END-USER DEVELOPMENT IN A GRAPHICAL USER INTERFACE SETTING

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Abstract: In many areas, software applications must be highly configurable—using a pre-defined set of options or preferences is not flexible enough.
One way to improve an application's flexibility is to allow users to change parts of the source code—and thus the application's behavior—on-the-fly; modern languages like Java greatly facilitate this by providing reflection features. Such an approach, however, is often limited to user-defined mathematical formulas, e.g., in software like cash flow engines, reporting tools etc.
This paper applies the concept to a more generic area: the graphical representation of diagrams in a UML tool. Users can create new types of graphical elements by directly programming how the elements are drawn, all within the UML tool, and at run time. The approach is flexible, and the user-defined extensions are consistent with the tool's core source code.

1 INTRODUCTION

"Using a computer" evolved considerably over the last decades from an end-user point of view. In the early days, end users had to actually program the computer, which provided only a basic set of functionality. Soon, of course, some of those early programs evolved into ever more sophisticated special-purpose applications to be distributed to an ever-growing set of potential end users. These applications provided a specific, constrained set of high-level functionality (e.g., the Unix set of command line tools), while relieving end users from dealing with low-level programming. This process towards specialized, stand-alone applications was consolidated with the advent of graphical user interfaces (GUIs). These apps provide higher-level functionality (e.g., a word processor), and they are arguably easier to use for a wider audience. However, the flexibility and intra-tool communication is further restricted: the end user can no longer tweak the tool thoroughly.

This outline—from basic, general-purpose programming systems to less flexible, high-level custom applications—greatly simplifies the manifold currents in the evolution of software, its application and user base, and its flexibility. Several counter-trends can be readily identified:

1. Many modern applications (Eclipse, Excel, Firefox, to name but a few) can be enhanced and modified using plugins. The underlying techniques differ; the approaches are similar: in an external tool some partial functionality is defined and packaged, and then attached to the main application.
2. A variety of tools allows to add user-defined functions or statements. OLAP applications, for example, let users enter SQL statements if the usual drag-and-drop GUI can't easily assemble particularly complex queries. Financial applications like cash-flow engines and pricing tools let users enter additional business logic and payoff functions—basically additional mathematical formulas and functions. Usually, the end user is allowed to access some basic set of mathematical functions, to which some restricted data structures are exposed. The modifications can usually be done within the tool, at run time.

3. On a larger scale, applications or operating systems can provide a whole macro language or framework (VBA for MS Office, AppleScript..). In this discussion, we'll focus on VBA-like macro languages due to their wide-spread use. This approach exposes more of the main application's functions and data structures to the end user. The macro language's scope, however, is often still restricted to a subset of the internal APIs, in part because the language is usually simpler that the application's core language (e.g., Basic vs. C++). Often, inconsistencies arise: see, for example, how Excel's native cell formulas like *MMult* are accessed within VBA. Advanced operations are possible, but often require embedding externally created library functions (in VBA, with the *Declare Function* command).
4. Finally, open source software discloses an application's entire source code. End users can inspect and modify all aspects of the software. Users, particularly large institutions, regularly adapt open source software to their needs, e.g., database software like PostgreSQL is modified to handle new data types.

Approach (1) is appealing—our main critique is the media break: the plugin is developed externally and must be included explicitly in the main application. In many instances, it is preferable to allow run-time modifications seamlessly, within the application, like in approach (2).

Approach (4) is geared towards power users; other end users might be overwhelmed by the setup and sheer complexity of the code. Too much is exposed—many parts of the code are unlikely to be modified. The highest degree of flexibility is achieved, but at the expense of severely reducing the target audience.

This paper describes an approach of providing seamless flexibility for many end users, by letting users alter parts of the core source code at run time. Conceptually, it lies between approach (2) and approach (3):

- Users can access the full core API and data structures of the tool, unlike in (2). Not only mathematical functions, but the graphical behavior and the GUI's reaction to user input can be modified.
- Users can use the tool's core language (Java in our case), not a stripped-down or simplified macro dialect. API calls and data access are thus consistent in the user-defined code parts and the surrounding original code, unlike in (3). This avoids redundancies in the interfaces, data structures, and their documentation; it is also preferable, for example, if the code should later be included in the official distribution branch of the application.
- There is no media break, i.e., no need for external tools or explicit imports like in (1), or for external DLLs like in (3). Such media breaks are tedious, time-consuming and a prime source for errors.
- While the end user has access to the full range of the internal API and data structures, he can modify only those parts of the code that are expected to require this additional level of flexibility. The proposed approach thus resembles "sand box", as opposed to the "sand bucket" in (2) or the "sand mine" in (3).

This paper addresses two target audiences: end users and developers of flexible software applications. To end users we present where and how UMLet provides flexibility. To developers we outline the implementation setting and some technical details. We argue that users should demand this increased level of flexibility, not only in a setting where they are allowed to define mathematical expressions, but in ones with more complex tool behavior as well. Developers, in turn, should embrace this way of deferring design decisions to later stages, up to the end user. Often, they themselves will find that developing new tool features is best done at run time, within the tool.

