Institut für Architektur von Anwendungssystemen

Universität Stuttgart
Universitätsstraße 38
D - 70569 Stuttgart

Diplomarbeit Nr. 3181

Configurable Visual Representations for Business Process Monitoring

Andrejs Rapoports

Course of Study:	Software Engineering
Examiner:	Prof. Dr. Frank Leymann
Supervisor:	Dipl.-Inf. David Schumm
Commenced:	April 28, 2011
Completed:	October 28, 2011
CR-Classification:	D.2.2, H.4.1, H.5.2, I.3.2, I.3.3, I.3.4

Abstract

Business processes are one of the most important assets that a company has. The success of the business depends directly on the quality of these processes. This makes business process reengineering and business process improvement the key task of a business analyst. To support monitoring and analysis steps, an advanced approach for process visualization is required.

The main problem is that several different professionals have to collaborate in order to prepare an expressive visualization for a monitoring and analysis application. Only advanced visualization will allow the business analyst to analyze the process and improve it. It implies that a process can change rapidly. Under these conditions the visualization has to be created rapidly, too.

This work proposes a concept of collaboration between professionals who prepare the visualization: between the visual designer and information designer. The artifacts they work with are loosely coupled: visual templates, visual configurations and data. The visual designer prepares visual templates and knows very little details about the rest of the system. The information designer applies these templates to the monitoring and analysis application, since it is very unlikely that visual designer will be able to do this. This work proposes visual templates, which are decoupled from the rest of the system, and visual configurations, which reference templates to build concrete process visualizations for analysis and monitoring.

To prove this concept, it has been put in practice as part of this work. The realized framework is named “Vipro”. A new template format, fully compatible with SVG (Scalable Vector Graphics), and a visual configuration format have been defined. An editor for visual configurations has been developed. Finally, a Web service for visualization has been developed to enable the integration with existing systems.

In the very end, a set of test cases inspired by real requirements illustrate the capabilities of the Vipro framework.

Table of Contents

1 Introduction

1.1 Motivation

Thousands of business processes are running every day all over the world in many companies. In order to cope with them a company has to be able to monitor them effectively – to see where the problems are and what can be improved. Processes are dynamic and so the monitoring has to be too.

Improvement of existing business processes happens quicker and quicker from year to year. The possibility to react fast to the changing world is a major advantage. In the context of the Business Process Lifecycle [1] (Figure 1) process improvement takes place on all steps except the “Execution”. One can imagine that the processing of these steps (Monitoring, Analysis, Modeling, IT Refinement and Deployment) will take five minutes in the nearest future and will be done by one person in a single Web application.

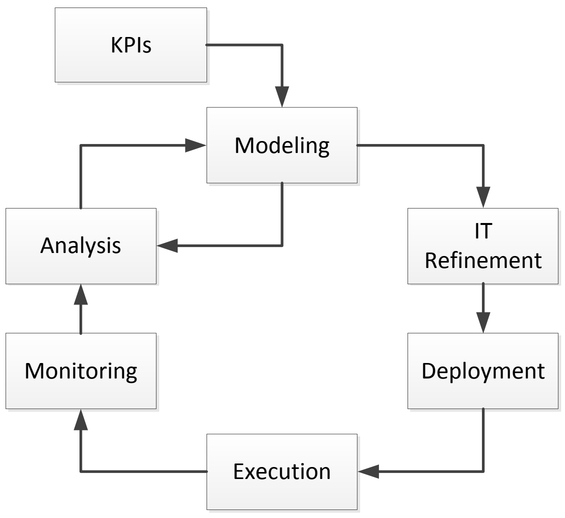


Figure 1. Business Process Lifecycle [1].

The high cognitive effectiveness of graphical representations of running processes should allow a person to see all important things at once. The person will be able to quickly decide what has to be changed in the process in order to improve it. And if the process is changed its graphical representation must be updated to match the new process model.

And this is the problem. Creation of a comprehensive and cognitive effective graphical representation is a complex problem that is not automated yet. Although some techniques exist, they are far from being perfect. Those, which are automated, cannot provide all relevant Run-Time information in an expressive way. And vice versa – graphical representations, which are expressive, require lots of manual work.

The key parameters of a good graphical representation were already mentioned: cognitive effectiveness and comprehensiveness. Existing solutions require a trade-of between them. Let's take a closer look at each parameter.

Cognitive effectiveness is defined as the speed, ease and accuracy with which a representation can be processed by the human mind [2] [3]. Creation of a graphical representation that meets these criteria is a complex task that often requires creative skills.

Comprehensiveness means that the graphical representation reflects all relevant Run-Time information. In the modeling step this information is not available to the modeler. For instance, the industry standard for Web service-based workflows BPEL (Business Process Execution Language) [4] does not standardize Run-Time data definitions. These definitions must be made by an expert who knows how each step of the process is being performed, where the data is stored, and what data formats look like.

So the creator of a graphical representation must be both: a good artist and a process insider. These requirements are rarely met in a single person. The idea of this work is to decouple the task and let two different people do their job.

1.2 Objectives

Based on the motivation following objectives were defined for this work:

O1: Create a concept for business process monitoring and analysis that would achieve a loose coupling between visual templates and the rest of the system. It should be possible to separate the work of the Template Designer and the Information Designer.

O2: Use process instance data in visualization of running processes without tight coupling to templates or to any concrete WfMS (Workflow Management System).

O3: Create a tool that utilizes the concept and makes it usable in existing environments.

1.3 Document Structure

The document is divided into nine chapters. Chapter 1 “Introduction” contains introductory information, explains the motivation, defines the problem, defines objectives and prepares the reader for the rest of the document. Chapter 2 “Concept” makes the problem clearer, defines Use Cases and explains the abstract solution to the problem. Chapter 3 “Vipro Specification” defines the term “Vipro”, specifies the proposed concepts, and defines which formats and tools need to be invented. Chapter 4 “Vipro Architecture” describes the chosen architecture that fulfills the specification. It describes how the components work and what the relations between the components are. Chapter 5 “Vipro Artifacts” defines all new formats that have been created in the framework of this work: Vipro Template, Vipro Instance Metadata, Vipro Instance Data and Vipro Configuration. Chapter 6 “Vipro Implementation” begins with a coarse-grained overview of implemented components and then describes each of them in detail: Vipro Library, Vipro Web service and Wipro Editor. Chapter 7 “Challenges and Solutions” is dedicated to some challenging problems that have been solved and are worth discussing them in a separate chapter. Chapter 8 “Test Cases” shows different scenarios that illustrate the capabilities of the developed system. Chapter 9 “Summary and Outlook” summarizes the document and gives an outlook on the problems that were identified by this work. Acknowledgments, bibliography, table of figures, table of listings and list of table can be found in the very end.

2 Concept

2.1 Loose Coupling

To set up an advanced business process monitoring and analysis environment different specialists have to cooperate. At least two different sets of skills are required: one has to create comprehensive graphics and the other has to deploy them in the monitoring and analysis tool. These sets of skills are rarely present in a single person, because both are not trivial and require special knowledge and experience.

The main idea of this work is to decouple one from the other. It must be possible for the visual designer to prepare graphics that do not depend on a concrete business process implementation. And for those who work on the business process it should be possible to use any visual template for business process monitoring and analysis.

Templates should not depend on a concrete workflow language. And they both should not depend on a concrete WfMS, as there is no standard engine. All three pieces must be loosely coupled between themselves. They should be composed by a component they are unaware of. Figure 2 illustrates this statement. Visual configuration composes thisngs together.

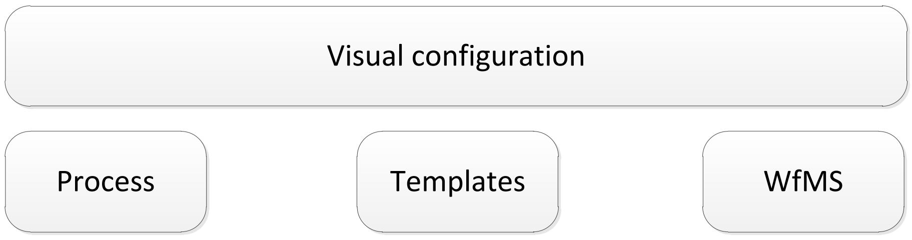


Figure 2. Templates must be decoupled from both process and WfMS. Visual configuration brings the pieces together.

The idea of loose coupling is also described in [5] where the following statement is made: “Graphical configurations provide loose coupling of process elements, graphics, and data. Through such an information linkage a process model can be augmented with data related to a particular analytical task without polluting the process model. Design templates developed in-house or provided by third parties provide custom visualization support for process elements in context of the augmented data and analytical scenario.”

2.2 Use Cases

As mentioned above different specialists will have to work together. In order to specify this statement roles and Use Cases were defined.

Roles:

- Business Analyst
- Process Modeler
- Template Designer
- Information Designer [5]

Use Cases:

- UC1 – Creation of the business process.
- UC2 – Creation of visual templates.
- UC3 – Creation of the visual representation configuration.
- UC4 – Deployment of the visual representation into the monitoring and analysis environment.
- UC5 – Monitoring the process using the visual representation.

2.2.1 UC1 – Creation of the Business Process

The business process is created by the Business Analyst and the Process Modeler. First Business Analyst creates an abstract process in an informal way. Usually a Business Analyst is a businessman who is not familiar with the formal notations used for process enactment. Process Modeler receives the abstract process made by Business Analyst and implements it in a particular workflow language [1]. Also Process Modeler specifies what the Run-Time data will look like – instance metadata.

This Use Case results in two artifacts:

- Complete process definition (A1)
- Run-Time data definition (A2)

2.2.2 UC2 – Creation of Visual Templates

Visual templates are created by the Template Designer. This is a more creative task and requires knowledge of comprehensive visual communication. Template Designer creates templates based on the request of Business Analyst. Template Designer uses a standard graphics editor and marks the variable places of the template.

The result is a set of visual templates. (A3)

2.2.3 UC3 – Creation of the Visual Representation Configuration

The Information Designer receives the outputs from two previous Use Cases: process definition, Run-Time data definition and visual templates. Using a visual editor, the Information Designer creates a visual representation configuration for the specified process: process activities are mapped to templates and variable places of templates are mapped to Run-Time data definition.

As result a single visual representation configuration is created. (A4)

2.2.4 UC4 – Deployment of the Visual Representation into the Monitoring and Analysis Environment

The Information Designer deploys a prepared visual representation configuration into the monitoring and analysis environment.

2.2.5 UC5 – Monitoring and Analyzing the Process Using the Visual Representation

The Business Analyst monitors and analyses processes using their visual representations. The visual representation configuration is interpreted automatically to produce visualizations of the running process. To do this the monitoring and analysis environment retrieves Run-Time data from the WfMS and uses it to fill templates and complete the visualization. This Run-Time data is also an important artifact but unlike previous artifacts it is created automatically.

2.2.6 Design-Time vs. Run-Time

Use Cases mentioned above can be split in two phases:

- Design-Time: UC1, UC2 and UC3. These Use Cases are preparation steps where artifacts are created: process definition, templates and visual representation.
- Run-Time: with UC4 and UC5. In these two Use Cases no more artifacts are created manually. Results of first three Use Cases are executed.

Further these two phases will be often mentioned. The separation between them goes throughout the whole work.

2.2.7 Artifacts Overview

In Use Cases many different artifacts are created. Table 1 summarizes them. Both Use Cases and artifacts are numbered and will further be referenced by their codes.

Phase	Use Case	Role	Output artifacts
Design-Time	Creation of the business process (UC1)	Business Analyst, Process Modeler	Process definition (A1);
		Process Modeler	Run-Time data definition (A2)
	Creation of visual templates (UC2)	Template Designer	Visual templates (A3)
	Creation of the visual representation configuration (UC3)	Information Designer	Visual representation configuration (A4)
Run-Time	Deployment of the visual representation into the monitoring and analysis environment (UC4)	Information Designer	None
	Monitoring the process using the visual representation (UC5)	Business Analyst	Run-Time data (A5)

Table 1. Use Cases and their outputs – artifacts.

2.3 Editor Concept

As mentioned above a new editor for visual representations of a process should be created in order to support the Information Designer. Figure 3 shows a sketch that illustrates proposed inputs and outputs of the editor. Different files holding process definition, Run-Time data definition and graphic templates are imported in the editor, where the Information Designer combines them into a configuration of the graphical representation for the process monitoring and analysis.

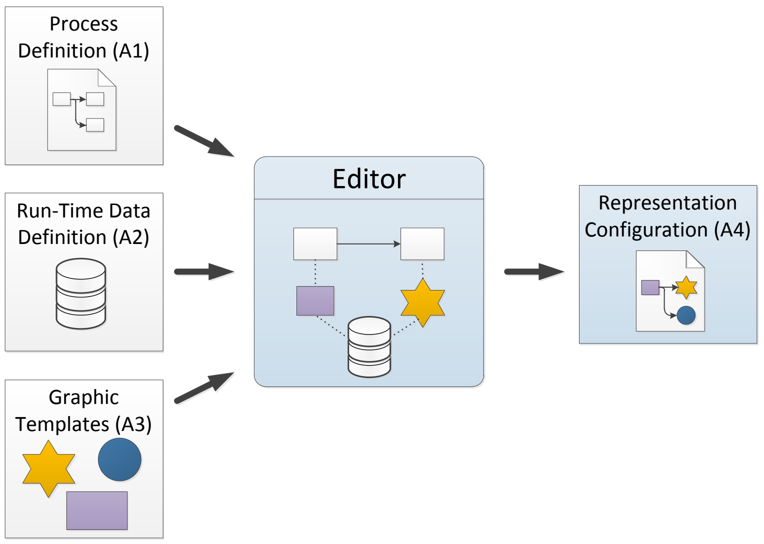

Process Definition (A1)
Run-Time Data Definition (A2)
Graphic Templates (A3)
Editor
Representation Configuration (A4)

Figure 3. Sketch for the editor's inputs and outputs.

2.4 Assumption about Visualization of Running Processes

It is assumed that generally a running process should be visualized similar to how a process definition is visualized. Widely spread notation for process visualization uses rounded rectangles to represent activities and arrows to represent control flow transitions. The effectiveness of this visualization approach is not discussed in this work. It is enough that this approach is widely used in many tools (Figure 4): Eclipse BPEL Designer [6], Oracle JDeveloper [7], Signavio Process Editor [8]. BPMN 2.0 (Business Process Model and Notation) [9] language, which defines visual syntax for process definitions, in the core uses similar concept.

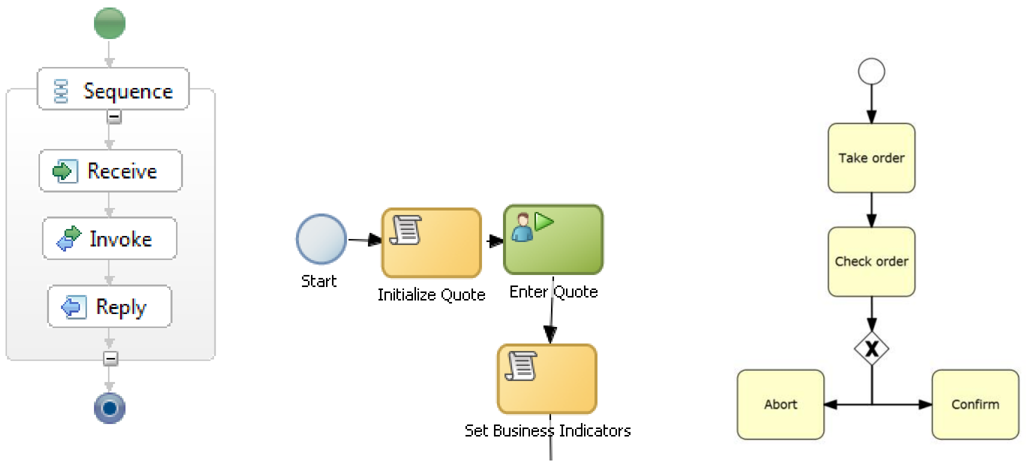


Figure 4. Process definition visualization in Eclipse BPEL Designer (left), Oracle JDeveloper (middle) and Signavio Process Editor (right).

This common approach is also used in this work. Figure 5 shows a very abstract example of the assumed visualization approach. Various geometrical shapes (e.g. rounded rectangles or ellipses) are used to demonstrate activities. Control flow transitions are shown as arrows. Information about the activity execution should be displayed directly inside the activity's shape.

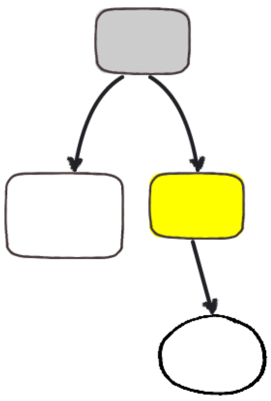


Figure 5. The assumed abstract way of visualizing process instances.

There might be completely different approaches that could probably be more effective. But since they are not standard ones this work will not cover the problem.

2.5 Similar Works

2.5.1 “Customizable Representation of Process Models”

In his diploma thesis “Customizable representation of process models” [10] Eugen Krämer tried to find a proper model for flexible representation of process activities. The aim was to find a way to visualize running process instances where each activity would have its own graphic, which would correspond to the state of the activity and make the whole visualization more readable.

He came up with a model that is based on rules that modify the used notation. The notation consists of SVG (Scalable Vector Graphics) [11] graphics. These SVG graphics can be modified by special rules. He used the fact that SVG is an XML format and any modification can be achieved by changing the DOM (Document Object Model) node tree [12]. Three types of operations were defined: change attribute, change content, replace target node. Using these operations a new element can be added to the graphics. These rules can also be mapped to concrete activities of the process. Activities can be referenced only by using their type or name. Rules can also be mapped to process data. How the process instance data is obtained was out of scope of the work and only an abstract definition was given.

Modification rules, templates and abstract process data were composed together into “visual configurations”. Figure 6 illustrates how this happens.

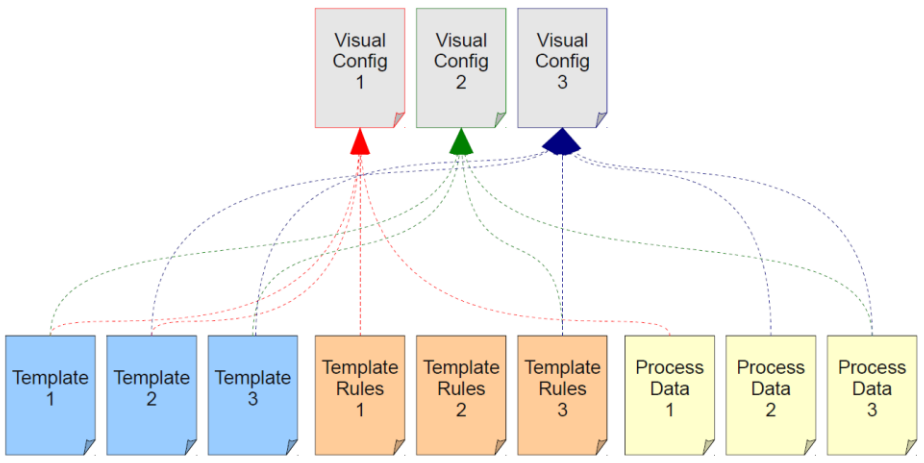


Figure 6. Composition of visual configurations in [10]. Figure is taken without any modifications from [10].

To check the model Eugen created a prototype for the template system. The prototype was based on BPI – an existing framework for process visualization – a detailed report about BPI is provided in chapter 3.4.1. The prototype proved that the concept works. Additional tools were out of scope of the work. However, the template rules were created manually and process data was not really used because Process Mining was intentionally left out of the work.

Following advantages and drawbacks of the solution, which Eugen proposed in his work, are important for this work:

Advantages:

- SVG, as the format for templates, works very well.
- BPI, as the base for customizable process visualization, works well too.

Drawbacks:

- The usage of modification rules, that are separate from the template, is not the best choice, because they are difficult to maintain. Rules are maintained outside of the template, because the template is a standard SVG file. Nevertheless, the rules are tightly coupled with the template and cannot be reused without it.
- Limited number of ways to reference activities. According to the BPEL specification "name" attribute of an activity element is optional. As a result, in some cases the original process definition must be changed and "name" attributes must be inserted.
- Although the activities are visualized dynamically no additional Run-Time data can be shown.

Conclusion: Eugen's work showed that it is possible to make process representation customizable. In his work he defined most of the main problems: how to define templates, which visualization engine to choose, how to reference activities. Also he showed possible ways to solve them. Some ways were successful: BPI as visualization engine, SVG for graphics. Some proposed solutions were not satisfactory: rules defined externally, referencing activities by name or type. All the solutions, regardless of their success, are important and were taken into consideration when writing this work.

2.5.2 "Configurable Visualization of Complex Process Models"

In his PhD thesis [13] Ralph Bobrik described an approach for configurable visualization of processes. It is also described in [14]. He proposed a way to make process visualizations configurable and personalizable. Visual configurations are made by using a notation definition that is based on SVG. Personalization is made by using CSS (Cascading Style Sheets) and allows different users, who monitor the process, to have own settings applied. Notation definition consists of template definitions, where each template definition "consists of three specification parts: 1) input parameters of the template, where references to processes elements are handed over; 2) representation of the symbol in SVG; 3) parameters (e. g. name of activity, activity state, starting time, etc.) to be filled with process data values. <…> Within the parameter sections, XPath expressions (relative to the SVG-symbol root) are used to describe the location of the corresponding text area" [14]. A template can define data transformations using Java Script. Application of templates to a process is done in a complicated language "using 'if-then-else'-like statements together with a first-occurrence-wins policy" [14]. Both formats are shown in Listing 1.

