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Abstract

Resumo

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Abbreviations

FEUP	Faculty of Engineering of the University of Porto (<i>Faculdade de Engenharia da Universidade do Porto</i>)
RIA	Rich Internet Applications
API	Application Programming Interface
AST	Abstract Syntax Tree
AUA	Application Under Analysis
CIO	Concrete Interaction Objects
EFG	Event Flow Graph
FSM	Finite State Machine
GUI	Graphical User Interface
MBT	Model-Based Testing
SU	System Under Testing
TDD	Test-Driven Development
UI	User Interface
HTML	HyperText Markup Language
UML	Unified Modeling Language
AUIDL	Abstract UI Description Language
HCI	Human Computer Interaction
REGUI	Reverse Engineering of Graphical User Interface
V&V	Verification and Validation
XML	eXtensible Markup Language

Chapter 1

Introduction

This chapter aims at giving a general overview about the themes addressed by this thesis. We will address the context in which the thesis is inserted, as well as the motivation that led to its proposal. Furthermore there will be a brief description of the main objectives of this thesis, and the methods that will be used to achieve those objectives.

1.1 Context

Web applications are getting more and more important. Due to their stability and security against losing data, there is a growing trend to move applications towards the Web, with the most notorious examples being Google's mail and office software applications. Web applications can now handle tasks that before could only be performed by desktop applications [G⁺05], like editing images or creating spreadsheet documents.

Despite the relevance that Web applications have in the community, they still suffer from a lack of standards and conventions [CL02], unlike desktop and mobile applications. This means that the same task can be implemented in many different ways, which makes automated testing difficult to accomplish and inhibits reuse of testing code.

GUIs (*Graphical User Interfaces*) of all kinds are populated with recurring behaviours that vary slightly. For example, authentication (*login/password*) is a common behaviour in many software applications. However, the implementation of those behaviours may vary significantly. For a login, in some cases an error message may appear when the authentication fails; in others, the software application simply erases the inserted data and doesn't send a message to the user. These behaviours (patterns) are called User Interface (UI) patterns [VWVDVE01] and are recurring solutions that solve common design problems. Due to their widespread use, UI patterns allow users a sense of familiarity and comfort when using applications.

1.2 Motivation and Objectives

This thesis is part of an investigation project named PBGT (*Pattern-based GUI Testing*) [MPM13]. The goal of this investigation project is to develop a model-based GUI testing tool and approach, usable as an industrial tool. This project has five parts: a DSL (*Domain Specific Language*) named **PARADIGM** to define GUI testing models based on UI patterns; a modelation and testing environment, named **PARADIGM-ME**, made to support the creation of test models; an automatic test case generation tool, named **PARADIGM-TG**, that generates test cases from test models defined in PARADIGM; a test case execution tool, named **PARADIGM-TE**, which executes test cases, analyzes their coverage, and returns detailed execution reports; and finally **PARADIGM-RE**, a Web application reverse engineering tool whose purpose is to extract UI patterns from Web pages without access to their source code, and use the extracted patterns to generate a test model defined in PARADIGM.

The relationship between the different components can be better understood in Figure 1.1. The activities (rounded corner rectangles) with the human figure mean that they are not fully automatic requiring manual intervention. The activities with the cog mean that part (or all) of that activity is automatic. The numbers within the activities define their sequencing.

