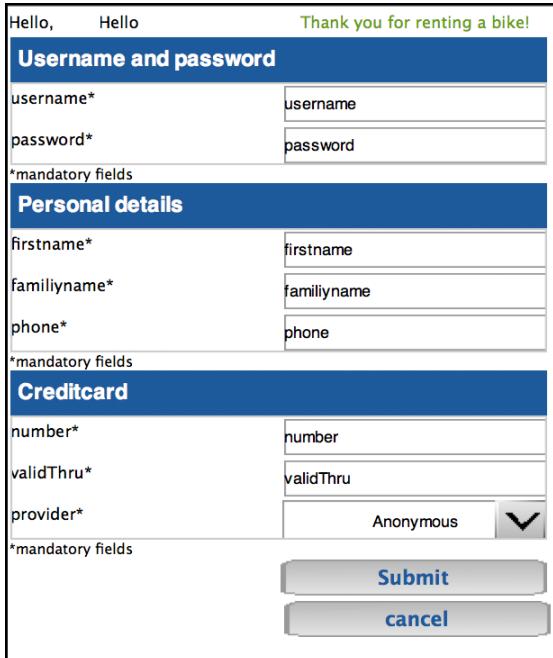


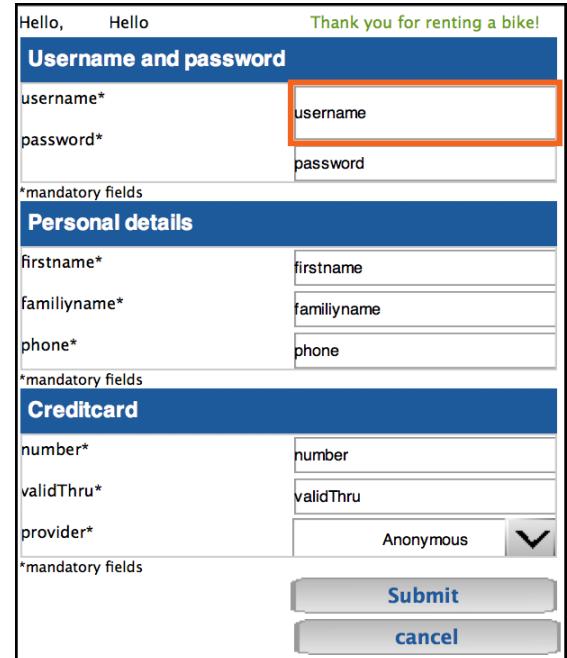
Figure 4.3: Screen PartitioningState\_87 of our running example

The **GSME** Pop-up bar provides access to the move and resize features, which can be used for layout customizations. These features automate the task “free the required space” if necessary. A simple example is presented in Paragraph [Resizing by use of the GSME Pop-up bar](#) on page 28, where one manual step with the **GSME** Pop-up bar triggers two additional steps to free the required space, which are automated by the **GSME**. The *execution time* for executing such a feature is defined from initiating the feature by the mouse-click, until the diagram shows the desired layout changes (e.g., the **Widget** with the new height).

Table 4.2 shows three examples of *resizing a Widget*, which need a different number of additional operations (i.e., move and resize) to free the required space. Figure 4.2 (a) visualizes the initial layout of the **Screen PartitioningState\_1** and (b) shows the customized layout after executing the feature *increasing the height*. To increase the height of the **Button** in *PartitioningState\_1*, one



(a) Initial Screen



(b) Customized screen after executed resize

**Figure 4.4:** Screen PartitioningState\_13 of our running example

move operation and 3 resize operations are necessary, which take 1.8 seconds for execution.

**Table 4.2:** Execution time comparison

Screen	Nesting-depth	Operations		Execution time
		Move	Resize	
PartitioningState_1 (Figure 4.2)	3	1	3	1.8s
PartitioningState_87 (Figure 4.3)	5	3	5	3.9s
PartitioningState_13 (Figure 4.4)	5	6	5	6.3s

Increasing the height of the TextBox in *PartitioningState\_87*, which is depicted in Figure 4.3 (a), takes 3.9 seconds and requires 8 operations. The resulting layout is presented in Figure 4.3 (b).

Applying the feature *increasing the TextBoxes height* on the more complex *Screen PartitioningState\_13*, in Figure 4.4 (a), needs 11 operations and 6.3 seconds. Figure 4.4 (b) shows the layout after executed resizing.

## 5 Discussion & Future Work

This section discusses limitations of the current **GSME** implementation and highlights potential topics for future work.

### Improving and extending the **GSME**

The **GSME** facilitates a preview of the final **GUI** without the need of an existing back-end application. A limitation of this preview is that it does not offer dynamic data, because this data can only be provided by the back-end application. However, the **GSME** offers static data (e.g., the title, labels, default-values), which is typically sufficient to provide a realistic preview of the final **GUI**.