Run-Time Data can be used to fill templates. The proposed approach requires, that in visual configuration some sort of generic “data requests” are declared. They rely on a special generic data provider component that can be connected to any WfMS. The architecture of the provider component is quite complicated and allows both pull and push strategies for data collection (chapter 7.2.3 in [13]).

```
<template id="default_act">
  <!-- input section -->
  <inputs>
    <input variable="act" type="activity">
      <descr>activity node</descr>
    </input>
  </inputs>
  <graphic>
    <!-- symbol section (SVG) -->
    <symbol>
      <g class="activity" pv:name="activity">
        ...
      </g>
    </symbol>
    <!-- parameter section -->
    <parameter name="name"
      location="g/text[@pv:name='name']"
      value="act.name" />
    ...
    <parameter name="endtime"
      location="g/text[@pv:name='endtime']"
      value="formatDate(act.end,'dd/mm/yyyy')"/>
  </graphic>
</template>
```

```
<if test="self.type=ACTOR">
  <template id="actor">
    <inputs>
      <input name="actor" value="self"/>
    </inputs>
  </template>
</if> <if test="self.type=ACTIVITY">
  <choose>
    <when test="self.type='testing'">
      <template ref="testing_act">
        <inputs>
          <input name="act" value="self"/>
        </inputs>
      </template>
    </when>
    <otherwise>
      <template ref="default_act">
        <inputs>
          <input name="act" value="self"/>
        </inputs>
      </template>
    </otherwise>
  </choose>
</if>
```

Listing 1. Definition of templates (left) and their usage (right) in [14]. Listing taken from [14].

The solution proposed by Ralph has the following (important for this work) properties:

- Creation of templates requires knowledge of a specific format. It means that the template creator must be familiar with this format and with technologies like XPath and Java Script. Although templates are SVG-based, normal SVG files cannot be used – they must be cut in pieces and put into the “symbol section” (Listing 1). Obviously this is a disadvantage.
- Visual configuration format is complicated and not straight forward. The drawback is that the visual configuration cannot be easily changed when the process changes.
- The way, how the Run-Time data is integrated into the visual configuration, is tightly coupled to the underlying data provider component. It makes the usage of the visualization functionality impossible without installation of that component.

Conclusion: Ralph’s work showed that the idea of configurable visual representations works. But his solution lacks loose coupling between the components. Visual templates cannot be created by a usual visual designer, because many technical skills are required, too. Such specialists rarely exist. But in the Vipro work one of the objectives (O1) is to make it possible for any visual designer to collaborate in an efficient way. Although the proposed way of collecting Run-Time data satisfies the other objective (O2), it is quite difficult and can be made in a simpler way.

3 Vipro Specification

This chapter describes the solution to the concept described in chapter 2. Similar works were also taken into account. The secondary aim here was to reuse existing formats and tools as much as possible.

In order to make the work more clear all new formats and tools got a prefix “Vipro” which stands for “Visualized Process”. Further this prefix will be frequently used and will mark originally created formats and tools or formats and tools that are based on some foreign solutions which were extended for needs of this work.

Specification is based on Use Cases defined before. Each of Design-Time Use Cases got an editor and file format which supports its execution.

3.1 Process Formats and Editor

Existing language BPEL and editor Eclipse BPEL Designer are used for creating process definition (A1). Own formats are used for process instance data definition. This chapter explains these decisions.

3.1.1 Process Definition Format

The BPEL format is used for process definitions [4]. It is an industry standard for business process definitions based on Web services technology. BPEL provides a language for the specification of abstract and executable business processes. “Abstract processes describe process behavior partially without covering every detail of execution. An Abstract Process can be ‘implemented’ by a set of executable processes” [15]. This corresponds to the Use Case UC1 were Business Analyst first creates an abstract process and then Process Modeler makes it concrete. The number of available tools and engines that support BPEL is another advantage.

In January 2011 a new language BPMN 2.0 [9] was approved. It combines the features of both BPEL and BPMN 1.2, which is purely graphic notation with no strict semantic. BPMN 2.0 is not widely supported at this moment.

The main disadvantage of both formats (BPEL and BPMN 2.0) is that they do not describe data that is created when a process runs. The reason is that there are many different WfMS supporting these languages and they save instance data differently. The fact is that there is no standard way of getting instance data. That is why a new format is required.

3.1.2 Process Editor

Since BPEL was chosen as the format for process definition any BPEL editor can be used to create processes. For test cases used in this work the Eclipse BPEL Editor [6] was used. No changes to the editor were required.

3.1.3 Process Instance Data

As mentioned above data that is created when process is executed is out of scope of the BPEL standard. Usually the stored data is data about the state of activities – start time, stop time, result. More diverse data is out of scope of the WfMS. For example, the amount of used electricity or security level. Information like this must be specially collected when the activity is executed.

Apache ODE [16] was analyzed as an example. It uses a mediator called “ODE Data Access Objects” that abstracts the data storage layer (Figure 7). It means that depending on concrete appliance different DBMS (Database Management System) can be used. ODE stores only basic data about the executed process that is required to restore execution in case of a crash. It is possible to get start time, end time, current state of activities and that is all. Collection of other information is out of scope of ODE.

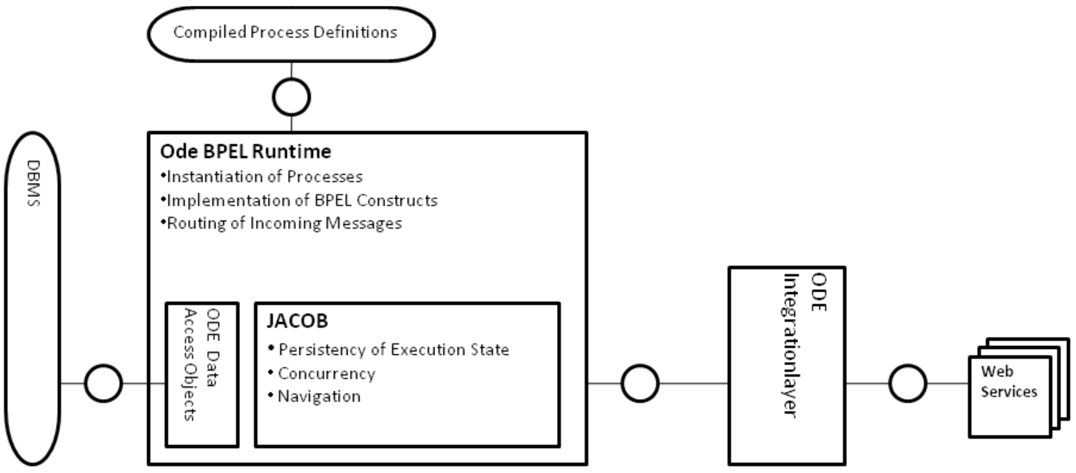

Compiled Process Definitions
DBMS
Ode BPEL Runtime
•Instantiation of Processes
•Implementation of BPEL Constructs
•Routing of Incoming Messages
ODE Data Access Objects
JACOB
• Persistency of Execution State
• Concurrency
• Navigation
ODE Integrationlayer
Web Services

Figure 7. Architectural overview of ODE. Figure taken from [17].

This motivation resulted in the decision that somewhere the line must be drawn. As a result, a new format for instance data has been created. The Vipro solution will use this format and if it will be necessary to integrate it into a system then a corresponding mediator must be implemented. The creation of mediators is left outside of this work. It is assumed that it is a simple task.

Requirements:

- Format for Run-Time data (A5) must be found. Regardless of the implementation it is named Vipro Instance Data.
- Because the structure of instance data is also unknown and depends on a process there should also be a way to specify it (A2). This format is named Vipro Instance Metadata.
- Both formats must be based on XML since it is de-facto the base of all up-to-date formats.
- Vipro Instance Metadata must help at Design-Time to build the configuration.
- Vipro Instance Metadata must validate at Run-Time the incoming data instance data.

3.2 Visual Templates

For visual templates (A3) an extended SVG format is used – Vipro SVG. This chapter explains why it was chosen and what the requirements are.

3.2.1 Vector or Raster

The first question was whether to use a vector or a raster format.

Vector format – graphic consists of compose geometrical primitives such as point, lines, curves and shapes. It can be scaled without any limits. Some elements may be made variable, because it is possible to manipulate with the primitives. Main drawback is that vector format is not applicable for graphics that are originally in raster format (like photos). But raster graphics can be included in some vector formats (this is shown in chapter 7.2).

Raster format – consist of pixels. Main drawbacks are that it cannot be scaled and it is hard to make some places dynamic. It is only possible to manipulate with pixels.

Vector format was chosen because it has fewer drawbacks, no open issues for required purposes.

3.2.2 Which Vector Format

Next question was which vector format to choose? It could be an own format but it would be an extremely difficult solution, since both an editor and a viewer are required. There is already an industry-standard open format for vector graphics: SVG (Scalable Vector Graphics) [11].

“SVG files are designed to be platform- and device-independent, with a hierarchical structure enabling sets of vector graphic primitives to be grouped together and manipulated as shapes. <..> Certain graphics elements (e.g. circle, polygon, rectangle) and groups are defined as XML elements. The properties of these elements are defined using XML attributes to describe their appearance e” [18]

SVG can be viewed in any modern browser or converted to a raster format PNG (Portable Network Graphics), which can be viewed anywhere.

[10] has also showed that SVG can be used for similar purpose. Critical drawback there was the external rules definition. From this follows that a new format based on SVG should be defined and it must remain compatible with SVG. Concrete realization of the Vipro SVG is discussed in chapter 5.2.2.

3.2.3 SVG Editor

An editor for templates was necessary. It could be any SVG editor because the chosen format is compatible with SVG. For this work Inkspace [19] is proposed. It is available for free.

3.3 Visual Representation Configuration

The purpose of visual representation configuration is to compose the rest of the artifacts together. Artifacts created in Use Cases UC1 and UC2 – process definition (A1), Run-Time data definition (A2) and visual templates (A3) – are created independently. Visual representation configuration (A4) makes them work together. It should have been a new format, as no analogous standards exist. The new format is called “Vipro Configuration”. Vipro Configurations should be created by the Information Designer using “Vipro Editor”. Requirements for both Vipro Configuration and Vipro Editor are described in this chapter.

3.3.1 Configuration Format

Vipro Configuration file format has to meet following requirements:

- XML-based. As any other format used in this work.
- It should combine process definition, Vipro Templates, Vipro Instance Metadata and Vipro Instance Data.

3.3.2 Value Mapping

Vipro Configuration defines how the values of the Vipro Instance Data should be brought into the template. Vipro Configuration does not define any transformation for the values. However sometimes it may be required.

It is intentionally not covered in this work in order to keep it simple. In this work this problem will be only outlined but not solved.

The outline of the problem. Two value ranges are given. They may be of different types. Ssimple and complex types are permitted: integer, string, boolean, HEX color (a string consisting of six HEX numbers), enumeration etc. In general, there must be a way to map all possible combinations of these types. For example a set of values (string enumeration) may be mapped to a HEX color representation. Another example is easier: an integer range 1...100 should be mapped to an integer range 1...5. Sometimes the ranges may be dynamic too and will be provided only at execution time.

A concrete and more complex example: WfMS provides information about electricity consumption by each activity. It is measured in kWh (kilowatt hour). It should be visualized by using the size of the activity rectangles. A corresponding template assigns width in range of 100 and 500 pixels. The range of possible electricity consumption is generally not limited but Business Analyst wishes for the maximum value to have the width of 500 pixels in each concrete case.

A formal notation that would support such transformations is not trivial. I. e. it is an inherently complex task. Also another upcoming diploma thesis is going to cover it [20]. Those are the reasons why it is left outside of this work.

In some cases there may be another way to achieve the required functionality. As will be shown later in chapter 4.1.2, the monitoring and analysis application has to transform the concrete WfMS instance data to the Vipro Instance Data. Here the pattern “Messaging Mapper” can be a used. Figure 8 shows the sketch of the “Messaging Mapper” pattern. When used, the monitoring and analysis application would transform instance data talking into account the needs of the template. The main drawback would be tight coupling between template and the mapper software.

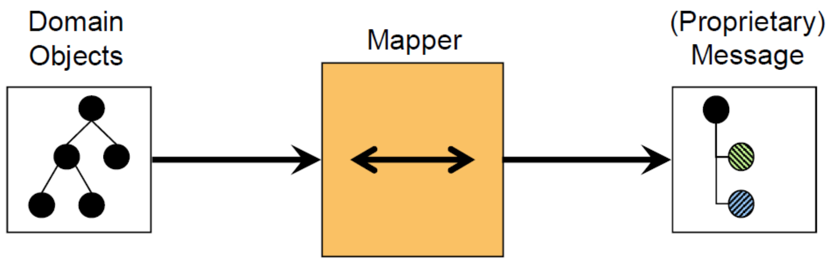


Figure 8. Sketch of the “Messaging Mapper” pattern [21].

3.3.3 Editor

Vipro Configuration editor should be an application where a new Vipro Configuration can be built from scratch.

3.4 Monitoring and Analysis Service

The purpose of the monitoring and analysis service is to utilize everything created before and create a visualization of process that can be used for monitoring or analytical purposes.

3.4.1 Layout Engine

To create a complete visualization of a process a layout engine is required. It should arrange graphics of single activities into a complete picture that represents the state of the process instance. For this purpose the existing layout engine within BPI was used. BPI stands for “Business Process Illustrator” and was developed as part of the diploma thesis “Business process views as tool for running instances visualization” by Gregor Latuske [22].

The goal of that work was to define methods and techniques that would allow to use process view transformations for business process monitoring purposes. The central point was the development of an algorithm for process views visualization. In his work Gregor implemented a data model for process models and process instances and kept it independent from process definition language. In the reference application BPEL is used. Because of special interface, BPI does not depend on any WfMS. An adapter to Apache ODE was also implemented. BPI works only with basic information about running process requiring following properties for each activity: start time, stop time, state, type and name. But these properties are enough to generate different views.

BPI features an advanced layout engine that is inspired by BPEL2SVG generator from Sun [23]. In the kernel it utilizes a layout algorithm that consists of two steps: size calculation of each activity including their child activities and positioning of activity boxes. Both steps start at the root activity and are recursively executed on all child activities until leaf activities are processed. All graphics that represent activities are made in SVG and hard-coded into BPI. Due to ability of BPI to support two different display modes – full and compact – the layout engine can work with boxes of different sizes. Figure 9 shows an example visualization made by BPI.

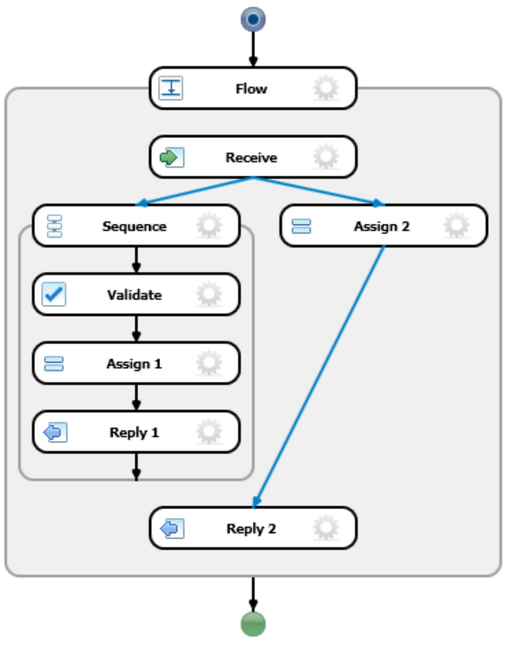


Figure 9. Made with BPI visualization of a process.

Two major limitations –fixed set of activity properties and hard-coded graphics – prevent the direct utilization of BPI for purposes of this work. However, the layout engine can be reused with relatively small effort as shown by Krämer [10]. BPI is licensed under Apache Software License, Version 2 [24] meaning that the source code is available and can be reused without any obligations (except license notice). Krämer [10] has also shown that BPI can be extended.

3.4.2 Visualization Service

A monitoring and analysis service itself is out of scope of this work because it is a complex system that usually depends on a concrete WfMS. But without any real service implementation at all this work would be incomplete. In order to solve this problem a Web service should be created. It has to remain stateless and get the complete context with every visualization request. Such an interface will make it easy usable by any monitoring and analysis framework and this work will be logically complete.

3.5 Process Views

A process view is an abstract variant of a process model, in which some details were omitted and some transformations were applied [25]. Different process viewing patterns exist [25]: “four pattern groups that concern transformations of (i.) process structure, (ii.) presentation, (iii.) inter-view relation and (iv.) augmentation.” All the “Presentation patterns” do no transformation to the process and only affect its visualization. Moreover, “Presentation patterns” are applied after all other types of patterns. “Presentation patterns” are divided in few subgroups:

- “Scheme patterns” – affect the fundamental visualization principle (graph, tree, block scheme etc.).
- “Layout patterns” – affect the layout (horizontal, vertical etc.)
- “Theme patterns” – adds additional structuring to the visualization (activities can be grouped according to some additional parameters)
- “Appearance patterns” – affect the appearance of each activity being visualized (size, color etc.)

Vipro corresponds solely to the group “Presentation patterns”. It enables the custom “Appearance patterns” to be used. It uses a fixed “Scheme pattern”, a fixed “Layout pattern” and no “Theme pattern”. As shown in chapter 9.2 “Outlook”, Vipro can be improved to cover all the “Presentation patterns”.

All other process viewing patterns were left outside of this work. Vipro is focused of the “Presentation Patterns” and might be used together with other transformations.

3.6 Summary

Many different pieces mentioned before are needed to realize the concept. Table 2 lists all those pieces and decisions that were made for each of them.

Artifacts/Components	Realization way
Process definition format (A1)	Use existing – BPEL
Process definition editor	Use existing – Eclipse BPEL designer
Process instance metadata format (A2)	To define
Process instance data format (A5)	To define
Template format (A3)	To define (based on SVG)
Template editor	Use existing – Inkspace
Visual representation configuration format (A4)	To define
Visual representation configuration editor	To create
Visualization service	To create (based on BPI)

Table 2. Required components and documents and their realization way

Next chapters show the way how the elements in this list have been implemented.

4 Vipro Architecture

This chapter describes the developed architecture. It is based on the specification from the previous chapter and satisfies all the requirements stated there.

4.1 Vipro Web Service

As decided before a monitoring and analysis application was left outside of this work. Only a Web service was implemented and this chapter explains its architecture.

4.1.1 Structural View

A monitoring and analysis application should work on top of Vipro Web service, WfMS and DBMS as shown on the Figure 10. Vipro Web service is used to request visualizations of processes. The information about the process instances or analytical data comes from DBMS that is augmented by the WfMS or other components. Monitoring and analysis application can also directly communicate with WfMS if there is an interface.

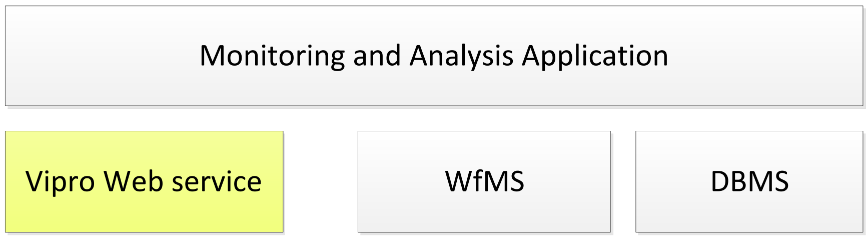


Figure 10. Place of Vipro Web service in overall architecture of a monitoring and analysis application.

4.1.2 Behavioral View

Vipro Web service is meant to be utilized by the monitoring and analysis application. Vipro Web service is stateless and has a single operation that creates visualization for a specified context. That context should be maintained by the monitoring and analysis application. To the context belong:

- BPEL process definition – it is taken from the WfMS once in the very beginning.
- Set of templates – templates produced by the Template Designer, they are deployed together with Vipro Configuration.
- Vipro Instance Metadata – Run-Time data format definition is prepared by the Information Designer and describes what the Run-Time data should look like. It is deployed together with Vipro Configuration.
- Vipro Configuration – it is prepared by the Information Designer. It maps process definition with templates and with instance metadata. It is deployed to the monitoring and analysis application in the very beginning.

- Vipro Instance Data – it should be generated by the monitoring and analysis application from the Run-Time instance data provided by the WfMS. The concrete way depends on the WfMS implementation but usually all the data can be read from the database that is used by the WfMS.

Figure 11 illustrates the proposed behavior of a monitoring and analysis application that utilizes Vipro Web service. Each time visualization is created two steps should be performed. First, retrieve the Run-Time instance data (step 1). Then send it together with context data to the Vipro Web service and get the requested graphic (step 2).

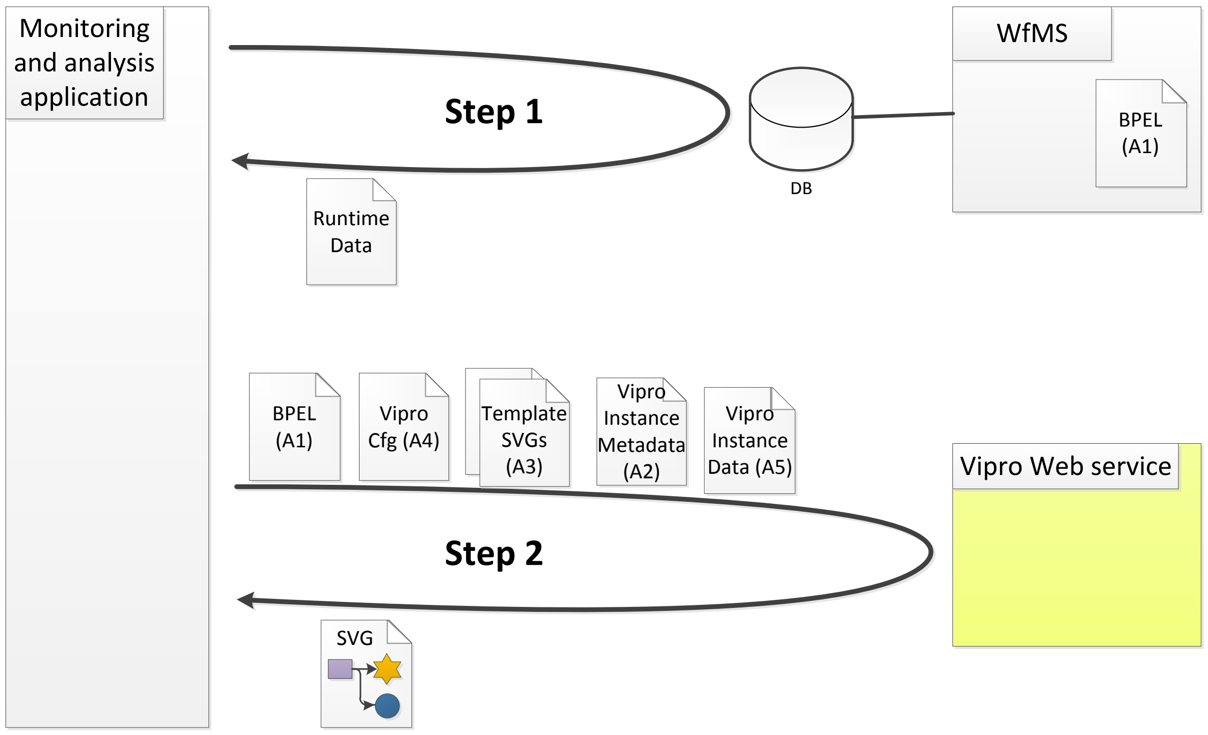


Figure 11. Reference behavior of the monitoring and analysis application that wants to utilize Vipro Web service

4.2 Vipro Editor

4.2.1 Structural View

Vipro Editor allows Vipro Configuration and Vipro Instance Metadata to be created. It is a Web application that uses three-tier architecture. User Interface runs in Web browser at the user side. Web browser communicates with Servlet container at the server side. Servlet container is logic tier and uses a file system to store data. Figure 12 illustrates this architecture.