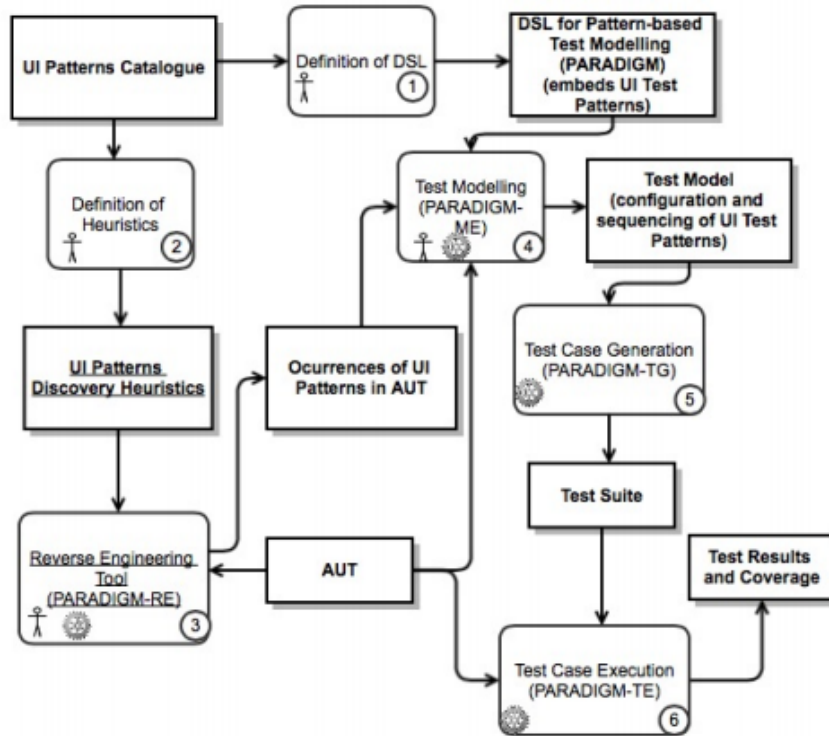


Figure 1.1: An overview of the PBGT project [NPCF13]

The proposal aims to continue the work done on PARADIGM-RE [NPCF13]. This tool identifies interface patterns using Machine Learning inference with the Aleph ILP system ¹. The tool was extended in [NPF14], introducing a

Considering the problem described and the proposed solution, the main goal for this research work is

1.3 Expected Contributions

1.4 Structure of the Report

This document is structured into four main chapters. In this first section, Chapter 1, we start by introducing the theme to be developed during the course of the dissertation, starting by defining the context and issue at hand and describing the goals of this thesis.

Chapter 2 introduces essential concepts to understand the problems with which this document deals, presents the state of the art of approaches that reverse-engineer Web applications, and lastly, gives some insight about data mining algorithms and how they will be applied to this work.

Chapter 3 explains the solution proposed to the problem at hand. This chapter itself is also divided into several sections. First, to give a better understanding on the context in which the tool to develop will be implemented, a brief overview of the PARADIGM-RE tool is provided. Following this exposition, one then explains the approaches the author is considering to take, although these might be subject to change as the work progresses.

Chapter 4 outlines the main steps in the development of this thesis (and the respective software prototype) and attempts to provide a feasible schedule for the execution of the work to be done.

Chapter 5 sums up the what has been defined in the report, emphasizing the problem that the thesis addresses and the work that will be executed towards solving that problem. It will also give a brief idea of what are the expected results at the end of the project.

¹ Aleph: http://www.cs.ox.ac.uk/activities/machlearn/Aleph/aleph_toc.html

Introduction

Chapter 2

State-of-the-Art

2.1 Introduction

In order to find the best approach to this problem, some research on already existing methodologies and concepts was needed. First an overview for the general categories researched is given, followed by the actual state of the art found, divided by relevant subcategories.

2.2 Reverse Engineering

Reverse engineering is “the process of analysing the subject system to identify the system components and interrelationships and to create representations of the system in another form or at a higher level of abstraction” [CC⁺90].

There are two methods of applying reverse engineering to a system: the dynamic method, in which the data are retrieved from the system at run time without access to the source code, and the static method, which obtains the data from the system source code [Sys99]. There is also the hybrid method, which combines the two previous methods, and the historical method, which includes historic information to see the evolution of the software system [CDPC11]. These approaches follow the same main steps: collect the data, and analyse it and represent it in a legible way, and in the process allow the discovery of information about the system’s control and data flow [PRW03].

2.2.1 Extraction of Information from Execution Traces

Plenty of approaches that extract information from execution traces have been found. TraceServer [AA11] is an extension of the Java PathFinder model checking tool [jpf] which collects and analyzes execution traces. jRapture [SCFP00] is a technique and a tool for capture and replay of Java program executions. ReGUI [CMPPF11, CMPPF12] is a dynamic reverse engineering tool made to reduce the effort of modelling the structure and behaviour of a software application GUI.

Duarte, Kramer and Uchitel defined an approach for behaviour model extraction which combines static and dynamic information [DKU06]. Fischer *et al.* developed a methodology that analyzes and compares execution traces of different versions of a software system to provide insights into its evolution, named EvoTrace [FOGG05]. Amalfitano’s approach [AFT10] generates test cases from execution traces to help testing from Rich Internet Applications (RIAs), with the execution traces being obtained from user sessions and crawling the application.

