Universidade do Minho
Escola de Engenharia

Paulo Cristiano Pinheiro Faria

Web-base user interface prototyping and simulation

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Paulo Cristiano Pinheiro Faria

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Professor José Francisco Creissac Campos

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A special thanks to the family who gave me the conditions to study and support my decisions; to my friends who helped me and contributed to my motivation; to Paolo Masci and Patrick Oladimeji, researchers at QMUL, for the availability and willingness to answer questions about PVSio-web; and to my advisor José Francisco Creissac Campos for the opportunity and continuous help, for making corrections and valuable suggestions.

ABSTRACT

Animation of user interface prototypes simulating their behavior and analyzing the correctness of their specifications, resorting to formal methods.

PVSio-web is a platform for the simulation and prototyping of user interfaces that has been developed by researchers at Queen Mary University of London. This platform aims to reduce barriers to the use of PVS by users unfamiliar with formal methods.

The main features of PVSio-web focus on creating, opening and saving projects, loading images and creating widget areas over them, and not least, editing PVS files. Editing files is limited to only one file per project and the platform also does not have image editing features. PVSio-web can then be improved by implementing features to support editing multiple files and images (such as cropping and resizing). The interaction areas can also be improved to thereby enhance the quality of the prototype, by adjusting the precision of the dimensions and positioning of the area relatively to the image.

In this dissertation the improvements achieved on the editing of files, images and interaction areas in PVSio-web, in order to increase the quality and optimize its use in a real environment, are described.

Key words (Theme): User interfaces; PVSio-web; image; file; widget area

Key words (Technologies): JavaScript; D3.js; Node.js; EasyImage.js; CropperUI.js

RESUMO

Animação de protótipos de interface de utilizador, simulando o seu comportamento e analisar a justeza das suas especificações, recorrendo a métodos formais.

PVSio-web é uma plataforma para prototipagem e simulação de interfaces de utilizador que tem vindo a ser desenvolvida por investigadores da Queen Mary Universidade de Londres. Esta plataforma tem por objectivo diminuir as barreiras à utilização do PVS por parte de utilizadores não familiarizados com métodos formais.

Para dar suporte à criação de protótipos, o PVSio-web possui funcionalidades para criar, abrir e gravar projectos, carregar de imagens e definir áreas de interação sobre esta e, não menos importante, edição de ficheiros PVS. A edição de ficheiros está limitada a apenas um único ficheiro por projecto e a plataforma não possui também funcionalidades de edição de imagem. O PVSio-web pode então ser melhorado com a implementação de funcionalidades para o suporte de edição de múltiplos ficheiros e de imagem (por exemplo corte e redimensionamento). As áreas de interação podem também ser melhoradas para assim aumentar a qualidade do protótipo, ajustando a precisão das dimensões e posicionamento da área em relação à imagem.

Nesta dissertação são descritos os melhoramentos realizados a nível de edição de ficheiros, imagens e áreas de interação no PVSio-web de modo a aumentar a qualidade e otimizar o seu uso em ambiente real.

Palavras Chave (Tema): Interfaces de utilizador; PVSio-web; imagem; ficheiro; área de widget

Palavras Chave (Tecnologias): JavaScript; D3.js; Node.js; EasyImage.js; CropperUI.js

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CODE LISTING

GLOSSARY

PVS – Specification and Verification System

AMD – Asynchronous Module Definition

JS – JavaScript

SVG - Scalable Vector Graphics

HTML – HyperText Markup Language

CSS – Cascading Style Sheets

QMUL – Queen Mary, University of London

1. INTRODUCTION

The growing number of software users increases the challenges of industry: more experienced and demanding users, more diverse interfaces, software used in critical situations requiring higher reliability. Formal methods can perform an important role supporting systematic and exhaustive reasoning about the design of a system, leading to the creation of more reliable software [22, 23]. However, being more reliable does not necessarily means being better in terms of usage experience. As such, the need to validate the model from a user perspective has been identified. Thus, prototyping may have the ability to complement formal verification.

Researchers at Queen Mary University of London (QMUL) have been using a web-based approach – PVSio-web [21] – where the process of generating a prototype starts with an image of the user interface which is then animated in a browser by linking parts of the image to calls to a model of how the interface should behave. PVSio-web is under development and this project will reflect on further contributions to it.

1.1 Project Description

PVSio-web is a tool for the rapid prototyping of devices' user interfaces, which extends the simulation component of the PVS (Specification and Verification System) proof system [21]. PVS is a verification system that provides a specification language integrated with a suite of tools that supports editing and proving properties of formal models written in its specification language.

PVSio-web supports image and file editing. On the one side, file editiing enables showing and editing a PVS specification and type-checking the specification in the PVS system. On the other, at this point image editing enables uploading an image and drawing widget areas over it. Widget areas are drawn to identify interaction areas, such as buttons or displays, to be linked to the specification variables that they will represent. After created and, even, saved, widget areas can be edited to adjust or correct their configurations.

In summary, PVSio-web supports the editing of one file source, image upload and widget area editing. PVS specifications, however, can be constituted by more than one file, which creates the opportunity to improve PVSio-web to support multi-files editing. Currently, image editing may not be a correct term for what is supported as it is a single upload feature. Editing the image by resizing or cropping in order to better define the limits of the image or highlight a specific area may increase the prototyping quality. Image editing features can be explored to better adjust the image to the prototyping needs. Speaking of increase prototyping quality, widget areas are not always drawn with the right dimensions or in the correct coordinates to match the intended areas of the image. These make resizing widget area another, and not least important, feature to consider for contribution.

1.2 User interface prototyping from formal models

A number of other tools also support some form of user interface prototyping from of formal model of the user interfaces.

The IVY workbench, which has been developed at the Department of Informatics of the University of Minho, is a model based tool for the analysis of interactive systems designs, using formal methods [1,2]. The tool act as a front end to the *NuSMV model checker* [6], creating an abstraction layer where models of interactive systems can be developed and analyzed. The *model checker* tries to prove properties of the interface and generates counterexamples when failures happen. These counterexamples illustrate behaviors in which the property is not verified. The model checking process can be time and computational resources intensive. While it is good to prove that the model exhibits desired properties, it is not ideal as a validation tool during model development. In this context, the need for an animator tool that allow user to ‘play’ with the model has been identified.

The latest version of IVY workbench already allows prototyping of interfaces. For one side, a prototyping component for models that supports building a mockup of a user interface in order to playback counterexamples in a more real user interface [3]. For another side, a tool that enables the animation of the models but does not support a representation of the user interface [4].

The power of simulation through an interface prototype is an advantage of PVSio-web against IVY. PVSio-web is able to present a prototype of the user interface and to animate it in runtime according to the model. It can better represent the behavior to the user and provides extra support for the analysis.

Without belittling other model-based prototyping tools or systems, it is also worth mentioning PetShop [24]. PetShop supports and promotes an interactive design process. At run time, users can interact with the specification and the actual state of the application which is an advantage of model-based prototyping regarding to immediately evaluate the impact of a modification.

1.3 Report Structure

The report contains five chapters which are:

1. Chapter 1 – **Introduction:** This chapter presents the scope, project description with a brief state-of-art and intervention areas and related work.
2. Chapter 2 – **PVSio-web:** Introduces PVSio-web giving a state-of-art overview.
3. Chapter 3 – **Web applications background:** Introduces the main concepts of web applications and describes some JavaScript libraries relevant to PVSio-web.
4. Chapter 4 – **PVSio-web implementation:** This chapter describes the PVSio-web implementation, identifying the main components, modules and objects.
5. Chapter 5 – **PVSio-web improvement contribution**: This chapter presents the analysis and implementation of the features added to PVSio-web.
6. Chapter 6 – **Usage example**: This Chapter presents the PVSio-web usage, giving emphasis to the new features.

7. Chapter 7 – **Conclusion:** Description of the objectives achieved, final remarks and presentation of possible future work.

2. PVSIO-WEB

PVSio-web is a tool for the rapid prototyping of device's user interfaces in PVS. PVSio-web extends the simulation component of the PVS proof system, providing a web based prototyping approach. The tool has the aim to reduce the barriers that prevent non-experts in formal methods from using PVS, promoting and facilitating the use of verification tools when developing device user interfaces.

The process of generating a prototype starts with an image of the user interface which is then animated in a browser. Such animation is obtained by linking parts of the image to functions of a model of how the interface should behave. This concept of linking parts of an image – *image mapping* – in HTML, is used to define areas that can be linked in order to animate the image, supporting user interactions.

This image mapping approach consists of a list of coordinates on a specific image intended to identify areas to be linked to different destinations, giving an extended flexibility to the prototyping and simulation environment. It allows the inclusion of idealized images of the user interfaces and the selection of the part that need to be linked to calls to a model in order to support the interactive actions.

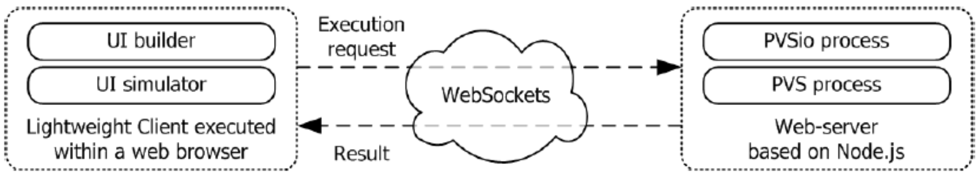
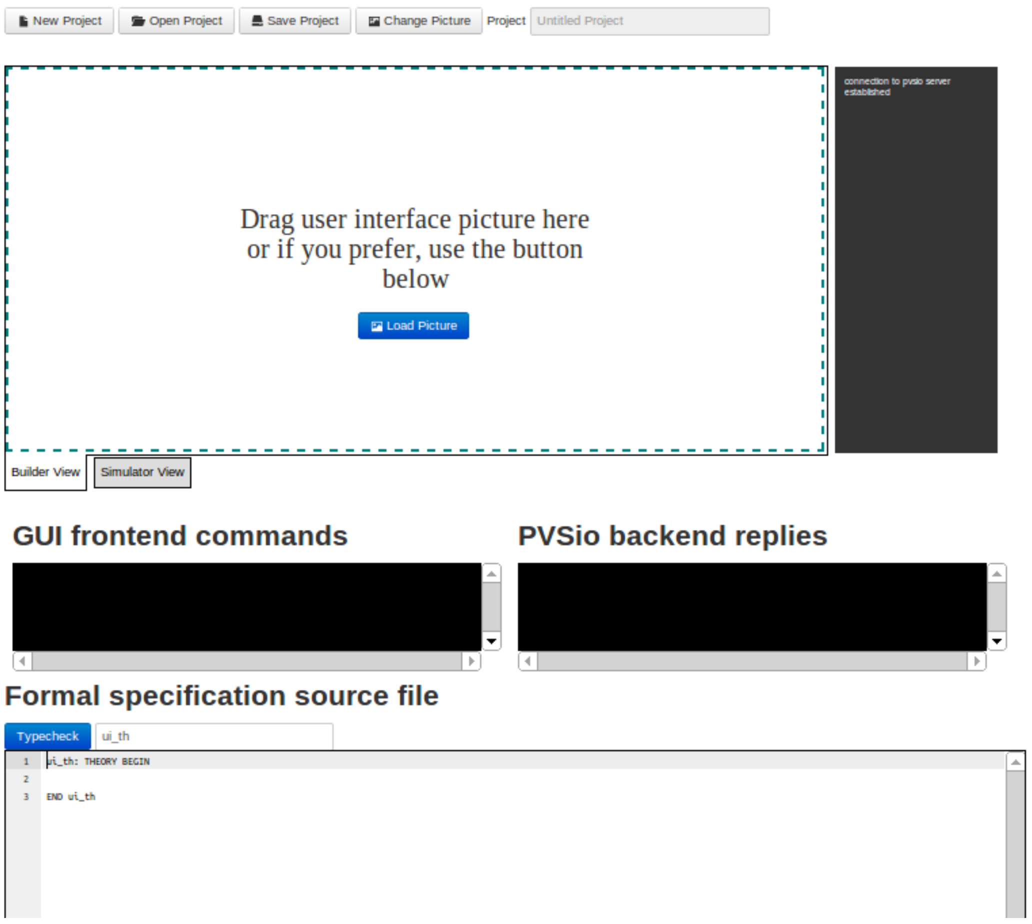


Figure 1 - PVSio-web Architecture [21]

PVSio-web is entirely written in JavaScript. Its distributed architecture is based on a lightweight client and a web-server (see Figure 1).