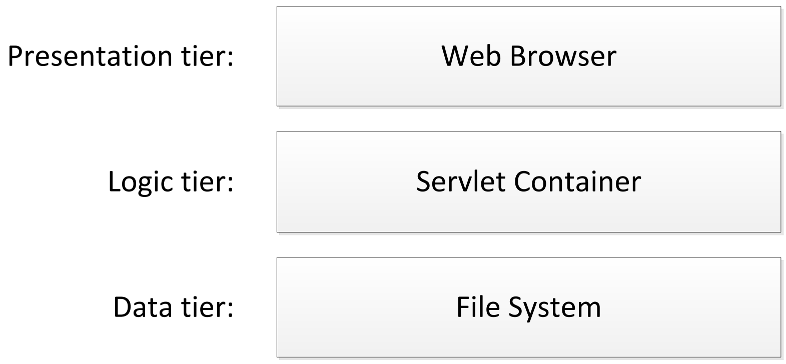


Figure 12. Architecture of the Vipro Editor – it is a three-tier Web. Elements placed directly above other elements utilize them.

This architecture's main advantage is simplicity. The Information Designer does not need to install anything and can start the application from any computer with a Web browser. Data tier is realized using a file system. This is not a common solution for Web applications, usually a DBMS is used. But for needs of Vipro Editor a DBMS is not necessary and file system is much easier to use and no installation is needed. Since the purpose of this work is scientific, it is not necessary to fill the Vipro Editor with a variety of functions and features for marketing or productizing.

4.2.2 Behavioral View

Vipro Editor should be used by the Information Designer to help create Vipro Instance Metadata and Vipro Configuration. The reference interaction is illustrated in Figure 13. First, required artifacts – process and templates – are uploaded (step 1) and saved to the file system (step 2). Then, using interactive interface, the user creates Vipro Instance Metadata (step 3) which is also saved to the file system (step 4). After that the user creates a Vipro Configuration (step 3), which is also saved to the server's file system (step 4). Finally, the user downloads all artifacts as a single archive (step 5). The received archive together with Vipro Instance Data can be used to request visualization from Vipro Web service.

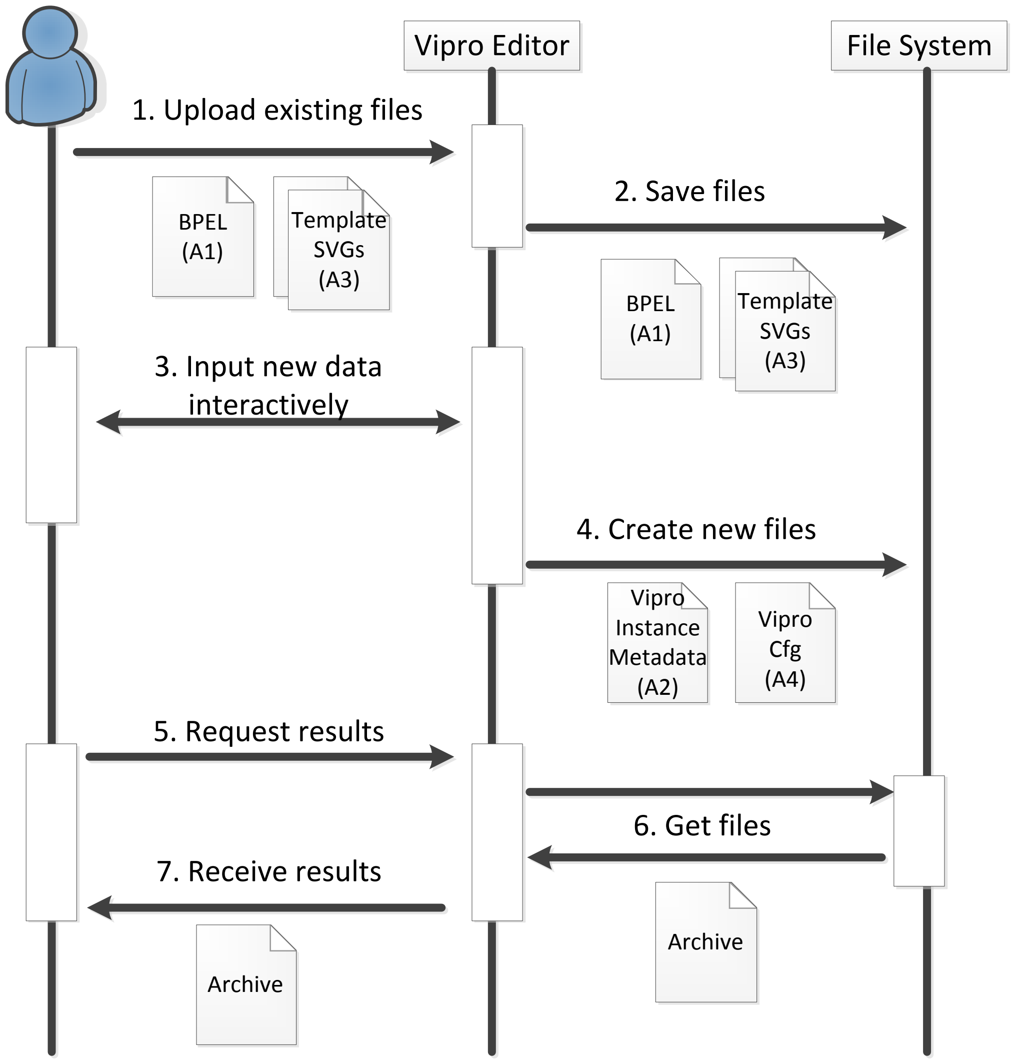


Figure 13. Reference interaction of the user with Vipro Editor.

5 Vipro Artifacts

This chapter describes all artifacts that were created for Vipro: Vipro SVG Template (A3), Vipro Instance Metadata (A2), Vipro Instance Data (A5) and Vipro Configuration (A4). BPEL process definition (A1) is not being discussed in detail because no changes to BPEL standard were made.

5.1 Artifacts Stack

A number of different artifacts was defined before. Figure 14 illustrates their dependencies. Elements placed directly above other elements depend on them. BPEL process (A1) does not depend on any other element. So do Vipro SVG templates (A3). Vipro Instance Metadata (A2) is build based on Database schema that is used by WfMS. Vipro Instance Data (A5) depends only on Vipro Instance Metadata. Vipro Configuration (A4) depends on all of them because it composes them together.

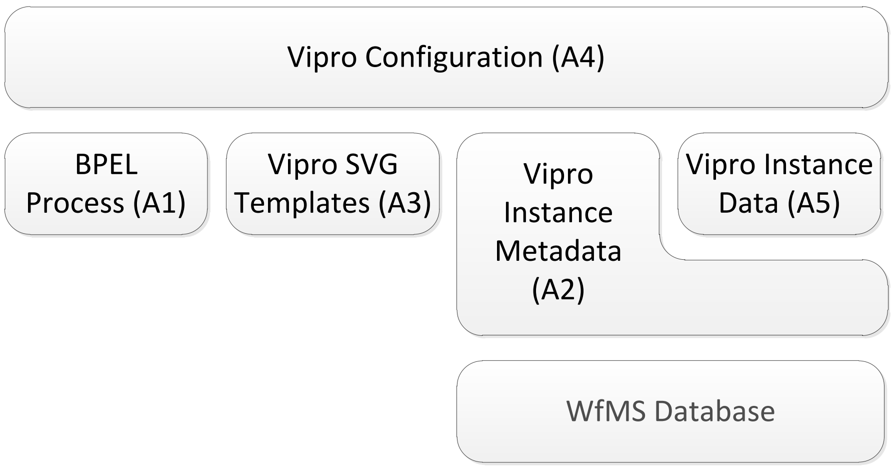


Figure 14. Artifacts and their dependencies. Elements placed directly above other elements depend on them.

5.2 Vipro Templates

Vipro Templates (A3) are created in UC2. As defined in chapter 3.2, Vipro Templates must be compatible with SVG.

5.2.1 Extensions Points

The next question was how to make SVG serve as a template. Some places of the graphics must be filled later at Run-Time. SVG does not support such a feature, so some changes had to be made.

Two options were possible:

- Extend the SVG format.
- Add an additional file that defines extension points in the SVG file.

Extended SVG file was chosen, because it does not require an additional file which would make the management of the artifacts more complicated. The extensions can be made without breaking the compatibility with existing SVG editors. It is possible because SVG is an XML-based format.

5.2.2 Vipro SVG

Through using own imported schema it is possible to add additional attributes to any node of the SVG file.

5.2.2.1 Namespace Import

Own namespaces have to be added to the document first – prefixes “vipro” and “viprometa”. On the Listing 2 two additional namespaces are imported.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<svg
   xmlns="http://www.w3.org/2000/svg"
   ...
   xmlns:vipro="http://arapoport/vipro-svg"
   xmlns:viprometa="http://arapoport/vipro-svg-meta"
   > ...
</svg>
```

Listing 2. Import of additional namespaces into the ordinary SVG file.

The “vipro” prefix will allow attributes and nodes to be made dynamic. “viprometa” prefix will allow to set the size for the template.

5.2.2.2 Spots Definitions

Places where the content of SVG file is made dynamic are called “Spots”. A Spot has an identifier that is used to map it to a data field from Vipro Instance Data or to a static value. It serves as a placeholder.

Using two new namespaces it is possible to add own attributes to any node. Listing 3 shows the attribute “vipro:style” that makes a new Spot from the ordinary attribute “style”.

```
<rect
   id="rect2985"
   ...
   style="fill:#0000ff;"
   vipro:style="fill:#{BackgroundId:'Color of the background':hex-color};"
   />
```

Listing 3. Vipro attribute that makes ordinary attribute dynamic without breaking the SVG syntax. The content of curly brackets describes the Spot and will be replaced at Run-Time.

Using the namespace *“http://arapoport/vipro-svg”* (mapped to the prefix “vipro”) any attribute or node can be made a dynamic Spot. Each Spot will be filled with data at Run-Time. If something goes wrong or no data is mapped to the Spot then the default value from the original attribute will stay in its own place.

To make an attribute a Spot a new additional attribute next to it has to be inserted. The value of the original attribute can stay unchanged – it will be replaced at Run-Time. Name of the additional attribute has to consist of the namespace prefix ("vipro:") and the name of the original attribute, where all colons (":") are replaced by two underscores ("__"). The value of the additional attribute must have a dynamic part marked by curly brackets ("{…}"). At Run-Time everything outside these curly brackets will be left untouched and the curly brackets and their content will be replaced by the dynamic value. Inside the curly brackets a special syntax applies:

```
[Spot ID]:'[Spot description]':[Type]:[Optional]
```

Each element in square brackets has its own semantic:

- Spot ID – is the identifier of the Spot. Different Spots can have same identifier but in this case they both will get same value at Run-Time. It can consist of any alphanumerical characters.
- Spot description – is the description of this Spot. It will be shown to the Information Designer who will work with the finished template. It can consist of any character that are allowed for XML attributes except apostrophe (‘).
- Type – is the type of value that can be put into this Spot. Allowed values are: "int", "string", "hex-color", "enum".
- Optional – is an optional parameter that may be required for some types.

Type declaration allows checking at Run-Time if the inserted values are valid. Type "int" corresponds to an integer type, "string" – to a string, "hex-color" – to a hexadecimal number with 6 positions (a common way to define colors), "enum" – an enumeration type, all possible values must be specified in the "Optional" parameter as a comma separated string.

5.2.2.3 Node Values

In some cases a node value must be made dynamic. For example value of the "text" node in SVG. It is solved using a special attribute too. Another solution would be a special additional node. But in this case it would possibly break SVG schema in places where no additional child nodes are allowed.

The special additional attribute must belong to the node that needs to be dynamic. The name of the attribute must be "vipro:viproNodeValue". This will make the node value a Spot. The value of the attribute has the same syntax as dynamic attributes. Listing 4 illustrates how it is done.

```
<text
   id="text6658"
   ...
   vipro:viproNodeValue="{NameId:'Name of the activity':string}"
   > Name
</text>
```

Listing 4. Vipro attribute that makes a node value dynamic.

The value of the node will be replaced with the dynamic value at Run-Time. The original value can still be shown at Run-Time if no value was mapped to this Spot.

5.2.2.4 Size Definition

The Vipro SVG must have a special size definition. Width and height in pixels must be put into special attributes in the SVG root element as shown in Listing 5.

```
<svg
   ...
   xmlns:viprometa="http://arapoport/vipro-svg-meta"
   viprometa:templateWidth="150"
   viprometa:templateHeight="30"
   > ...
</svg>
```

Listing 5. Two special attributes in the root element of an SVG document that tell the size of the template.

These values are necessary because not every SVG document has a fixed size. Concrete size is required for working with the graphic and placing it in complex layouts where many activities are displayed.

The size of the template can be made dynamic by making these two attributes dynamic. In order to do this, two more attributes must be placed in the root element. They will make the “viprometa” attributes dynamic. Also two additional attributes must be inserted into the SVG document at the place where graphic’s normal width and height are set. Listing 6 illustrates this case.