2.2.2 Extraction of Information from Web Applications

The following approaches extract information from Web applications for analysis and processing.

Ricca and Tonella’s ReWeb [RT01] dynamically extracts information from a Web application’s server logs to analyze its structure and evolution, and so aims to find inconsistencies and connectivity problems. Benedikt *et al.* introduced a framework called VeriWeb [BFG02] that discovers and explores automatically Web-site execution paths that can be followed by a user in a Web application. Di Lucca *et al.*’s approach [DLDP05] integrates WARE [DLFT04], a static analysis tool that generates UML diagrams from a Web application’s source code, and WANDA [ADPZ04], a Web application dynamic analysis tool, to identify groups of equivalent built client pages and to enable a better understanding of the application under study. Crawljax [Roe10] is a tool that obtains graphical sitemaps by automatically crawling through a Web application. WebDiff [CVO10] is a tool that searches for cross-browser inconsistencies by analyzing a Website’s DOM and comparing screenshots obtained in different browsers. Mesbah *et al.* proposed an automated technique for generating test cases with invariants from models inferred through dynamic crawling [MvDR12]. Artzi *et al.* developed a tool called Artemis [ADJ⁺11] which performs feedback-directed random test case generation for Javascript Web applications. Artemis triggers events at random, but the events are prioritized by less covered branch coverage in previous sequences. Amalfitano *et al.* developed a semi-automatic approach [AFT11] that uses dynamic analysis of a Web application to generate end user documentation, compliant with known standards and guidelines for software user documentation. Another approach by Mesbah *et al.*, named FeedEx [FM13] is a feedback-directed Web application exploration technique to derive test models. It uses a greedy algorithm to partially crawl a RIA’s GUI, and the goal is that the derived test model capture different aspects of the given Web application’s client-side functionality. Dallmeier *et al.*’s Webmate [DBOZ12, DBOZ13] is a tool that analyzes the Web application under test, identifies all functionally different states, and is then able to navigate to each of these states at the user’s request. Dincturk *et al.* [DCvB⁺12] proposed a RIA crawling strategy using a statistical model based on the model-based crawling approach introduced in [BVBD⁺11] to crawl RIAs efficiently. Bernardi *et al.* [BDLD08] presents an approach for the semi-automatic recovery of user-centered conceptual models from existing web applications, where the models represents the application’s contents, their organization and associations, from a user-centered perspective.

2.2.3 Inferring Patterns from Web applications

Despite the fact that there are plenty of approaches to mine patterns from Web applications, no approaches have been found that infer UI patterns from Web applications beside the work this thesis means to extend [NPCF13, MPFC12]. The approaches found deal mostly with Web mining, with the goal of finding relationships between different data or finding the same data in different formats. Brin [Bri99] presents an approach to extract relations and patterns for the same data spread through many different formats. Chang [CHL03] proposes a similar method to discover patterns, by extracting structured data from semi-structured Web documents. Freitag [Fre98] proposes a general-purpose relational learner for information extracting from Web applications.

2.2.4 Capture-Replay Tools

The execution traces of a Web application, on the client side, are usually captured via a capture-replay tool. Here we present the most popular capture-replay tools used nowadays.

Selenium ¹ is an open-source capture/replay tool that captures an user's interaction with a Web application in HTML files. It has multi browser, OS and language support, can be installed server-side and as a Mozilla Firefox add-on, has its own IDE (*Integrated Development Environment*), and allows recording and playback of tests.

Watir Webdriver ² is an open-source (BSD) family of Ruby libraries for automating Web browsers and Web application testing. It has multi browser and OS support, a rich API, and has a functionality for non-tech users: the 'Simple' class. There also exist ports for other programming languages, such as Watij (for Java) and Watin (.NET).

IBM Rational Functional Tester (RFT) ³ is an automated functional testing and regression testing tool. This software provides automated testing capabilities for functional, regression, GUI, and data-driven testing. Rational Function Tester supports a range of applications, such as .Net, Java, Siebel, SAP, terminal emulator-based applications, PowerBuilder, Ajax, Adobe Flex, and others. It permits storyboard testing, automated testing, data-driven testing, and test scripting.