Section 2 gives on overview on related work. Section 3 describes this paper's goal in greater detail. Section 4 outlines implementation issues. Section 5 presents several examples of UMLet's end-user development process. Section 6 concludes and points out future research directions.

2 RELATED WORK

2.1 End-User Development

The concept of *end-user development* (EUD)—defined by Beringer as a "design problem to enable subject matter experts to create or modify executable software components" (Beringer, 2004)—has been investigated for several decades (Martin, 1984). However, as several authors notice, the advances are behind expectations (Sutcliffe, 2005; Fischer et al., 2004). Beringer, for example, notes that EUD applications "only realize a fraction of EUD's potential and still suffer from several flaws" (Beringer et al., 2008). He lists only a handful of partially successful applications, like macros, spreadsheets, and email filters.

The need for EUD applications, however, becomes more evident as increasing numbers of domain experts need to customize their software tools to ever higher degrees, preferably at "use time" (Ko and Myers, 2005): they become “unwitting programmers” (Costabile et al., 2008) as they evolve from customizing software to creating new software functionalities. Fischer identifies an even bigger group of end users, the “much larger population of intellectually disenfranchised knowledge workers who are forced into a consumer role” as opposed to the traditional “population of elite scribes who can act as designers” (Fischer and Scharff, 2000).

Several papers describe the requirements for successful EUD applications: Ruyter, for example, stresses that such applications should be simple, give proper user feedback, and motivate the end user to play with the system (Ruyter and Sluis, 2006). Segal, on the other hand, focuses on the problems such approaches need to deal with and overcome, especially the problems of sharing knowledge and of software reuse in a EUD context (Segal, 2007). Also, common important software engineering activities (like documentation) are unlikely to be performed by the task-focused end users (Segal, 2007). The “conflict between complexity and power” (Fischer et al., 2004) leads Sutcliffe to a cost-benefit analysis of EUD (Sutcliffe, 2005). Others, like Heng (Heng, 2003), emphazize the need for more communication between system developers and end users to achieve flexible and maintainable systems.

Another issue—the possible technical frameworks underlying EUD applications—is discussed, for example, by Paterno, who states the need for a transformation between intuitive representations of functionality to more precise, but more difficult to develop, ones (Berti et al., 2006). Similarly, Fischer describes some frameworks (like the high-level language Java) as having a high cost of learning, and thus not being an ideal EUD environment (Fischer et al., 2004).

Several organizations have recently focused on this topic, for example, EUD-Net[1], EUDISMES[2], EUSES[3].

2.2 UML

The *Unified Modeling Language* (UML) (Booch et al., 2005) is widely used for modeling object-oriented software systems. It aims to cover most parts of the software development process and has been applied in various environments (e.g., real-time systems (Evans and Wellings, 1999), or decentralized production control systems (Kohler et al., 2000)). It was developed between 1994 and 1997 by the “3 Amigos”: Jim Rumbaugh, Ivar Jacobson, and Grady Booch. Version 1.1 was standardized in November 1997 by the *Object Management Group* (OMG)[4]. The OMG is a non-profit industry group now responsible for defining and maintaining the UML specification. The next major revision—UML 2.0—became the standard in October 2004 and since then evolved to the current version 2.1.2 of the UML superstructure and infrastructure specifications.

UML has unified and standardized the concepts of previous graphical notations like Booch or OMT. It currently features six types of structure diagrams (e.g., class diagram, deployment diagram..), as well as seven types of behavior diagrams (e.g., activity diagram, use case diagram..). All in all, UML defines more than 130 elements[5]; new ones are being added in each new version. This puts some strain on UML tools—they often do not cover the whole range of the graphical notation, and need to be continuously updated to reflect new UML versions.

Due to the widespread use of UML, a large number of tools is available. According to Smith (Smith, 2004), these can be categorized into:

- UML drawing tools;
- code-centric tools; and
- framework tools.

UML drawing tools focus on fast diagram sketching and offer great flexibility. Code-centric tools restrict the UML specification to fit specific programming languages, but provide additional features like code generation and reverse engineering. Framework tools go one step further by supplying the user with extended code generation mechanisms as well as providing automated test case generation.

An overview of many UML tools is available on Jeckle’s Web site[6]. IBM Rational Rose[7] and Visual Paradigm[8] are two commonly used commercial framework tools that attempt to support a host of development procedures, as well as code generation and reverse engineering. In contrast, the open source tool UMLet[9] (Auer et al., 2003) concentrates on fast diagram sketching (Auer et al., 2007) and flexibility. Another aspect of UMLet—presented in this paper—is the adaptability to new element types via *custom elements*, where users can define new UML element types at run time.