Another limitation of the **GSME** is that it currently does not support the simulation of the **GUI** behavior, which was actually out of the scope of this diploma thesis. Simulating the **GUI** behavior would be a beneficial extension of the already existing **GSME** as it would allow for an early evaluation of the application. In principle, information about possible sequences and their initiation is specified in the **Behavior Screen Model** and already available. Pressing a **Button** can trigger opening a new diagram with the corresponding **Screen**. For that, a mode-switch could be implemented, to select between *editing* and *simulation* mode. One further limitation of the current implementation of the **GSME** in this context is that it takes a few seconds to render a **Screen** in a diagram view (see Chapter 4).

A potential solution for this performance problem would be to use Standard Widget Toolkit (**SWT**) directly, without the overhead of **GEF/GMF**. **SWT** is a library for creating **GUIs** in Java. The visualization of the **Widgets** could possibly be implemented more efficiently, but this approach would require additional effort for basic implementations like listeners to support drag and drop, providing information about the dragged part, the position, creating a feedback-figure, etc., to facilitate customizations. Additionally, the **GridLayout** of **SWT** uses different properties to specify the layout than the **GridLayout** of the Structural Screen Model. This means that layout specified in the Structural Screen Model needs to be mapped to an **SWT** layout (e.g., **SWT** **GridLayout** or **XYLayout**). The classes for transforming the Structural Screen Model **GridLayout** into an **XYLayout**, developed and implemented in this work, could be used in this solution as well.

Currently, the implementation of the layout transformation, considering the layout-constraints, is persisted in separate files of the plug-in `org.ontoucp.structuralui.diagram`. A similar calculation is used in several parts of the Unified Communication Platform (**UCP**). In future work,

these functions could be combined into a common part of the **UCP**, to facilitate its maintenance. For example, these calculations could be moved directly into the implementation of the Structural UI Meta-Model, because they just need the **LayoutManagers** of **Containers** and the **LayoutData** of the **Widgets**.

The computational performance of the **GSME** move and resize features depends on the number of operations (i.e., intermediate **Requests**), which are needed to free the required space. The execution time of these features consists of the time needed for the iterative constraint-checks, the creation of **Requests** and their **Commands**, and the execution of the **Commands** with updating the visuals (i.e., **Figures**) for every intermediate **Request**. The computational time could be reduced by calculating the finally resulting layout and creating one single **Request** that performs all the layout changes in one execution.

### Customization persistence

As stated in [Ran14], the problem of customizing the **Structural Screen Model** on the **CUI**-level is that these customizations are lost in case of regenerating the **Screen Model**, because the previous **Structural Screen Model** and the **CSS**-file are overwritten. Thus all customization performed through the **GSME** are lost. Customizations can be made persistent if they are specified in the form of a transformation rule [KFK09, RPK13], because such customizations are applied while generating the **Screen Model** (see Figure 2.1). To additionally make customizations performed through the **GSME** persistent, such customizations need to be saved explicitly and re-applied again after the **Screen Model** has been re-generated. We already created a *Changes Model* to store the customizations with the corresponding **Requests** in a separate file [Ran14], which supports developing the **GUI** in full iterations, in principle. The drawback of this solution is that such customizations cannot be taken into account by **UCP**'s automated device tailoring approach [Ran14], because they are applied only after the tailored **Screen Model** has been generated.

### Customization propagation

**GUI Widgets** that trigger the same functionality are potentially contained in more than one **Screen** (e.g., a log-out **Button**). Customizations of such **Widgets** typically have effects on more than one **Screen**, the same customizations have to be repeated manually several times. A solution for this problem would be to create and store such a customization in a dedicated transformation rule, instead of storing the **Requests** in our *Changes Model*. Such a transformation rule should be created automatically based on customizations performed through direct manipulations. Additionally, the designer should be enabled to select the “scope” of such transformation rules. The scope could, for example, be either a given **Screen** or all **Screens** of a given **Structural Screen Model**.

### Tool use

So far, the **GSME** has only been used by expert users (i.e., the author of this thesis and his supervisors). A usability evaluation of the tool was out of the scope of this diploma thesis. However, we created a “getting started” document (see Chapter A) to provide an introduction to the graphical diagrams, their features and how to use the **GSME**. This document is intended to facilitate using the **GSME** for novice users in the future.

## 6 Conclusion

In the course of this diploma thesis we developed the tool **GSME**, which intends to support the designer to improve the usability of automatically generated **GUIs**. Such improvements alter the Structural Screen Model (on the **CUI** level) directly, which is an intermediate output of the generation process. In particular, the **GSME** provides an overview of the **Frames** with all **Screens**, which allows for selecting a specific **Screen** to be visualized. Furthermore, the **GSME** facilitates the visualization of the **Screens**, including the layout and style information without the need of an application back-end. Additionally, it allows the designer to customize the layout and the style through direct manipulation and additionally facilitates customization through advanced features.