2.1 Lightweight client

The client shows the graphical front-end that runs on a web-browser as an interactive webpage (see Figure 2). Functionalities such as creating interactive areas over a picture of the layout, support for point-and-click interactions translated into a command for PVS and rendering the returned result visible on the same picture of the layout allow designers to graphically animate the specification of an interactive system. The user interface layout is a picture – like a sketch, rendered image or photography – selected by the designer.



connection to pvsio server established

Drag user interface picture here or if you prefer, use the button below

```
ui_th: THEORY BEGIN

END ui_th
```

Figure 2 - PVSio-web graphical front-end

2.1.1 UI builder

The *UI builder* allows designers to create interactive areas over the layout of the user interface under development, and bind them to a PVS specification. The interactive areas can take one of two types:

1. *Button areas* – input elements whose behavior is specified by functions in the PVS specification;
2. *Display areas* – output elements whose value is specified in the state of the user interface defined in the PVS specification.

The *UI builder* also supports editing the definitions of areas already created. With a single click, areas can be selected and a border is highlighted to identify the selected area. With a double click over some area, an editing form is shown, with configurations that can be modified of a selected area.

2.1.2 UI simulator

The *UI simulator* section is where the user interface is animated. Such animation allows essentially user point-and-click interaction through the interactive areas previously defined in the *UI builder*.

User interactions with button areas will send a request to the web-server specifying the name and arguments of the functions in the PVS specification, to be evaluated by PVS. Results of the execution are returned from the web-server and parsed though regular expressions by the UI simulator.

The value of the state variable associated with display areas are extracted and rendered on the corresponding display areas defined on the user interface layout.

2.1.3 Text editor

The *Text editor* presents the PVS specification. It is the ACE code editor that allows the edition of the shown specification. A button "Type check" sends a command to the web-server for type-checking the specification, with the changes present on the editor.

2.2 Web-server

The web-server hosts processes that runs PVS and PVSio. The PVS process is used to type-check the PVS specification. The PVSio process is used to animate the PVS specification. The input, output and error streams of these processes are accessed over a generic interface exposed by the server.

The client-server communication is based on websockets. After initializing a websocket connection, the client can send requests to the server to start or close a process, or commands to be executed in the running processes. The server will respond with results from the processes through the same connection.

The web-server runs on the Node.js platform. This technology uses an event-driven, non-blocking I/O model which makes scalable applications.

2.3 Conclusion

This chapter has introduced PVSio-web, the system under improvement. An overview was given summarizing its architecture and existing features.

3. WEB APPLICATIONS BACKGROUNG

This chapter discusses concepts considered relevant for a better understanding of PVSio-web as a web application in JavaScript (JS). JavaScript is a programming language generally used by programmers to easily design webpages and add interactive features.

The first section gives an overview of a web applications' architecture and the following ones describe JavaScript libraries that support PVSio-Web functionalities.

3.1 Web applications architecture

"A configurable skeleton of any kind of software beast on which you hang implementation specific muscle to make it live." [1]

Software architecture can be seen as a structured organization (*skeleton*) of different parts of software and how they communicate with each other. Together, the different parts form just one system which provides the required functionalities (*muscles*). Web applications architectures are mainly client-server. This is a network architecture in which tasks or workloads are partitioned between the servers, that provides the resources, and the clients, that requests the resources. Figure 3 presents a usual distributed structure where the client-server architecture is applied. In this example, the clients communicate with a server though the Internet.

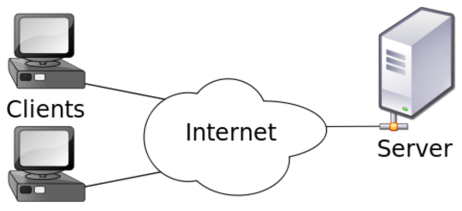


Figure 3 - Client-Server Architecture

[1] Adu Matthaeus, available at: http://www.sei.cmu.edu/architecture/start/glossary/community.cfm [last accessed: 30-09-2013]

In client-server applications the client and server sides are often called frontend and backend respectively. In general, the frontend is what the user can see like a user interface design. Furthermore, the frontend has the responsibility to collect and process the user inputs and then make necessary requests to the backend. The backend gives support to the frontend handling the requests and returning the responses that will be used on frontend. The backend is usually responsible of business logic and database access.

Moreover, frontend and backend may have a complex structure to provide the expected functionalities with quality. Developing Web applications implies the development of the client component and the server component, each having its own architecture and implementation technologies. Since they are often complex structures, it is necessary to manage dependencies between all components. JavaScript has developer's communities that contributes with platforms, frameworks and libraries for both the server and client sides. Particularly relevant to this project's context, node.js is a platform for server development, and d3.js supports operational functionalities on the client. Providing the capability to manage dependencies between different parts of a system, require.js can be used in both server and client components.

3.2 NodeJS

"Node.js is a platform built on Chrome's JavaScript runtime for easily building fast, scalable network applications. Node.js uses an event-driven, non-blocking I/O model that makes it lightweight and efficient, perfect for data-intensive real-time applications that run across distributed devices." [2]

The more well-known applications of JavaScript are related to the frontend, where it is nice to have libraries like jQuery [26], or Prototype [25] at our disposal. JavaScript on the server side is a relatively new concept. Node.js supports this approach which means that it is possible to write an entire application with JavaScript [12]. Node.js makes use of Google's V8 Virtual Machine to

[2] http://nodejs.org/ [accessed at 16-01-2014]

execute JavaScript in the server. Google's V8 Virtual Machine[3] is an open source JavaScript engine written in C++ and is used in the Google Chrome browser. As other libraries, Node.js provides a pack of modules that gives support to common operations.

Node.js underlying execution mode is different from common runtime environments. Node.js introduces the concept of event-driven asynchronous callback. Understanding this concept, event-driven regards detecting and handling events such as user interactions like clicking a submit button or system messages. Each event is assigned a Callback. Callback respects to functions that are evaluated when certain events happen. This permits to subscribe a callback function to an event that will be called when the event happens. Asynchronous means that the system will permit various requests without blocking the entire application (non-blocking), multiple events can be processed simultaneously.

Node.js is used in PVSio-web. To help understand the basis of Node.js, this provides a step-by-step explanation on how to create a simple "Hello World" application [13].

In order to create a simple http server the http package, which is installed by default, must be loaded. This is achieved by using the next code line:

```
var http = require('http');
```

Once the load is done all methods of the module can be used. The server can now be created and started by recurring to the following code:

```
var http = http.createServer();
server.listen(1337, '127.0.0.1');
```

[3] https://code.google.com/p/v8/ [accessed at 16-01-2014]

Where the parameters of the 'listen' method represent a specific port number and URL, respectively. This code should create and start a server doing nothing. The createServer method can take a function as it arguments that is passed in details on the request and response: http.createServer(function(req,res){});. Thus, the "Hello World" can easily be written in the browser by adding the *head* and the *end* response - res. The *end* will contain the words and the *head* will include the content type and status. Code listing 1 presents a simple "Hello World".

```
var http = require("http");
http.createServer(function(req, res) {
      response.writeHead(200, {"Content-Type": "text/plain"});
      response.end("Hello World");
}).listen(1337,'127.0.0.1');
```

Code listing 1 - Simple server in Node.js

In order to handle the requests, the backend needs to be able to look at the HTTP request and extract the requested address as well as GET or POST parameters from it. The information of the request will be available through the *request* object which is passed as the first parameter to the request function – request(request,response). In order to interpret such information, Node.js provides additional modules like *url* which has the utilities for uniform resource locator (URL) resolution and parsing.

3.3 RequireJS

"RequireJS is a JavaScript file and module loader. It is optimized for in-browser use, but it can be used in other JavaScript environments, like Rhino and Node. Using a modular script loader like RequireJS will improve the speed and quality of your code."[4]

Organizing pieces of code into useful modules and accessing the capabilities of modules has been a concern of developers. Separating code into components eases the effort with maintenance and increases reusability. Despite the advantages, organizing code into modules also raises problems. An important aspect is managing dependencies.

[4] http://requirejs.org/ [accessed at: 18-01-2014]

Usually, JavaScript files are loaded using the <script> tags and each file can be dependent on another files. However, the order in which the files are loaded has to obey a rule for correct execution. To load a module that depends on other modules, the other modules need to be loaded first (coming first on the tags list) [14]. Apart from that hand-writing <script> tags is not very scalable, this can be difficult to manage on large projects particularly when scripts start to have many dependencies.

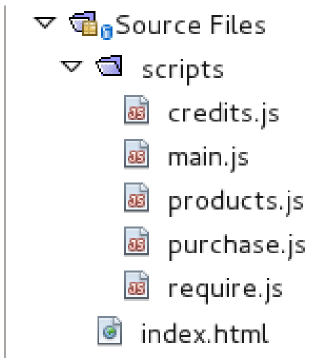

```
Source Files
  scripts
    credits.js
    main.js
    products.js
    purchase.js
    require.js
  index.html
```

Figure 4 - RequireJS, structure exemple [14]

RequireJS' concern is the management of dependencies, contributing with a significant abstraction level to this concern when writing or loading modules [15]. Consider the structure represented in Figure 4. In the example presented, all JavaScript file are located in the scripts folder. The main.js file, like the name suggests, is the initialization point of the application. It is specially used for initialization. The other files contain application logic. In order to get started, it is necessary to add the following line of code to the index.html file.