Sahi ⁴ is an open-source automation and testing tool for web applications. It allows recording and replaying across browsers, provides different language drivers for writing test scripts, and supports Ajax and highly dynamic web applications.

2.3 Data Mining

Data mining is "(...) *the non-trivial extraction of previously unknown and potentially useful information from data*" [FPSS96]. It is the analysis step of a Knowledge Discovery in Databases 18 (KDD) process, and an interdisciplinary sub-field of computer science. It combines artificial intelligence, machine learning, statistics and database systems [CEF⁺04].

¹Selenium: <http://docs.seleniumhq.org/>

²Watir: <http://watirwebdriver.com/>

³IBM RFT: <http://www-03.ibm.com/software/products/en/functional>

⁴Sahi: <http://sahi.co.in/>

The goal of data mining is to extract information from a dataset, or past data, and transform it into an understandable structure. Discovering information from data takes two major forms: description and prediction [MR05]. Common types of data mining analysis include:

Anomaly detection (can also be called outlier/change/deviation detection) involves getting a sense of the typical cases that the dataset tends to contain, to better detect cases that are different from the regular pattern.

Association learning aim to find correlations between different attributes in a dataset.

Cluster detection is the task of discovering groups and structures in the data that are in some way or another "similar", without using known structures in the data.

Classification classifies new cases based on pre-determined categories. Learning from a large set of pre-classified examples, algorithms can detect systematic differences between items in each group and apply these corresponding models to new classification problems.

Regression aims to fit an equation into a dataset, in order to predict one or more continuous variables, such as profit or loss, based on other attributes in the dataset.

The performance of an algorithm depends greatly on the characteristics of the data. There is no single algorithm that works best on all given problems [WM95] so in the interest of determining the best approach, the best choice is to try a wide variety and then compare their results.

2.3.1 Data Mining Tools and Frameworks

Except in rare cases of very specific problems, it typically makes no sense for someone to implement any data mining algorithm that they might need. There are many data mining tools (many of which free) that already implement many of those algorithms and have customization capabilities that make it easy to adapt them to most problems; and there are also many data mining frameworks and libraries who implement a wide variety of algorithms. A data mining tool is a powerful software that makes use of data mining algorithms, and supports a complete KDD process [MR11]. In the following sections we will briefly address some of the most commonly used tools and frameworks, namely RapidMiner, WEKA, SPMF, and R.

2.3.1.1 RapidMiner

RapidMiner ⁵ is a complete solution for data mining problems. It's available as a standalone GUI based application, as seen in Figure 2.1. It is a commercial application, although its core and earlier versions are distributed under an open source license, and it offers a free version, beyond its multiple paid versions. Being one of the most popular data mining tools used today, its applications span several domains, including education, training, industrial and personal applications, among others. Its functionality can also be easily extended through the use of plugins. reflecting in an increased value for this tool.

⁵<http://www.rapidminer.com>

State-of-the-Art

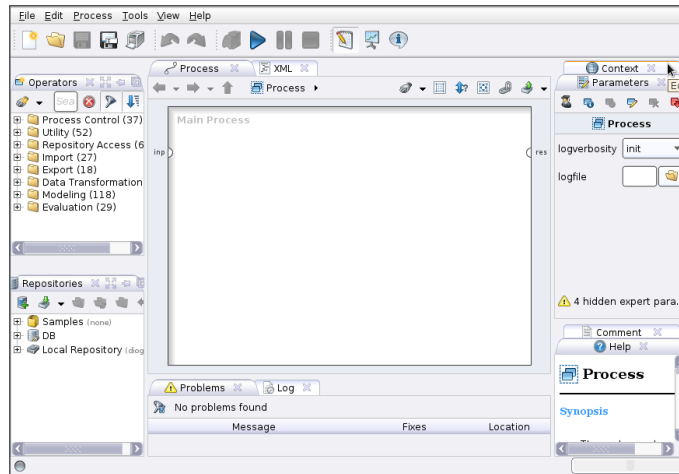


Figure 2.1: RapidMiner's interface

2.3.1.2 WEKA

Weka ⁶ is an open source tool that collects several machine learning algorithms and allows its user to easily apply those algorithms to data mining tasks [HKP06]. Created at the University of Waikato, New Zealand in 1997 (the current version was completely rewritten in 1997, despite the first iteration of the tool being developed as early as 1993), it's still in active development to date. Weka supports several common data mining tasks, like data preprocessing, classification, clustering, regression and data visualization. Its core libraries are written in Java and allow for an easy integration of its data mining algorithms in pre existing code and applications. Other than that, Weka can be used directly through a command line/terminal or through one of its multiple GUIs (Figure 2.2). Its simple API and well structure architecture allow it to be easily extended by users, should they need new functionalities.



