A Lightweight Framework for Graphical Editors on Android Devices

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Abstract: During the last few years, mobile devices and corresponding applications gain more and more attention. The number of users of mobile devices like phones or tablets has been increasing dramatically. Thus, software engineering for mobile applications becomes more and more important. While development frameworks for such devices provide rich support for sophisticated input mechanisms like gestures, etc., they lack support for graphical editors. In this paper, we present a lightweight framework which fills this gap. As a running example, we present editors for UML class diagrams and activity diagrams which have been built using our framework.

1 INTRODUCTION

Over the last few years, we observe an increasing popularity of touch-enabled devices. Smart phones nowadays have even more processing power than desktop computers had a couple of years ago. Many people are now equipped with smart phones or tablets and mobile applications which make their every day lives easier. But not only for personal use, but also for professionals, smart phones and tablets are very useful.

Model-driven software engineering (Völter et al., 2006) is a discipline which evolved during the last decade. A wide variety of different tools exist, which support the modeler during the development process. Since model-driven software development is not tied to a special software development methodology, these tools usually can be used with any development process.

Agile model driven development (AMDD) (Ambler, 2002) applies commonly known principles and practices from traditional source code based agile software development to model-driven development. In his book (Ambler, 2002), Scott W. Ambler states, that agile modeling (AM) asks to use the simplest tools possible (e.g. papers and whiteboards). Complex modeling tools should only be used, when they provide the best value possible.

However, sketches drawn on papers or whiteboards have to be distributed to all involved team members, e.g. by scanning or photographing the result. This raises several problems. While in source code based approaches, where diagrams are only used for documentation purposes, a photograph of a whiteboard sketch might be enough, model-driven approaches demand for models as first class entities. Thus, every diagram that has been sketched on a whiteboard or on a piece of paper has to be redone in the respective modeling tool, which results in an additional overhead. Furthermore, sketches on whiteboards or papers are often missing some essential details like role names or cardinalities of associations for example. Usually these errors are fixed at a later time, when the sketch is redone with the respective modeling tool.

Modern devices are also equipped with HDMI video output and can therefore be easily attached to big TV screens or beamers. This motivated us to add sketching capabilities to our UML-based modeling environment called *Valkyrie* (Buchmann, 2012b; Buchmann, 2012a). This approach provides several advantages: (1) a device running our tool might replace papers or whiteboards in agile modeling processes as sketches directly result in corresponding model instances. No manual redrawing of whiteboard sketches in a modeling tool is required. (2) Since the tool follows common UML standards, inconsistencies like missing role names or cardinalities are immediately reported to the user and thus can be fixed right away. However, when creating the extension to our tool, we observed that the Android SDK lacks support for creating graphical editors.

Our contribution in this paper is a lightweight framework which aids developers in creating touch-enabled graphical editors for Android devices. In

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general, graphical editors are used to visualize graph-based data structures. In software engineering processes, graph-based structures are the underlying data model for various use cases, e.g. petri nets, process modeling or UML modeling just to name a few. Furthermore, we also present a small example of how to use our framework for a touch-enabled UML class diagram editor.

The paper is structured as follows: In the next section, we discuss related work. An overview about our framework is given in section 3. In section 4, we demonstrate our framework by presenting cutouts of the code of an UML class diagram editor which we built, while section 6 concludes the paper.

2 RELATED WORK

To the best of our knowledge, there is no framework for Android devices at the time this paper was written which aids developers when building touch-enabled graphical editors. Of course, there are a lot of WYSIWYG / Visual editors available which aid developers in designing user interfaces for their apps, but those tools do not provide support for building graphical editors. Thus, we decided to compare our framework to existing ones which are designed for regular desktop applications (without touch support).