- `<script src="script/require.js" data-main="script/main"></script>`

That line loads the RequireJS source and defines the initialization point of the application (data-main attribute), loading the main.js. RequiresJS uses the main.js to identify other modules and dependencies.

In order to identify and load modules, require and define functions are the base of the code. The require function is concerned with loading dependencies, and the define function allows modules to be defined. The first parameter of these two functions is used to specify dependencies. Each module can be dependent on one or more modules.

```
o   require( ["dependency01", "dependency02", "dependency03", ...] ,
         function( module01, module02, ... ){
               //callback function code
        });
```

The require function has two arguments. The first is the list of dependencies necessary to be loaded and the second is the callback function. This callback function will be called when all dependencies listed in the first argument are loaded, receiving as parameters the modules that were loaded.

```
define(["credits","products"], function(credits,products) {
   console.log("Function : purchaseProduct");
        return {
            purchaseProduct: function() {
                var credit = credits.getCredits();
                if(credit > 0){
                    products.reserveProduct();
                    return true;
                }
                 return false;
        }
}});
```

Code listing 2 - RequireJS, file purchase.js, define function example 14

Looking again at Figure 4 and assuming that purchase.js depends on credits.js and products.js, consider Code listing 2 as the code contained in the purchase.js file. Analyzing that code it can be seen that a purchase is being defined as a module by the inclusion of the *define* function. The define function follows the same approach as the require function. The dependencies are declared on the first argument and on the second a callback function is defined to be called when all dependencies are loaded. Going back to the example in Code listing 2, the object returns a boolean value that will be passed as a variable to the callback function (this value will be bound to what the module will return). The other modules (credits.js and products.js) present a similar implementation, but will not have any dependencies. The credits.js may return an object while products.js may not return anything.

Finishing this background on RequireJS, it is important to refer that top level files (files that do not define a module) can have a configuration object. A configuration object supports creating reference names to file paths or urls. For example:

- `require.config({ paths: { “dep01”: “scipt/dependency01”, } } ) ;`

With this code, the module dependency01 from the script folder can be referenced through its defined reference name – dep01 – in the configuration object.

3.4 D3js

“With D3, designers selectively bind input data to arbitrary document elements, applying dynamic transforms to both generate and modify content.” [16]

D3 is a JavaScript library for manipulating documents based on data. This exposes the full capabilities of web standards such as CSS, HTML and SVG, combining powerful visualization components and a data-driven approach to DOM manipulation. It supports the generation of an HTML table from an array of numbers or, even, using the same data to create an interactive SVG bar chart with smooth transitions and interaction.

The main operation area of D3 is the construction and manipulation of SVG graphs and charts. SVG – Scalable Vector Graphics – is a language that describes images or two-dimensional graphics with vectors [17]. The DOM allows for straightforward and efficient vector graphics animation via scripting which enables dynamic and interactive SVG drawings.

D3 is fast and supports large datasets and dynamic behaviors for interaction and animation. Further, it supports code reuse through a diverse collection of components and plugins. Although D3 is specialized in SVG, PVSio-web uses it for data manipulation via DOM, similarly to JQuery.

Getting and modifying HTML elements can become a hard chore with traditional methods. D3 employs a declarative approach, operating on arbitrary sets of nodes called selections. For example, if what is intended is to change the text color of paragraph elements, with D3 this can be done with just one single line of code - avoiding the use of manual loops -, as follows:

- d3.selectAll("p").style("color","white");

The "selectAll" method will, as its name suggest, select all html elements with the tag passed as parameter. In the example presented, the method will select all paragraph (p) elements and will apply a style change - all paragraphs will take the color white.

To manipulate individual nodes the "select" method can be used. This method receive as parameter the tag name (if only one node is represented by that name) or the element identification (id).

Furthermore, D3.js supports asynchronous requests through the XHR module which also provides a set of features for data parsing. The main advantage of this is to support interactivity data at the same time that something is being loaded.

3.5 ACE

Ace is a standalone code editor written in JavaScript. It matches features, usability and performance of existing native editors. Furthermore, Ace can be easily embedded in any webpage or JavaScript application.

Among its various features, search and replace with regular expressions, syntax highlighting for over 40 languages, automatic indent and outdent, text drag and drop using the mouse, live syntax checking (currently JavaScript/CoffeeScript/CSS/XQuery), fully customizable key bindings including vim and Emacs modes and more can be highlighted.

Ace can be easily embedded by using one pre-packaged version or by loading contents from the remote repository. The first way will just need the source subdirectory somewhere in a project, like Code listing 3. The second way will need the use of requireJS to load contents.

```
<div id="editor">some text</div>
<script src="src/ace.js" type="text/javascript" charset="utf-8"></script>
<script>
        var editor = ace.edit("editor");
</script>
```

Code listing 3 - Ace editor initialization

The code snippet presented on Code listing 3 shows "editor" as id of the element that should be converted to an editor. This element must be explicitly sized and positioned.

3.6 Conclusion

This chapter has presented the background needed to understand the implementation of PVSio-web, as well as, the structure of its client-server architecture. The server implementation resorts to node.js while the client makes use of d3.js and embeds the ace.js editor. Require.js is used in both sides (client and server) to manage dependencies between the used JavaScript libraries and PVSio-web modules.

4. PVSIO-WEB IMPLEMENTATION

The objective of this project is contribute to PVSio-web with some improvements. In this chapter a description of the PVSio-web implementation state is presented, identifying its relevant architectural elements.

4.1 PVSio-web description

PVSio-web has already a consistent structure. Thus, a detailed study of the architecture was necessary in order to understand the implementation state of PVSio-web. This allowed identify components, packages, modules and objects and libraries in use.

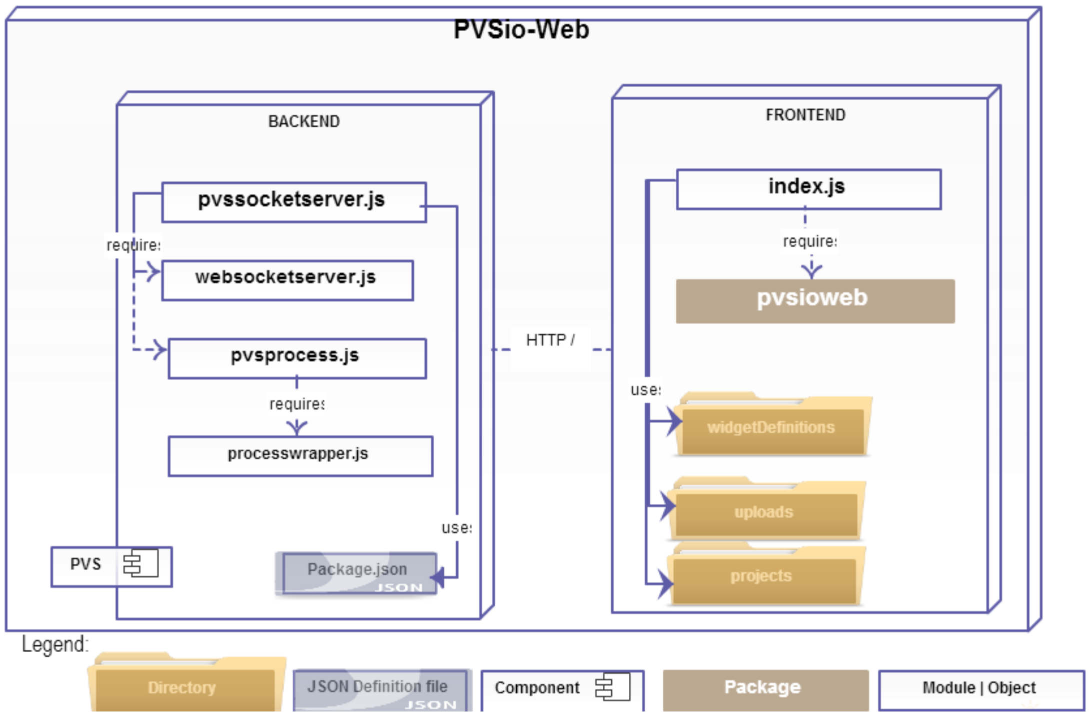


Figure 5 - PVSio-web platform, detailed architecture

As referenced in Chapter 2, PVSio-Web has a client-server architecture. Figure 5 presents the architecture of the tool. A number of different architectural elements is used. The most relevant architectural elements represent (see also the legend in Figure 5):

- Packages, modules and objects are the components of PVSio-web implementation;
- Components represent external systems or services;
- Definition files contain useful definitions to be used by the system;
- Directories represent folders where the system saves files that can be definitions files, temporary files or project files.

The main module of the system is pvssocketserver.js. This module is responsible for creating a node server and a web socket server. The web socket server is specially used for connections to the PVS process. The node.js server answers to PVSio-web and http frontend requests. Complementarily to node.js, PVSio-web uses express.js. Express.js is a node.js framework that provides a roubust set of features to build application, providing a large set of HTTP utility methods.

As the web socket server is used to connect with the PVS process, it is responsible for supporting three interaction commands supported by PVS process. These commands are the following ones:

- sendCommand – for send a PVSio command to the process;
- startProcess – for start the PVS process;
- getSourceCode – for get the PVS source code being executed.

PVSio is a package of the external PVS component. PVSio extends the ground evaluator with a predefined library of imperative programming language features [18]. pvsprocess.js is a module for communicating with a PVS process using PVSio. It resorts to processwrapper.js for spawning, shutting down and sending messages to a PVS process.

The front end is responsible for managing data and dealing with user interactions. index.js is the main object, responsible to managing functionalities and delegating responsibilities. It requires a set of modules and libraries provided in the pvsioweb package. Code listing 4 shows a code snippet with the modules and libraries required by index.js.

```
require(['websockets/pvs/pvsiowebsocket', 'pvsioweb/displayManager',
        'pvsioweb/createOverlay',
        'ace/ace', 'pvsioweb/widgetMaps', 'util/shuffle',
        'pvsioweb/widgetEditor', 'pvsioweb/widgetEvents',
        'pvsioweb/buttonWidget', 'pvsioweb/displayWidget',
        'pvsioweb/displayMappings', "pvsioweb/forms/newProject",
        "pvsioweb/forms/events", "pvsioweb/forms/openProject",
        "pvsioweb/forms/saveProjectAs", 'd3/d3'],
```

Code listing 4 - index.js, code snippet showing required modules and libraries

In order to better understand the frontend dependencies between modules, the forms implementation structure (see Figure 6) will be taken as example. Thus, index.js requires modules that handles creating a form, such as openProject, saveProjectAs and newProject. These modules return a form object but they are not responsible to create the object. Instead, forming a hierarchy line, each one requires the formBuilder module that is the responsible for building forms and emitting events for data change. formBuilder defines form object’s global creation parameters and provides functions for data management. In its turn openProject, saveProjectAs and newProject acquire global characteristics from formBuilder and have their own characteristics defined in an object model.