[1] http://giove.isti.cnr.it/eud-net.htm

[2] http://www.eudismes.de

[3] http://eusesconsortium.org

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

[5] http://www.omg.org/spec/UML/2.1.2

[6] http://www.jeckle.de

[7] http://www-306.ibm.com/software/awdtools/developer/rose

[8] http://www.visual-paradigm.com

[9] http://www.umlet.com

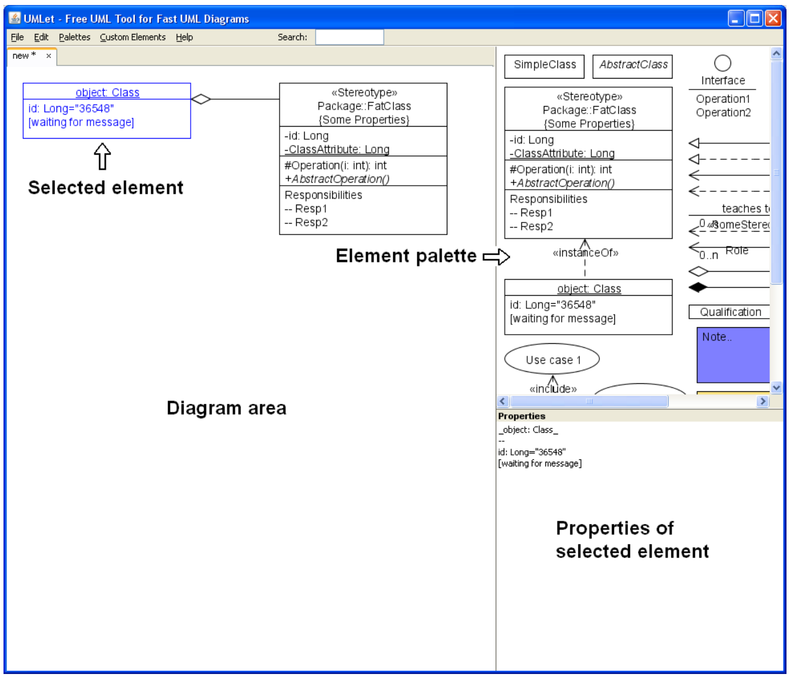

UMLet - Free UML Tool for Fast UML Diagrams
File Edit Palettes Custom Elements Help
Search:
Selected element
Element palette
Diagram area
Properties of selected element
SimpleClass
AbstractClass
Interface
Properties

Figure 1: UMLet screenshot

2.3 Reflection

Reflection is the ability of a programming language to query and operate with language meta-information, e.g., to get a list of all available members of a class in an object-oriented framework. Cazzola (Cazzola et al., 2000) describes its properties of “transparency, separation of concerns, and extensibility” as “accepted as useful for software development and design” and as “likely to be of increasing relevance in the modern software engineering scenario”.

Reflection is especially useful to delay parts of a software design from compile time to run time. This property is valueable for addressing flexibility issues in modern software development—it is applied in COTS components (e.g., Hibernate[10]), in plug-and-play supporting software (e.g., Firefox[11]), and in highly customizable software (e.g., UMLet).

A prominent example of a language providing reflection capabilities is Java. An established application of reflection concepts in the Java environment is, e.g., the Enterprise JavaBeans component technology[12].

[10]`http://www.hibernate.org`

[11]`http://www.mozilla-europe.org/en/firefox`

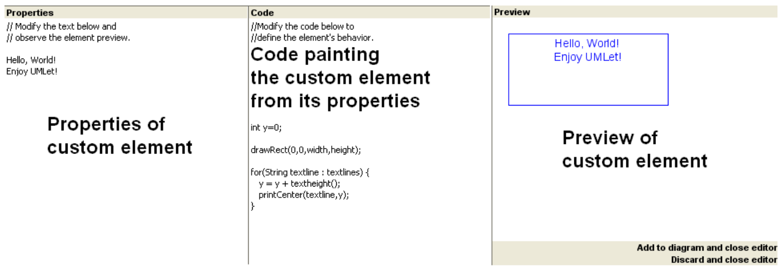
[12]`http://java.sun.com/products/ejb`

3 GOALS AND APPROACH

UML defines a wide variety of graphical elements; each new UML version modifies them, or adds new ones—so there is a constant need for UML tool updates. End users can thus either wait for a new version of a given UML tool, or design their own UML elements. This paper proposes a way how end users can develop such new graphical elements within the UML tool UMLet (Auer et al., 2003).

Following Ruyter’s suggestions (Ruyter and Sluis, 2006), the goal is to keep the approach simple and to provide immediate feedback to the user—see section 3.1. The way users create new elements is that they can specify—via Java code—how new elements are painted. This definition takes place within the tool UMLet, at run time. To reduce the complexity of this user generated code we use a code frame or template to avoid exposing unnecessarily complex objects to the user—see section 3.3.