Graphical Editing Framework (GEF). GEF[1] is a framework which supports interactive diagrams and graphs. It is directly integrated into the Eclipse platform. Its core architecture strictly follows the MVC design pattern. The graphical editing framework is a generic framework which can be used to build graphical editors for arbitrary Java models. Basically, the framework is composed from three different building blocks: (1) Draw2D - a lightweight framework used to display figures on SWT basis, (2) Zest - a visualization toolkit based on Draw2D which is used to combine Java model elements and Draw2D diagrams and (3) GEF - a model-view-controller framework which is also based on Draw2D and which provides an API for interactive functions, like Drag and Drop, Undo/Redo capabilities, etc. While it does not provide native support for touch-enabled devices, recently two projects emerged which address input of diagrams using sketching techniques (Sangiorgi and Barbosa, 2010; Scharf, 2013). While (Sangiorgi and Barbosa, 2010) and (Scharf, 2013) realize an a posteriori integration of sketching capabilities into an existing framework for building graphical editors (GEF), our approach aims at an a priori combination of gestures and such a framework.

Graphical Modeling Framework (GMF). The Graphical Modeling Framework (GMF) (Gronback, 2009) is the model-driven extension of GEF. The added value compared to GEF is that basic graphical editors may be created without writing a single line of Java code. GMF uses models to describe the graphical primitives and the tool palette of the graphical editor. Another model is used to link model elements, graphical elements and their respective tools. This model acts as a basis for the Xpand-based code generator. While this approach works well for simple editors, manual adjustments /extensions of the generated code are needed in many cases (Buchmann et al., 2007; Buchmann, 2012b). Furthermore GMF is not as generic as GEF as it requires Ecore-based (Steinberg et al., 2009) semantic models. While our framework presented in this paper is more general, as it allows for any Java-based model, we successfully applied it to Ecore-based models as well.

Graphiti. Graphiti[2] is another Eclipse project, which provides a graphical tooling infrastructure. Similar to GMF its primary purpose is to provide graphical representations fo EMF models, but nevertheless it also works for Java-based objects on the domain side as well. In contrast to GMF, it does not provide a model-driven approach as it comes with a plain Java API for building graphical tools. While both GEF and GMF are intended to be used within the Eclipse environment, Graphiti provides the option to support different platforms. Just like the above mentioned frameworks, Graphiti also does not provide native support for touch-enabled devices.

Sirius. Sirius[3] is another Eclipse based project, which empowers developers to build graphical editors for domain specific languages. Like GMF it leverages model-based architecture engineering by providing a generic workbench that could easily be tailored to fit specific needs. In contrast to GMF, the description of a Sirius modeling workbench is dynamically interpreted by a run-time within the Eclipse IDE. Again, also Sirius does not provide native support for touch-enabled devices.

Upgrade. UPGRADE (Böhlen et al., 2002b; Böhlen et al., 2002a) is another Java-based framework which is used for building graph-based inter-

[1]http://www.eclipse.org/gef

[2]http://www.eclipse.org/graphiti

[3]http://www.eclipse.org/sirius

active tools. Primarily it was designed to be used as a visual front-end for PROGRES (Schürr, 1996) models. It puts focus on reusability and customizability, decoupling of application logic and user interface, platform independence and many more. Platform independence is achieved by using the Java programming language. While the other frameworks discussed in this section are also written in Java, they contain a lot of dependencies to the Eclipse workbench and their SDKs which make it impossible to use them on Android. UPGRADE on the other hand is independent from any IDE, but it turned out that the framework is outdated and development activities have been stopped a long time ago.

Web-based Approaches. In the past few years, web-based approaches for graphical editors have emerged. Gordon et al. (Gordon et al., 2005) present a framework for light-weight web-based visual applications. However, while a web-based graphical editor could be used on any device which is capable of running a browser, the approach presented by Gordon et al. also misses support for gestures.

All of the approaches mentioned above provide flexible support to create graphical editors for arbitrary models. The major drawback of all frameworks in the context of this paper is, that they do not work on Android devices and moreover, they do not provide native support for sophisticated input mechanisms, like gestures.