```
<svg
   ...
   viprometa:templateWidth="150"
   viprometa:templateHeight="30"
   vipro:viprometa__templateWidth="{WidthId:'Width':int}"
   vipro:viprometa__templateHeight="{HeightId:'Height':int}"
   >
   ...
      <rect
         width="150"
         height="30"
         vipro:width="{WidthId:'Width':int}"
         vipro:height ="{HeightId:'Height':int}"
         ... />
   ...
</svg>
```

Listing 6. Two attributes that make width and height definition dynamic.

In this example first width and height are set to default values. Then both pairs of attributes are made dynamic and get corresponding common Spot IDs. Due to common IDs there will be only two Spots – “WidthId” and “HeightId” available in this template. Illustration of this behavior can be found in chapter 8.1.

5.2.3 Editor

The editing process consists of two steps: creating a graphic and adding Vipro Spots. The first step can be done in Inkspace [19]. The second step can be completed in Inkspace or in any XML editor. Inkspace has a built-in XML editor. If the Template Designer is aware of the SVG syntax then Vipro Spots must be added by the Information Designer.

5.3 Vipro Instance Metadata and Data

Formats for two artifacts – Vipro Instance Metadata (A2) and Vipro Instance Data (A5) – are tightly coupled because Vipro Instance Data must correspond to Vipro Instance Metadata. Figure 15 shows the relation between Vipro Instance Data and Vipro Instance Metadata in context of 4-level modeling architecture [26]. Vipro Instance Data describes the real data of a running process. Vipro Instance Data is described semantically by Vipro Instance Metadata and syntactically by XML Schema [27]. XML Schema describes both Vipro Instance Metadata and XML Schema (self-reference). XML Schema appears because both formats must be XML formats (see 3.1.3).

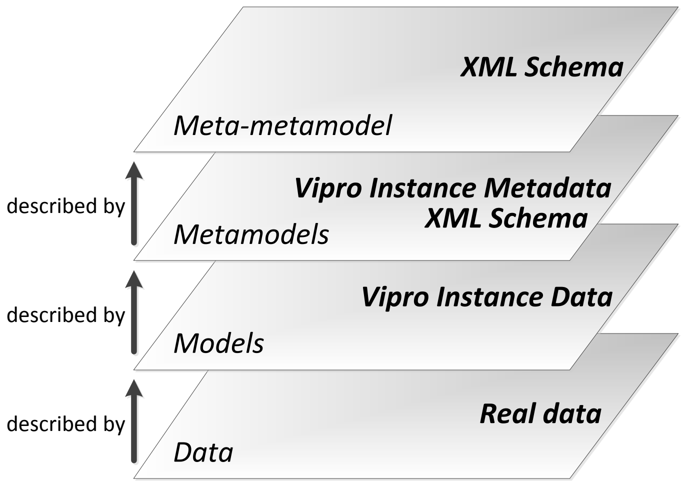


Figure 15. Relation between Vipro Instance Data and Vipro Instance Metadata in 4-level modeling architecture.

5.3.1 Vipro Instance Metadata

5.3.1.1 Choice of Format

Vipro Instance Metadata has three main purposes:

1. Metamodel for Run-Time data (model for Vipro Instance Data).
2. At Design-Time to help building the Vipro Configuration.
3. At Run-Time to validate the incoming Vipro Instance Data.

Two solutions are possible:

- XML Schema
- New format

XML Schema is an industry standard for metamodels. Another advantage is that many enterprises that run WfMS might already have an XML Schema for their instance data and could reuse it. First drawback is that it is too powerful. At Design-Time (Purpose 2) it would be a complex task to completely support the XML Schema. Because of the time limit of this work it is not possible to create a tool that would support XML Schema at Design-Time. Another drawback is that validation (Purpose 3) would not be fault-tolerant. XML validators report an invalid document even if there is only a single error. For real-world applications it is not a problem, but for the prototype, the main goal of which is proving the concept, it would make things more complicated.

New format. Anything can be defined here. But since XML Schema would be the perfect solution for the production use, the new format must fix its disadvantages for the use in this work. Also, it must be simple and small errors like exceeding the range of a variable must be tolerated.

Only because of simplicity reasons the new format was chosen.

5.3.1.2 Format Description

Although XML Schema was not chosen as the format for Vipro Instance Metadata it is used to define the syntax of the new format.

The new format was named RTD-Format (Run-Time Data Format). It contains a list of parameters. Each parameter has a type. At Run-Time each activity must have a single value for each of the parameters.

Namespace for the new format: *"http://arapoport/rtd-format"*. Figure 16 shows its root type – "RTDFormatType". It has two child nodes – optional "meta" of "MetaType" and required "parameters" of "ParametersType". "MetaType" holds information about the file, for example, name of the defined format. "ParametersType" holds list "ParameterType" elements.

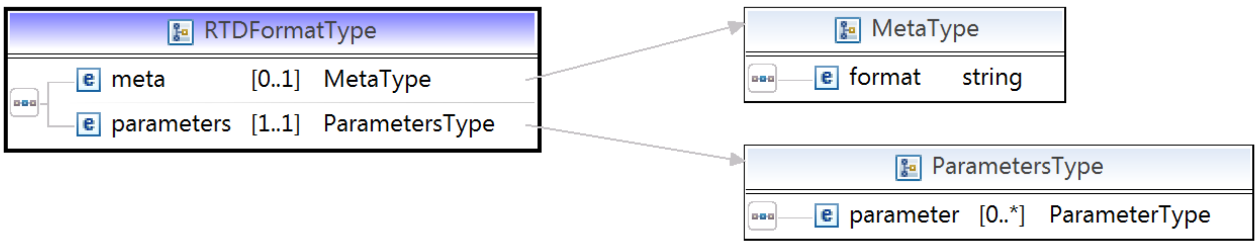


Figure 16. Root element of the Vipro Instance Metadata format. It has two child nodes – "meta" and "parameters".

Figure 17 shows "ParameterType". It has two required attributes and three optional child nodes. Attribute "name" holds the identifier of the parameter. Attribute "type" holds the type of the parameter and can have only two values – "string" or "int". The type "string" means string type and can be constrained by optional "enumeration" node. "enumeration" node, if present, must contain a comma-separated string of all allowed values. The type "int" means integer type. It can be limited to a specific range using two optional nodes "min" and "max". "min", if present, defines the lower inclusive boundary and "max" – the higher inclusive boundary. Error-tolerance: if "type" has an incorrect value then "string" must be used. If an optional node contains an incorrect value or does not correspond with the type then it must be ignored.

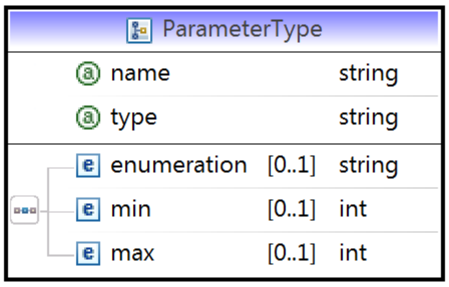


Figure 17. "ParameterType" of the Vipro Instance Metadata format. It has two required attributes and three optional child nodes.

5.3.2 Vipro Instance Data

If XML Schema would be used as Vipro Instance Metadata then Vipro Instance Data would be a normal XML document that corresponds to the schema. However, a new format was chosen for Vipro Instance Metadata. It implies the content of Vipro Instance Data.

XML Schema is used to define the syntax of Vipro Instance Data. New format was named RTD-Instance (Run-Time Data Instance). It contains a list of activities where each activity has a set of own values for each parameter that were defined in Vipro Instance Metadata.

Namespace: *"http://arapoport/rtd-instance"*. Figure 18 shows the type of the root element. It has two child nodes – "meta" and "activities". "meta" of "MetaType" holds the name of the used Vipro Instance Metadata format. "activities" is of "ActivitiesType" and holds a list of activities.

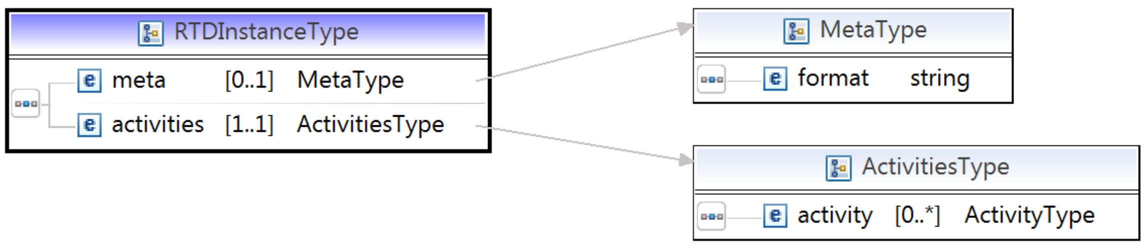


Figure 18. Root element of the Vipro Instance Data format. It has two child nodes – "meta" and "activities".

Figure 19 shows the "ActivityType". It holds a list of "ParameterType" elements. Attribute "name" of "ParameterType" references the parameter from Vipro Instance Metadata. Value of the "ParameterType" node is the value of the referenced parameter. "ActivityType" also holds three optional attributes that are used to reference one or more activities. With the use of "nodeName" the activity type can be specified – in BPEL activity type is specified by the name of node that was used. Using two remaining attributes – "attrName" and "attrValue" – it is possible to reference an activity by its attributes, for instance, by its name. If an activity has an attribute with a name that is equal to "attrName" and value of the attribute equals "attrValue" then it will be referenced.

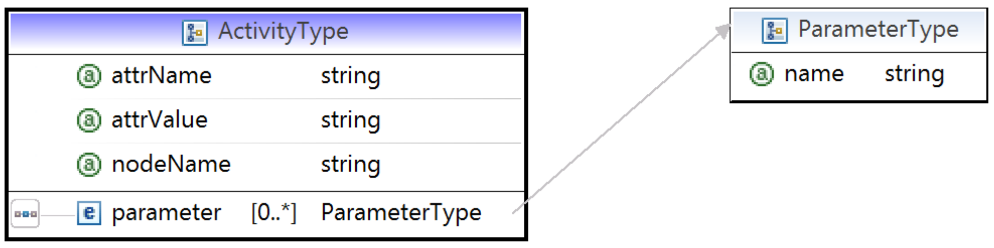


Figure 19. "ActivityType" of the Vipro Instance Data format. It holds three attributes that reference an activity and a list of parameter values.

All three attributes can be used. In that case both conditions must be satisfied. If none of the three attributes is present then all activities are referenced. If an activity is referenced by multiple "ActivityType" nodes then only one must be selected and following priority order applies:

- Both type of activity and its attribute match the activity.
- Only type was specified and it matches the activity.
- Only custom attribute was specified and it matches the activity.
- Nothing was specified.

In case of two "ActivityType" elements having same priority the first of them should be chosen.

5.4 Vipro Configuration

For the Vipro Configuration a new format was defined. It is described in this chapter. Editor for Vipro Configurations is described in further chapters.

Vipro Configuration composes other artifacts: process definition, Vipro Templates and Vipro Instance Metadata: each activity gets a template assigned and parameters of instance metadata are assigned to variable places of the template

XML Schema is used to define the syntax of Vipro Configuration. Namespace used for it: *"http://arapoport/vipro-cfg"*. Figure 20 shows the root type "ViproCfgType" of the Vipro Configuration. It has a child "meta" that holds an optional description. The child "rtd-format" references Vipro Instance Metadata. The child "process" – BPEL process definition. The child "mappings" holds a list of "MappingType" elements.

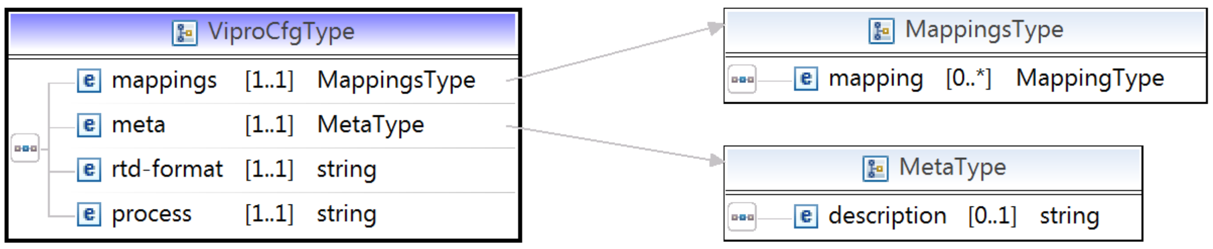


Figure 20. Root element of the Vipro Configuration format. Besides of the meta information it references a process definition and RTD-Format. Main content is the list of mapping rules.

Each "MappingType" contains two required child nodes (Figure 21) – "activity" of "ActivityType" and template of "TemplateType". "ActivityType" references one or more activities using their type or an attribute. The same concept is used in Vipro Instance Data format, more details can be found in chapter 5.3.2. "TemplateType" references a single template by its file name. Also using list of "ParameterType" elements it defines the way how the template must be filled with instance data.

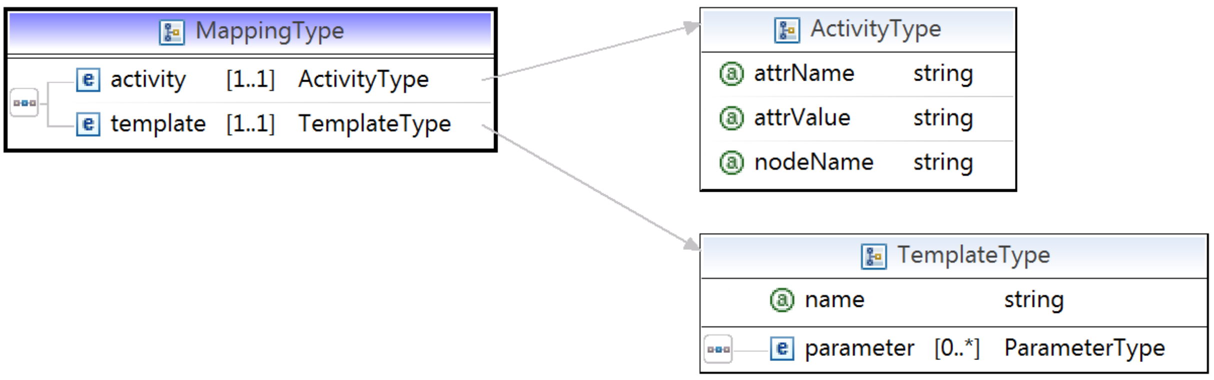


Figure 21. "MappingType" of the Vipro Configuration format defines a mapping rule – which activity gets which template applied. "TemplateType" defines the template and how it should be filled.

"ParameterType" is described in Figure 22. "ParameterType" references a single Spot from template using "spotid" attribute. It means that that Spot must be filled. It can be filled either with a value from Vipro Instance Data or with a static value. "paramid" references a parameter from Vipro Instance Metadata by its identifier. In that case parameter's value from Vipro Instance Data will be inserted into the template.

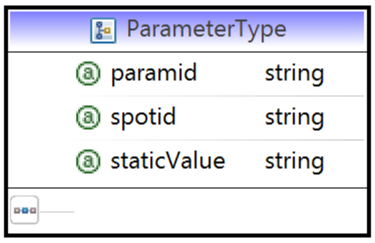


Figure 22. "ParameterType" of Vipro Configuration format defines how a single Spot ("spotid") in Vipro Template should be filled. It can be a static value ("staticValue") or value from Vipro Instance Data ("paramid").

If "staticValue" is set, its value will be inserted into template without evaluating the Vipro Instance Data. Two exceptions apply there. If "staticValue" equals "vipro:name" or "vipro:type" then respectively name of the activity ("name" attribute in BPEL) or type of the activity will be used. Type of the activity is limited to those which are used in BPEL: *assign*, *catch*, *catchall*, *compensate*, *compensateScope*, *compensationHandler*, *else*, *elseif*, *empty*, *end*, *eventHandlers*, *exit*, *extensionActivity*, *faultHandlers*, *flow*, *forEach*, *if*, *invoke*, *onAlarm*, *onEvent*, *onMessage*, *opAqueactivity*, *pick*, *receive*, *repeatUntil*, *reply*, *rethrow*, *scope*, *sequence*, *start*, *terminationHandler*, *throw*, *validate*, *wait*, *while*.

These two shortcuts provide an easy way to reference most important properties of the BPEL process. These properties do not depend on process execution results and it would be highly ineffective to put them into Vipro Instance Data every time. Even icons that illustrate the type of the activity can be used, since all possible values are explicitly defined.

6 Vipro Implementation

This chapter describes all Vipro components and tools that have been implemented. Top-down strategy is used for the explanation. First everything is explained on a very abstract level – which components exist and what are the relations between them. Then the internal structure of each component is described. Afterwards, every subcomponent is described.

6.1 Components Overview

The usage scenarios of Vipro Editor and Vipro Web service are completely different and belong to different Use Cases: Vipro Editor helps the Information Designer in UC3. Vipro Web service is utilized by the monitoring and analysis system in UC5. However, both applications deal with a common set of Vipro artifacts: A1, A2, A3, A4, A5. It implies a common set of required functionality. The coarse-grained component diagram (Figure 23) shows the relation of Vipro components. Common functionality is covered by Vipro Library. Vipro Editor and Vipro Web service both use Vipro Library but do not depend on each other.

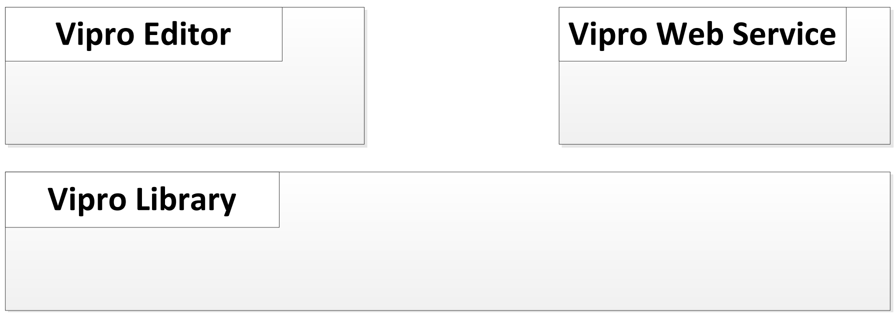


Figure 23. Coarse-grained diagram of Vipro component shows that Vipro Library covers all common functionality used by both Vipro applications that are independent between themselves.

Vipro Library does not depend on any other Vipro component and can be reused by external applications.

Figure 24 shows the fine-grained diagram of Vipro components. The overall structure is the same with Figure 23, but much more detail is shown. Everything is based on Java EE 6 (Java Enterprise Edition 6) [28]. Vipro Library uses Apache Commons libraries [29] that contain some common functionality missing in Java 6. Internally. Vipro Library has different subcomponents. “BPEL Parser” is responsible for working with A1 (BPEL process definition) and was taken from BPI. Another subcomponent is “Template Processor” that processes A3 (Vipro Templates) and produces visualizations for single activities. Three subcomponents “Instance Metadata Processor”, “Cfg Processor” and “Instance Data Processor” work respectively with following artifacts: A2 (Vipro Instance Metadata), A4 (Vipro Configuration) and A5 (Vipro Instance Data). They utilize JAXB (Java Architecture for XML Binding) [30] to work with corresponding files. Next subcomponent is “Layout Engine” which builds the resulting process visualization from single activity visualizations. “Combiner” subcomponent utilizes all subcomponents mentioned before to provide flexible and customizable visualization functionality for external components.

Vipro Editor uses Apache Commons libraries and Vipro Library. Vipro Editor is based on Vaadin – “a web application framework for Rich Internet Applications (RIA)” [31]. Vipro Editor utilizes JST (Java Servlet Technology) [32] that is available in Java EE 6.

Vipro Web service uses Vipro Library and is based on Axis2/Java [33] – an engine for Web services based on SOAP [34] and WSDL (Web Services Description Language) [35]. Vipro Web service has its own interface defined using WSDL. Vipro Web service utilizes JST, too.

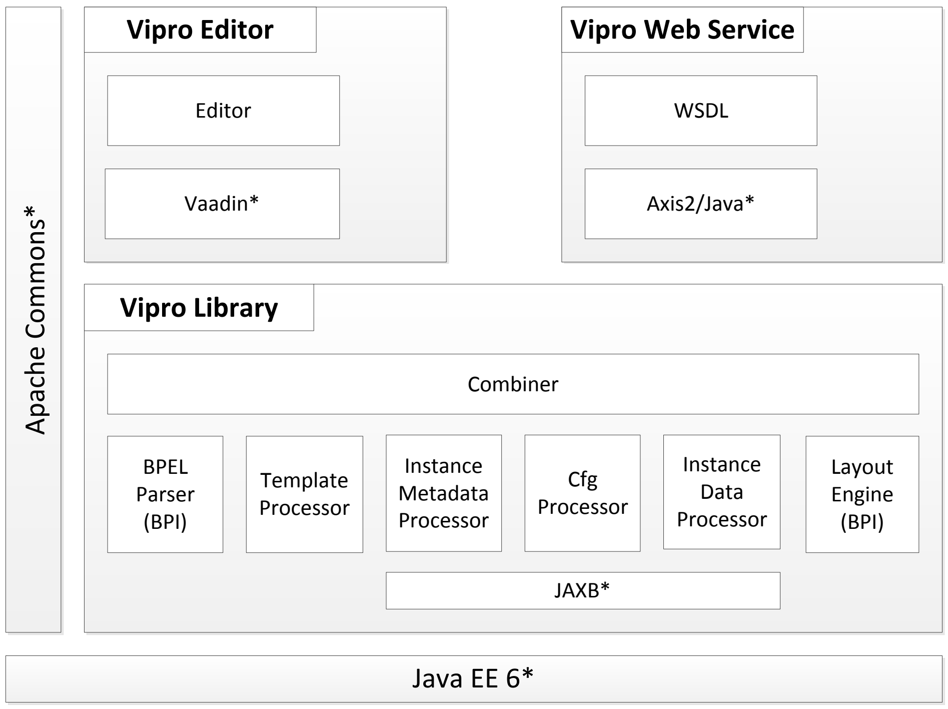


Figure 24. Fine-grained diagram of Vipro components. Elements placed directly above other elements or at the same level with other elements utilize them. Elements marked with asterisk (*) are imported components.

In the following each subcomponent will be described in every detail.

6.2 Vipro Library

Vipro Library consists of multiple subcomponents. Each will be described in this chapter. Figure 25 shows the components diagram from Vipro Library's point of view: it does not know what is on top of it. It uses Apache Commons library and Java EE 6 and that is all.

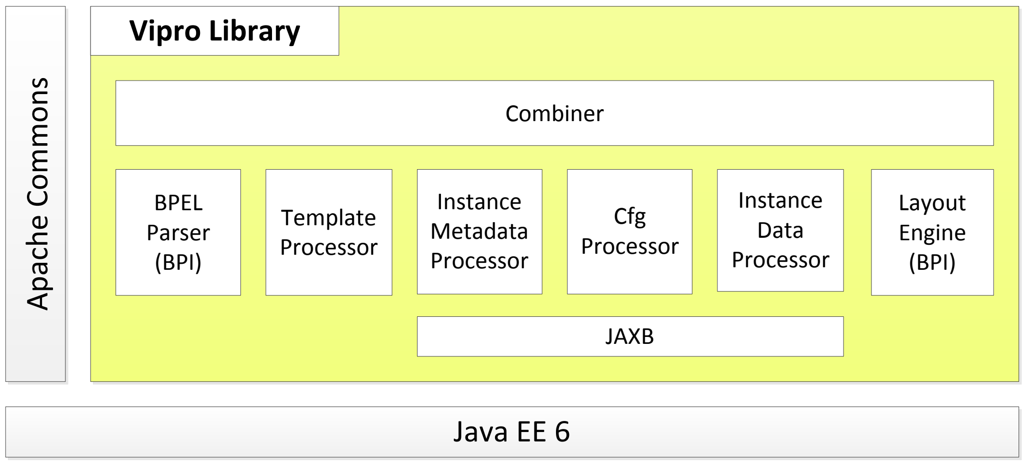


Figure 25. Components diagram for Vipro Library.

6.2.1 BPEL Parser

This subcomponent's main purpose is to parse BPEL files (A1). It was taken from BPI and was slightly modified. It is placed in following Java package:

```
de.unistuttgart.iaas.viewService.service.bpel
```

The original variant [22] parses a BPEL file specified by an URL (Uniform Resource Locator). The parsing result is a tree-like object model of the process. Each activity is represented by an object that holds name, type and children. BPEL links are saved in one list that is associated with the process. For Vipro some modifications were made: process file can be specified by a single string; all attributes of each activity are also parsed and are available using the object model.

6.2.2 Template Processor

This subcomponent is responsible for processing of Vipro Templates. Used Java package:

```
arapoport.vipro.lib.template
```

It offers two functions:

1. Parse and get all Spots of a template. It is meant only for Design-Time.
2. Apply template to an activity. It is meant for both Design0Time and Run-Time.

Function 1 is implemented by the public and static method `getAllSpots`. It takes the content of a template file represented by a string. Then it creates a corresponding DOM (Document Object Model) document using standard Java XML parser. Finally it goes recursively through the DOM document and looks for attributes starting with “vipro:”. The method, that does this, is shown in Listing 7. It gets a node, that needs to be parsed, and list, where all found Spots should be stored (line 1). First, it checks all attributes of the node (line 3). If an attribute starts with “vipro:” (line 6), then it is parsed into `ViproTemplateSpot` data structure (line 7) and added to the resulting list, if it is not already there (line 8). After that this method is invoked for all child nodes (line 17).

```
 1: private static void getAllSpotsFromNode(Node node, ViproTemplateSpotList res) {
 2:
 2:   /* Check in attributes. */
 3:   for (int i = 0; i < node.getAttributes().getLength(); i++) {
 4:     Node attr = node.getAttributes().item(i);
 5:
 6:     if (attr.getNodeName().startsWith("vipro:")) {
 7:       ViproTemplateSpot spot = ViproTemplateSpot.factoryCreateInstance(attr.getNodeValue());
 8:       res.addIfNotAlreadyIn(spot);
 9:     }
10:   }
11:
12:   /* Recursively check child nodes. */
13:   for (int i = 0; i < node.getChildNodes().getLength(); i++) {
14:     Node child = node.getChildNodes().item(i);
15:
16:     if (child.getNodeType() == Node.ELEMENT_NODE) {
17:       getAllSpotsFromNode((Element) child, res);
18:     }
19:   }
20: }
```

Listing 7. Recursive method that looks for Spot definitions.

Each Spot definition (class `ViproTemplateSpot`) contains full information about the Spot: identifier, description, type, type options and two strings with text that must be added before and after the value. All created Spots are returned wrapped into a list (class `ViproTemplateSpotList`).

Function 2 is implemented by another public and static method `applyTemplate`. It requires five arguments to be specified. Their meaning and source are presented in Table 3.

Argument	Description	Source artifact
template	template to be applied to the activity	A3
Run-Time data	instance data of the activity that should be used to fill template	A5
mapping rules	set of mapping rules that define how template should be filled	A4
name of the activity	string that can be used to fill the template	A1
type of the activity	string that can be used to fill the template	A1

Table 3. Arguments used to fill in a template.

The template filling algorithm works as follows: it builds a DOM document from the template (A3) and traverses it. In parallel, a new DOM document is created. While going through the original document, the algorithm copies all the content to a new document. If a Spot is found, then it is processed and the resulting value is put in the new document as shown in Listing 8.

First, the spot definition is parsed (line 5). Then it browses the in mapping rules (line 12) for a corresponding rule (line 14). The rule tells what the parameter and static value are. If static value is set, then it is used (line 24). The static value can reference name of the activity (line 27) or its type (line 29). If neither of them matches, then the static value is used (line 31). If the static value is empty, instance data is used (line 34). The algorithm looks for a corresponding parameter (line 39) in the values of the activity (line 38). Finally, the value is applied to spot (line 48) and returned.