Figure 2.2: WEKA's interface

⁶WEKA: <http://www.cs.waikato.ac.nz/ml/weka/>

2.3.1.3 R

R⁷ is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS. R provides a wide variety of statistical (linear and nonlinear modelling, classical statistical tests, time-series analysis, classification, clustering, among others) and graphical techniques, and is highly extensible. R is typically used by statisticians and data miners, either for direct data analysis or for developing new statistical software [FA05].

R is an open-source implementation of the S programming language, borrowing some characteristics from the Scheme programming language. Its core is written in a combination of C, Fortran and R itself. It is possible to directly manipulate R objects in languages like C, C++ and Java. R can be used directly through the command line or through several third party graphical user interfaces like Deducer⁸. There are also R wrappers for several scripting languages.

R provides several different statistical and graphical techniques, including linear and nonlinear modeling, classical statistical tests, time-series analysis, classification, clustering, among others. It can also be used to produce publication-quality static graphics. Tools like Sweave [Lei02] allow users to embed R code in L^AT_EX documents, for complete data analysis.

arules

The arules package⁹ is a R package for mining association rules and frequent itemsets. Its sister package, arulesViz¹⁰, allows the visualization of the results found by arules. Since it is common to work with large sets of rules and itemsets, the package uses sparse matrix representations to minimize memory usage. The infrastructure provided by the package was also created to explicitly facilitate extensibility, both for interfacing new algorithms and for adding new types of interest measures and associations.

TraMineR

TraMineR¹¹ (a contraction of Life Trajectory Miner for R) is a R-package for mining, describing and visualizing sequences of states or events, and more generally discrete sequential data. An example of the visualization features can be found in Figure 2.3. Its primary aim is the analysis of biographical longitudinal data in the social sciences, such as data describing careers or family trajectories. Most of its features also apply, however, to non temporal data. TraMineR is developed at the Institute for Demographic and Life Course Studies (IDEMO), University of Geneva, Switzerland under the responsibility of the TraMineR Scientific Committee.