3 FRAMEWORK OVERVIEW

The basic design decision when developing a framework for graphical diagram editors is which functions should be encapsulated and which ones should be implemented by the developers using it. The main goal is to encapsulate as many functions as possible while providing developers with the freedom to design corresponding editors according to their specific needs. Since the framework is targeted towards building graphical editors for Android-powered devices, they should be controlled using gestures. In general, graphical editors are used to display nodes and edges of a graph. The graphical representation of those nodes and edges differs according to the application domain and the respective visual language. Thus, developers using our framework should be able to specify the following:

Gestures. Specify all gestures which should be available to control the final editor.

Actions. Which actions should be executed once a predefined gesture is performed.

Nodes. All visual elements which are used to display different node types of the graph.

Edges. All visual elements which are used to display the graph's edge types.

On the other hand, certain operations which are common for all types of graphical editors may be encapsulated within the framework, like e.g. moving elements, zooming, scrolling, etc. Our framework encapsulates the following operations:

1. Drawing / editing nodes
2. Drawing / editing edges and their labels
3. Gesture processing
4. Zooming
5. Scrolling
6. Undo / redo of editing operations
7. Persistency mechanisms
8. Consistency with the Android SDK in terms of the app life-cycle

In the following, we are going to discuss the major building blocks of our framework in detail: visual elements, gesture processing, undo/redo management, and persistency.

3.1 Visual Elements

3.1.1 Shapes and Figures

Visual representation of nodes and edges is the most important task of a graphical editor. When creating a generic framework aiding the development of graphical editors, only a few assumptions concerning the shapes of the visual elements can be made. As a consequence, we chose an approach which allows as much flexibility as possible. As the visual elements are directly rendered on the visible user interface of the app, we had to pick the appropriate rendering technique first. Basically, the Android SDK supports two different approaches: (1) The graphical element is rendered into a view which is part of the layout (the Android run-time takes care of the rendering in this case). (2) The graphical element is rendered directly to the UI using a canvas (manual control about the rendering is possible here). Furthermore there are two different ways of how to create complex visual objects when working with the canvas: (1) Visual elements may be composed from graphical primitives or (2) visual elements may be represented using bitmaps.

While using elements composed from graphical primitives requires less processing power and memory resources, it is not feasible for complex objects. Using bitmaps provides benefits in terms of allowing transparency, possibility of matrix transformations and an easy implementation. Bitmaps may contain transparent areas and such allow to display circles for example. As a result, creating complex visual elements is transferred to standard bitmap processing tools, like e.g. Gimp[4], which are perfect for this task. Images are stored in an Android resource which can easily be loaded into a bitmap during runtime. Furthermore, bitmaps may be rendered using a transformation matrix. Thus, transformations like rotation, translation or scaling can easily be applied. The Android SDK provides a special extension to bitmap images – NinePatchDrawable – which allows *context-sensitive* scaling, i.e. areas near the image boundaries are duplicated during scaling while unmarked areas are not affected. Within the Android SDK, a NinePatchDrawable is used for example for buttons.

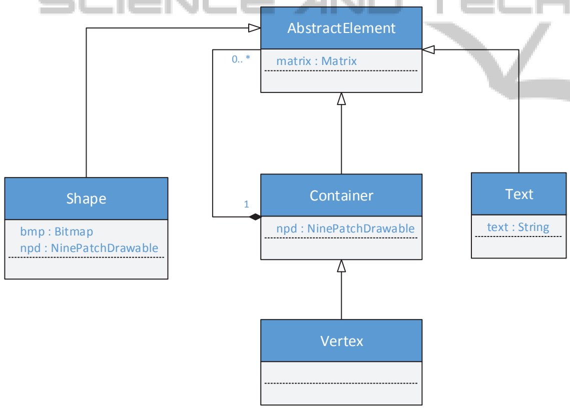


Figure 1: Cutout of the class diagram responsible for handling visual elements.