```java
private String processValue(String value, String activity) {

  /* Parse Spot description. */

  ViproTemplateSpot spot = ViproTemplateSpot.factoryCreateInstance(value);

  /* Find which parameter should be put on the Spot. */

  String paramId = "";
  String staticValue = "";

  for (ParameterType parameter : this.cfgMapping.getTemplate().getParameter()) {

    if (parameter.getSpotid().equals(spot.getId())) {
      paramId = parameter.getParamid();
      staticValue = parameter.getStaticValue();
    }
  }

  /* Find the value to be applied */

  String valueToApply = null;

  if (StringUtils.isStringEmptyOrNull(staticValue) == false) {
    /* Static value was set. Use it an do not forget about shortcuts. */

    if (staticValue.toLowerCase(Locale.ENGLISH).equals("vipro:name")) {
      valueToApply = this.activityName;
    } else if (staticValue.toLowerCase(Locale.ENGLISH).equals("vipro:type")) {
      valueToApply = this.activityType.toLowerCase();
    } else {
      valueToApply = staticValue;
    }
  } else {
    /* Static value was not set. Look for a parameter's value. */

    if (this.activity != null) {
      for (rtdinstance.binding.ParameterType param : this.activity.getParameter()) {
        if (param.getName().equals(paramId)) {
          valueToApply = param.getValue();
        }
      }
    }
  }

  /* Apply value to the Spot and return. */

  return spot.applyValue(valueToApply);
}
```

Listing 8. Method that calculates the value of a Spot.

In the end, the new XML document contains the template with all Spots filled with values.

Because Vipro Templates are fully compatible with SVG, there was no need of building a special object model for SVG. A standard DOM for XML was enough to implement both functionalities, because they do not require interpretation of SVG syntax.

6.2.3 Vipro Instance Metadata Processor

This subcomponent is responsible for processing of Vipro Instance Metadata. Used Java package:

`arapoport.vipro.lib.rtdformat`

Vipro Instance Metadata was defined using XML Schema. It allows to generate the binding classes that can process files of this type. The binding was generated using JAXB. As a result an object model was automatically created. This object model corresponds one-to-one to the Vipro Instance Metadata format. The model can be saved into XML files or loaded from them. Also it is possible to work with objects, to modify them or to create new model instances.

6.2.4 Vipro Configuration Processor

This subcomponent is responsible for processing of Vipro Configuration. Used Java package: `arapoport.vipro.lib.cfg`.

Since Vipro Configuration is also defined using XML Schema, the same approach as in 6.2.3 was used (XML binding).

6.2.5 Vipro Instance Data Processor

This subcomponent is responsible for processing of Vipro Instance Data. Used Java package: `arapoport.vipro.lib.rtdinstance`

Since Vipro Instance Data is also defined using XML Schema the same approach as in 6.2.3 was used (XML binding).

6.2.6 Layout Engine

This subcomponent is responsible for building a composed graphic from single activity graphics. It was taken from BPI and was extended. It is placed in following Java package: `de.unistuttgart.iaas.viewService.svg`.

6.2.6.1 BPI's Layout Engine

The original BPI layout engine [22] builds SVG graphic from scratch. It manipulates SVG primitives on the code level. BPI uses only vertical layout. The general idea of the layout algorithm is to place activity blocks in an invisible grid. The idea of the grid is that each block gets its own cell as shown in Figure 26. Blocks that share the same row get same height available for use. The height is calculated by taking into account the block with maximum height. Blocks that share the same column get same width available for use. The width is calculated by taking into account the block with maximum width.

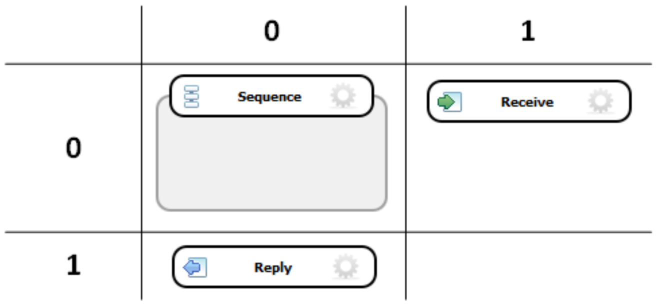


Figure 26. Grid used in BPI. Grid lines and numbers are for clarity only and normally are not visible, Figure taken from [22].

In order to do this, first the required size of each block is calculated. Complex activities (activities that have children) get own internal grid and their size depends on their content. Grid is filled from top to bottom. Additional columns are used only for flow and choice activities. More about the layout algorithm can be found in the work of Gregor Latuske [22], pages 43-58.

6.2.6.2 Extended BPI's Layout Engine

It was possible to use this layout engine in Vipro without making big changes. The main modification was to let BPI use prepared SVG graphics for activities instead of creating them from SVG primitives. Vipro Templates can have any size. It can even be calculated at Run-Time. But as shown before, BPI can deal with custom sized blocks. In BPI, each activity block was rendered by one of the classes from the following package: `de.unistuttgart.iaas.viewService.svg.element`.

Each class was replaced by a new one as shown in Table 4.

Original class	New class
`ActivitySimpleElement`	`ActivityTemplatedSimpleElement`
`ActivityComplexElement`	`ActivityTemplatedComplexElement`
`ActivitySequenceElement`	`ActivityTemplatedSequenceElement`
`ActivityFlowElement`	`ActivityTemplatedFlowElement`
`ActivityChoiceElement`	`ActivityTemplatedChoiceElement`

Table 4. Original classes from BPI that were replaced in Vipro by new classes.

The class diagram in Figure 27 illustrates how the new classes were integrated into BPI. Most changes are placed into two main classes: `ActivityTemplatedSimpleElement` and `ActivityTemplatedComplexElement`. Other three classes are almost identical to original classes except that they extend from `ActivityTemplatedComplexElement`.

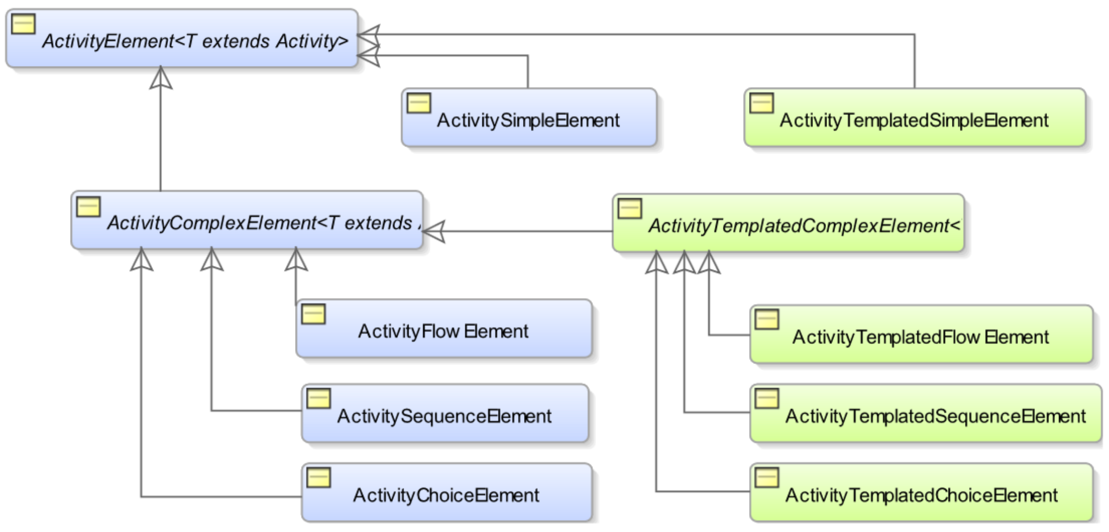

ActivityElement<T extends Activity>
ActivitySimpleElement
ActivityTemplatedSimpleElement
ActivityComplexElement<T extends
ActivityTemplatedComplexElement<
ActivityFlow Element
ActivityTemplatedFlow Element
ActivitySequenceElement
ActivityTemplatedSequenceElement
ActivityChoiceElement
ActivityTemplatedChoiceElement

Figure 27. Class diagram showing relations between original classes (blue) and new classes (green) in BPI.

Both main classes override two methods: one method returns the size of the activity block and the other returns SVG markup of that block. Both classes prepare the template using the subcomponent Template Processor immediately after they were created. Both classes return size taken from the prepared template. `ActivityTemplatedComplexElement` also takes into account the size of its children. Both classes also return the SVG markup of the prepared template. Possible options, that have been elaborated to do this, are described in chapter 7.1.

In order to be able to use the Template Processor, both classes need the context with all required artifacts. This context is passed using `Settings` class of the BPI. It was extended to contain the `ViproContext` class that holds all artifacts.

Sequence diagram on Figure 28 illustrates the way the visualization is created. Everything starts when a “processConfiguration” method of the “Combiner” component is invoked. It prepares the context and invokes the “generate” method from the layout engine component. It creates the activity root element, which recursively creates the complete activity tree model. Then “getSvg” method is invoked on the root activity. It recursively calculates sizes and then recursively builds resulting SVG, which is then returned back.

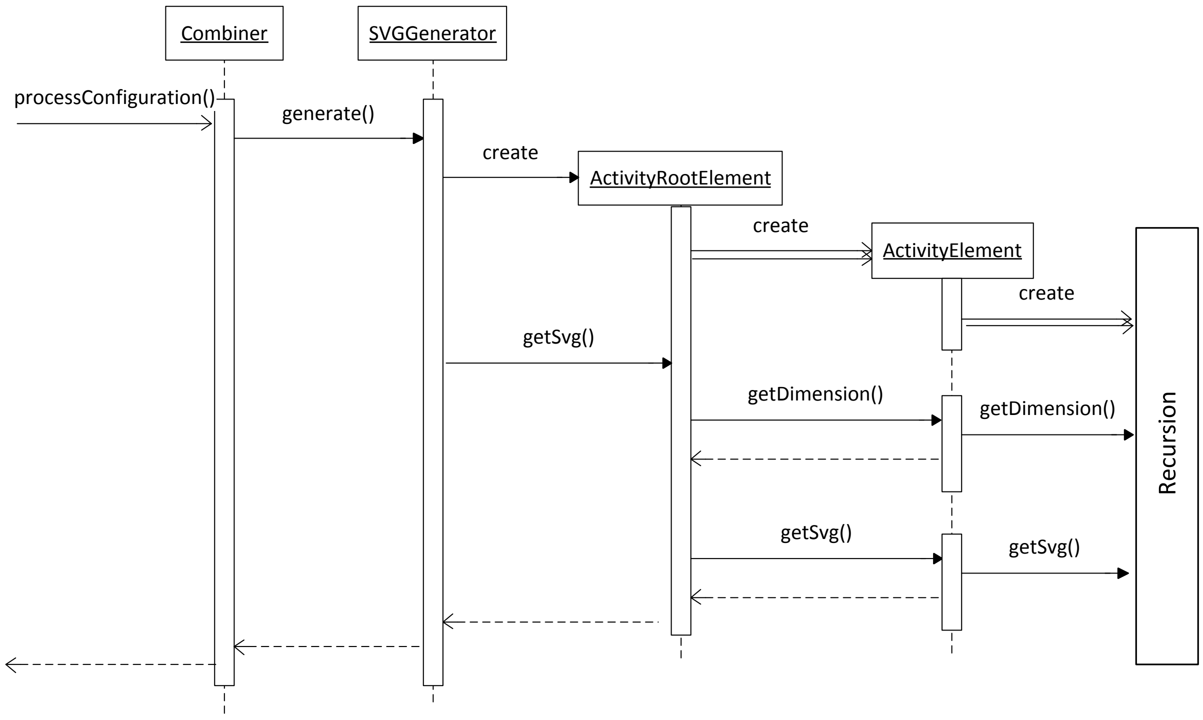


Figure 28. Sequence diagram for the visualization routine.

6.2.7 Combiner

Last subcomponent of Vipro library sits on top of other subcomponents, which means that it utilizes them and provides visualization functionality for external components. Java Package:

`arapoport.vipro.lib.combiner`.

Basically, its main function is to process a Vipro Configuration and return its visualization. It is done in public and static method `processConfiguration(ViproStringModel)` of the class `ViproManager`. This method takes one argument that is a container for all artifacts represented by the strings. It parses all of them using other subcomponents and stores them in a new container (class `ViproContext`). Then it uses the layout engine to produce the visualization. Visualization is a single SVG file and its content is returned.

6.3 Vipro Web Service

Second component is Vipro Web service. Figure 29 shows the components diagram from Vipro Web service's point of view: it uses Vipro Library and Java EE 6.

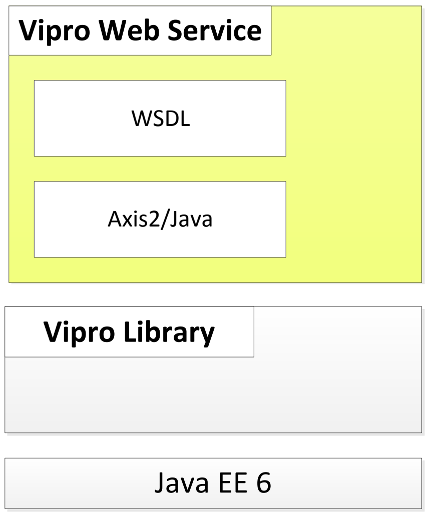


Figure 29. Components diagram for Vipro Web service.

Vipro Web service is a SOAP/WSDL Web service. It uses Axis2/Java [33] as engine. It was built using a top-down approach – first service definition was created and only then the service was implemented. Vipro Web service is made stateless. Another possibility would be to make it stateful. Stateless approach has many advantages over stateful approach:

- Web service can be easily deployed – no configuration is required.
- Web service can be scaled out by deploying it on multiple nodes – they do not need to share common state storage.
- Web service is easy to use for demonstration purposes – for this work it is an advantage.
- SOAP/WSDL Web services are stateless as such – a stateful service must be built on top of them. It means more work and usage of additional components like WSRF (Web Services Resource Framework) [36].

Main disadvantage is that each invocation is resource consuming – each time all artifacts have to be passed to the Web service. In real-world it could be a possible bottleneck. A stateful Web service implementation would be more efficient, but for the prototyping of concepts of this work it is less important.

6.3.1.1 WSDL Definition

WSDL interface was named "viproService" and got the namespace *"http://arapoport/viproService"*. It has only one operation – `getViproVisualization`. This operation is of type "Request-response" [35] Figure 30 illustrates its request type. The request contains all artifacts: process definition, Vipro Instance metadata, Vipro Instance Data, Vipro Configuration and templates. All artifacts, except templates, are represented by a single string that should hold the complete XML markup of the corresponding artifact. Templates are represented by a list of "SvgTemplateType" elements where each holds name of the template file and its content. Template content is also represented by a single string that holds complete XML markup of the corresponding template.

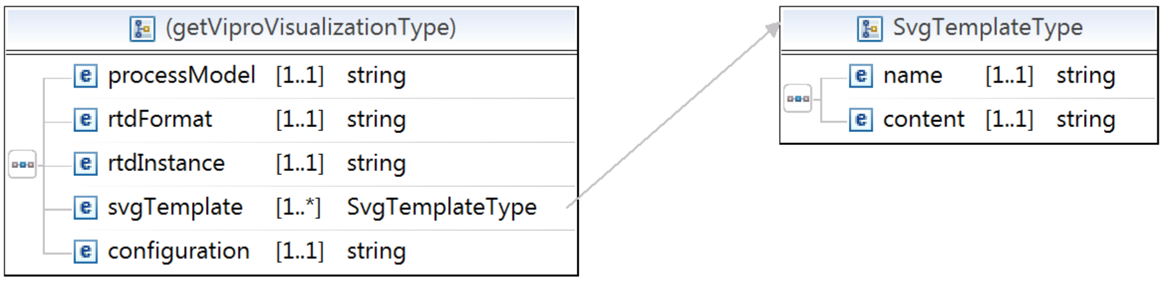

(getViproVisualizationType)
processModel [1..1] string
rtdFormat [1..1] string
rtdInstance [1..1] string
svgTemplate [1..*] SvgTemplateType
configuration [1..1] string
SvgTemplateType
name [1..1] string
content [1..1] string

Figure 30. Request type for the operation `getViproVisualization` of the Vipro Web service.

The response type is much simpler and contains a single string. This string holds complete SVG markup of the generated visualization.

6.3.1.2 Service Implementation

Service implementation was done on top of Axis2/Java. It provides both Run-Time library and tools for code stubs generation. From the WSDL definition a service stub was generated. Java package for the service implementation is `arapoport.viproservice`. Only one class was changed – `ViproServiceSkeleton`. Method `getViproVisualization` was implemented there. It builds `ViproStringModel` instance from request data and invokes `processConfiguration` method from Vipro Library. The returned string with visualization is the response of the operation.

6.4 Vipro Editor

The last Vipro component is Vipro Editor. Figure 31 shows the components diagram from Vipro Editor’s point of view. Vipro Editor uses Vipro Library, Apache Commons library and Java EE 6.

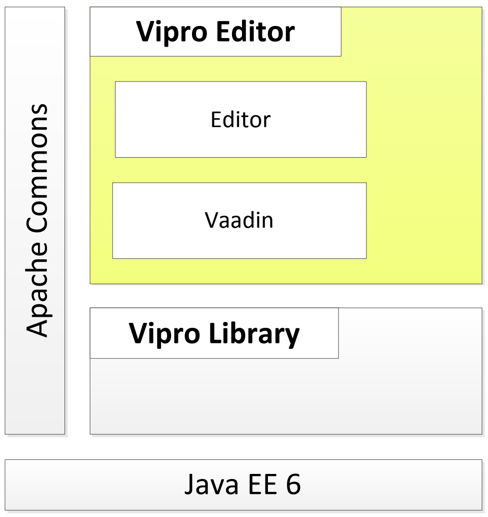


Figure 31. Components diagram for Vipro Editor.

Vipro Editor uses three-tier architecture (chapter 4.2.1). Presentation tier runs in browser, logic tier is the servlet and data tier is the file system.

6.4.1 Vaadin

Vipro Editor uses Vaadin – a web application framework for RIA. Vaadin is licensed under the Apache Software License, Version 2 [24]. It allows to build Web applications rapidly without dealing much with browser technologies – HTML (Hypertext Markup Language), Java-Script or CSS (Cascading Style Sheets). The presentation tier is completely covered by the framework. The GUI (Graphical User Interface) is defined on server-side in Java language. The overall concept is very much like Swing – a very popular Java GUI toolkit. Applications created with Vaadin look almost like desktop applications – they are single page applications, they are stateful and almost all operations are controlled by buttons.

Architecture of Vaadin is shown in Figure 32. “Client-Side Engine of Vaadin manages the rendering in the Web browser using Google Web Toolkit (GWT). It communicates user interaction and UI changes with the server-side Terminal Adapter using the User Interface Definition Language (UIDL), a JSON-based language. The communications are made using asynchronous HTTP or HTTPS requests” [37]. The Terminal Adapter is an abstraction layer that enables support of different browsers. Although modern browsers claim to be compatible with HTML and Java Script standards, in real life there are still differences in browser behavior.

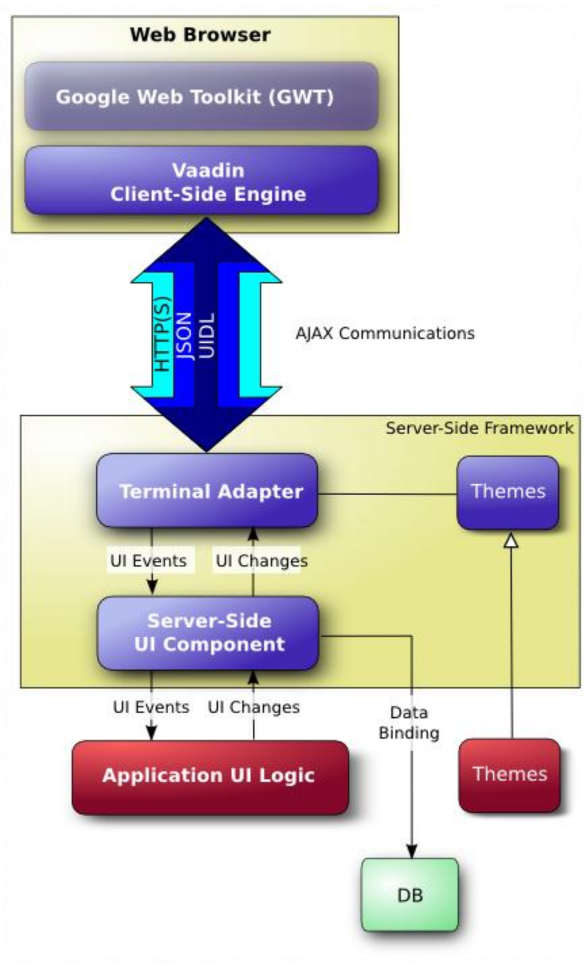


Figure 32. Architecture of Vaadin. Figure taken from [37], Chapter 3.1.

Vaadin is fully compatible with Java Servlet Technology and is provided in a single-file library. Also there is a beta version of WYSIWYG (What You See Is What You Get) editor that makes GUI building even easier.

Vaadin was chosen because it is meant for Java applications, it is compatible with JST, it allows rapid building of Web GUI applications, it requires only Java skills and it does all the browser rendering and communication work.

6.4.2 Main Window

To demonstrate the user interface, the test case “Long Operation Process” from chapter 8.3 will be used. It is based on a simple BPEL process shown in Figure 33.

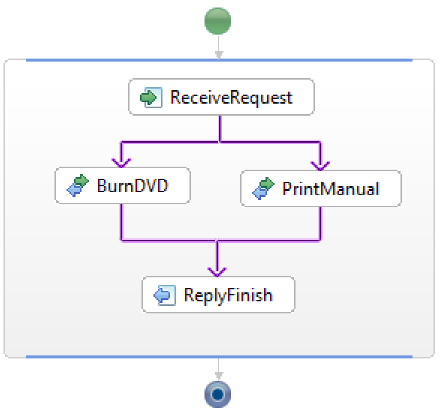


Figure 33. BPEL process for the “Long Running Process” test case. This visualization was made with Eclipse BPEL Editor.

As shown in Figure 34, the Vipro Editor main window consists of three areas: header, left menu and tab pane. Header holds the title and two links: one is a link to the Vipro Web service and the other is a link to the Web service client. The left menu contains a list of projects and a form for creating new projects. Tab pane is the main working area. It has five tabs and they correspond to five steps that are necessary for creating a Vipro Configuration. Such structure of interface proposes sequential work with the editor, but any step can be opened any time.

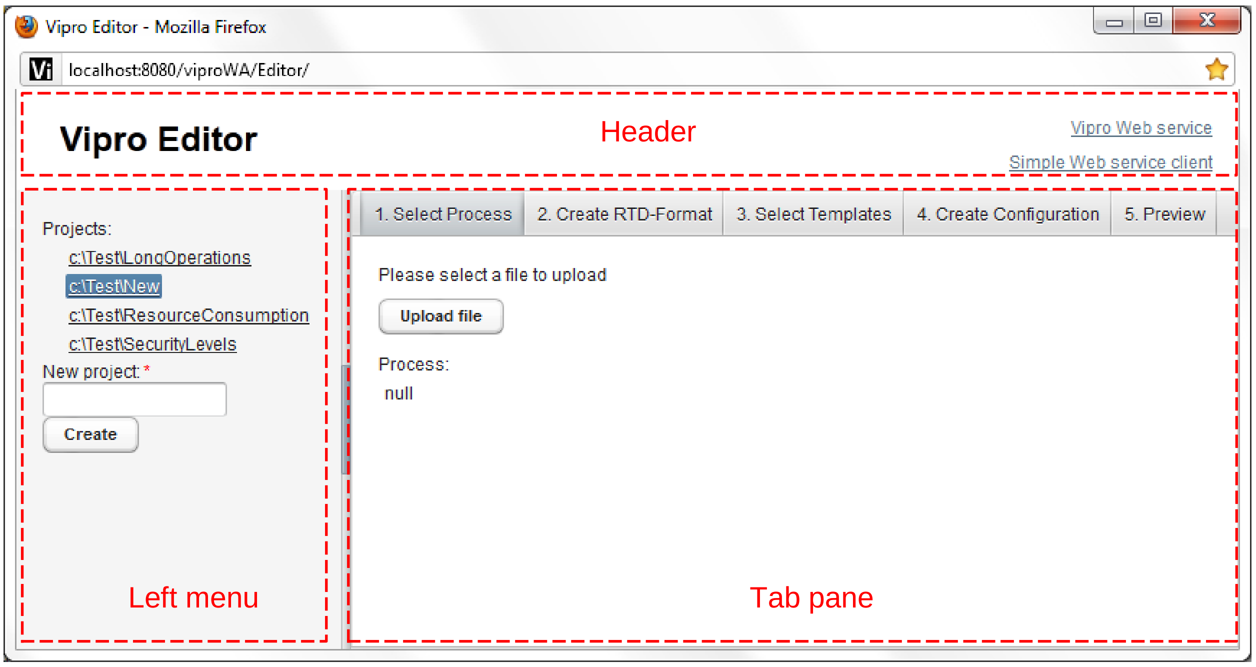
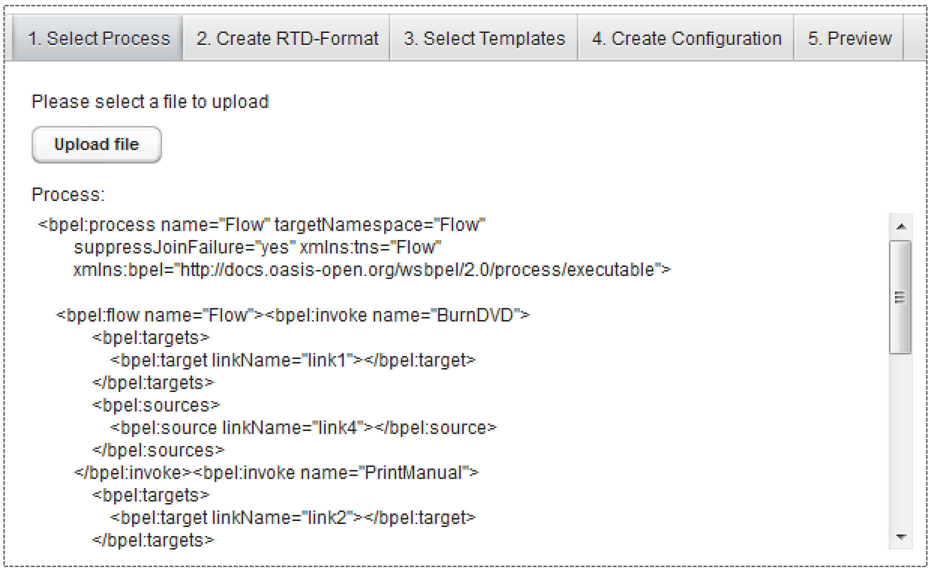


Figure 34. Main window of Vipro Editor consists of three areas. They are marked red.

All projects correspond to directories in working directory. Vipro Editor cannot work without a working directory and asks the user to enter it when starting first time. If Vipro Editor is accessed from the same computer where the servlet runs, then the absolute path to the project is shown in the menu. All artifacts, which belong to the project, will be saved in its directory.

6.4.2.1 Step 1 – Select Process

The prepared BPEL process (A1) has to be uploaded here. Only files with "bpel" extensions can be uploaded. As shown in Figure 35, the content of uploaded process is immediately previewed. No visualization is used here.



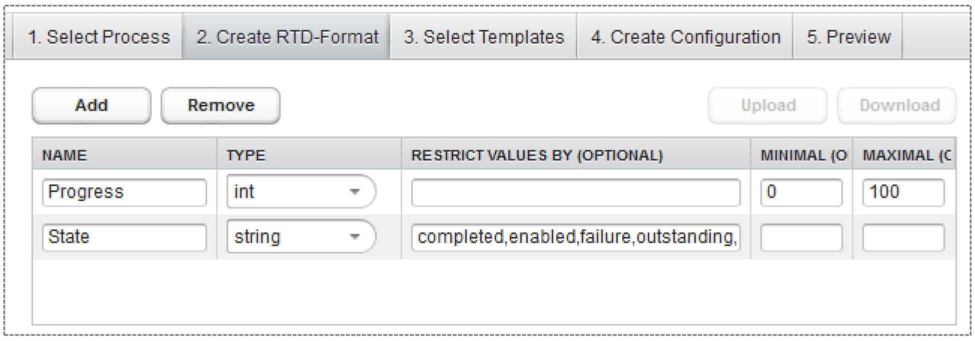
```
<bpel:process name="Flow" targetNamespace="Flow"
      suppressJoinFailure="yes" xmlns:tns="Flow"
      xmlns:bpel="http://docs.oasis-open.org/wsbpel/2.0/process/executable">