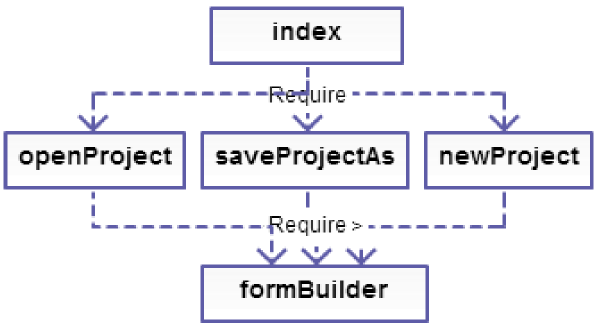


Figure 6 - Forms example, dependencies between modules

Complementarily, formBuilder requires tree modules and one library – util/property, util/eventDispatcher, events and d3/d3, respectively (see Figure 7). d3/d3 is the D3.js library. formBuilder uses d3/d3 to select and append elements in forms, get or set element properties and assign data to the form elements. A map of form events is defined in events. In PVSio-web, each form object handles three types of events: FormCancelled, FormSubmitted, FormDataChanged. The responsible for firing an event on an object, registering an event and invoking a handler is the eventDispatcher module. Finally, and not least, formBuilder uses the property module for defining a form property. It fires property changed events if an incoming configuration property is not equal to an old configuration property.

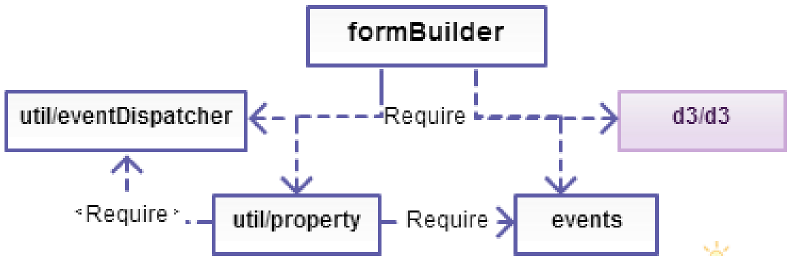


Figure 7 - Forms example, dependencies between event modules

Furthermore and relevant to better understand the next subsections, PVSio-web frontend defines two objects that may be highlighted: currentProject and currentFile.

1. **currentProject** – contains the project definitions relating to the active project. The main properties present on this structure is a project name (property name in Code listing 5), image name (property image), PVS file name (property spec), and a widget definitions object containing regions definitions and widget maps (property widgetDefinition). Code listing 5 presents a complete currentProject structure example.
2. **currentFile** – contains the name and source of the file currently in the editor. An example of this structure is shown in Code listing 6.

```
currentProject = {
        name : "projectname",           //identifies the project name
        projectPath: "../../projectname",//identifies the full path to the project folder
        image: "image.jpg ",  //contain the name of a picture in the project folder
        imageFullPath: "../projectname/image.jpg",//identifies the full path to a picture
        spec: "file.pvs ",  //will contain a PVS file name in the project folder
        specFullPath: "../projectname/file.pvs",//identifies the full path to a PVS file
        widgetDefinition: {//contain region definitions and widget maps read from a widgetDefinition file
        regionDefs: {                   //will contain all region definitions created
                0: {
                class:"ButtonReferenceName",//Two types are supported, Button and Display
                //the area name should contain a type name in the beginning more a reference name
                coords:"25.89,20.20,25.89,20.20",//top,left,with,height coords respectively
                href:"#",               //hyperlink reference, used only for update cache data
                shape:"rect"                    //type of the drawing area
                }
        },
        widgetMaps: {                   //will contain all widget maps related to the region definitions
                ButtonReferenceName: {//area name, this name should be equal to one of the region definitions class.
                events:{                //Two events are supported, click and press/release.
                0:"click",              // Each area may reference one or, even, two events
                1:"press/release"
                },
                functionText:"up",//identifies the name of the function in the PVS specification
                recallRate:"250",//identifies the fraction of relevant instances that are retrieved
                type:"Button"       //Two types are supported, Button and Display
                }
        }
        }
};
```

Code listing 5 - currentProject structure example

```
currentFile = {
        name: "file",
        source: "file:THEORY..."
};
```

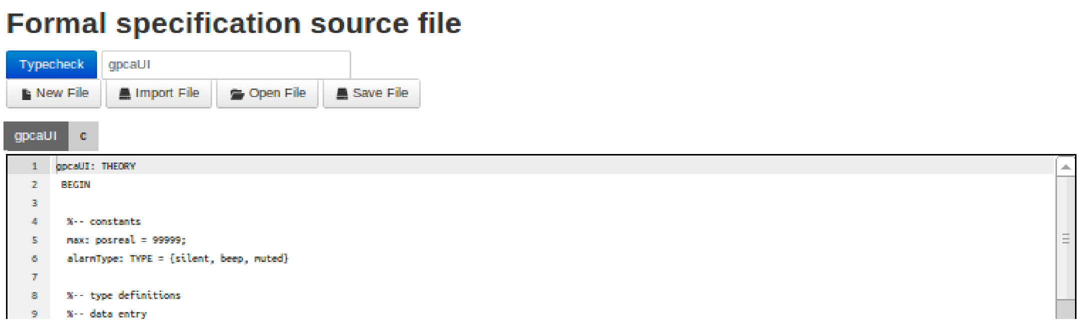
Code listing 6 - currentFile structure example

4.2 Conclusion

This chapter described the PVSio-web implementation, identifying its components, packages, modules, objects and libraries in use. PVSio-web only supports one PVS file editing and does not have image editing features (only supports upload and creating areas over an image). In the next chapter the new functionalities implemented in PVSio-web will be described.

5. PVSIO-WEB IMPROVEMENT CONTRIBUTION

New features were identified to improve PVSio-web. These improvements regard to file and image editing. This chapter will describe the implementation of the new create, open, import and save file functionalities, and the cropping and resizing image functionalities.



```
gpcaUI: THEORY
 BEGIN

  %-- constants
  max: posreal = 99999;
  alarmType: TYPE = {silent, beep, muted}

  %-- type definitions
  %-- data entry
```

Figure 8 - PVSio-web toolbar and file editor

5.1 File Editing

PVSio-web currently supports editing and type-checking of specifications. However, it only supports the presence of a single PVS file per project. This is limiting because the PVS allows structuring specifications into several files. Thus arises the need to add the ability to work with multiple files at PVSio-web. The intention is to add a toolbar (Figure 8) providing create, import, open and save files functionalities.

Once identified the possible improvement to make, it was necessary to understand how they were meant to be implemented. The knowledge of how PVSio-web deals with more than one PVS file in the same project folder was critical to advance the implementation. When trying to use more than one PVS file in the same project folder it was found that the system loaded the last PVS file found, and the process is initialized with that file. This can cause errors or, even, crash the server if the file sent to the process does not correspond to the main PVS file. These errors can happen when the source file does not have the expected syntax or, when receiving calls, the command contains a function name that is not defined on the loaded PVS specification.

In order to guarantee that only the main PVS file is sent to the PVS process, a configuration file was added where the name of the file can be kept. Code listing 7 presents a code snippet of the “listProjects()” function in the backend file “pvssocketserver.js”. The mentioned function was changed so that it would read the configuration file (Code listing 7, line 7) and extract the name of the main PVS file (Code listing 7, lines 8 to 22). That name will be assigned to the “specMain” response object attribute (Code listing 7, line 13). The source of the PVS main file will be assigned to the “specMainSource” attribute (Code listing 7, line 17). If, for some reason, the configuration file is not part of the project or becomes corrupted, the “specMain” attribute of the response will be returned empty (Code listing 7, line 20).

```
1 else if(confExts.indexOf(ext) > -1) {
2         //existing the configuration file, it will read the content for
3         // extract the name of the PVS main file and then read the source
4         // the name and the source will be assigned to the response object
5         p.conf = f;
6         p.confFullPath = projectDir + d + "/" + f;
7         var fileText = fs.readFileSync(projectDir + d + "/" + f, "utf8");
8         if (fileText !== ""){
9                 var lines = fileText.split("|");
10                if (lines.length==2){
11                  p.imageMain = lines[0].split(":")[1];
12                  p.imageFullPathMain = projectDir + d + "/" + p.image;
13                  p.specMain = lines[1].split(":")[1];
14                  p.specFullPathMain = projectDir + d + "/" + p.spec;
15                  var source = fs.readFileSync(projectDir+d+"/"+p.specMain,"utf8");
16                  if (source !== null){
17                          p.specMainSource = source;
18                  }
19                }else{
20                          p.specMain = "";
21                }
22        }
23 }else{
```

Code listing 7 - Part of the listProject() function on the backend

As expected, the frontend also requires some changes in order to make sense of this improvement. It was necessary to update the “openProject()” function in the “index.js” file. In general, this function requests the project collection to the server, show each project name as a select option in a form and tries to open a chosen project after user selection.

As previously mentioned, the “specMain” attribute of the server object response will be empty if the configuration file is corrupted or does not exist. If it comes empty, a feature was added to ask the user which is the main PVS file. After the user chooses a file, the system will update or create the configuration file for the project, initialize the PVS process and really open the project. With correct configurations, it directly initializes the PVS process and opens the project in the frontend.

```
filesOpened = {
        0: {
                name: "file",
                source: "file:THEORY..."
        },
        1: {
                name: "file2",
                source: "file2:THEORY..."
        }
};
```

Code listing 8 - filesOpened structure example

In addition, a global “filesOpened” array structure (Code listing 8) was implemented at the frontend. This structure is used to maintain in the client’s cache the name and source of each PVS file already opened by the user. The array structure is initialized when opening a project with the main PVS file name and source.

Furthermore, a system of tabs was implemented for the editor in order to allow users to edit multiple files. Clicking in some element – tab – of the menu, it should open the source of the respective file in the editor.

As said before, the intention is to add a toolbar for support user create, import, open and save files. These functionalities will be active and allowed only when a project is opened. A detailed description of the available functionalities on the toolbar will be presented next.

5.1.1 Create File Functionality

Supporting the creation of a new file is the “New File” button. After clicking the button a form is shown asking the name for the new file (see Figure 9).

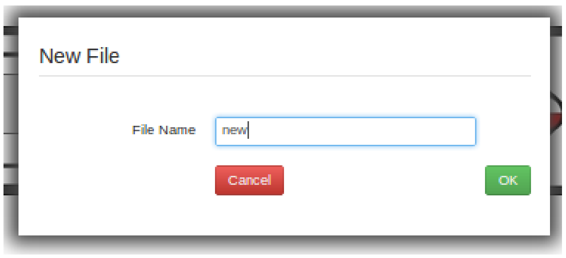
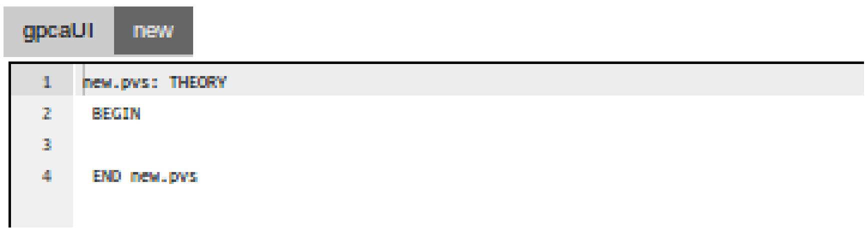


Figure 9 - New File form

The frontend has a global variable identifying the current file in the editor. As said before, a structure was also added containing the opened files source and name – filesOpened.