Figure 1 depicts a class diagram which contains the structure of the visual elements representing nodes as provided by our framework. Developers working with our framework create visual elements by creating images and loading them. Furthermore, elements may be composed hierarchically into an arbitrary tree structure. The alignment of elements may be specified by layout information. The class diagram in Figure 1 contains a class Container which serves as a container for child elements, while Vertex is the root element. Shape is used as a container for the (bitmap) image and Text is the container for string literals. The hierarchical structure of visual elements is modelled using the composite association between Container and AbstractElement. Vertex is a dedicated Container which is the root of the containment hierarchy and which is directly rendered onto the canvas of the app, while Shape and Text represent the leaves.

[4]http://www.gimp.org

Besides child elements, a Container may also have a bitmap or a NinePatchDrawable as background which are scaled to match the correct size of the visual element. The scaling behavior depends on the layout information which offers a distinction between *wrap_content* and *fill_parent* when scaling along x and y directions. While the first one is used to match the container's size according to the size of its contained children, the latter one is used to fit the container's size to its parent Container. Figure 2 depicts the differences of both mechanisms. While the blue box in the attribute section of the class depicted in Figure 2 symbolizes the scaling effect of *wrap_content*, the red box marks the result when choosing *fill_parent*.

Figure 2: Difference between *wrap_content* and *fill_parent*.

The alignment (either horizontally or vertically) of the contained elements is also part of the container's layout information. Furthermore a container has a minimum size which avoids the visual element to shrink in case its content is deleted.

3.1.2 Diagram Links and Decorators

Similar to shapes that are used to visualize nodes, the diagram links that depict edges may have a different visual appearance – which is also defined by the developer – according to the application domain. When creating diagram links, several different aspects need to be taken into account:

Line Properties: color and thickness of the line as well as the visualization kind (solid, dashed, dotted, etc.).

Anchor Points: An anchor point is a point which serves as an interconnection between the visual element representing a node and the link object.

Bend Points: A bend point of a link needs to satisfy certain requirements, like the ability to be moved.

End Decorators: End decorators are custom shapes which are located at the corresponding ends of the link, e.g. arrow heads.

Labels: A link may contain different labels which are used to display arbitrary string literals.

The Android Canvas object provides a native method drawPath(), which we used to display the links. Thus, the link and all of its bend points needs to be transformed into a Path object. Figure 3 depicts a simplified class diagram which is responsible for handling links and decorators. A Link object is always connecting two Vertex objects and may contain an arbitrary number of BendPoints. In our case, an end Decorator is a specialized BendPoint.

Our framework offers a set of different predefined end decorators as well as the possibility to create new ones. As a result, the usage of elements visualizing edges is very easy and can be achieved with only a few lines of code.

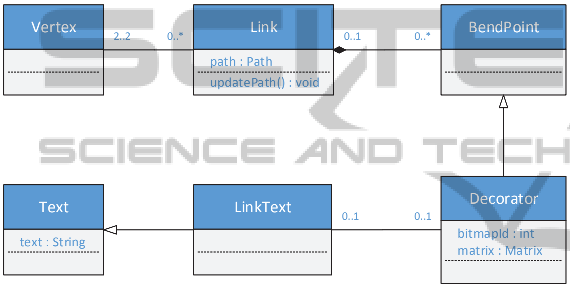


Figure 3: Simplified class diagram responsible for handling links and decorators.