# A Getting Started

## A.1 Preface

The Graphical Screen Model Editor (GSME) is a collection of plug-ins, containing two graphical editors (i.e., diagrams).

The first diagram is the overview-diagram, which provides an overview of the **Screen Model**. It depicts the **Frames** with their containing **Screens** with the purpose to select a **Screen**. The content of the selected **Screen** is visualized with the second diagram, i.e., the *StructuralUI-Diagram* (or **Screen**-based diagram), which is a WYSIWYG editor providing a representation of the automatically generated Screen Model. Furthermore, it is a toolkit supporting a set of customizations.

## A.2 Create a Screen Model Diagram

### Initialize Diagram File

In the **Package Explorer**, select the previously created **Screen Model** “yyy\_ScreenModel.structuralui”. In the corresponding context-menu, you can find “Initialize model-diagram diagram file” (see Figure A.1). This command renders the *Overview Diagram* showing all screens of the model.

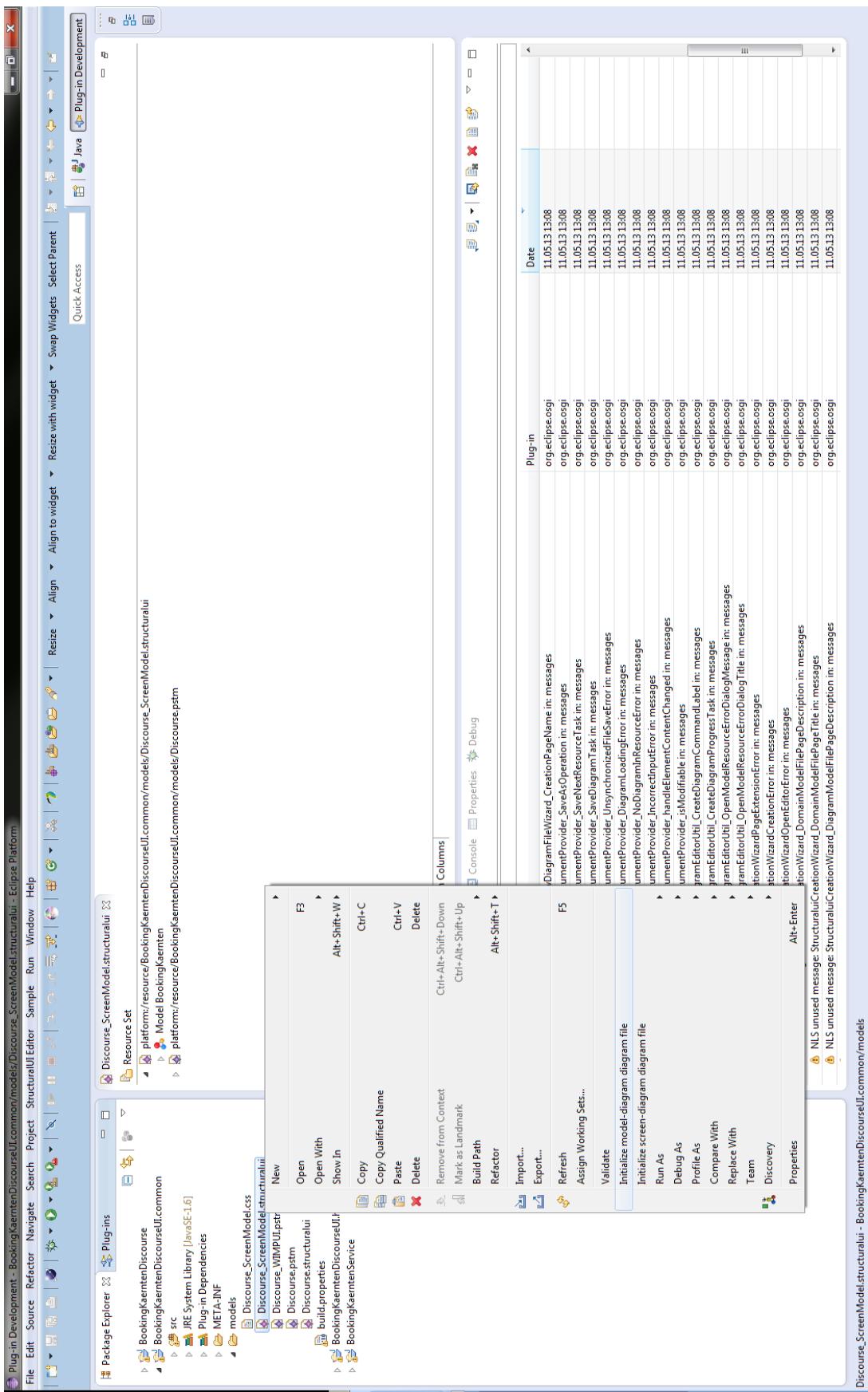


Figure A.1: Context menu: initialize model-diagram file

## Overview Diagram

On the top of Figure A.2, you can see the name of the **Frame**. The boxes below represent the **Screens** in a table with three columns and as many rows as necessary to show all **Screens** within this **Frame**. If more than one **Frame** exists, further **Frames** are displayed in separate blocks below.