Proceeding with file creation, the new file is added to the filesOpened structure. The current file object is also changed with the new file definitions. In the user interface, the editor is changed with a default file source and a new element is added to the menu of files opened (see Figure 10).



```
new.pvs: THEORY
 BEGIN

 END new.pvs
```

Figure 10 - New File menu element and default source

5.1.2 Open File Functionality

Open File intends to open PVS files from the open project. The client requests a list containing the name of all files currently bound to the project and lists them in a form for the user to select from (see Figure 11).

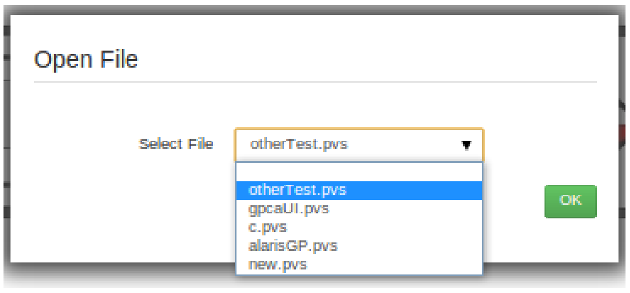


Figure 11 - Open File form

After the user selects a file, the frontend verifies if that file is already opened. This is done by comparing the selected name with all other file names in cache – on the filesOpened structure – (Code listing 9, lines 4 to 9). Verifying that the file is in cache, the frontend resorts to the cache information to update the editor source and change the current file (Code listing 9, lines 25 to 30). Otherwise, the frontend makes a request to the server identifying the project and file names in order to get the source of the intended file (Code listing 9, line 13). Successfully receiving the server response, the frontend is updated by registering the file in cache, adding a new menu tab and updating the editor source (Code listing 9, lines 17 to 23).

```
//verifying if the file is already in cache or not, if is in cache updates the id
var verifyExistence = false;
var selected = 0;
for (var i = 0; i < filesOpened.length; i++) {
        if (filesOpened[i].name == currentFile.name.split(".")[0]) {
                verifyExistence = true;
                selected = i;
        }
 }
  if (!verifyExistence) {
        //file is not in cache, request the source of the file
        // fd is a formData containing the current project name and the selected file name
        d3.xhr("/openFileCode").post(fd, function (err, res) {
                if (err) {
                        console.log(err);
                } else {
                //change current file object, add to cache, add a menu tab, update Editor source
                        currentFile.source = res.responseText;

        filesOpened.push({name:currentFile.name.split(".")[0],source:res.responseText});
                        selected = filesOpened.length - 1;
                        addTabFile(selected);
                        updateSourceCode(res.responseText);
                }
        });
 } else {
        //file is in cache, change current file object and update Editor Source
        changeCurrentFile(selected);
        updateSourceCode(filesOpened[selected].source);
 }
```

Code listing 9 - Part of the "openFile()" function on the frontend

5.1.3 Import File Functionality

Import File gives support to load a PVS file outside PVSio-web and bind it to the opened project. Figure 12 presents the form for importing a file. Clicking “Choose File” opens an operating system window where the user can select the file to be imported.

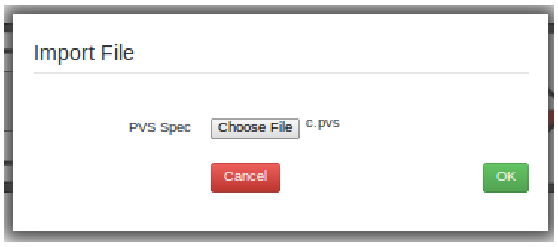


Figure 12 - Import File form

Imported files must be copied to the project's folder. Hence, once the file is uploaded, the fronted makes a request to the backend for the file to be saved in the project. Before saving the file, the backend performs a validation to check for the existence of another file with a same name. There being no other file with the same name, the new file is saved and a response is sent to the frontend containing the name and source of the imported file. Otherwise, the response will contain an error message. On successfully conclusion of the import process, as for opening files, a new tab is added in the menu of files and the editor is updated with the source of the imported file.

5.1.4 Save File Functionality

PVSio-web has only a "Save Project" functionality supporting to save the entire project changes. Specifically for files editing, it only saves the main PVS files. To support saving other files, the save file functionality was added to the editor toolbar. Its purpose is to save the changes of the source of a selected file being edited. It requests the server to save the current file content by sending the project name, file name and the changed source. The backend receives this data and replaces the previous file by a new file with a same name and the updated data.

5.2 Image Editing

PVSio-web provides an image editing area. Image uploading and widget areas creation over an image are supported in this area. However, there was no image editing features. Thus, a toolbar providing crop and resize buttons was made available to users. These functionalities may be relevant to have when the image is too big or too small or, even, when it contains unnecessary parts.

In order to support image editing features, the EasyImage module was used. EasyImage is a module for image processing and manipulation in Node.js. EasyImage is built on top of ImageMagick[5] providing a user-friendly sintax. ImageMagick is a popular serverside technology for image manipulation. EasyImage supports image resizing, cropping and format converting (for example, converting a png image to jpg) [19]. This module has been added to the PVSio-web to meet the server side needs for the new features of image editing.

The crop function in EasyImage (see Code listing 10) needs the path of the original image (src) and the path to save the cropped image (dst), the crop dimensions (cropwidth and cropheight), the beginning crop point coordinates (x and y) and the gravity. By default the gravity is defined to center, it means that the crop will be from the center of the image. In the case of PVSio-web, the crop was implemented as northwest, from the upper left corner. The decision to be northwest was taken to be in conformity with the approach already implemented for widget areas.

The resize EasyImage function (see Code listing 11) regards to the full picture, so needs only the path of the original image (src), the path to save the cropped image (dst) and the new dimensions (width and height).

[5] http://www.imagemagick.org

```
easyimg.crop(// Crop image
        {
                src:imageSrc, dst:imageDst,
                cropwidth:width, cropheight:height,
                gravity:'NorthWest',
                x:cropx, y:cropy
        },
        function(err, stdout, stderr) {
                if (err) {
                        response.err = err;
                        throw err;
                }else{
                        response.success = "Crop succefully done";
                        console.log('Cropped');
                }
        }
);
```

Code listing 10 - EasyImage crop function

```
easyimg.resize(//  Resize image
        {
                src:imageSrc, dst:imageDst, width:width, height:height
        },
        function(err, stdout, stderr) {
                if (err) {
                        response.err = err;
                        throw err;
                }else{
                        response.success = "Resize succefully done";
                        console.log('Cropped');
                }
        }
);
```

Code listing 11 - EasyImage resize function

5.2.1 Crop Functionality

Activating the crop functionality by clicking on the Crop button from the toolbar, the image editing area changes to provide a crop environment (see Figure 13). In order to carry out crop, an interface for defining the crop area and a way to change the image is required. Changing the image is supported by the previously referenced EasyImage module in the backend. In the frontend, the interface is supported by the cropperUI library. CropperUI supports area selection over a picture through mouse interations. When mousing down the crop area begins until mousing up. The selected area is highlighted with dashed lines. In addition to the crop environment, a button to save crop changes and another to cancel crop changes are provided.

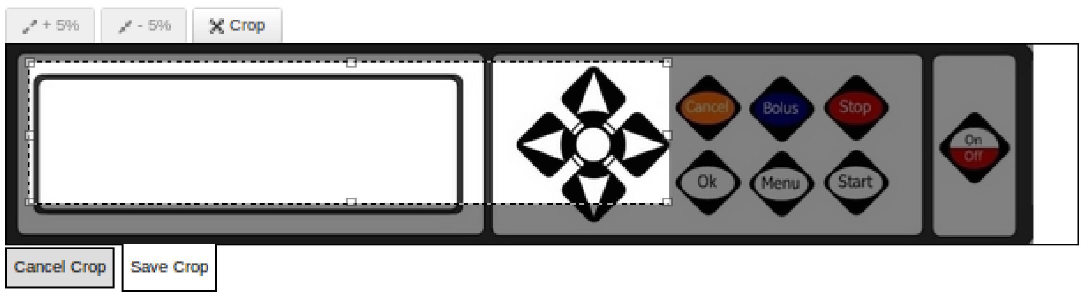


Figure 13 - Image editing, crop

The cropping starts attaching the Copper.Img object, from the cropperUI library, to the image (see Code listing 12). Throught a callback function attached to the onEndCrop event of the object, the crop results are captured, registering the top and left coordinates and the width and height sizes. Code listing 13 presents the onEndCrop function source code where cropx1, cropy1, cropwidth and cropheight are global variables regarding to the top, left, width and height, respectively.

```
imageForCrop = new Cropper.Img(//attach CropperUI to the Image
        'image',   //id of the image element for crop
        { onEndCrop:
                onEndCrop //name of the callback function that will handle the results
        }
);
```

Code listing 12 - CropperUI, new Cropper.Img example

```
function onEndCrop( coords, dimensions ) {
        //function for "capture" the values to image crop
        cropx1 = coords.x1;
        cropy1 = coords.y1;
        cropwidth = dimensions.width;
        cropheight = dimensions.height;
}
```

Code listing 13 - onEndCrop callback function

Saving the crop changes, a request with the values captured by the onEndCrop callback function for croping the image will be sent to the backend. A success response returned means image cropped successfully.

After cropping the image, some widgets areas may be out of the area that was selected, or only partially inside. In any case the coordinates have to be adjusted to the new measurements of the image. In order to calculate the new coordinates of the widget areas, the coordinates captured by onEndCrop are subtracted to the old widget areas coordinates. The old coordinates are replaced by the new ones and widget areas with coordinates outside the boundaries of the changed image are deleted. This will cause the widget areas move to the left and top in order to match with the changed image.

5.2.2 Resize Functionality

The resize functionality is achieved through two main buttons. One to increase the image size by 5%. Another to reduce the image size by 5%. The resize environment, presented in Figure 14, also shows buttons to cancel or save the resize changes. Resizing is not allowed when an image is being cropped.