3.2 Gestures

All diagram editors which may be created using our framework should be controlled using gestures. As a consequence, a core requirement is that the framework supports developers during this task as much as possible. Furthermore common, predefined gestures are encapsulated within the framework and are thus common for all editors:

- Zooming
- Reset zoom factor
- Scrolling
- Move diagram nodes and links
- Select diagram nodes and links
- Delete diagram nodes and links
- Edit diagram nodes and links
- Connect nodes using links

Basically, the Android SDK provides two different ways how gesture recognition may be handled in an app. It provides an app (GestureBuilder) which allows to draw and save gestures which can then be used to compare the recognition result with the currently drawn one. The comparison is done automatically by the framework and quickly provides a result. Alternatively, the developer can decide to not use the automatical recognition which requires more programming effort, but is much more flexible. The best approach is to use the automatic recognition whenever possible, and to use the manual recognition only in cases where the automatic recognition fails. This process is sketched in figure 4.

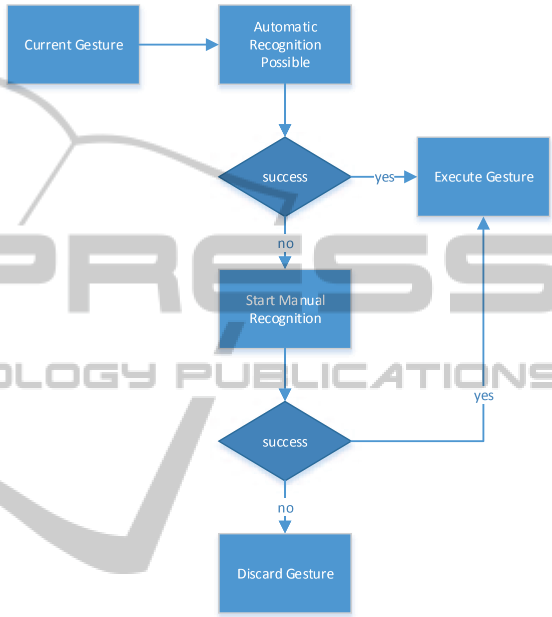


Figure 4: Gesture recognition process.

While the automatic gesture recognition provided by Android is suitable for standard apps, gestures in diagram editors might become much more difficult to handle. In general, when using the automatic recognition, only one axis (x or y direction) is useable for gestures as the other one is automatically reserved for scrolling purposes. It only raises one event OnGesturePerformedListener which indicates a complete gesture. The resulting gesture object can be passed to the recognition algorithm. The Android SDK provides another listener (OnGestureListener) which provides a greater flexibility. It has three different call-backs which indicate start and stop and all intermediate points of a gesture. The draw-back is that composite gestures have to be assembled manually. To this end, our framework provides a listener thread which can be configured with custom timeout values. As long as the timeout is not raised, all gestures performed are considered to be part of one single composite gesture (c.f. Figure 5). We chose to use the second gesture listener, since it allows to also implement instant gestures, like moving, zooming etc. which are used in resulting editors.

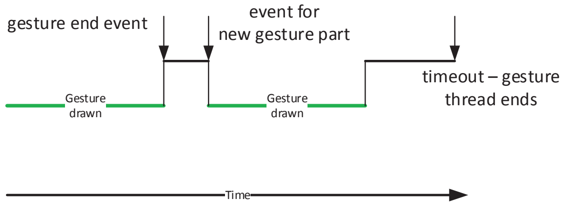


Figure 5: Gesture recognition process.

3.2.1 Gesture Recognition

After a gesture has been recorded, it needs to be interpreted. In our framework, the abstract class GestureRecognizer is responsible for this task. Framework users have to inherit from this class and put their custom behavior into the corresponding method bodies. The standard implementation of the GestureRecognizer passes gestures to the Android recognition algorithm and returns corresponding results, if the prediction score exceeds a predefined threshold – the gestures are ignored otherwise. If the GestureRecognizer is not able to identify the gesture, a check is performed, if a connection between two visual elements was made. Regarding connections, a distinction between gestures for solid and dashed connections is made and the gesture with all affected visual elements is passed to the GestureMapping object for further processing. In case there is no connection, a check has to be performed if the user intended to delete diagram elements. Figure 6 depicts the chain of responsibility during gesture handling in our framework.