We use Java as end-user programming language. The main reason for choosing Java is the greater flexibility compared to a custom domain specific language (DSL). This allows the user to access both some methods pre-defined for user convenience, as well as Java’s complete set of graphics and core libraries. Furthermore, Java’s reflection features make the implementation of this additional degree of flexibility straightforward. Another reason for using a popular object-



Properties
Code
Preview
Properties of custom element
Code painting the custom element from its properties
Preview of custom element
Add to diagram and close editor
Discard and close editor

```
// Modify the text below and
// observe the element preview.

Hello, World!
Enjoy UMLet!
```

```
//Modify the code below to
//define the element's behavior.

int y=0;

drawRect(0,0,width,height);

for(String textline : textlines) {
   y = y + textheight();
   printCenter(textline,y);
}
```

```
Hello, World!
Enjoy UMLet!
```

Figure 2: UMLet screenshot - custom element UI

oriented language is that many UML tool users are already familiar with it.

3.1 UMLet's User Interface

UMLet's user interface (figure 1) basically provides three panels - the diagram panel, the palette panel, and the property panel. The diagram panel, of course, displays the diagram and all the UML elements it contains, and lets the user modify their location—just like other graphical tools. The palette panel exposes all available elements and lets users add instances of those elements to the diagram panel (it does not represent elements by icons; instead, it represents them like they would look on the diagram). Finally, the properties panel is a text panel that lets users view and modify the properties of a UML element.

In most UML tools, element properties are modified via pop-up windows, where users can change element attributes. The property panel in UMLet provides a shortcut to this workflow: it displays—as a single string—all relevant properties; users can fast and easily modify the element's properties by changing this string. For example, to add new methods to a UML class element, one can simply enter their names as several new lines to the string given in the property panel.

For each UML element, UMLet's display or drawing logic is simple: the string given in the property panel is interpreted, and the graphical representation of that UML element is modified according to this interpretation. More specifically, all UML elements on a diagram correspond to a Java object that "draws itself", i.e., interprets its own property panel string and modifies its own graphical representation.

For example, in figure 3 the property panel's text of a UML class element is interpreted by that class element to draw itself. The first line is interpreted as the class name and printed on top of the class, aligned centrally. Subsequent lines are treated as method or attribute names, which are printed left-aligned. The string "– –" (a double dash) is interpreted as a horizontal line separating class name, attribute names, and method names; the string "bg=green" sets the element's background color to green.

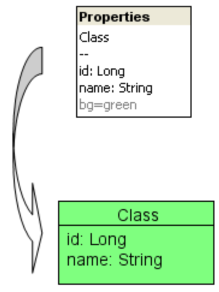


Figure 3: Property text parsing example

3.2 Custom Elements

To keep the development of new custom elements simple, the development environment has to be integrated into the application itself. Integration via a separate window or by providing a plugin interface would be possible, but it would represent a media break and an additional barrier for end users. A more direct way is provided: as soon as a new custom element is created, the property panel expands into three panels. The panels shown in figure 2 are (from left to right) the property panel, a source code panel, and a preview panel. The user can now modify the custom elements on two different levels. First, as before, he can change the text in the property panel and see the consequences in the graphical representation in the preview panel. But in addition, in the source code panel he can change the source code that is responsible for interpreting the property panel text and for drawing the element in the preview panel. At the same time, thus, a user can change an element's properties, and how those properties are transformed into a graphical representation.

The code is compiled continuously in the background, and immediate feedback is provided to the end user by re-drawing the element in the preview panel. If the code contains errors, the affected source code lines are highlighted. Several examples of simple custom elements are shown in section 5.

3.3 Code Template

End users can thus modify the Java code that determines how a UML element properties are converted to that UML element's graphical representation. To avoid exposing to much application logic to the end user, UMLet provides a code template that hides most of the the UML element's internal structure (i.e., its Java class definition) from the user. Now, the user only has to modify the source code for a single method—the drawing method of the graphical component. Implementing a single method rather than a full class is easier because it does not require background knowledge of the object-oriented architecture; in addition, most surrounding or support functionality—like file dialogs, context menus, file exports—are unlikely to need change, and would only be a distraction.

Another simplification is that the user does not need to worry about color settings and command parsing. In general, this is done by a global parsing method. The template takes care of applying the global parsing mechanism like the color settings, or the default behavior of element resizing. This way, some settings are consistent for all, even newly created, elements. Only properties specific to a new element have to be processed by the user's code.

Whenever the user's code needs to be compiled, it is inserted at the appropriate position in the template class, and the entire class is compiled. If successful, the element is generated (i.e., an object of that class is instantiated), and put on the preview panel, where it draws itself using the user-provided drawing method.