   <bpel:flow name="Flow"><bpel:invoke name="BurnDVD">
         <bpel:targets>
            <bpel:target linkName="link1"></bpel:target>
         </bpel:targets>
         <bpel:sources>
            <bpel:source linkName="link4"></bpel:source>
         </bpel:sources>
      </bpel:invoke><bpel:invoke name="PrintManual">
         <bpel:targets>
            <bpel:target linkName="link2"></bpel:target>
         </bpel:targets>
```

Figure 35. Step 1 – Select Process of the Vipro Editor.

The uploaded process is saved immediately to the project directory under name "process.bpel".

6.4.2.2 Step 2 – Create RTD-Format

Vipro Instance Metadata has to be created here. As shown in Figure 36, it is presented as a table of parameters. Columns of the table correspond to fields of “ParameterType” from Vipro Instance Metadata format. Entries can be added and removed; all changes are automatically saved to the file “rtd-format.xml” and are immediately available for other steps.

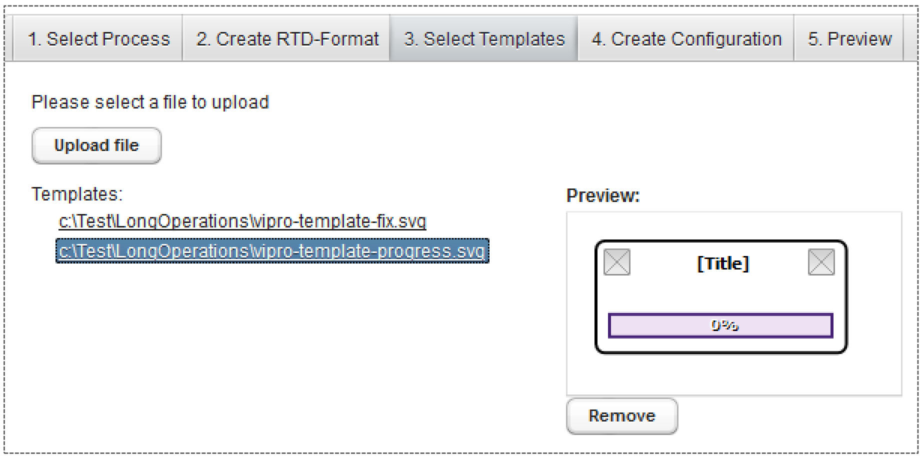


NAME	TYPE	RESTRICT VALUES BY (OPTIONAL)	MINIMAL (O	MAXIMAL (C
Progress	int		0	100
State	string	completed,enabled,failure,outstanding,		

Figure 36. Step 2 – Create RTD-Format of the Vipro Editor.

6.4.2.3 Step 3 – Select Templates

Vipro Templates are uploaded here. As shown in Figure 37, many templates can be uploaded. They are saved to the project directory. File names are saved and serve as an identifier. On the right to the list of available templates a preview of the selected template is shown. Templates are shown in default mode - no substitutions of Spots are made. A template can be made in such a way, that when it is displayed in default mode, the placeholders are visible and give the user an impression about their capabilities. Template’s SVG markup is inserted directly into HTML markup, this feature is supported by HTML5. More about this is discussed later in chapter 7.3.



Please select a file to upload

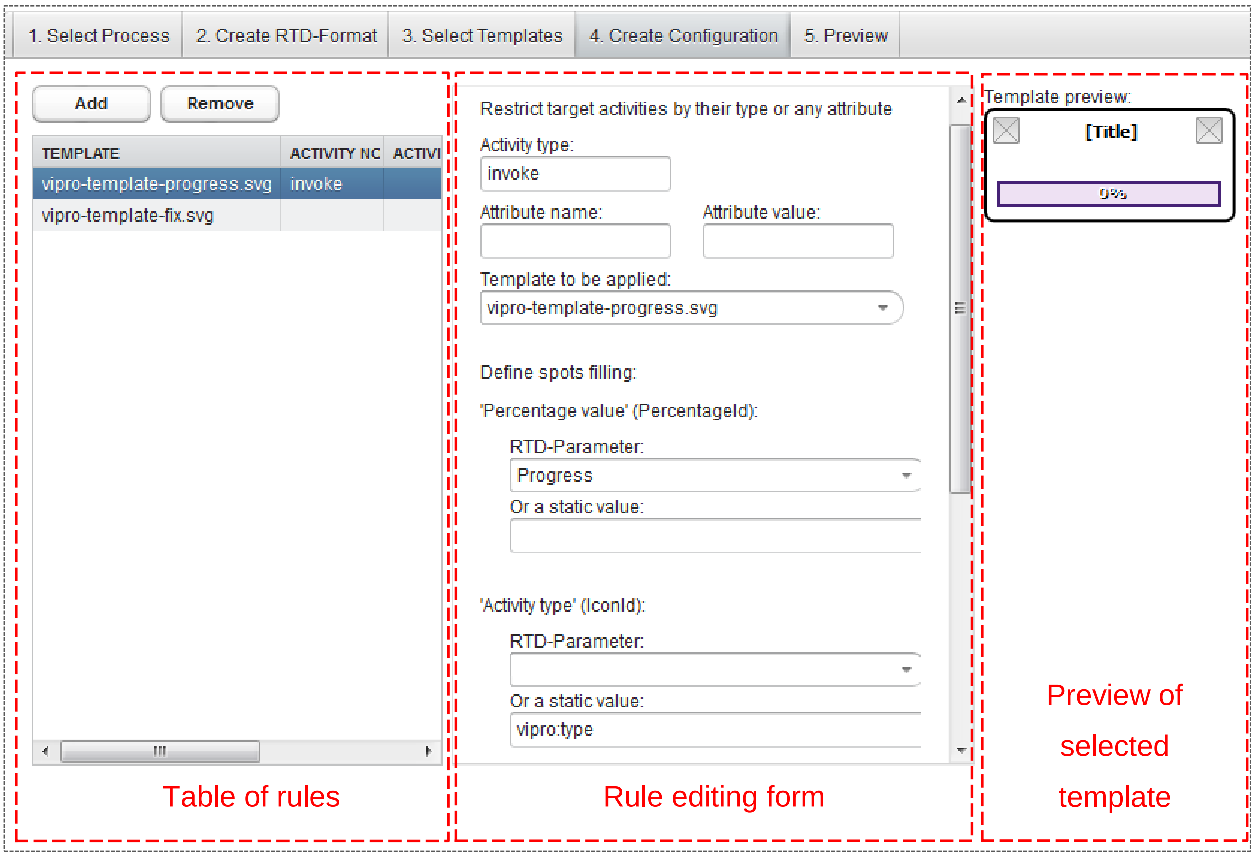
Templates:

c:\Test\LongOperations\vipro-template-fix.svg
c:\Test\LongOperations\vipro-template-progress.svg

Figure 37. Step 3 – Select Templates of the Vipro Editor.

6.4.2.4 Step 4 – Create Configuration

Vipro Configuration has to be created here. This step depends on all proceeding steps because Vipro Configuration depends on all artifacts entered earlier. As shown in Figure 38, the area is split into 3 zones. The first zone is a table of mapping rules. The second zone shows a form for editing the selected mapping rule. And the last zone shows a preview of the template used in selected mapping rule.



TEMPLATE	ACTIVITY NC	ACTIVI
vipro-template-progress.svg	invoke	
vipro-template-fix.svg		

Restrict target activities by their type or any attribute
Activity type: invoke
Attribute name:
Attribute value:
Template to be applied: vipro-template-progress.svg
Define spots filling:
'Percentage value' (PercentageId):
RTD-Parameter: Progress
Or a static value:
'Activity type' (IconId):
RTD-Parameter:
Or a static value: vipro:type

Figure 38. Step 4 – Create Configuration of the Vipro Editor. It consists of three zones marked with red color.

Mapping rules can be added or removed. When selected, they can be edited: on the top of the forms three text fields allow to reference one or more targeted activities. It corresponds to "ActivityType" of the Vipro Configuration format. Next comes a combo box where a template can be selected. Further content of the form depends on the graphical capabilities of the template. For each Spot found in a template a block of two fields is shown: user can select a mapped RTD-Parameter from Vipro Instance Metadata file or enter a static value. It corresponds to the "ParameterType" of the Vipro Configuration format.

6.4.2.5 Step 5 – Preview

In the last step the user can preview the configuration and download all artifacts as a single archive file. Figure 39 shows this step and a preview of the entered process. The previewed visualization of the process is incomplete because no Vipro Instance Data is available, yet. Only static values are applied to the template. For example, in the visualized process only the left icons are set and the right icons show placeholders. This is because left icons were mapped to the activity type, which is available at Design-Time. And right icons were mapped to Run-Time data and cannot be filled at Design-Time.

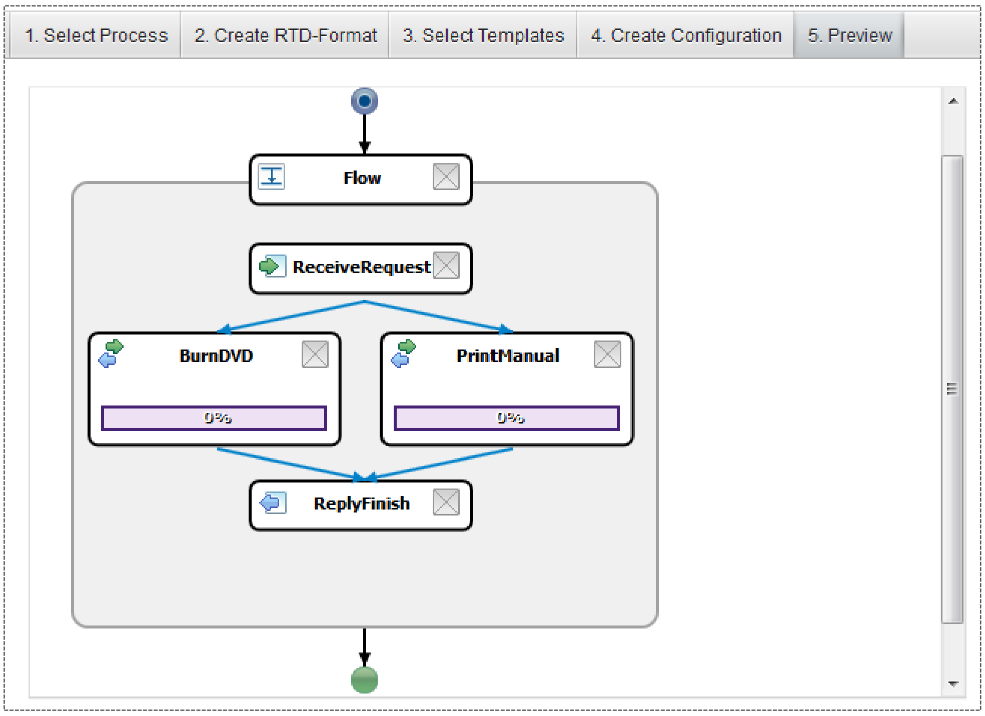


Figure 39. Step 5 – Preview of the Vipro Editor.

6.4.3 Simple Client for Web Service

In addition to the Vipro Editor a simple Web service client was created. It is a single JSP (Java Server Pages) page that uses code stub generated by Axis2/Java for the Vipro Web service. It accepts ZIP-archive files. The content of the archive is used as artifacts for the request to the Web service. Archive file must contain following files:

- A single file with “bpel” extension – it is interpreted as BPEL process definition.
- A file that ends with “format.xml” – it is interpreted as Vipro Instance Metadata file.
- Files with “svg” extension – all of them are interpreted as Vipro Templates.
- A file that ends with “instance.xml” – it is interpreted as Vipro Instance Data file.
- A file that ends with “cfg.xml” – it is interpreted as Vipro Configuration.

All this artifacts are passed to the Vipro Web service and the output is visualized on the same page (Figure 40). The same process as in Figure 39, is used but this time with a sample instance data. This and more test cases will be explained in chapter 8.

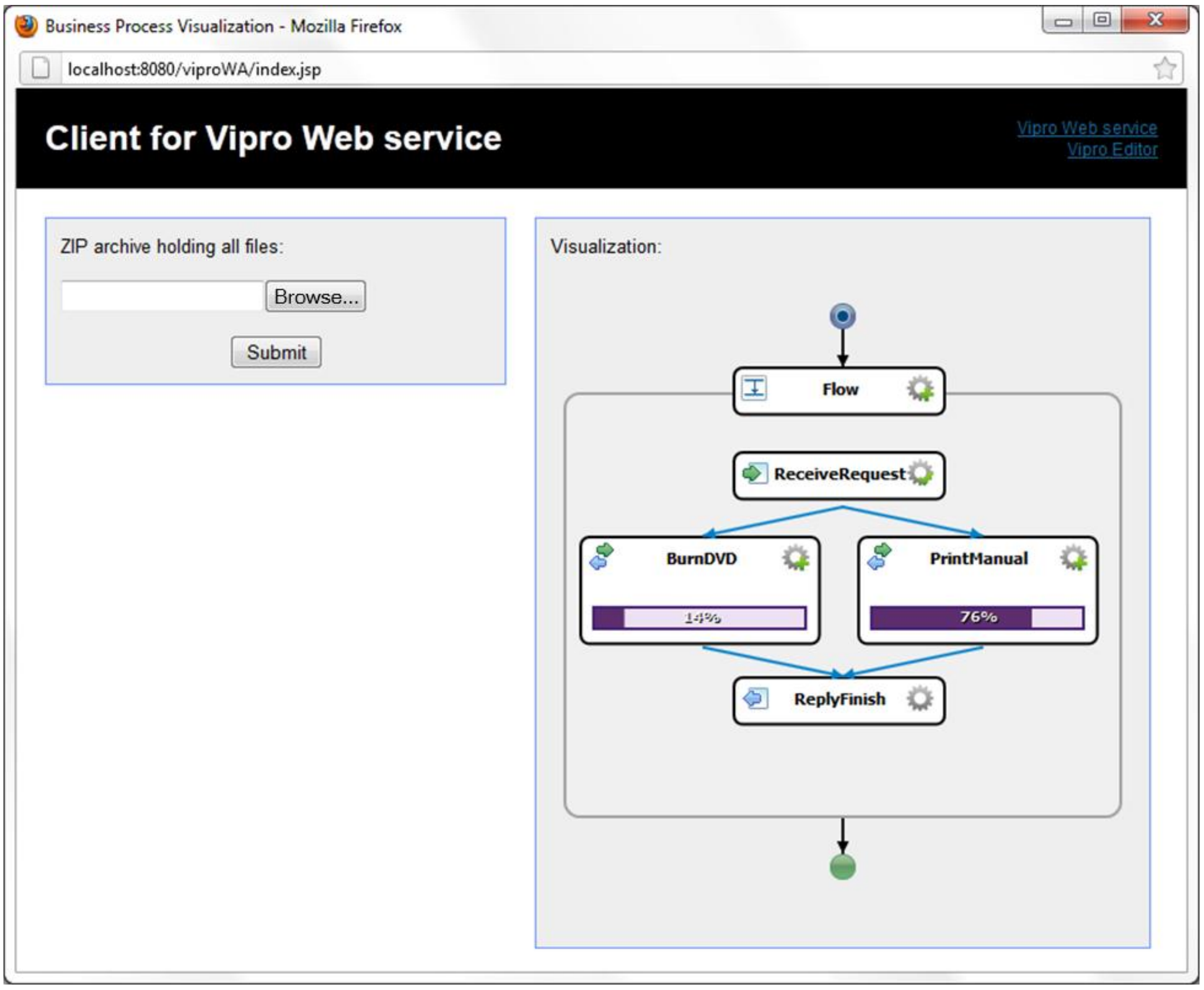

Business Process Visualization - Mozilla Firefox
localhost:8080/viproWA/index.jsp
Client for Vipro Web service
Vipro Web service
Vipro Editor
ZIP archive holding all files:
Browse...
Submit
Visualization:
Flow
ReceiveRequest
BurnDVD
14%
PrintManual
76%
ReplyFinish

Figure 40. A simple client for Vipro Web service showing a visualization of a process instance.

7 Challenges and Solutions

7.1 Integration of SVG Documents

As a result, Vipro should produce an SVG file built of other SVG files and additional notation elements (arrows, borders etc.).

This technical task was formulated in a more abstract way: there are two graphics A (square) and B (circle). The graphic B must be placed into graphic A. SVG format is flexible and provides many ways to combine multiple graphics:

- Define the graphic B directly in the graphic A in the right place. SVG files are XML documents and it is possible to take pieces of one document and put them into another. There are some caveats: SVG file might have a global style sheet and element definitions. These parts must be integrated in the graphic A too. And there are possible name conflicts. So a complicated logic is required to complete this task.
- Insert the complete SVG markup of the graphic B directly into the graphic A. The root tag "svg" of the graphic B must be changed and position coordinates must be set. This solution also has the caveat that style sheet definitions will be global and the main document will override styles of child documents.
- Link the graphic B from the graphic A. This option is much easier to implement. But the graphic B must be linked using a global identifier (URL). It means that it will not be possible to use the graphic offline. It will consist of two files with no possibility to link them with a relative path. This solution, however, allows the graphic B to be cached and reused it in different graphics. This reduces resource consumption and should be used in real-world environments.
- Embed the graphic B into the graphic A. SVG allows a graphic to be embedded using Base64 encoding [38]. Instead of an URL a complete file can be inserted as an encoded string. The embedded document will be decoded by the viewer program and interpreted as a separate file. This is easy to implement and the result is a single file that is context-independent. Mayor draw-back is resource consumption: Base64 encoding will make the graphic B 150% the size of the original. Another drawback is that the graphic B will not be reusable.

Now it is necessary to check if all the options are applicable to the concrete problem – how to integrate multiple templates into one SVG file:

- A single SVG file where all templates are merged into the main file.
- A single SVG file with multiple appearances of large "svg" tags.
- Multiple SVG files where the main file is linked to all the templates.
- A single SVG file where all templates are embedded into the main file.

No contradictions in these four options mean that all of them are possible. But the decision which option to take should be made on an abstract level:

Taking into account that the aim of this work is to create a concept and to prove it, the fourth option is the best choice, because it is easy to implement and the resulting file remains content-independent. The problem with resource consumption is not important for the proof of concept.

Vipro thus uses the fourth option – embedding templates using Base64 directly into the final graphic.

7.2 Icons in Templates

Very often a template needs to contain one or more icons. Nowadays, icons are mostly distributed using a raster format. SVG format is a purely vector format but allows raster images to be linked or embedded.

The BPI used raster icons (for activity types and states) by linking them. This implied that icons must be deployed on the Web server separately. This concept does not fit well in the Use Case UC2, where the Template Designer creates templates independently and supplies only template files.

But there is another option to solve this problem. All icons can be embedded into the SVG file using Base64 encoding [38]. Listing 9 shows the way how it can be done.