3.3 Undo / Redo Management

Nowadays, almost every editor provides means for the end users to record editing operations which can be undone or redone. Thus, our framework incorporates mechanisms to allow developers to build editors with undo/redo functionality. To this end, all editing operations are wrapped into actions implementing our IAction interface. The interface provides the methods execute() and unexecute() respectively. While execute() performs the desired action (e.g. creating a new object), unexecute() resets the editor in its previous state. All actions are stored on an undo-stack and thus may be undone in the correct order. Our framework distinguishes between regular actions, composite actions (like moving) and actions which can not be undone like zooming or scrolling (as these actions do not change the state of the editor). Once a corresponding action is undone, it is pushed onto the redo-stack, while redoing an action has the opposite effect. As soon as a new action is pushed onto the undo-stack,

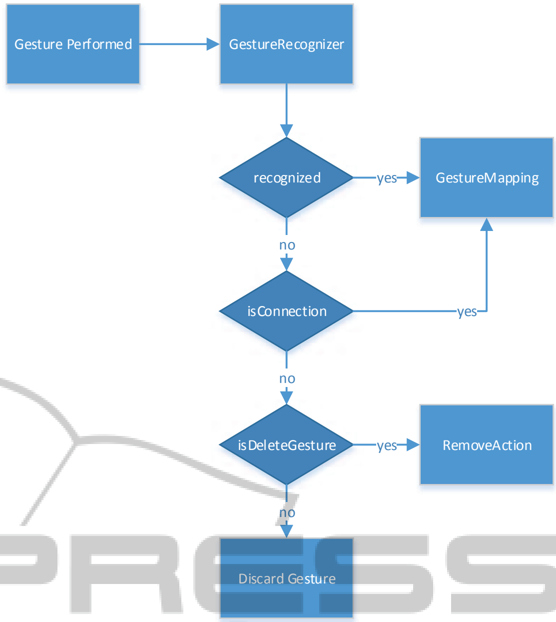


Figure 6: Chain of responsibility during gesture recognition.

the redo-stack is cleared since all actions stored in the redo-stack might not be sensible any more.

4 EXAMPLE

This section demonstrates the creation of a graphical diagram editor using our framework. We demonstrate that only a few steps are required to create a touch-enabled UML class diagram editor. We use the GestureBuilder app provided by Android to record the gestures which should be used in the class diagram editor. The first task is to inherit from the following abstract classes and implement the corresponding methods:

GestureRecognizer is responsible for recognizing the gestures.

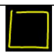
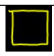
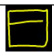
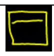
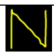
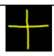
DrawableFactory is used to create the visual elements.

GestureMapping is used to map gestures and visual elements and the corresponding editor actions respectively.

EditorsActivity is used to assemble the other classes and to provide the UI of the editor. Extensions of the user interface are possible in this class.

Table 1 shows a cutout of different gestures and their mapping to corresponding editor actions used in our example. Please note that the drawing direction of

Table 1: Gestures used for the sample class diagram editor.

Gesture	Name	Description
	square	Create new class
	square	Create new class, gesture performed in opposite direction
	square	Create new class, multi-part gesture
	square	Create new class, multi-part gesture performed in opposite direction
	n	Create new interface
	plus	Add attributes and methods to classes / interfaces

gestures is crucial. To this end, we performed gestures like the square both clockwise and counter-clockwise.

Our framework offers the possibility to deal with miss-interpretations of gestures. E.g. the *plus* gesture was recognized with a high probability even if only one line was drawn with the standard gesture recognition. Thus, we added a second test, if the gesture in fact consists of two lines with an intersection. After a positive recognition, the corresponding gesture is handed over to the gesture mapping for interpretation.