4 IMPLEMENTATION

The following sections gives a brief implementation overview of the approach presented in section 3: it describes the workflow to create a new custom element, the available predefined methods, the saving of custom elements, error handling, and code completion. Finally, some security issues are discussed that arise when custom elements are exchanged between users. Although UMLet is implemented in Java, the implementation details are presented—when possible—in a language-independent way. The approach should be readily applicable in other programming languages

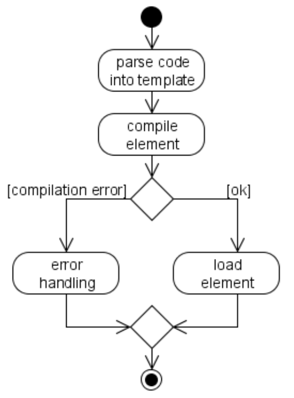


Figure 4: Compilation process

that support reflection, provide a compilation API, and some sort of security manager.

4.1 Element Generation

The general workflow of the element generation is shown in figures 4.

First, the custom element class is generated by inserting the user code into the template. Then the class is compiled, loaded, and instantiated via the Java class loading mechanism. If a compilation error occurs, an error element is returned instead. After a successful compilation the generated element may be used just like predefined elements.

4.2 Class Template API

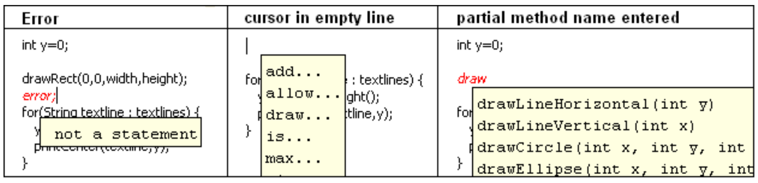
The template class provides several predefined methods. Since the entire Java API is still available, these methods are not a restriction for the end user but rather a help to get started.

4.2.1 Text Drawing Methods

The text drawing methods provide the user with drawing functionality such as text printing and boundary calculation. Text can be printed at either a fixed position or at a fixed vertical position with an alignment relative to the element's horizontal bounds.

The *textheight* and *textwidth* methods return a text line's height and width in pixels.

```
void print(String text, int x, int y)
void printLeft(String text, int y)
void printRight(String text, int y)
void printCenter(String text, int y)
int textheight()
int textwidth(String text)
```



```
int y=0;

drawRect(0,0,width,height);
error;
for(String textline : textlines) {
 not a statement
}
```

```
add...
allow...
draw...
is...
max...
```

```
int y=0;

draw
drawLineHorizontal(int y)
drawLineVertical(int x)
drawCircle(int x, int y, int
drawEllipse(int x, int y, int
```

Figure 5: Compilation panel

4.2.2 Drawing Methods

The predefined drawing methods just call some of the Java AWT package's drawing methods. The advantage when using these methods is that they automatically use a consistent back- and foreground color handling.

```
void drawRect(int x, int y, int width, int height)
void drawLine(int x1, int y1, int x2, int y2)
void drawLineHorizontal(int y)
void drawLineVertical(int x)
void drawCircle(int x, int y, int radius)
void drawEllipse(int x, int y, int radiusX, int
     radiusY)
void drawPolygon(Polygon polygon)
```

4.2.3 Resizing Methods

Resizing methods help the user to handle elements that dynamically resize themselves. If the *allowResize* method is invoked with the value *false*, the user will be unable to resize the element manually. In this case the element's dimensions have to be set in the—user-provided—*paint* method.

The *setElementCentered* method moves the element's anchor point to its horizontal center. Any update to the element's width is then applied in equal measure on both sides. If the element resizable—i.e., the *allowResize(false)* method has not been called—the *setElementCentered* method has no effect.

The *isManualResized()* method enables the handling both manual and automatic resizing. The element's dimensions still have to be computed in its paint method but only if *isManualResized()* returns *false*. It returns *true* if the user has already manually resized the element—in this case, automatic resizing is suppressed. To switch back to automatic resizing, the user has to remove the property *autoresize=false* that is automatically added to the element's properties as soon as the user manually resizes the element.

```
void allowResize(boolean allow)
void setElementCentered()
boolean isManualResized()
```

4.2.4 Other Methods

The *addStickingPoint* method alters the element's *sticking polygon*. The sticking polygon specifies where exactly UML relations (basically, the arrows in a diagram) stick to the element and if they should be repositioned when a UML element they stick to is moved by the user. The sticking polygon defaults to a rectangle enclosing the entire element.

The *min* and *max* methods return the minimum or maximum of its parameters. This is a shortcut to Java's *Math* package to provide faster access to these frequently used methods.

```
int min(int value1, int value2)
int max(int value1, int value2)
void addStickingPoint(int x, int y)
```

4.3 Error Handling

The error handling mechanism (figure 5) for showing compilation errors in the code follows standard IDE conventions: it takes the generated compiler error messages and marks the erroneous lines. If the user moves the mouse over those lines, the error message is displayed.