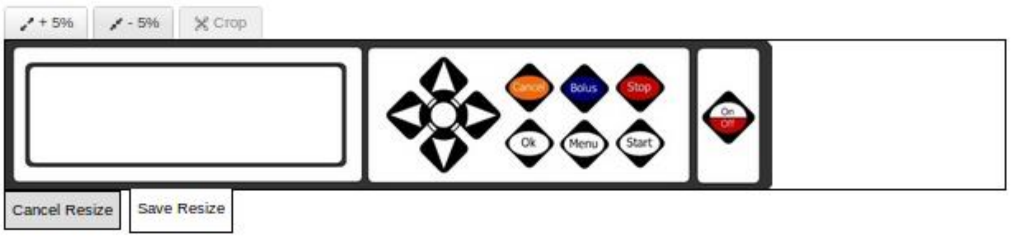


Figure 14 - Image editing, resize

The resize is always relative to the original image dimensions. The variable which registers the quantity of resize clicks increases one unit when clicking the *+ 5%* button and decreases one unit when clicking the *- 5%* button. This approach allows defining the following formulas to calculate new image dimensions:

- $imgResizeWidth = widthOriginal + widthOriginal * {}^{resizeIteration} * {}^{5}/_{100}$;
- $imgResizeHeight = heightOriginal + heightOriginal * {}^{resizeIteration} * {}^{5}/_{100}$;

Where, imgResizeWidth and imgResizeHeight will be the new width and height dimensions values, while widthOriginal and heightOriginal are the original width and height image dimensions values and resizeIteration is the quantity of resize clicks.

After resizing, the widget areas are redefined by using the following formula:

- $newCoord = oldCoord + oldCoord * {}^{resizeIteration} * {}^{5}/_{100}$.

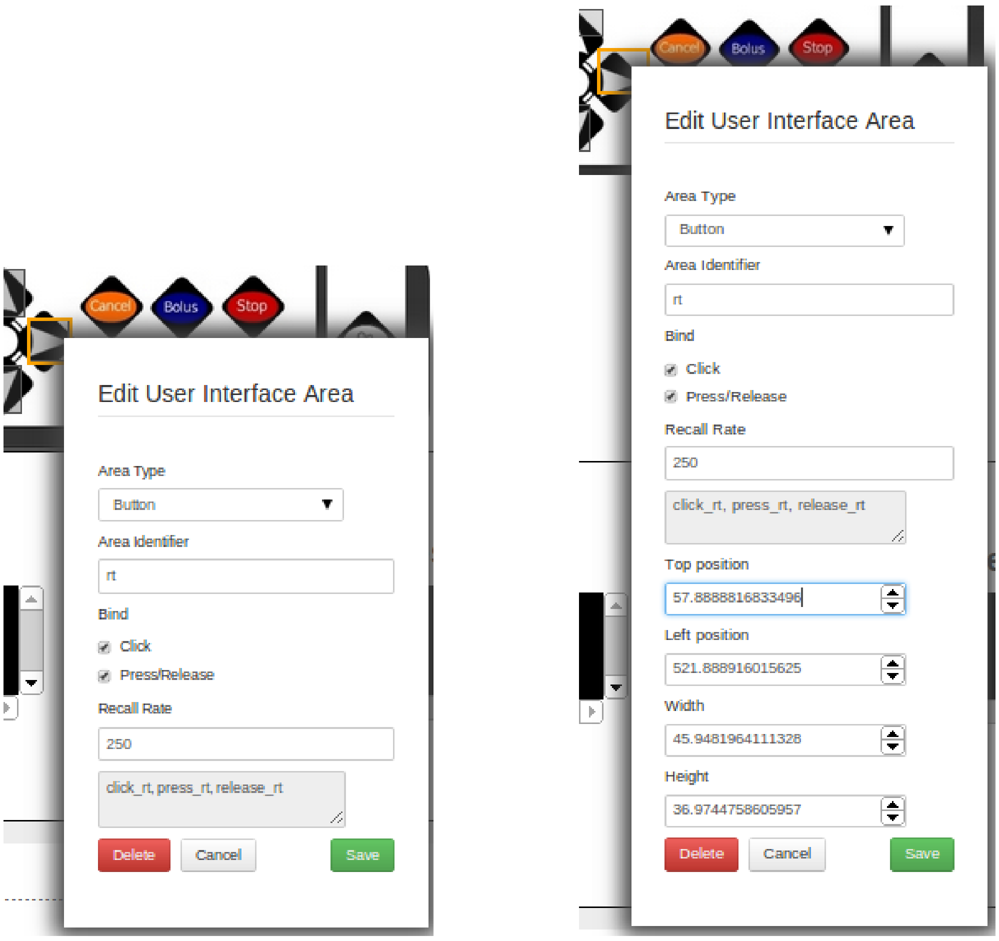
newCoord and oldCoord represent the top, left, right or button coordinates that will take the new value and that contains the old value, respectively.

5.3 Widget Area Editing

PVSio-web supports creating widget areas and moving them by mouse action. When creating a new area, with mouse actions, the widget area dimensions may not be best suited. The configuration properties of a widget area can be edited through a widget editor form. Thus, it is intended to add four new elements – Top position, Left position, Width, Height – to that form in order to enable the user to adjust the position and dimensions of a widget area.

A selected widget area is marked as selected by assigning it the class “selected”. Selected a widget area, its coordinates and dimensions values can be accessed and assigned to the form elements. The top and left properties are the coordinates that identify the point where the area begins and the height and width are the area dimensions. Assigning these values to the respective elements of the widget editor form, the user will be able to change them. Saving the changes to the widget area, the redraw of the widget area will happen in order for it take the new appearance.

Figure 15 presents in the left side the original widget editing form and in the right side the new form with elements to support widget area position and dimensions adjustments: Top position, Left position, Width and Height. These elements are HTML5 numeric inputs [20]. One advantage of using HTML5 numeric inputs is that they includes a side bar with arrows to move up or down, to quickly increment or decrement their value. The inclusion of limit values is also supported by these elements.



Edit User Interface Area

Area Type: Button
Area Identifier: rt
Bind: ☑ Click ☑ Press/Release
Recall Rate: 250
click_rt, press_rt, release_rt

Edit User Interface Area

Area Type: Button
Area Identifier: rt
Bind: ☑ Click ☑ Press/Release
Recall Rate: 250
click_rt, press_rt, release_rt
Top position: 57.8888816833496
Left position: 521.888916015625
Width: 45.9481964111328
Height: 36.9744758605957

Figure 15 - Widget areas editing form

The implementation of this feature led to the discovery of a problem that was replicating widget areas. When loading them, they were appearing replicated. Initially it was thought that this could be a problem related to the widget areas loading. By looking at a widget definitions file from a project it was found that the bug was from save actions. The code for saving widget edits was always creating a new area instead of updating the existing ones. Thus, a condition to restrict areas creation was added in order to create a new area only if an area does not already exists. The absence of an area is validated when the identification property – id – is empty, meaning that the area is new and still needs to be created. Otherwise, widget areas will only be updated with new definitions. Code listing 14 presents the code snippet responsible for verifying the existence of an area, and create or update an area as appropriate.

```
//if the area does not exist in the project, is created and added
if (d3.select("#prototypeMap area." + e.widget.id()).empty()) {
        overlayCreator.createInteractiveImageArea(
                e.mark,
                widgetMaps.get(e.widget.id()),
                ws
        );
}

//update the regex for this mark if its a display widget and give it a display class
if (e.widget.type() === "Display") {
        e.mark.classed("display", true);
        displayMappings.active[e.widget.id()] = {
                regex: e.widget.regex(),
                uiElement: e.widget.id()
        };
}
```

Code listing 14 - Code snippet, Create and/or Update widget area

5.4 Conclusion

The contributions, carried out in this project, to enhance PVSio-web like file editing with multi-file support, image editing (options for cropping and resizing) and widget area editing with support for redimensioning and repositioning were described in this chapter.

6. USAGE EXAMPLE

In the previous chapter were described the changes made to the PVSio-web. In this chapter will present an illustrative example of the new features. For this example will be used a model of the AlarisGH AsenaCC syring pump.

6.1 The AlarisGH AsenaCC

The AlarisGH AsenaCC is a variable pressure syringe pump suitable for critical care applications. Researchers from Queen Mary, University of London (QMUL) wrote a PVS specification that focuses on number entry. In this particular pump number entry is made through chevrons keys. Figure 16 presents the AlarisGH AsenaCC interface. The chevrons buttons are highlighted with a black border square and the display area with an orange border. The chevrons are double or single for faster or slower increase or decrease of the value shown on the display.

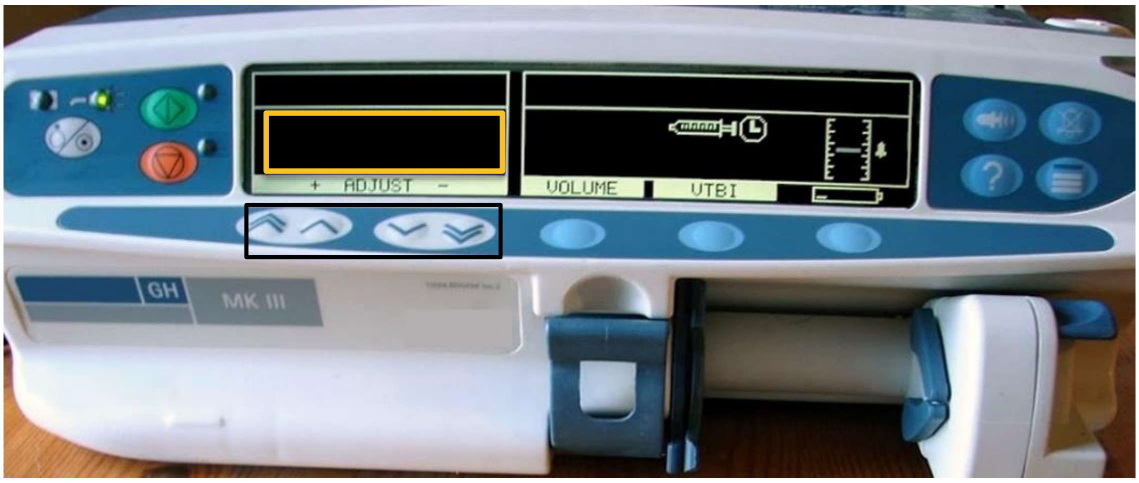
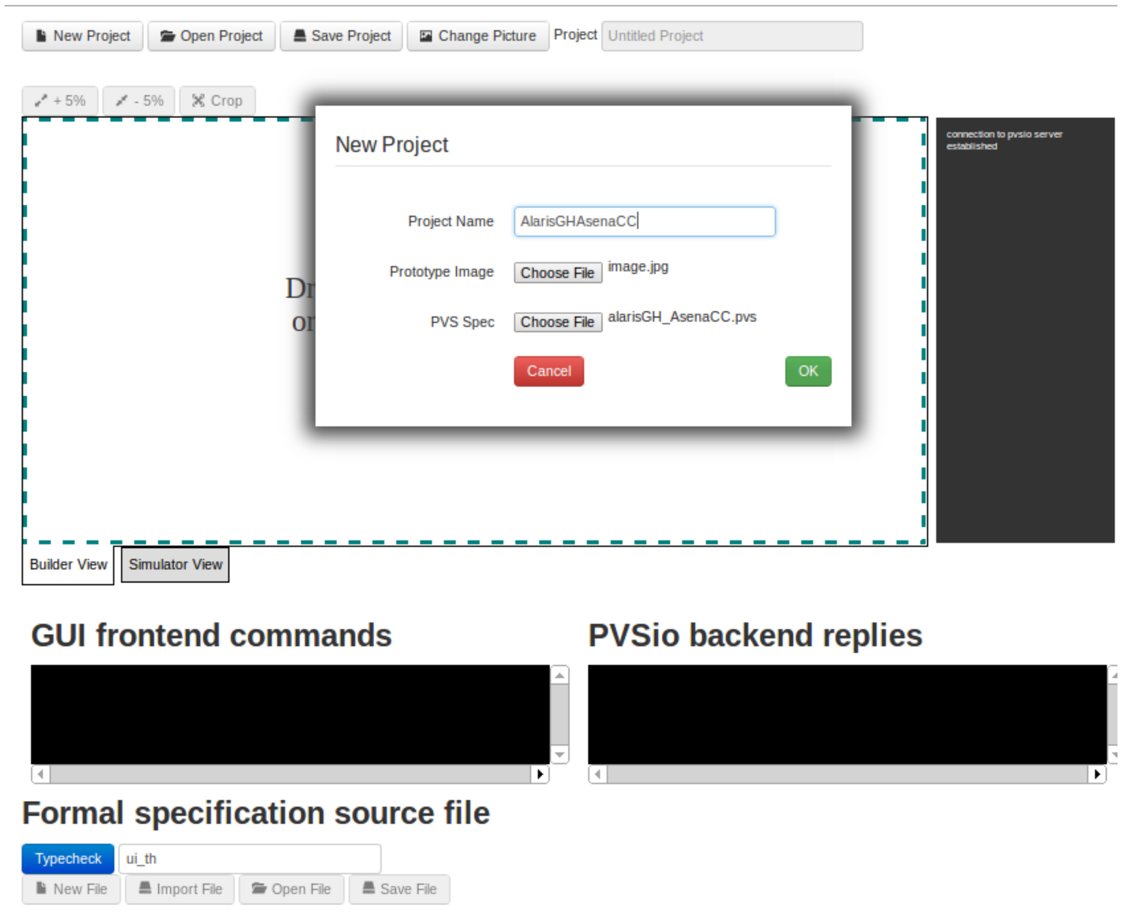