The DrawableFactory is used to create all visual elements. A new subclass ClassDiagFactory is created for our sample editor. The new class contains factory methods for visual elements which are called from the corresponding GestureMapping class. E.g. to create new classes in our class diagram editor, a method public Vertext createClass() is added to the ClassDiagFactory. Each factory method, which creates visual elements has to return a Vertex. Our framework already provides factory methods to create connections between visual elements. This method needs the two Vertices which are connected by the line as well as start and end anchor points and the corresponding line style.

The GestureMapping class is used to interpret recognized gestures and assign editor specific actions to them. Again, we created a new subclass ClassDiagGestureMapping and implemented the abstract methods which are used to interpret gestures for visual elements and connections between them.

The EditorsActivity class is used to connect the classes mentioned above and to modify the user interface of our class diagram editor app. In order to use the class diagram editor with our model-driven development toolchain *Valkyrie*(Buchmann, 2012b), we use Eclipse UML2 as data model. The corresponding methods are also implemented in the ClassDiagEditorsActivity subclass. Figure 7 depicts the resulting class diagram editor in action. In (1) the gesture (*square*) for creating a new class is performed. After the gesture has been recognized and interpreted, the corresponding class and the visual representation is added. In the next step (2), an association between the two classes depicted in Fig. 7 is created by performing the association gesture. The final result is shown in (3).

5 DISCUSSION

In a recent project (Buchmann, 2012a), we investigated the usage of touch-enabled devices in software engineering processes. To this end, we created a graphical editor for UML class diagrams from scratch on an android device. Building such editors is a tedious and error-prone task, especially when integrating gesture support. For this reason, we developed the framework presented in this paper, allowing users to abstract from lower-level implementation issues. As a consequence, the creation of gesture-enabled graphical editors on android devices is facilitated considerably. While the framework is still under development, it is evident that even in its current state it provides an added value for developers.

Typically, mobile devices are equipped with small screens compared to desktop computers. While they provide similar screen resolutions, it is obvious that the content is displayed in a much smaller size, and thus, is harder to read. Furthermore, diagrams tend to become very large. As a consequence, a user of a diagram editor on a mobile device has to scroll and zoom very often. While our framework provides native support for scrolling and zooming gestures, we are still trying to improve the editing experience. We are thinking of supporting different levels of detail, where certain information may be hidden.

Modern devices do not only provide sophisticated input mechanisms using the touch screen, they also