Double-clicking a **Screen**, visualizes the selected **Screen** with the *StructuralUI* diagram.



**Figure A.2:** Overview diagram

## StructuralUI Diagram

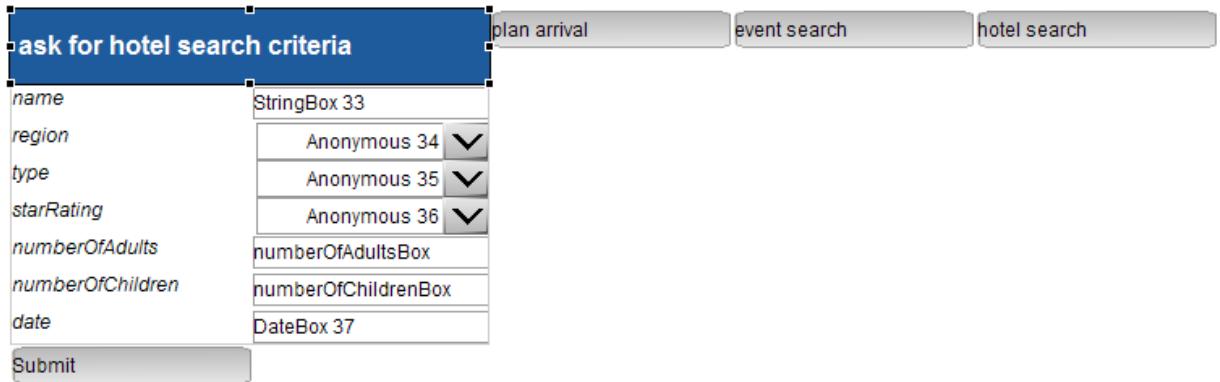
This is the main part of the GSME, which visualizes a graphical representation of a single **Screen**, see Figure A.3. It includes all layout information from the **Structural Screen Model** and the style information from registered **CSS**-files.

Layout customizations are stored back in the \*.structuralui-file, overwriting the initial data. Additional helper-information about the layout are stored in a newly created **CSS**-file, which also contains the style customizations. This file is stored in the model-folder with the name **modelname\_gsme.css**.

## A.3 Layout Customizations

### Definition of Customizations

The GSME provides a set of layout customizations, which can be applied on **Widgets** within a **Screen**. A customization is defined to be manually initiated, either directly on the **Figure** (i.e.,



**Figure A.3:** StructuralUI diagram

the graphical representation of a **Widget**) or via the menu (i.e., toolbar or pop-up bar). An automatically generated **Request** (i.e., an **AutoSizeRequest**) is initiated by another **Request** or a customization and a certain condition. This condition could be “lack of space for the desired resize-operation”. The resulting **AutoSizeRequest** could then be: “extend the container”. As you might have guessed, this could result in a series of recursive operations.

### Direct Resize

When a **Figure** is selected, it is wrapped by so-called “resize-handles” as depicted in the example of a **Label** in Figure A.3. If you drag such a handle, you can resize this **Figure**, but restricted by the constraints in Table A.1.

**Table A.1:** Constraints

Constraining part	Constraint	
1	Containers	must wrap their children
2	Widgets	must be within their parents
3	Widgets	must not overlap with siblings

### Direct Move

A **Figure** can either be moved by the cursor-keys, or by dragging the whole part (not the resize-handles) using the mouse. For this operation the constraints from Table A.1 also apply.

Some **Widgets** have a **Container** with a size equal to the **Widget**’s size. You may notice a strange behavior because of this “invisible” **Container**. To resize this **Container** before resizing the **widget**, you can select it either from the context-menu, or even more conveniently from the toolbar-menu, which is described next.

### Toolbar

The **GSME Tool-bar**, depicted in Figure A.4, provides several advanced features. These are described in Table A.2.