4.4 Code Completion

Many popular development tools (e.g., Eclipse) implement a code completion feature, where a list of all available methods and variables is displayed as the user types. In order to provide the user with a quick overview of the available predefined methods (see section 4.2), the method prefixes are displayed when the user moves to an empty line (figure 5); as soon as the user starts typing, a detailed list of methods and variables matching the user input is displayed.

4.5 Saving and Sharing an Element

There are several ways to save and distribute a custom element; they have different advantages and disadvantages:

1. The custom elements can be stored in separate files, or within the UML diagram file they are part of.
2. The custom elements can be stored as Java code, or as compiled class file.
3. If a copy of a custom element is created on the same or a different diagram, it can be treated as another instance of the same custom element (the copy changes when the original custom element's source code is modified), or as a new type of custom element (changes to the source code in the original custom element do not affect the copy).

UMLet stores the element's code directly in the diagram (or palette) containing the element, mostly because it eases the exchange of diagrams as they remain single, self-contained files, and don't exhibit additional dependencies on external files. To keep the diagram file as small as possible, only the user's code is stored, not the surrounding template class. Loading a custom element internally works just like generating a new custom element—see section 4.1. The obvious drawback is the performance impact when loading a diagram that contains a large number of custom elements. The transparency of the source code-based file format, though, makes up for the performance penalty.

Finally, UMLet treats copies of custom elements as new element types, instead of new instances of the same element type, in order to handle copies of elements within a diagram and between diagrams consistently.

One drawback of this "hidden" element exchange is that an attacker could distribute diagrams containing malicious custom elements. This security aspect will be discussed in more detail in section 4.6.

4.6 Security

As mentioned in section 4.5, loading a custom element may be a security risk if the user is allowed to use the entire scope of the underlying programming language (e.g., a custom element could access the file system). To protect end-user systems from damage, several measures can be taken.

The first measure is very easy to implement and thus commonly used. Whenever a diagram containing custom elements is loaded, a warning message that informs the user about the potential risk is displayed. The diagram is only loaded after the user confirms that the source can be trusted. One problem with this simple solution is that a lot of users will ignore these warnings as they are not aware of security risks or have become insensitive to security related alerts.

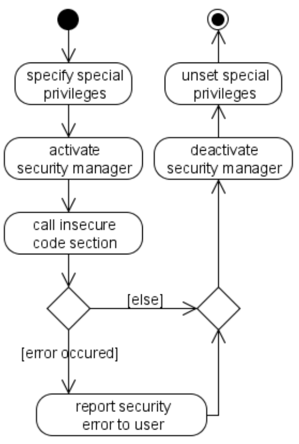

specify special privileges
activate security manager
call insecure code section
[else]
[error occured]
report security error to user
deactivate security manager
unset special privileges

Figure 6: Security workflow

Even if the user is aware of the risks he may be still be fooled to open a malicious diagram—e.g., if the attacker resembles a trusted source. Another problem is that users may create malicious elements by accident and thus harm their own system during custom element development.

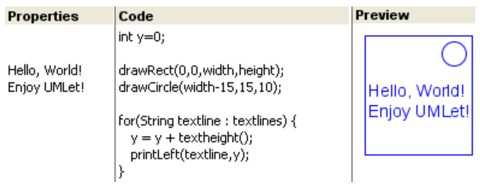
The second security measure does not depend on the user but relies on the programming language's security mechanism. First, all but the paint method of the abstract custom element class are declared as *final* methods—this ensures that these methods cannot be overridden by the custom element. As a consequence, custom code can only be placed in the paint method, even if the attacker finds a way to break out of it. A security manager (like the one in Java) then enforces that no security critical operations (e.g., file access) are performed during execution of the paint method. To ensure that end users are unable to deactivate the security manager, a random token only visible to the method calling the paint method is used for authentication.

Figure 6 gives an overview how a method call to *paint* is handled.

5 EXAMPLES

The following four custom element examples give a quick overview of UMLet's live-compilation possibilities. The examples' figures show the property panel, the code panel, and the preview panel.

The *textlines* variable inside the code panel contains the property panel's text. The user code then parses this text to generate the appropriate graphical representation for the preview panel.


Properties

```
Hello, World!
Enjoy UMLet!
```

Code

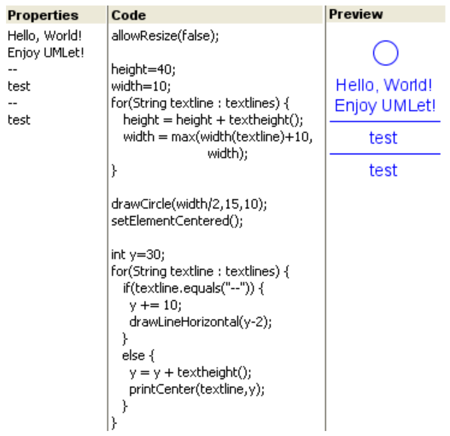
```
int y=0;

drawRect(0,0,width,height);
drawCircle(width-15,15,10);

for(String textline : textlines) {
  y = y + textheight();
  printLeft(textline,y);
}
```