Figure 16 - AlarisGH AsenaCC

The PVS specification defines functions to cover user interactions as click, press or release events through buttons. As example, the UP chevron key have the click_UP, press_UP and release_UP functions defined on the PVS specification. The click event regards a single click interaction. The press event regards a continuous pressing interactions. The release event regards a finalization of the press event. The display area reflects the state of the variable display which change when some event happens.

6.2 Building the prototype

In order to start prototyping the AlarisGH AsenaCC in PVSio-web, a new project, called AlarisGHAsenaCC was created. Loading the picture and the PVS specification file was required to create a new project, as shown in Figure 17.



New Project

Project Name: AlarisGHAsenaCC

Prototype Image: image.jpg

PVS Spec: alarisGH_AsenaCC.pvs

Figure 17 - Usage Example, New Project

After the project has been created, it was seen that the picture did not fit the dimensions of the UI Builder area. In order to adjust this, the image was resized resorting the new image editing features. As the image was bigger than the UI Builder area, the resize was done by clicking on the decrease "-5 %" button until the desired size was reached. Figure 18 presents first the loaded image as seen after project creation and then resize editing with the desired size. Clicking on the "Save Resize" botton, the picture was resized and reloaded, and the application returned to the UI Builder area.

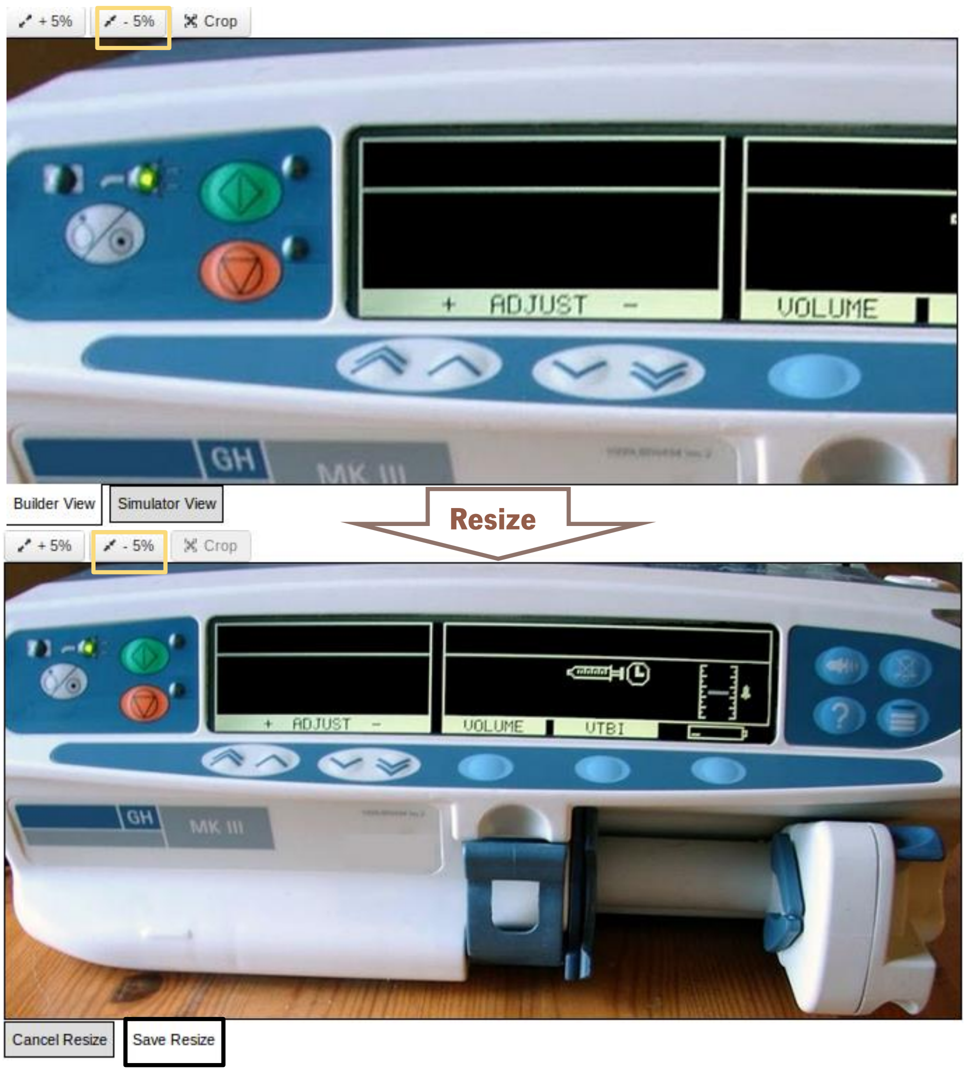


Figure 18 - Usage example, Resizing

The image presents the desired side of AlarisGHAsenaCC, containing the operation panel. However, some parts are not relevant for this prototyping example. The crop feature helped display only the main panel. Figure 19 shows on top the crop environment. The coordinates for cropping the image were identified through the area selection feature supported in the crop environment. At the button, the redefined image after cropping is shown. The image is now on a better state with the desired area for prototyping.

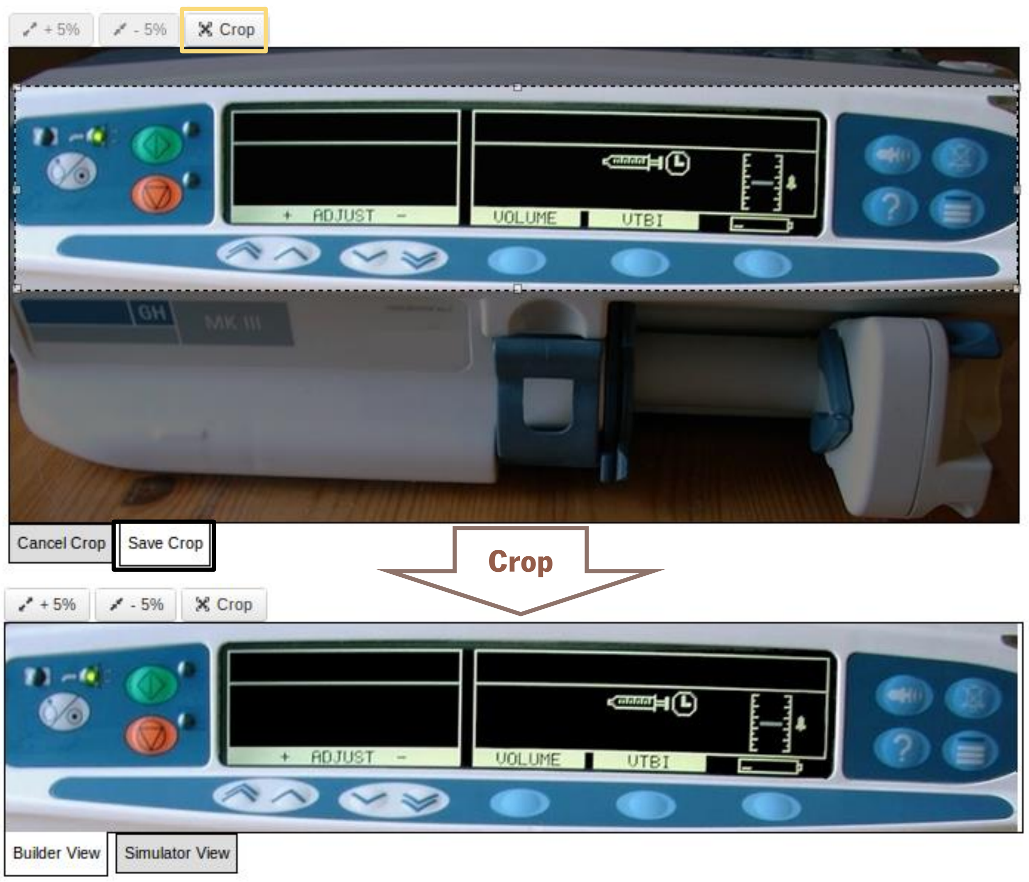
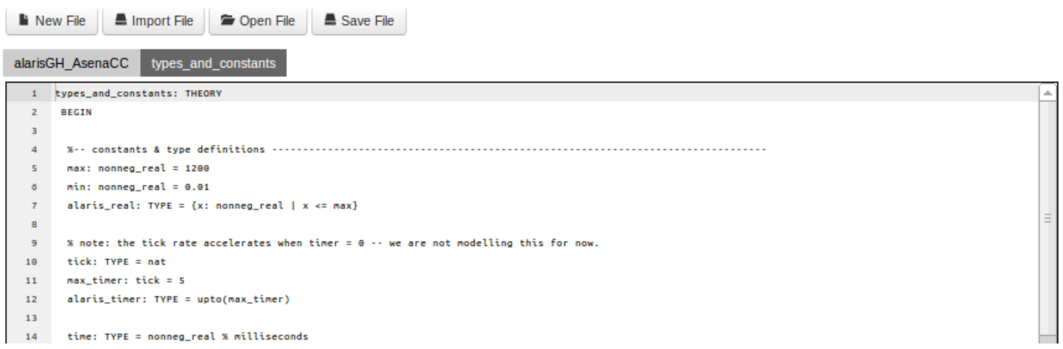


Figure 19 - Usage example, Cropping

Before widget areas creation, it is necessary to look at the PVS specification in order to identify which commands will be necessary in the prototyping interface. First of all, in the beginning only one PVS file was uploaded. However, the specification consisted of two files: The uploaded file AlarisGH_AsenaCC.pvs – that is the main file – and the other types_and_constants.pvs – that is identifying and declaring variables and constants. The file editing toolbar includes the "Import File" button that supports upload an external file to PVSio-web. It gives the agility to upload the file containing the variable and constants declarations. The imported file will be associated with the project and will open in the file editor area. A new tab with the name of the file will also be added above the editor as shown in Figure 20.