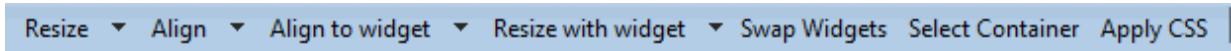


Figure A.4: GSME Toolbar

Table A.2: Toolbar Menu

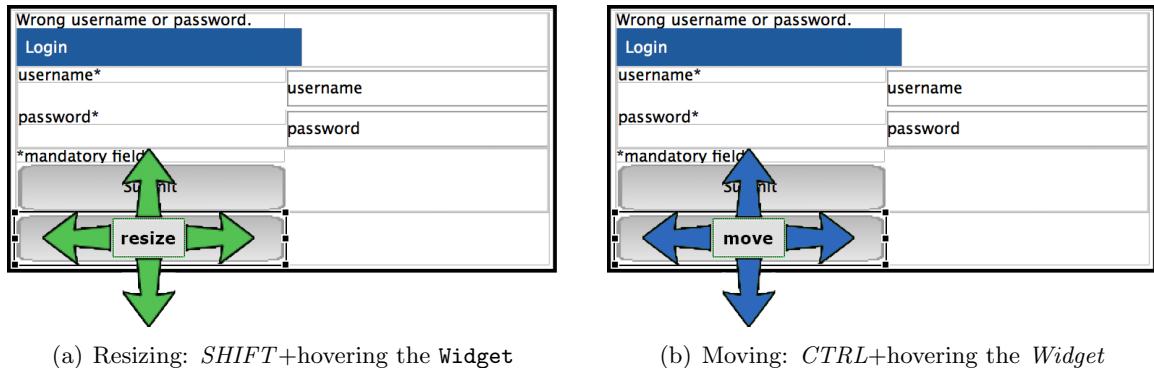
Menu	Submenu	Selection	Description
Resize	Max Top Right Bottom Left	one	Extending the size of the selected Widget to the maximum possible in the selected direction. “Max” stretches the size in all directions.
Align	Top Right Bottom Left	one	Moving the selected Widget to the maximum possible position in the selected direction.
Align to Widget	Top Right Bottom Left	several	The last selected Widget is the <b>Reference Widget</b> . All others are aligned to match with the selected edge of this reference.
Resize with Widget	All Horizontal Vertical	at least two	The last selected Widget is the <b>Reference Widget</b> . All others are resized according to match its size in the selected plane.
Swap Widgets	-	exactly 2	The two <b>Widgets</b> change their places if possible. This is just possible if they have a common ancestor and if there is enough space. The best result is achieved, if the <b>Widgets</b> have the same size.
Select Container	-	one	This is very useful to select an “invisible <b>Container</b> ” whose size is equal to that of its single child- <b>Widget</b> .
Apply CSS	-	several	This applies the loaded CSS-files to the selected <b>Widget</b> and all its children, e.g., selecting the <b>Screen</b> will apply the styles to all <b>Widgets</b> within this <b>Screen</b> .

## Pop-up Bar

GMF provides a pop-up bar, usually to create new parts. In our case, creating new **Widgets** would not be very useful, so we used the pop-up bar for another advanced feature. Figure A.5 shows the two types of the GSME Pop-up bar. By pressing *CTRL* or *SHIFT* and moving the mouse-pointer over a **Widget** (i.e., *hovering*), the corresponding GSME Pop-up bar appears. The type of operation is displayed in the center of the selected part, surrounded by colored arrows to initiate the operation.

The main advantage of modifying a layout in this way, is the recursive freeing of space to make the desired operation possible. This is achieved by resizing the container and moving siblings.

There are also some drawbacks on this kind of customization:



**Figure A.5:** The GSME Pop-up bar

- Move- and resize-delta is a fixed value of 10px.
- Containers don't support a pop-up bar (Panels, ListPanels, etc.)

## A.4 Style Customizations using the Properties View

### Core

In the property sheet **Core**, you get information about the selected **Widget**. Some of the values are allowed to be altered (e.g., width, height, format and text). Altering height and width of a **Widget** is constrained as described Table A.1. A message-box appears if the altered value violates the model.

### Appearance

The property sheet **Appearance** is a standard property sheet, where you can change **Fonts** and **Colors** of selected **Figures**. The *Lines and Arrows* section can be used to change the border width of a **Figure**. For these operations, we recommend to use the property sheet **CSS**, which is described next.