Preview

Figure 7: Custom element example 1


Properties

```
Hello, World!
Enjoy UMLet!
--
test
--
test
```

Code

```
allowResize(false);

height=40;
width=10;
for(String textline : textlines) {
  height = height + textheight();
  width = max(width(textline)+10,
                    width);
}

drawCircle(width/2,15,10);
setElementCentered();

int y=30;
for(String textline : textlines) {
  if(textline.equals("--")) {
    y += 10;
    drawLineHorizontal(y-2);
  }
  else {
    y = y + textheight();
    printCenter(textline,y);
  }
}
```

Preview

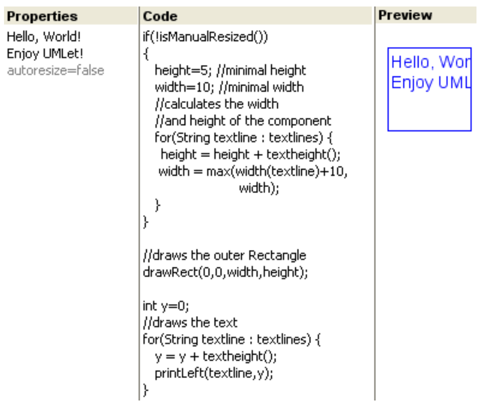
Figure 8: Custom element example 2

As soon as the source code is modified in the source code panel, the code is recompiled. If it compiles successfully, the code is applied to the text in the property panel and the element's preview is updated. If the property panel's text is changed, the last successfully compiled code version is applied to the changed property text, and the element's preview is refreshed.

The example shown in figure 7 creates a rectangular textual element with a small circle in the upper right corner. The *drawCircle* and *drawRect* method calls draw the bounding rectangle and the circle in the element's upper right corner. Finally, the for-loop draws the text that has been entered in the property panel.

Figure 8 shows an example with more complex functionality. It prevents the user from manually resizing the element by calling the *allowResize(false)* method and goes on to calculate the component's dimensions. The *setElementCentered* method moves the element's anchor point to its horizontal center. Any update to the element's width is then applied in equal measure on both sides. The for-loop not only draws the text but also tests for lines containing "– –" and draws a horizontal line instead.

The example in figure 9 adds optional manual resizing to the element. The *isManualResized* function automatically checks if the element has been resized


Properties

```
Hello, World!
Enjoy UMLet!
autoresize=false
```

Code

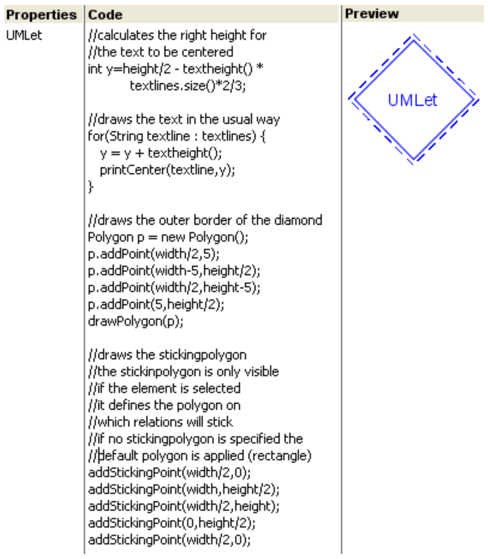
```
if(!isManualResized())
{
  height=5; //minimal height
  width=10; //minimal width
  //calculates the width
  //and height of the component
  for(String textline : textlines) {
   height = height + textheight();
   width = max(width(textline)+10,
                   width);
  }
}

//draws the outer Rectangle
drawRect(0,0,width,height);

int y=0;
//draws the text
for(String textline : textlines) {
  y = y + textheight();
  printLeft(textline,y);
}
```

Preview

Figure 9: Custom element example 3


Properties

```
UMLet
```

Code

```
//calculates the right height for
//the text to be centered
int y=height/2 - textheight() *
        textlines.size()*2/3;

//draws the text in the usual way
for(String textline : textlines) {
  y = y + textheight();
  printCenter(textline,y);
}

//draws the outer border of the diamond
Polygon p = new Polygon();
p.addPoint(width/2,5);
p.addPoint(width-5,height/2);
p.addPoint(width/2,height-5);
p.addPoint(5,height/2);
drawPolygon(p);

//draws the stickingpolygon
//the stickinpolygon is only visible
//if the element is selected
//it defines the polygon on
//which relations will stick
//if no stickingpolygon is specified the
//default polygon is applied (rectangle)
addStickingPoint(width/2,0);
addStickingPoint(width,height/2);
addStickingPoint(width/2,height);
addStickingPoint(0,height/2);
addStickingPoint(width/2,0);
```

Preview

Figure 10: Custom element example 4

manually. As soon as the user resizes the element, the *autoresize=false* string is appended to the property panel. The function *isManualResized* returns *true* whenever the property panel contains that string (*autoresize=false*). In example 9, the user has already resized the element manually so the if-block that calculates the size automatically is not executed. As soon as the *autoresize=false* string is removed from the property panel, the size is computed and adjusted automatically again.