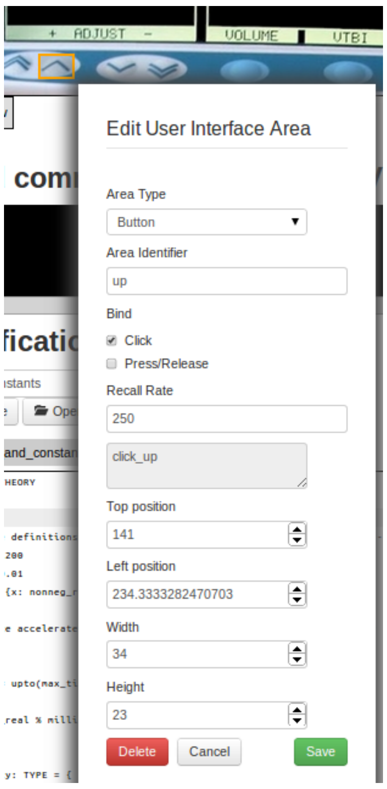


```
types_and_constants: THEORY
 BEGIN

  %-- constants & type definitions --------------------------------------------------------------------------------
  max: nonneg_real = 1200
  min: nonneg_real = 0.01
  alaris_real: TYPE = {x: nonneg_real | x <= max}

  % note: the tick rate accelerates when timer = 0 -- we are not modelling this for now.
  tick: TYPE = nat
  max_timer: tick = 5
  alaris_timer: TYPE = upto(max_timer)

  time: TYPE = nonneg_real % milliseconds
```

Figure 20 - Usage example, Import file

The source of the PVS file is specifying the chevron keys – UP, up, dn, DN – and the display of the pump. The widget editor supports the definition of an area's type as button or display. For each area an area identifier was defined to match the respective PVS function. Additionally, for buttons it must be defined when to send commands to the PVS process. This can be defined as "click" or "press/release" events. Regarding display areas, the value type such as "string" or "numeric" and the regular expression for values validation must be defined.

Figure 21 shows, on the left side, a widget editor for a button area. On the right side, a display area was being edited. This supports the redefinition of the area's position, by changing the top and left position coordinates, and resizing the area, by changing the width and height values. The benefits of this features is to adjust the area to the desired coordinates in the image. This increases the accuracy of the area's dimensions, enabling a better match between the image and the interaction areas.



Edit User Interface Area

Area Type: Button

Area Identifier: up

Bind

- [✓] Click
- [ ] Press/Release

Recall Rate: 250

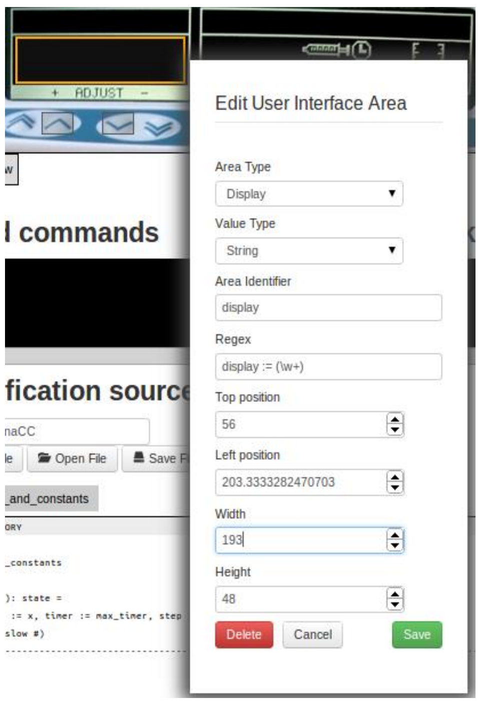
click_up

Top position: 141

Left position: 234.3333282470703

Width: 34

Height: 23



Edit User Interface Area

Area Type: Display

Value Type: String

Area Identifier: display

Regex: display := (\w+)

Top position: 56

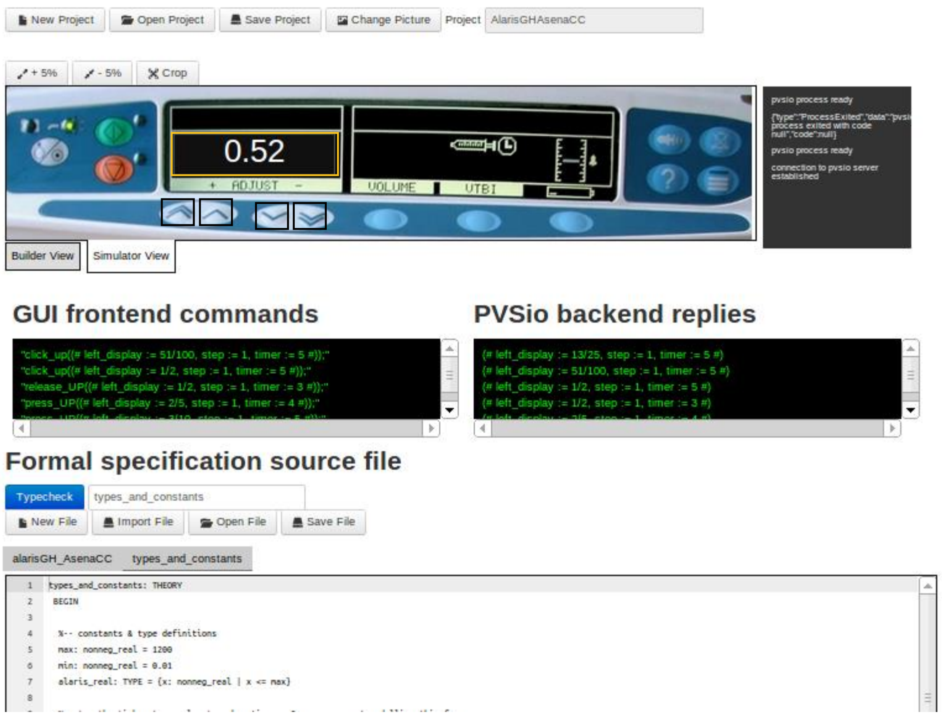
Left position: 203.3333282470703

Width: 193

Height: 48

Figure 21 – Usage example, Wiget area editing

Four button areas (UP, up, dn, DN) and one display area were created in this example. The four button areas were linked to the respective click, press and release function, defined in the PVS specification. The up and dn buttons increase, respectively decrease, the value displayed by a unit value. The UP or DN buttons increase / decrease faster by ten units. For example, the value 0.00 is increased to 0.01 by clicking in the up button area. By clicking in the UP button area, the value 0.01 is increased to 0.11. Figure 22 presents PVSio-web running the UI simulator environment. The yellow border is identifying the display area created, and the black border is identifying the button areas created.



```
pvsio process ready
{"type":"ProcessExited","data":"pvsi
process exited with code
null","code":null}
pvsio process ready
connection to pvsio server
established
```

GUI frontend commands

```
"click_up((# left_display := 51/100, step := 1, timer := 5 #));"
"click_up((# left_display := 1/2, step := 1, timer := 5 #));"
"release_UP((# left_display := 1/2, step := 1, timer := 3 #));"
"press_UP((# left_display := 2/5, step := 1, timer := 4 #));"
```

PVSio backend replies

```
(# left_display := 13/25, step := 1, timer := 5 #)
(# left_display := 51/100, step := 1, timer := 5 #)
(# left_display := 1/2, step := 1, timer := 5 #)
(# left_display := 1/2, step := 1, timer := 3 #)
```

Formal specification source file

```
types_and_constants: THEORY
 BEGIN

  %-- constants & type definitions
  max: nonneg_real = 1200
  min: nonneg_real = 0.01
  alaris_real: TYPE = {x: nonneg_real | x <= max}

```

Figure 22 - Usage example, UI simulator

6.3 Conclusion

This chapter has presented an example using PVSio-web with the developed new features. The platform worked as expected. The implemented features helped the interaction and increased the prototyping accuracy, by giving a more realistic and reliable user experience.

7. CONCLUSION

This dissertation described a PVSio-web improvement. PVSio-web extends the simulation component of the PVS proof system with functionalities for the rapid prototyping of device's user interfaces [21]. This comes as a high level environment to validate the behavior of these interfaces resorting to the specifications, and facilitates user interactions. More functionalities can be added to support more useful interactions and increasing the prototyping accuracy.

7.1 Achieved objectives and limitations

The original functionalities of PVSio-web supported creating, opening and saving a project, creating widget areas over an image and linking them to the specification, editing a specification file and, last but not least, running the prototyping simulator component. There are, however, a large set of features that could be implemented to improve PVSio-web.

A first aspect was related to the file editor supporting multiple files. A new toolbar was designed to support creating a new file, importing an external file, opening some internal file and saving file changes. These features are all associated with the current project under prototyping. Furthermore, a menu of tabs was implemented in order to identify files opened and allow switching between them.

A second aspect regarded to adjusting the image to better prototyping. An image editing toolbar was designed to support two points: cropping and resizing. Cropping resorts to area selection with mouse events supporting a redefinition of the image crop area limits. Resizing resorts to two buttons supporting resizing an image in less or more five percent of its dimension per click event. However, this characteristic of resizing may not to be too user friendly, being based on button events. It is intended to be improved in the future by implementing an approach based on mouse actions. Moreover, in the future this two points might also allow direct editing of values in order to cover possible mouse fails with more precision.

A last but not least aspect contributes to increase the accuracy of the widget areas' dimensions. Widget areas are created resorting to mouse actions. With this approach, the accuracy in the definition of the areas is low. In order to improve this, it was added a new feature for the widget area editor allowing direct values editing.

7.2 Future work

Although it already has a large set of functionality, PVSio-web can still grow. Analyzing new features that might be interesting for PVSio-web and the limitations identified above, it might be relevant to consider:

- Support for widget areas with distinct forms, such as circles, ovals and triangles among others, in order to increase flexibility in the definition of the prototype;
- Making the functionalities of image editing more similar, supporting resizing by mouse actions;
- Support for uploading multiple specification files when creating a new project, not being obligated and restricted to one and only one file;
- Possibility to create empty projects, not being mandatory to import an image and a specification file when creating a project.

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