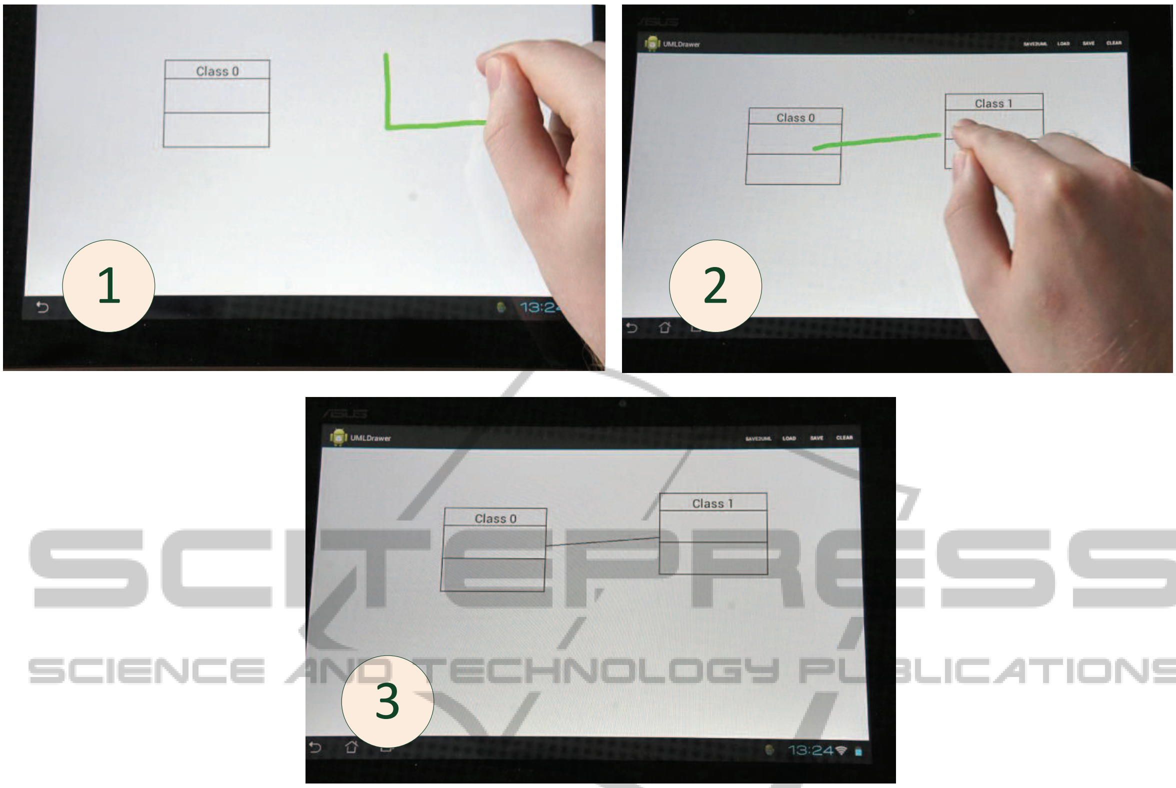


Figure 7: The example class diagram editor.

have different built-in sensors, which may be used as an additional source of input. In fact, we tried to exploit the speech recognition capabilities of android to assign names of graphical elements automatically. Unfortunately, it seems that the speech recognition is region-based. I.e. if you have a german device, the recognition algorithm always tries to recognize german words, which of course fails if someone wants to create an interface in an UML class diagram called IEObjectItemProvider for example. Thus, work is currently being addressed to investigate if support for handwritings is feasible. Furthermore, we are also investigating if other sensors, like the built-in camera, accelerometers, etc., may further improve the editing experience.

In its current state, our framework works very well for diagrams of medium complexity, e.g. class diagrams. Typically, those diagrams consist of nodes and edges and the nodes may contain compartments, which are used to display child nodes. So far, we did not try to implement highly-complex diagrams, but since this is even painful to implement with custom frameworks for ordinary diagram editors, like GEF, etc., we do not expect that our light-weight framework will perform better.

In general, our vision is not provide a complex framework, which allows to build graphical editors of arbitrary complexity. Instead, we are aiming at a lightweight framework, which allows to create applications allowing users to capture information in certain situations, like e.g., in meetings or when they do not have access to their usual modeling environments. In contrast to plain drawing tools, this information is persisted in the abstract syntax of tools which are used to further process this information in later stages. In (Buchmann, 2012a), we described an usage scenario, when the android app is used in addition to the UML modeling tool *Valkyrie*. A software developer may use the app in meetings to sketch use cases or early design decisions, which may be further refined seamlessly in a full-fledged modeling environment at a later stage of the development process.

6 CONCLUSION

In this paper, we presented a lightweight framework which empowers the user to easily build touch-enable graphical editors for android devices. Our contribution fills a gap which exists in the current Android SDK. While there is rich support for sophisticated input mechanisms in the Android SDK or third party frameworks, like gestures for example, they do not contain tools which allow developers to easily build graphical editors. As graphical editors as required for many different use cases and especially in modern software engineering processes, our contribution provides huge improvement for developers of such tools. Furthermore, mobile devices can now be seamlessly integrated in agile development processes, as demonstrated in our running example.

Future work on our framework comprises further extensions, like layout algorithms. Currently, work is addressed dealing with implementing different graphical editors, including UML diagrams (e.g. use case diagrams, activity diagrams, package diagrams, statecharts) as well as others. Furthermore, we are thinking about designing a DSL which is targeted towards a declarative specification of graphical editors.

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