The last example in figure 10 demonstrates the implementation of sticking polygons, which specify where relations stick to a UML element on the diagram. The *addStickingPoint* method adds points to the sticking polygon. At least two points are required. The sticking polygon is drawn as dashed lines. If no polygon is specified, the relations will stick to the rectangle defined by the outer borders of the component. The other methods used in example 10 are simple: first the text is drawn at the center of the element; then a diamond is drawn around it.

6 CONCLUSION

Letting users extend applications by programming has been a research topic for quite some time without producing many widely-used results (except custom mathematical expressions). In this paper we describe a UML tool that enables users to create new graphical UML elements by using the internal graphical API of the tool itself. While this is a very special application, the concept may be applied to other areas.

The approach is simple and provides immediate feedback to the end, addressing Ruyter's requirements for successful EUD applications. A crucial differences to other end-user development approaches is that the development environment is integrated into the main application window and thus no media break occurs. In addition, this paper addresses several problems including persisting the code, exchanging elements and security.

Future research will focus on an easier exchange of custom elements between end users, potentially over a Web service, and on custom UML relation types.

REFERENCES

Auer, M., Meyer, L., and Biffl, S. (2007). Explorative UML modeling: Comparing the usability of UML tools. In *Proceedings of the 9th International Conference on Enterprise Information Systems (ICEIS'07)*, pages 466–474, Madeira.

Auer, M., Tschurtschenthaler, T., and Biffl, S. (2003). A flyweight UML modeling tool for software development in heterogeneous environments. In *Proceedings of the 29th EUROMICRO Conference*, pages 267–272, Antalya.

Beringer, J. (2004). Reducing expertise tension. *Communications of the ACM*, 47(9):39–40.

Beringer, J., Fischer, G., Mussio, P., Myers, B., Patern, F., and Ruyter, B. d. (2008). The next challenge: From easy-to-use to easy-to-develop. Are you ready? In *Proceedings of the Conference on Human Factors in Computing Systems (CHI'08)*, pages 2257–2260, Florence.

Berti, S., Patern, F., and Santoro, C. (2006). Natural development of nomadic interfaces based on conceptual descriptions. In *End-User Development*, pages 143–160. Springer.

Booch, G., Rumbaugh, J., and Jacobson, I. (2005). *The Unified Modeling Language User Guide*. Addison Wesley, 2. edition.

Cazzola, W., Stroud, R., and Tisato, F. (2000). *Reflection and Software Engineering*. Springer.

Costabile, M., Mussio, P., Provenza, L., and Piccinno, A. (2008). End users as unwitting software developers. In *Proceedings of the 4th International Workshop on End-User Software Engineering (WEUSE'08)*, pages 6–10, Leipzig.

Evans, A. and Wellings, A. (1999). UML and the formal development of safety-critical real-time systems. In *IEE Colloquium on Applicable Modelling, Verification and Analysis Techniques for Real-Time Systems*, pages 2/1–2/4.

Fischer, G., Giaccardi, E., Ye, Y., Sutcliffe, A., and Mehandjiev, N. (2004). Meta-design: A manifesto for end-user development. *Communications of the ACM*, 47(9):33–37.

Fischer, G. and Scharff, E. (2000). Meta-design: Design for designers. In *Proceedings of the 3rd Conference on Designing Interactive Systems (DIS'00)*, pages 396–405, New York.

Heng, M. (2003). Beyond end user computing. In *Proceedings of the 5th International Conference on Enterprise Information Systems (ICEIS'03)*, pages 594–598, Angers.

Ko, A. and Myers, B. (2005). A framework and methodology for studying the causes of software errors in programming systems. *Journal of Visual Languages & Computing*, 16(1-2):41–84.

Kohler, H., Nickel, U., Niere, J., and Zndorf, A. (2000). Integrating UML diagrams for production control systems. In *Proceedings of the 22nd International Conference on Software Engineering (ICSE'00)*, pages 241–251, Limerick.

Martin, J. (1984). *An Information Systems Manifesto*. Prentice Hall, 1. edition.

Ruyter, B. d. and Sluis, R. v. d. (2006). Challenges for end-user development in intelligent environments. In *End-User Development*, pages 243–250. Springer.

Segal, J. (2007). Some problems of professional end-user developers. In *Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC'07)*, pages 111–118, Coeur d'Alne.

Smith, H. (2004). On tool selection for illustrating the use of UML in system development. *Journal of Computing Sciences in Colleges*, 19(5):53–63.

Sutcliffe, A. (2005). Evaluating the costs and benefits of end-user development. *SIGSOFT Software Engineering Notes*, 30(4):1–4.