```
<image
    xlink:href="data:image/png;base64,iVBOR...5CYII="
    width="20"
    height="20"
    id="imageunknown"
    />
```

Listing 9. The way to embed graphics in the SVG document.

Mayor disadvantage is 33% overhead in size of the embedded graphic. Another disadvantage is that the graphic cannot be cached or reused by different SVG documents.

The Template Designer might also decide to make the image dynamic. To limit the set of allowed images Template Designer can define them all in the SVG file as shown in Listing 10. SVG has a section “defs” where any element can be defined. Later in the document they can be used by referencing their id. Template Designer can make this reference to a Spot which is filled later at Run-Time.

```
<defs>
  <image ... id="unknown" />
  <image ... id="flow" />
  <image ... id="sequence" />
</defs>
...
<use
  xlink:href="#unknown"
  vipro:xlink__href="#{IconId:'Activity type':enum:unknown,flow,sequence}"
  ...
  />
```

Listing 10. The way to make a dynamic icon in a Vipro Template.

If this approach is mixed up with embedded icons then the template file can become very large. And the final visualization will also be very large because each template is integrated into the resulting SVG. This can be resolved by using compression or conversion into a raster graphic. With a compression it is possible to reduce the size up to 20% of the original size [39]. Conversion of a vector graphic into a raster graphic can be resource-consuming and has to happen on the server-side, but it can be then viewed on any client, because raster formats are supported much widely.

7.3 SVG Integration into HTML5 Pages

The Vipro Web Editor displays final SVG graphic in a Web page using the HTML5 [40]. It allows the SVG document to be directly inserted into the Web page document.

Nowadays, the real-world usage of SVG images in Web pages still requires work-arounds, like server-side conversion into a raster format or usage of special plug-ins. The problem is that many old browsers are still in use and have to be supported. For purposes of this work it is of less importance. Vipro Web application requires a browser that supports HTML5.

8 Test Cases

This chapter presents test cases that were executed using Vipro.

8.1 “Resource Consumption”

The following situation is modeled by this test case: a business process consumes a lot of energy while being executed. Business Analyst wants to see where the most energy is consumed. The idea is to make the size of visualized activity to depend on spent energy.

This test case is inspired by [41], where a methodology is proposed that enables organizations amongst others things also “identify, localize and visualize their environmental impact”. Authors propose that KEIs (Key Ecological Indicators) have to be visualized to “enable analyzing the current environmental impact of a process model.” Energy consumption is one of the KEIs and the presented test case shows the way how it can be visualized.

Further in this chapter all artifacts will be presented and the resulting visualization will be explained.

8.1.1 BPEL Process

BPEL process is very simple and consists of few activities. Listing 11 and Figure 41 show the used BPEL file. Two activities – “InsertData” and “RemoveData” are assumed to be energy consuming steps. Other activities are only control activites.

```
<bpel:process ...>
    <bpel:scope name="Scope">
        <bpel:invoke name="InsertData"></bpel:invoke>
        <bpel:compensationHandler name="Compensation">
          <bpel:compensate name="RemoveData"></bpel:compensate>
        </bpel:compensationHandler>
    </bpel:scope>
</bpel:process>
```

Listing 11. BPEL process (A1) for the “Resource consumption” test case.

The process is very simple for demonstration purposes. It consists of one operation that inserts data into storage. It can be energy-consuming because magnetic tape data storage is used. If operation fails, then compensation action has to be taken and data has to be removed. A Business Analyst wants to see if the remove operation is consuming much more energy or not.

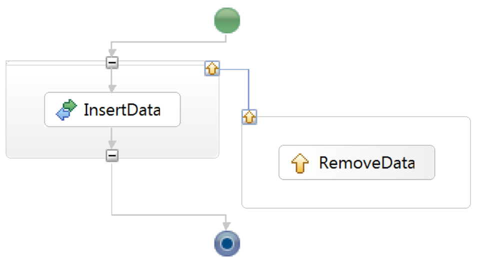


Figure 41. BPEL process for the “Resource Consumption” test case. The visualization was made with Eclipse BPEL Editor.

8.1.2 Vipro Instance Metadata

Vipro Instance Metadata (Listing 12) contains only two parameters: “consumptionValue” – the absolute energy consumption value and “consumptionCoefficient” – relative energy consumption coefficient that is limited to values between 100 and 1000 inclusive.

```
<rtdformat xmlns="http://arapoport/rtd-format">
    <parameters>
        <parameter type="int" name="consumptionValue"/>
        <parameter type="int" name="consumptionCoefficient">
            <min>100</min>
            <max>1000</max>
        </parameter>
    </parameters>
</rtdformat>
```

Listing 12. Vipro Instance Metadata (A2) for the “Resource consumption” test case.

8.1.3 Vipro Templates

Two templates are used in this test case:

- “vipro-template-size.svg” – a template with dynamic width. Figure 42 shows what it looks like without any applied values.
- “vipro-template-fix.svg” – a template with fixed size. Figure 43 shows it.

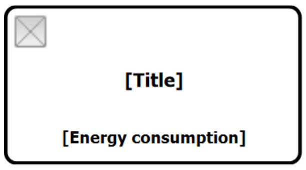


Figure 42. Preview of the Vipro Template featuring dynamic width, icon title and subtitle.

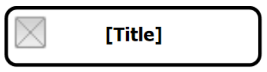


Figure 43. Preview of a Vipro Template featuring dynamic icon and title.

Listing 13 shows most important parts of the template with dynamic width. First two attributes of the root element define Vipro namespaces. Next four attributes define the default size of the graphic. The last two attributes make width attributes dynamic using Spot “WithId”. Apart from dynamic width this template has three more Spots. “IconId” should be used to represent icons that correspond to the type of the activity. “TitleId” is title text and “SubtitleId” is subtitle text.

```
<svg ...
   xmlns:vipro="http://arapoport/vipro-svg" xmlns:viprometa="http://arapoport/vipro-svg-meta"
   width="170" height="90" viprometa:templateWidth="170" viprometa:templateHeight="90"
   vipro:width="{WidthId:'Width':int}"
   vipro:viprometa__templateWidth="{WidthId:'Width':int}"
>
...
  <use ...
   xlink:href="#unknown"
   vipro:xlink__href="#{IconId:'Activity type':string}"
  />
 ...
  <text ...
    vipro:viproNodeValue="{TitleId:'Title text':string}" >
   [Title]
  </text>
 ...
  <text ...
    vipro:viproNodeValue="{SubtitleId:'Substitite text':string} kWh" >
   [Energy consumption]
  </text>
 ...

</svg>
```

Listing 13. Vipro Template for “Resource Consumption” test case. It features dynamic width, icon for activity type and two custom texts.

8.1.4 Vipro Instance Data

A sample Vipro Instance Data was created manually for this test case because a real monitoring and analysis system is out of scope of this work. The data used is shown in Listing 14. Only two activities got instance data associated with them, because others were just control activities. “InsertData” consumed smaller amount of energy than “RemoveData” did.

```
<rtdinstance xmlns="http://arapoport/rtd-instance">
    <meta/>
    <activities>
        <activity attrName="name" attrValue="InsertData">
            <parameter name="consumptionValue">2</parameter>
            <parameter name="consumptionCoefficient">200</parameter>
        </activity>
        <activity attrName="name" attrValue="RemoveData">
            <parameter name="consumptionValue">3</parameter>
            <parameter name="consumptionCoefficient">300</parameter>
        </activity>
    </activities>
</rtdinstance>
```

Listing 14. Vipro Instance Data for the “Resource Consumption” test case.

8.1.5 Vipro Configuration

The last artifact – Vipro Configuration – is shown in Listing 15. There are three mapping rules defined. First one matches all activities that are not matched by other rules. It assigns them the “vipro-template-size.svg” template. Its width is mapped to the “consumptionCoefficient” parameter. Subtitle is mapped to “consumptionValue”, icon – to activity’s type and title – to activity’s name. Two remaining rules set “vipro-template-fix.svg” template for activities of types “scope” and “compensationHandler”. This is done because these activities are control activities and do not have significant energy consumption.

```xml
<vipro-cfg xmlns="http://arapoport/vipro-cfg">
    <mappings>
        <mapping>
            <activity></activity>
            <template name="vipro-template-size.svg">
                <parameter spotid="WidthId" paramid="consumptionCoefficient"/>
                <parameter spotid="SubtitleId" paramid="consumptionValue"/>
                <parameter spotid="IconId" staticValue="vipro:type"/>
                <parameter spotid="TitleId" staticValue="vipro:name"/>
            </template>
        </mapping>
        <mapping>
            <activity nodeName="scope"/>
            <template name="vipro-template-fix.svg">
                <parameter spotid="IconId" staticValue="vipro:type"/>
                <parameter spotid="NameId" staticValue="vipro:name"/>
            </template>
        </mapping>
        <mapping>
            <activity nodeName="compensationhandler"/>
            <template name="vipro-template-fix.svg">
                <parameter spotid="IconId" staticValue="vipro:type"/>
                <parameter spotid="NameId" staticValue="vipro:name"/>
            </template>
        </mapping>
    </mappings>
    ...
</vipro-cfg>
```

Listing 15. Vipro Configuration for the “Resource Consumption” test case.

8.1.6 Result

All prepared artifacts were submitted to Vipro Web service. Produced visualization is shown in Figure 44. Although the test case process has only few activities, it is immediately clear that “RemoveData” consumes more energy than “InsertData” does.

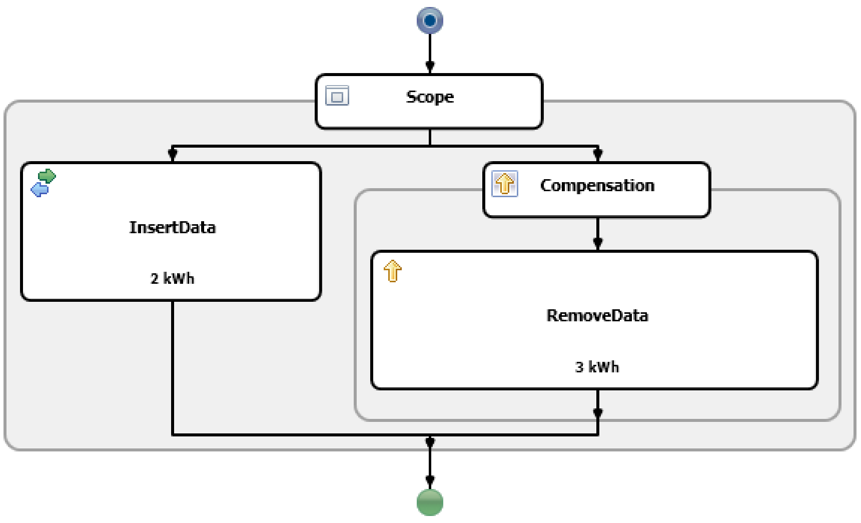


Figure 44. Visualization made by Vipro for the "Resource Consumption" test case. From the visualization it becomes immediately clear that "RemoveData" consumes more energy than "InsertData" does.

Also it is visible that icons and titles were set for all activities.

8.1.7 Aggregated Data Visualization

The situation modeled in this test case may also require showing the aggregated information about multiple executions of the process and not about a single process instance as before. Aggregated information can also be visualized using Vipro. To do this only Vipro Instance Data must be changed: the single execution values must be replaced with aggregated values.

8.2 “Security Levels”

The following situation is modeled in this test case: some activities of the process communicate with external processes and services. A different communication protocol is in use. They provide different level of security. A Business Analyst wants to check how secure the process is.

There are 4 security levels (Table 5).

Level	Name	Description	Color
0	n/a (not applicable)	No communication takes place	White
1	None	Not secure at all – anybody can access the data	Red
2	Low	Anybody within the involved companies can access the data	Yellow
3	High	Only sender and recipient have access to data	Green

Table 5. Security levels for the “Security Levels” test case.

Possible communication protocols are:

- HTTP (Hypertext Transfer Protocol) – a standard protocol of the Web. It is not secure at all and can be easily read by intermediaries. It corresponds to level 1.
- VPN (Virtual Private Network) – a virtual private network that is secured from rest of the internet. It corresponds to level 2.
- HTTPS (Hypertext Transfer Protocol Secure) – is a protocol that works over HTTP and provides secure communication between user and Web server. It corresponds to level 3.
- SSH (Secure Shell) – is another network protocol for secure data communication. It corresponds to level 3.

The used BPEL fulfills the order of the customer. First a customer places an order over the internet (using HTTP, or, probably, HTTPS). Then the order gets validated and is either processed or refused. If it gets processed then the shipping department is asked to make the shipping. The billing department also gets involved to charge the customer. Communication between departments can happen in different ways. In the last step the customer gets a confirmation over the internet. If the order is refused then the customer also gets a reply.

Vipro Template shown in Figure 45 is used for all activities. It has dynamic background color: four available colors are explicitly defined in the template using numbers from 0 to 3. It also features icons for type and state of the activity. Two titles can be set on it.

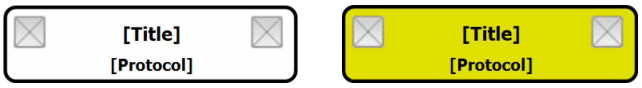


Figure 45. Vipro Template for the "Security Levels" test case. It features dynamic background color, two icons and two titles. Figure shows two possible background colors from four.

In the Vipro Configuration background color was mapped to the security level used by each activity. Title was mapped to the name of the activity. Subtitle was mapped to the used communication protocol.

Vipro Instance Data was also created manually and had following data: customer made order over HTTP, shipping was requested over VPN, billing was requested over SSH and the reply was made using HTTPS. Refusal branch was not executed at all.

The resulting visualization is shown in Figure 46. The Business Analyst can immediately see that a user makes an order over an insecure protocol and this is the weakest place of the process. The Business Analyst can also see that shipping requests can be more secure but is not critical. Other activities are OK or do not communicate at all.

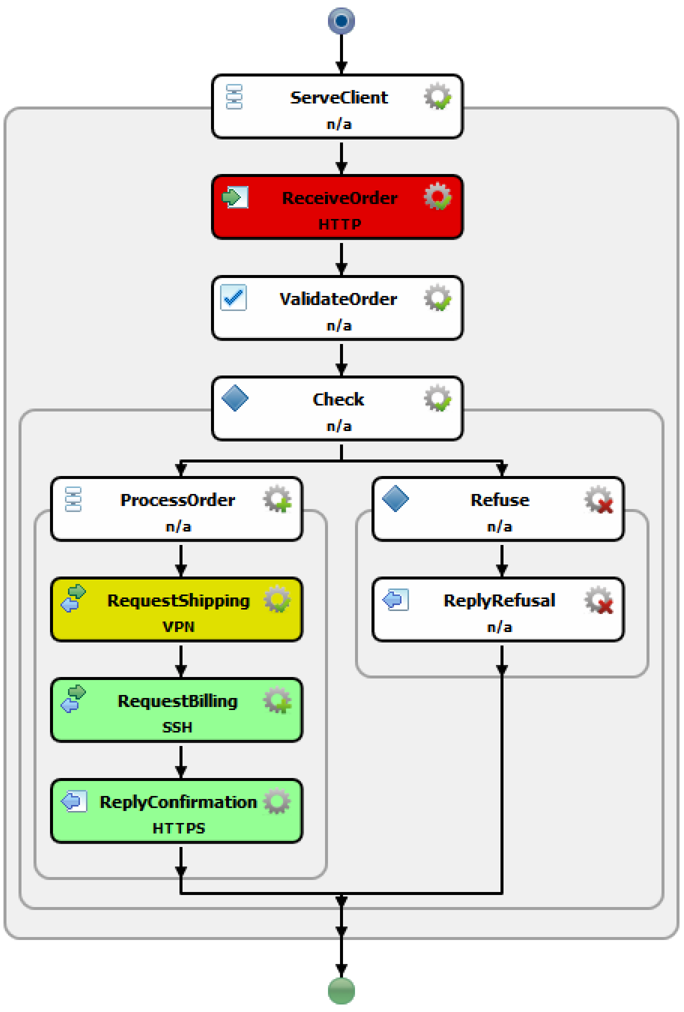


Figure 46. Resulting visualization for the "Security Levels" test case.

8.3 “Long Running Process”

Another test case that shows that templates can easily use progress bars.

The test case process is very simple: it has two long running activities executed in parallel (it was introduced before in Figure 33). One burns a DVD disc and another prints a manual. Because both of them take some time it is imaginable that somebody will want to check their progress.

To visualize the progress a template with a progress bar is used, as shown in Figure 47. Progress bar can show any value between 0 and 100.

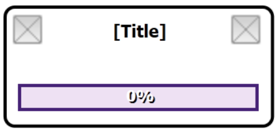


Figure 47. Vipro Template for the “Long Running Process” test case. It features a progress bar.

It is achieved solely using SVG. The progress value is controlled by a single Spot, as shown in Listing 16. The filling of the progress is represented by a single rectangle (Line 1). Its height is fixed because the progress bar is positioned horizontally. Its width should be 0 pixels if the value is 0% and 146 pixels if the value is 100%. To map two different intervals the SVG “scale” transformation is used (Line 3). It takes two arguments: the first is multiplied with original width of the element and the second is multiplied with the height. To use this transforamtion the original width of the rectangle is set to “1.46” (Line 2). First parameter of the “scale” transformation is made dynamic and second is set to 1 because the height must stay fixed (Line 4). The percentage value shown on top of the progress bar uses the same Spot ID and shows exactly the same value as drawn in the progress bar.