### CSS

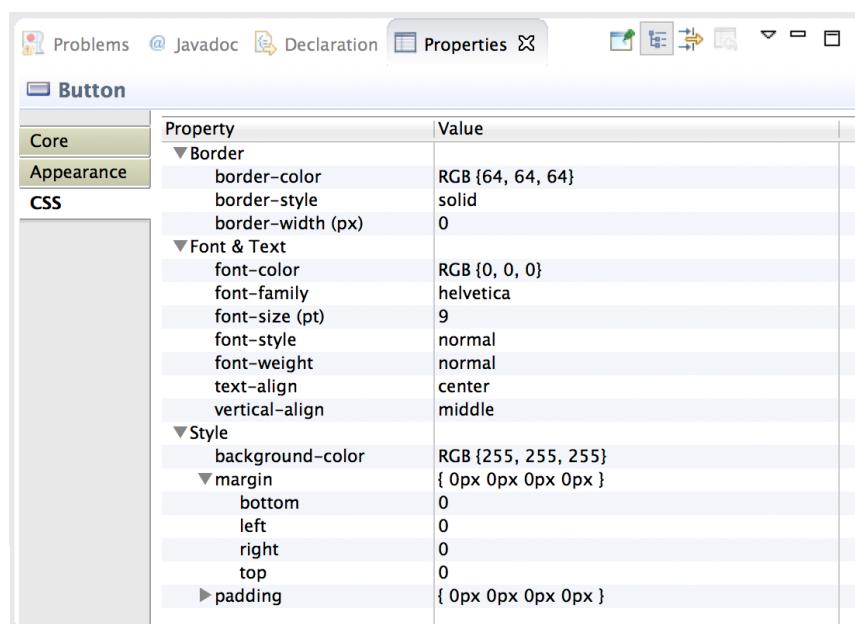
The property sheet **CSS** shows all styles that are allowed to be modified. They are persisted in the **CSS**-file.

**Attention:** Not all CSS-styles match with all widget-types (see Table A.3)  
 Not all defined CSS-rule-values are available in GSME

**Table A.3:** Widget-Style combinations not supported

Widget	Style
TextBox	border background-color dimension*
ComboBox	border background-color dimension* font-size font-style font-weight font-color
Button	border background-color

\* Increasing the dimension of the Widget only increases the space around the Widget. The Widget's size does not change.

**Figure A.6:** Property-Page CSS

## B The Structural UI Meta-Model

The Structural UI meta-model is the meta-model for the Structural Screen Model. It defines the types of `Widgets` and their properties and relations. It also defines the types of `LayoutManagers` and their corresponding `LayoutData`, which are available in the Structural Screen Model.