⁷R: <http://www.r-project.org/>

⁸Deducer: <http://www.deducer.org/pmwiki/index.php>

⁹arules: <http://cran.r-project.org/web/packages/arules/index.html>

¹⁰<http://cran.r-project.org/web/packages/arulesViz/index.html>

¹¹TraMineR: <http://mephisto.unige.ch/traminer/>

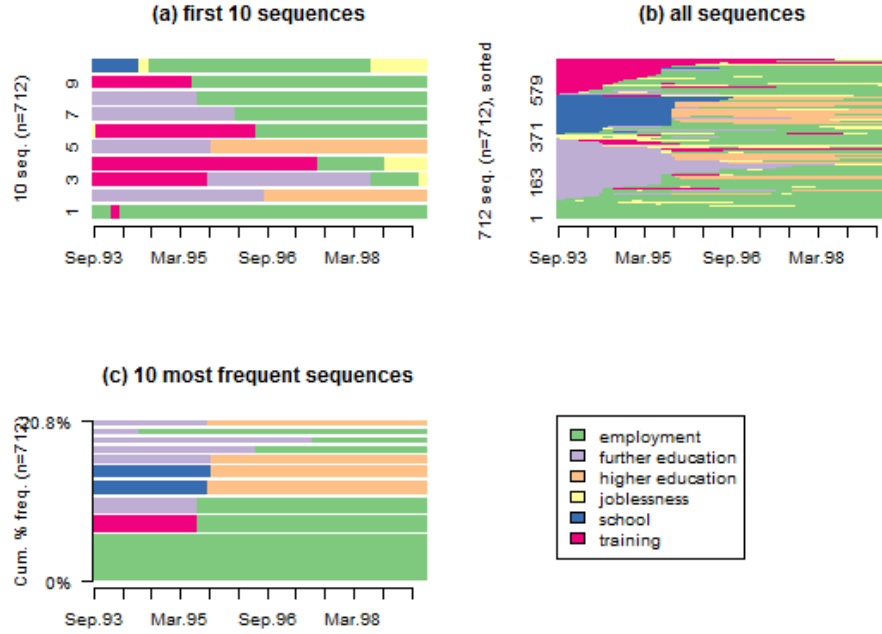


Figure 2.3: An example of data visualization using TraMineR

2.3.1.4 SPMF (Sequential Pattern Mining Framework)

SPMF¹² is an open-source data mining library written in Java and distributed under the GPL v3 license. It includes implementations for sequential pattern mining, association rule mining, frequent itemset mining, sequential rule mining, and clustering algorithms, and has over 80 citations.

2.4 Patterns

User Interaction (UI) patterns are well-documented in a various number of sources [Tid10, VWVDVE01, Nei, SGR⁺05]. The patterns already supported (like the Search and Master/Detail patterns) enter the list of most popular patterns, according to the sources found, and if the selection of supported patterns were to be broadened, the pick of the next one(s) would be heavily influenced by the literature. Lin and Landay’s approach [LL08] uses UI patterns for Web applications that run on PCs and mobile phones, and prompt-and-response style voice interfaces. Pontico *et al.*’s approach [PWL08] presents UI patterns common in eGovernment applications.

2.5 Chapter Conclusions

¹²SPMF: <http://www.philippe-fournier-viger.com/spmf/>

State-of-the-Art

Chapter 3

Suggested Approach

This chapter aims to give a brief overview of the PARADIGM-RE tool Following this exposition and explain the approaches the author is considering to take.

3.1 PARADIGM-RE

In this section, we'll provide a brief overview of the tool which this thesis means to improve, PARADIGM-RE [[NPCF13](#)].

3.2 Solution Approach

Suggested Approach

Chapter 4

Work Plan

The work plan for the proposed project can be divided into the following major tasks:

- State of the Art Research;
- Study of the existing PARADIGM-RE tool;
- Choice of approach to follow;
- Implementation/adaptation of the learning algorithm, additional patterns, and model export module;
- Period dedicated to running the algorithm on learning GUIs;
- Period dedicated to testing and validating the results obtained;
- Writing of a scientific report;
- Writing of the dissertation document

Whilst the dates for each work section are defined by this point, they could be subject to change along the course of the project. Since the periods in which each task is set to be worked upon are not independent, we believe the overall work structure in relation to the time available can be better understood by use of a Gantt diagram (Figure 4.1).

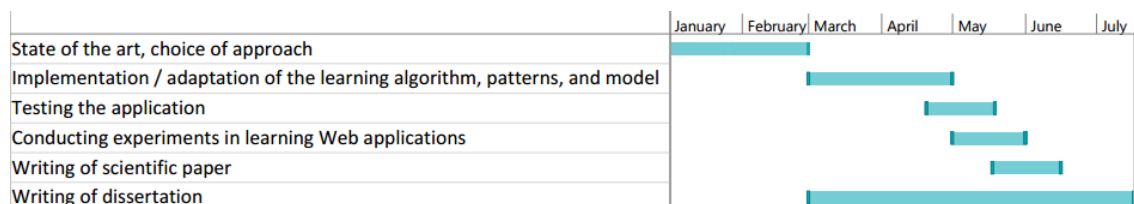


Figure 4.1: Gantt chart representing the proposed work plan.

As of the moment of the writing of this article, the research on both the state of the art regarding reverse engineering approaches, learning algorithms and the familiarization process with the

Work Plan

PARADIGM-RE tool will carry on being done until the ending of February. Following these steps, the effective work is then ready to be started, comprising a phase which should last until roughly the end of April. By then, the work developed thus far will undergo a learning phase (realization of experiences on learning GUIs, for the learning algorithm to draw conclusions on heuristics) and a testing and validation phase (of the newly developed patterns identified, the XMI model production and of the heuristics gotten via the learning algorithm, respectively) making adjustments as needed. This phase is expected to be concluded until the month of May at most.

This early deadline aims to make time to write a scientific paper, as well as to wrap up the dissertation document, which will be progressing in parallel with the previous phases. All the work here detailed is expected to be done by June of the current year.

Chapter 5

Conclusions

Conclusions

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