```
Line 1:  <rect ...
Line 2:   width="1.46"
Line 3:   transform="scale(0,1)"
Line 4:   vipro:transform="scale({PercentageId:'Percentage value':int},1)"
Line 5:   />
```

Listing 16. Implementation of the filling for a progress bar in a Vipro Template.

All other Spots in the template are identical to the Spots in previous test cases. Vipro Instance Metadata, Vipro Instance Data and Vipro Configuration have nothing special or interesting and were left out.

The resulting visualization is shown in Figure 48. State icons (on the right) show, that “BurnDVD” and “PrintManual” activities are executed. Their progress is 14% and 76%.

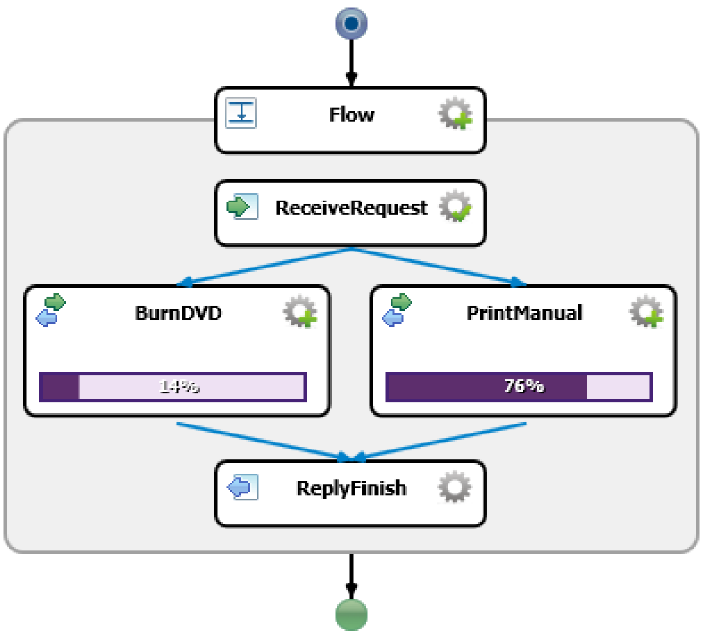


Figure 48. Resulting visualization for the "Long Running Process" test case.

8.4 "Car Wash"

Another test case is also inspired by resource consumption. The process model used is a car washing process, which consists of several sequential steps: prewash, soap, optional underbody wash, exterior wash, dry and optional wax polishing. The Business Analyst wants to check how much water is spent on each step. A straightforward solution with a standard template is shown in Figure 49 for some sample data. Although the information about water consumption is presented, the visualization is not very expressive.

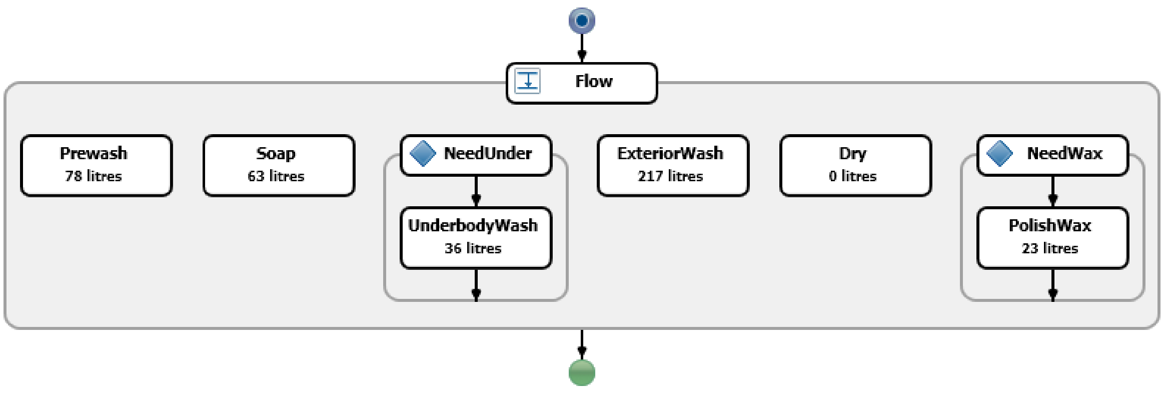


Figure 49. Straightforward visualization for the "Car Wash" test case.

To make it more expressive a special template is used. It is shown in Figure 50.

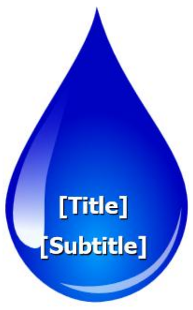


Figure 50. Vipro Template for the "Car Wash" test case. Size of the water drop is dynamic.

The resulting visualization made by Vipro is shown in Figure 51 for the same sample data. It is much more expressive. It is immediately clear that the most quantity of water is spent on the "exterior wash" step. "Wax polishing" step spends so little water that it is hard to read. And "dry" step is not visible at all, because it got a zero size assigned.

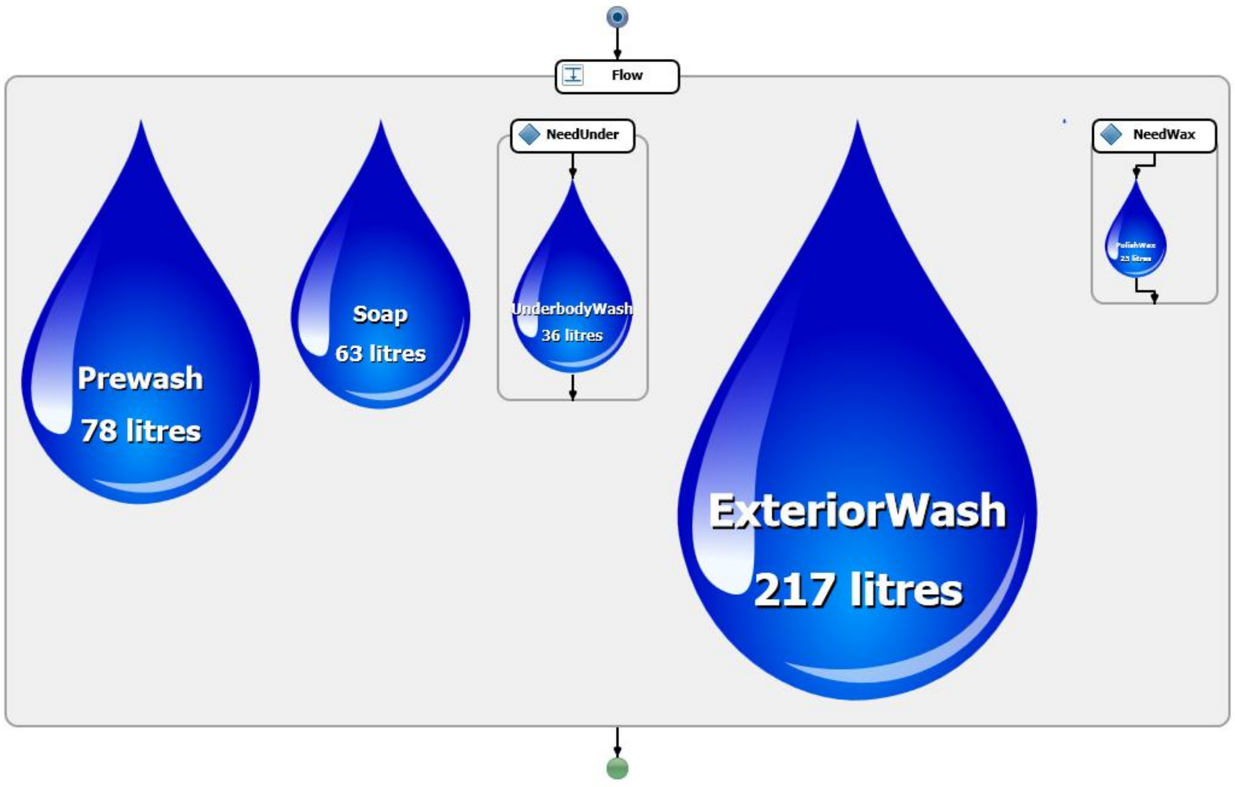


Figure 51. Resulting visualization for the "Car Wash" test case.

This test case shows that any kind of template graphics may be used.

8.5 “Large Process”

The last test case illustrates that larger processes with many activities can be visualized, too. The sample process model “Mobile Virtual Network Operators scenario” [42] has more than a hundred activities. The resulting visualization with random sample data is shown in Figure 52. Two templates were used. “Assign” activities are visualized using squares and all other activities use circles. The color of activities is mapped to the execution time of the corresponding activity. The redder is the color the more time the execution took.

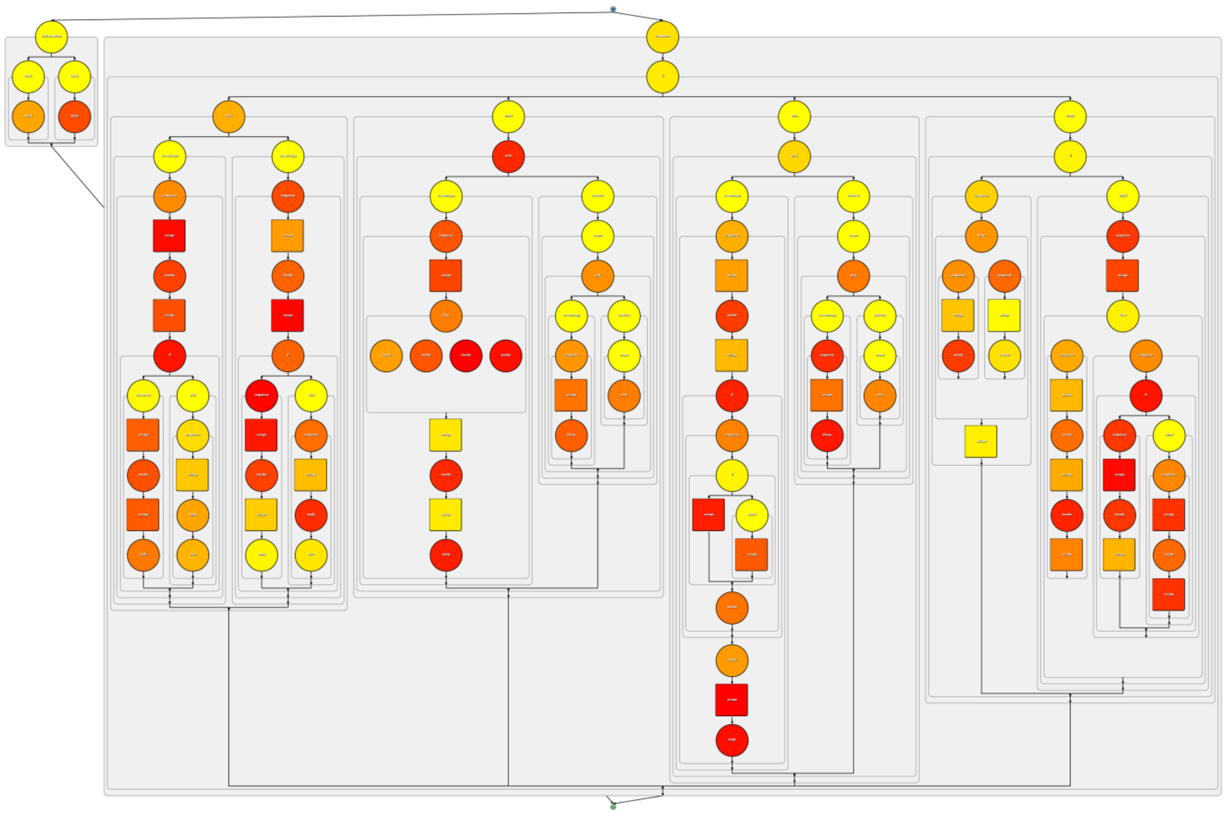


Figure 52. Visualization for the “Large Process” test case.

This visualization took approximately two seconds in total for the Web service to produce it and the browser to render it. This test case is also an illustration of the problematic described in chapter 7.2. This test case uses two templates with no embedded images. Final visualization takes 200 kilobytes (KB). If templates would have embedded images (for all possible activity types and states), then their size would increase from 2 KB to 100 KB. The final visualization would also take about 50 times more space – 10 megabytes. The final visualization being converted into the raster format PNG would take 600 KB. This illustrates the importance of the correct approach for using icons in templates.

8.6 Overview of Sample Templates

Table 6 shows an overview of templates used in test cases.

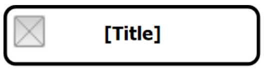
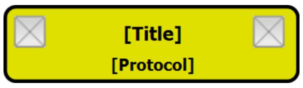
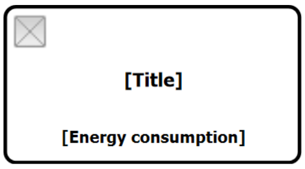
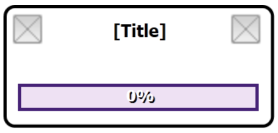
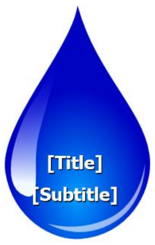
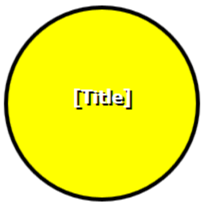
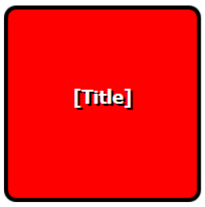
Template	Spots	Preview
“Small box”	• Activity type icon • Title	
“Normal box”	• Background color (white/red/yellow/green) • Activity type icon • Activity state icon • Title • Subtitle	
“Sizeable box”	• Width • Activity type icon • Title • Subtitle	
“Progress bar”	• Progress bar • Activity type icon • Activity state icon • Title • Subtitle	
“Drop”	• Width • Height • Title • Subtitle	
“Circle”	• Background color (yellow to red) • Title	
“Square”	• Background color (yellow to red) • Title	

Table 6. Overview of templates used in test cases.

9 Summary and Outlook

9.1 Summary

Concept and solution for configurable visual representations for business process monitoring have been created in this work. The concept enables the loose coupling between templates, processes and data. That, in its turn, allows visual designer, business analysts and information designer to collaborate in an efficient and independent way.

The concept has been prototypically realized and four new formats have been defined. Vipro format for template definitions is fully compatible with SVG because of special Vipro attributes that can be easily added to any SVG document. It allows any visual designer to prepare templates, because no technical knowledge is required. In comparison to [10] and [14], which keep the template format very complicated, this constitutes a major improvement. Vipro Instance Metadata describes the Run-Time data format. It is a metamodel for the Run-Time data and allows usage of any data provider without making any statements about its nature. In comparison to [13], it is a more simple and architecture-independent solution. Vipro Instance Data format is a model for the Run-Time data that meets the requirements of a concrete Vipro Instance Metadata. The fourth format is the Vipro Configuration, which composes all artifacts to define configured process visualization.

The Vipro prototype has been developed as proof of concept. It consists of three components. One is Vipro Library that provides functionality for work with each of the formats, plus it provides visualization functionality. The second component is Vipro Web service, which uses Vipro Library and provides visualization functionality to any kind of clients. The last component – Vipro Editor – is a Web application where Vipro Instance Metadata and Vipro configurations can be built using a GUI.

From the more general point of view, Vipro is an implementation of “Appearance Patterns” from [25].

Test cases that have been presented in the very end to illustrate the capabilities of Vipro.

9.2 Outlook

While this work was conducted, many new problems became clear. In some places it was necessary to draw a line and limit the work to some abstractions or assumptions. All of them can be developed further. In this last chapter they are all presented.

Instance data metamodel. Vipro Instance Metadata is a quite simple solution. As shown in chapter 5.3.1.1, XML Schema is a better solution but requires more advanced implementation.

“Presentation patterns”. Vipro realizes only “Appearance Pattern” from [25]. But there are also “Scheme pattern” and “Layout pattern”, which were not realized. Vipro can be extended to support them, too. For example, current layout engine can be extended to support horizontal layout, too. “Theme pattern” would require deeper changes in Vipro in order to be supported.

Interchangeable layout engine. Vipro uses a layout engine that extends BPI. It is possible to define the interface to the layout engine and make it interchangeable. This is directly connected with “Scheme pattern” because it is unlikely that one engine will be able to support different “scheme patterns”. It is more likely that different schemes are supported by different engines.

Instance Data transformation. Vipro Instance Data is put directly into the template. But often the data has to be transformed first (chapter 3.3.2). Here loose coupling is not yet fully achieved.

Embedding vs. linking. Vipro Templates can become relatively large because of embedded icons. Final visualization can have duplicate definitions of embedded style sheets (chapter 7.1). To solve this, images and style sheet should be linked using URLs. This will enable caching and reuse of resources, but will make templates tightly coupled to the resources used. This is already possible because Vipro templates are completely transparent and both approaches work well.

Stateful Web service. Vipro Web service is stateless (chapter 6.3). It implies that each time the full context must be provided with the request. This approach can be resource consuming. This problem can be solved by making the Web service stateful. For example, a session mechanism can be used. In this case process model, templates, Vipro Instance Metadata and Vipro configuration can be uploaded once and then be reused. Later in each request only the latest Vipro Instance Data will be provided. This will save not only the network traffic but also parsing time for artifacts.

Interactivity. Currently, visualizations made with Vipro are completely static and the user cannot interact with templates. But templates are SVG based and in SVG it is possible to add Java Script code to any elements. It makes an interaction with the user possible. For example, an activity can show more details when a user clicks it. In combination with HTML5, which supports SVG, even more is possible.

Vipro Editor can be made much better. Probably, the most useful feature would be the visually-enabled editing of a Vipro Configuration. For example, the process model can be visualized so that the user could select activities, which should be targeted by a mapping rule.

Acknowledgments

This work would not have been possible without the support of two people.

The author wishes to express his gratitude to his supervisor, David Schumm who was abundantly helpful and offered invaluable guidance and support.

The author wishes to express his love and gratitude to his wife Kate for her patience, love and language support.

Bibliography

[1] F. Leymann, *Skript Workflow Mamagement*, 2010.

[2] D. L. Moody, *The "Physics" of Notations: Towards a Scientific Basis for Constructing Visual Notations in Software Engineering,* IEEE, 2008.

[3] J. Larkin and H. Simon, "Why a Diagram is (Sometimes) Worth," *Cognitive Science,* no. 11, 1987.

[4] OASIS Open, "Web Services Business Process Execution Language Version 2.0," 11 04 2007. [Online]. Available: http://docs.oasis-open.org/wsbpel/2.0/OS/wsbpel-v2.0-OS.html. [Accessed 19 10 2011].

[5] D. Schumm, *Information Design for Business Process Management,* The 5th Summer School on Service Oriented Computing (Summer SOC), Poster Session, 2011.

[6] Eclipse Foundation, "BPEL Designer Project," 2011. [Online]. Available: http://www.eclipse.org/bpel. [Accessed 18 10 2011].

[7] Oracle, "Oracle JDeveloper," 2011. [Online]. Available: http://www.oracle.com/technetwork/developer-tools/jdev/overview/index.html. [Accessed 18 10 2011].

[8] Signavio GmbH, "Signavio Process Editor," 2011. [Online]. Available: http://www.signavio.com/en/products/process-editor-as-a-service.html. [Accessed 18 10 2011].

[9] Object Management Group, Inc., "Business Process Model and Notation (BPMN) Version 2.0," 01 2011. [Online]. Available: http://www.omg.org/spec/BPMN/2.0/. [Accessed 18 10 2011].

[10] E. Krämer, "Anpassbare Darstellung von Prozessmodellen, Diplomarbeit Nr.3062," *Universität Stuttgart, Fakultät Informatik und Elektrotechnik,* 2010.

[11] W3C, "Scalable Vector Graphics (SVG) 1.1 (Second Edition)," 16 08 2011. [Online]. Available: http://www.w3.org/TR/SVG/. [Accessed 24 10 2011].

[12] W3C, "Document Object Model (DOM) Technical Reports," 2004. [Online]. Available: http://www.w3.org/DOM/DOMTR.html. [Accessed 18 10 2011].

[13] R. Bobrik, "Konfigurierbare Visualisierung komplexer Prozessmodelle, PhD Thesis," 2008.

[14] R. Bobrik, T. Bauer and M. Reichert, "Proviado – Personalized and Configurable Visualizations of Business Processes," in *Proc. 7th Int'l Conf. on Electronic Commerce and Web Technologies (EC-WEB'06)*, Krakow, 2006.

[15] OASIS Open, "WS-BPEL 2.0 Primer," 09 05 2007. [Online]. Available: http://docs.oasis-open.org/wsbpel/2.0/Primer/wsbpel-v2.0-Primer.pdf. [Accessed 19 10 2011].

[16] The Apache Software Foundation, "Apache ODE," 06 02 2011. [Online]. Available: http://ode.apache.org/. [Accessed 19 10 2011].

[17] The Apache Software Foundation, "ODE - Architectural Overview," [Online]. Available: http://ode.apache.org/architectural-overview.html. [Accessed 19 10 2011].

[18] S. Probets, J. Mong, D. Evans and D. Brailsford, "Vector Graphics: From PostScript and Flash to SVG," New York, NY, USA, 2001.

[19] Inkspace, "Inkspace," [Online]. Available: http://inkscape.org/. [Accessed 16 10 2011].

[20] "Proposal for a diploma thesis "Environmentally-aware Visualization of Business Processes"," [Online]. Available: http://www.iaas.uni-stuttgart.de/lehre/studarb/diplomarbeiten/DA_Environmentally-aware_Visualization_of_Business_Processes.pdf. [Accessed 26 10 2011].

[21] F. Leymann, *Skript - Message-Based Applications - Messaging Endpoints*, 2010.

[22] G. Latuske, "Sichten auf Geschäftsprozesse als Werkzeug zur Darstellung laufender Prozessinstanzen, Diplomarbeit Nr. 3036," *Universität Stuttgart, Fakultät Informatik und Elektrotechnik*, 2010.

[23] Oracle, "BPEL2SVG Generator," 2008. [Online]. Available: http://blogs.oracle.com/toxophily/entry/open_esb_tip_generating_svg. [Accessed 16 10 2011].

[24] The Apache Software Foundation, "Apache License, Version 2.0," 01 2004. [Online]. Available: http://www.apache.org/licenses/LICENSE-2.0.html. [Accessed 16 10 2011].

[25] D. Schumm, F. Leymann and A. Streule, "Process Viewing Patterns," in *Proceedings of the 14th IEEE International EDOC Conference, EDOC 2010, 25-29 October 2010*, Vitória, 2010.

[26] F. Leymann, *Skript "Foundations Of Architecture Of Application Systems"*, 2009.

[27] W3C, "XML Schema," 28 10 2004. [Online]. Available: http://www.w3.org/XML/Schema. [Accessed 21 10 2010].

[28] Oracle, "Java EE at a Glance," [Online]. Available: http://www.oracle.com/technetwork/java/javaee/overview/index.html. [Accessed 21 10 2011].

[29] The Apache Software Foundation, "Apache Commons project," 13 10 2011. [Online]. Available: http://commons.apache.org/. [Accessed 21 10 2011].

[30] Oracle, "Java Architecture for XML Binding (JAXB)," 03 2003. [Online]. Available: http://www.oracle.com/technetwork/articles/javase/index-140168.html. [Accessed 21 10 2011].

[31] Vaadin Ltd, "Vaadin," 2011. [Online]. Available: https://vaadin.com. [Accessed 21 10 2011].

[32] Oracle, "Java Servlet Technology," [Online]. Available: http://www.oracle.com/technetwork/java/javaee/servlet/index.html. [Accessed 21 10 2011].

[33] The Apache Softwtware Foundation, "Apache Axis2/Java," 30 08 2011. [Online]. Available: http://axis.apache.org/axis2/java/core/. [Accessed 21 10 2011].

[34] W3C, "SOAP Specifications," 27 04 2007. [Online]. Available: http://www.w3.org/TR/soap/. [Accessed 21 10 2011].

[35] W3C, "Web Services Description Language (WSDL) Version 1.1," 15 03 2001. [Online]. Available: http://www.w3.org/TR/wsdl. [Accessed 24 10 2011].

[36] OASIS, "OASIS Web Services Resource Framework (WSRF) TC," 2011. [Online]. Available: www.oasis-open.org/committees/wsrf/. [Accessed 22 10 2011].

[37] Vaadin Ltd., "Book of Vaadin," 22 10 2011. [Online]. Available: https://vaadin.com/download/book-of-vaadin/current/pdf/book-of-vaadin.pdf. [Accessed 23 10 2011].

[38] Network Working Group, "The Base16, Base32, and Base64 Data Encodings (rfc4648)," 10 2006. [Online]. Available: http://tools.ietf.org/html/rfc4648. [Accessed 23 10 2011].

[39] Adobe Systems Incorporated, "Saving compressed SVG (SVGZ)," 2011. [Online]. Available: http://www.adobe.com/svg/illustrator/compressedsvg.html. [Accessed 24 10 2011].

[40] W3C, "HTML5," 25 05 2011. [Online]. Available: http://www.w3.org/TR/html5/. [Accessed 23 10 2011].

[41] A. Nowak, F. Leymann, D. Schumm and B. Wetzstein, "An Architecture and Methodology for a Four-Phased Approach to Green Business Process Reengineering," in *Proceedings of the 1st International Conference on ICT as Key Technology for the Fight against Global Warming - ICT-GLOW*, 2011.

[42] *The COMPAS Project: WatchMe Case Study*, 2010.

Table of Figures

Table of Listings

List of Tables

Erklärung

Ich versichere, dass ich diese Arbeit selbstständig verfasst und nur die angegebenen Hilfsmittel verwendet habe.

____

(Andrejs Rapoports)