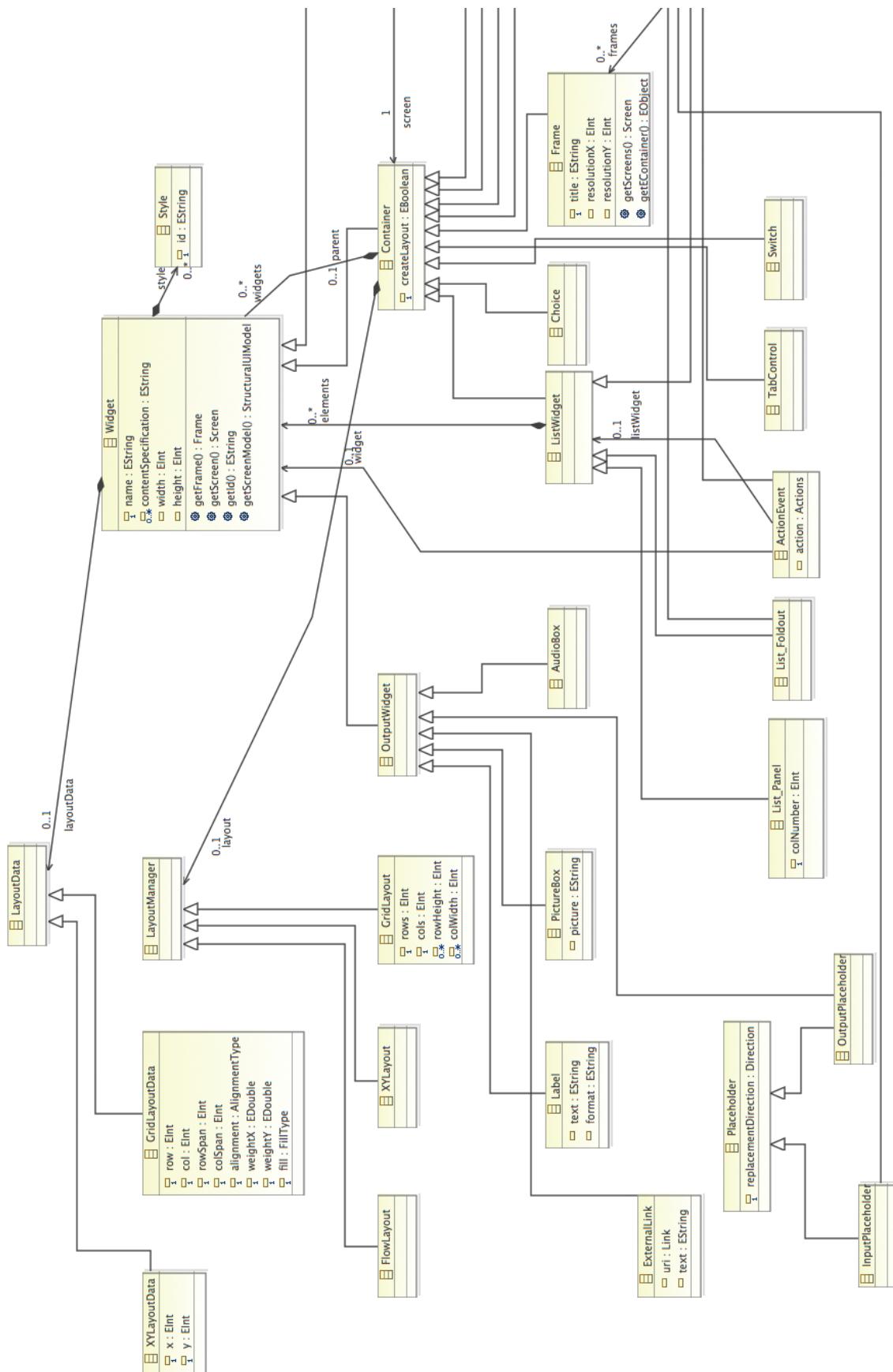


Figure B.1: StructuralUI Meta Model page 1/2

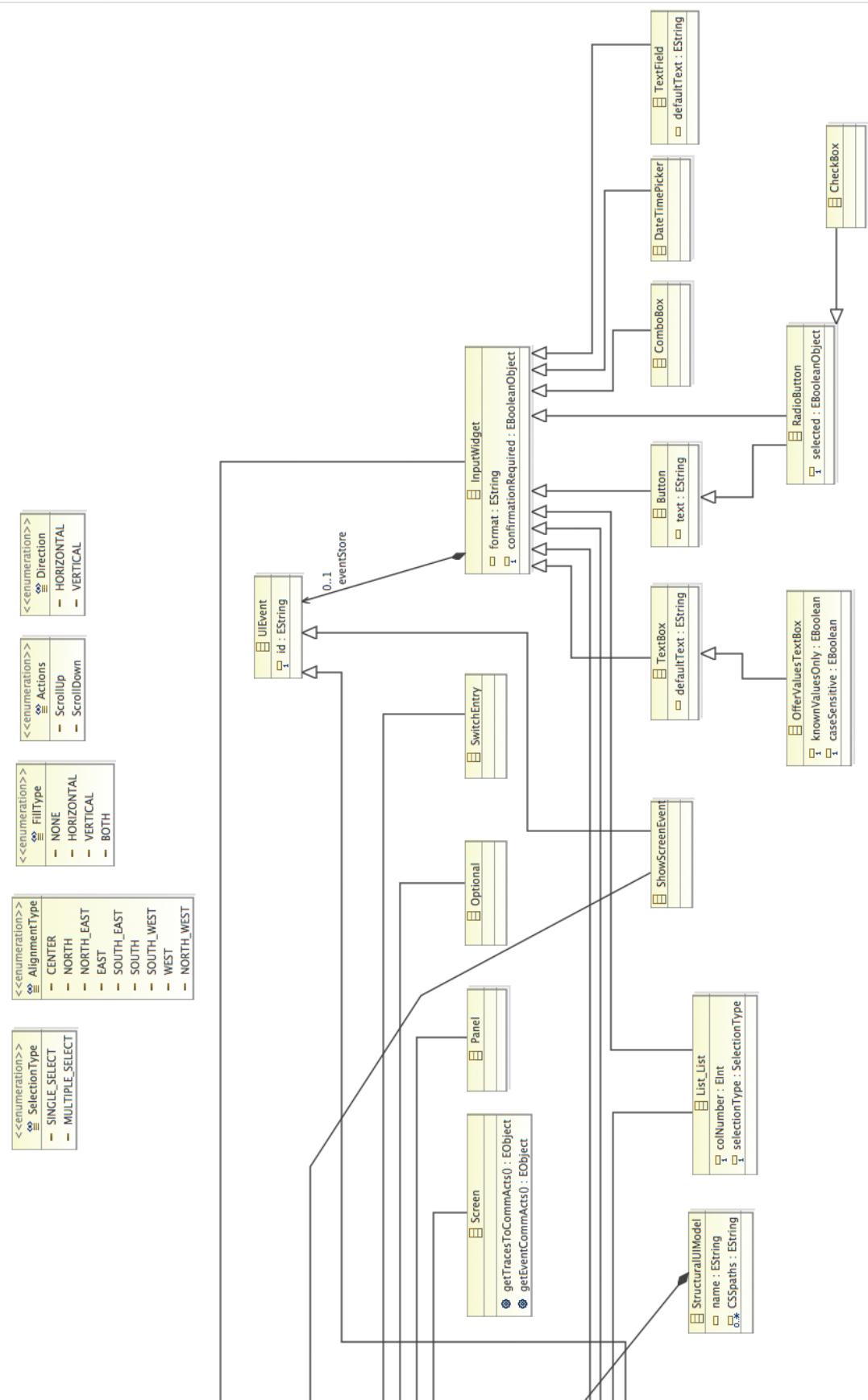


Figure B.2: StructuralUI Meta Model page 2/2

## C Sequence Diagram of the Command Execution “Stretching the Button”

Figure C.1 presents the full sequence diagram showing the creation of the `AutoSize-Requests`, their corresponding commands and their detailed execution. In particular, we present the details of the command execution *Stretching the Button* from the example in Paragraph [Resizing by use of the GSME Pop-up bar](#) on page [28](#).

Sequence Diagram of the Command Execution “Stretching the Button”

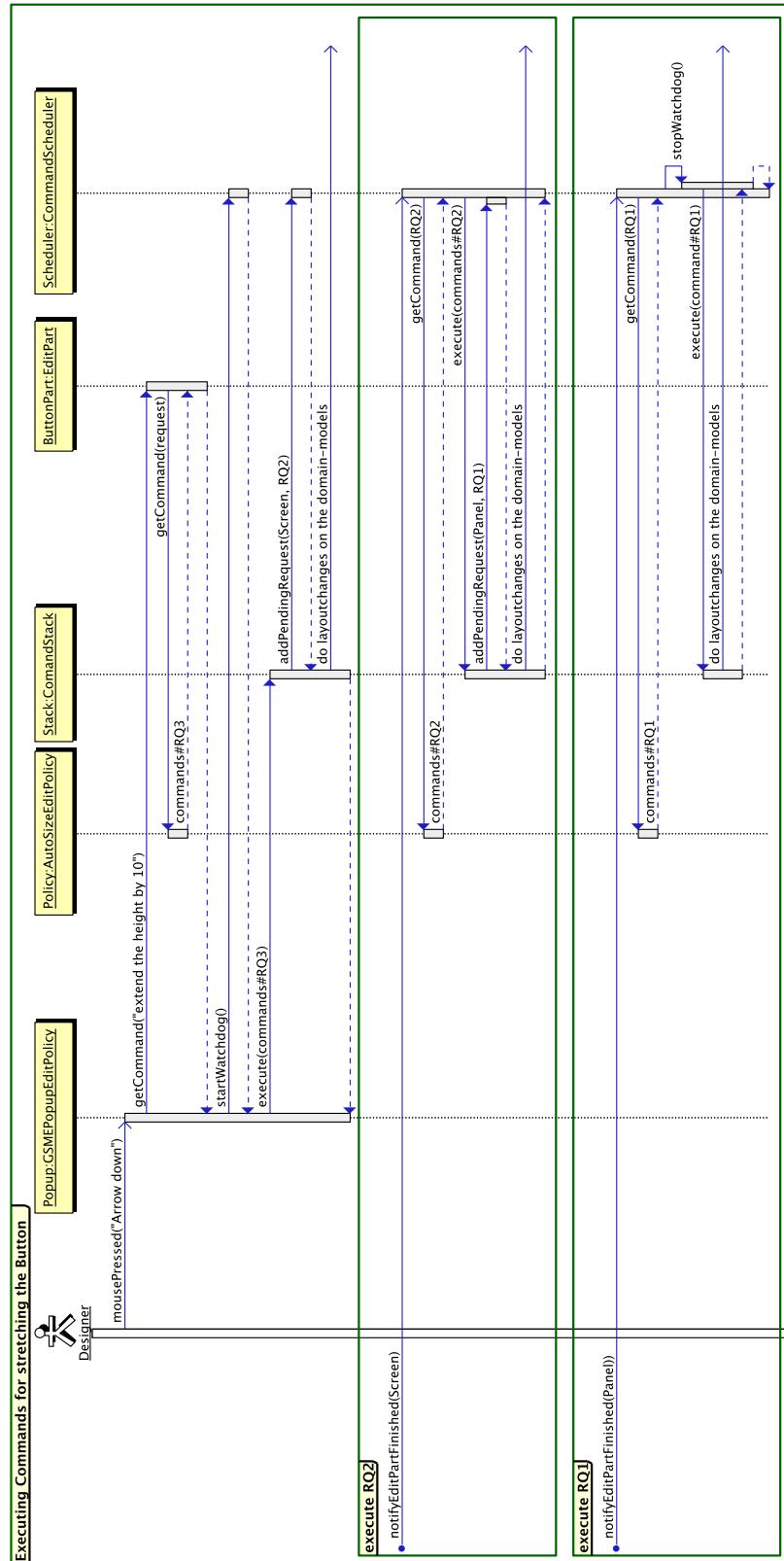


Figure C.1: Sequence diagram: Executing an AutoSize-Request

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