**MSc in Informatics Engineering**

**Entermediate Report**

# Evaluate the robustness of Cloud

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| | |
|---|---|
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*Dedication*

# Acknowledgements

I would like to thank to —— and to professors Raul Barbosa and Henrique Madeira, who are role models, by their support and help to take good decisions.

Thank my girlfriend for her support, understanding and the fellowship along this path. At my friends and colleagues of Department of Informatics Engineering the patience, support and for all times they have given me.

Last but certainly not least, I would like to thank my family for encouragement, love and all the unconditional and constant support that led me to fulfill this dream. Obrigado!

*Gonçalo Silva Pereira*

“Bridges are normally built on-time, on-budget, and do not fall down. On the other hand, software never comes in on-time or on-budget. In addition, it always breaks down.”

*Alfred Z. Spector, Google Research*

“"I have no special talents. I am only passionately curious."”

*Albert Einstein*

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# Abbreviations

**API** Application Programming Interface

**DDOS** Distributed Denial of Service

**IaaS** Infrastructure-as-a-Service

**ODC** Orthogonal Defect Classification

**PaaS** Platform-as-a-Service

**SaaS** Software-as-a-Service

## Abstract

The main goal of my dissertation is inject faults in code of applications, compile them and evaluate the results.

The theme of the dissertation is “Evaluate the robustness of Cloud”.

This thesis/dissertation presents an ????

**Keywords:** Faults, Errors, Failures, Vulnerabilities, Fault Injection, Fault Tolerance, Security, Robustness.

# 1 Introduction

In the next subsections will be introduced the context and the scope of this project.

## 1.1 Contextualization

The present dissertation describes the work developed in scope of MSc in Informatics Engineering. It is focused in "Evaluate the robusteness of Cloud" and this is one subject very important nowadays, because of the increase usage of these services. This services are characterized by the placement of data and software on remote infrastructure. Despite of the numerous benefits, the reliability of these platforms has not kept the needs, and users trust their applications to systems outside of personal control.

In this context, naturally arises the problem of confidence in the entity that manages the platform where applications have been executed. Any organization that put an application in the cloud (for example, Microsoft Azure or Amazon EC2) will have to accept the assurances given by the service provider.

This internship deals with the challenge of assessing the robustness of cloud platforms. The computing service provider uses virtualization to manage and allocate computing power to meet actual needs of the application. Although, there are solid virtualization platforms, fault tolerance is still a research problem.

## 1.2 The project

This project is based essentially in inject software faults. It was decided to inject software faults, since there are already other people involved in the part of hardware faults.

## 1.3 Objectives

The main objective of this work is to build a tool to inject software faults in code of some programs before the compilation.

But this main objective is divided in some other main goals:

- Generate derivations of main code of selected programs;
- Verify and analyze the effect of produced faults;
- Compile the programs with injected faults, by using make file.

## 1.4 Document Structure

In this document are specified all the related subjects with the project.

The second section will present the state-of-the-art in the related areas with particular emphasis to Cloud Computing and Fault Injection.

Third section is an important section of this report, because of the research involved in the execution of this work. I had to make decisions based in research results, knowledge and my own experience.

Fourth section describe the work that have been done in Fault Injector, and the work that I have to do in the next semester.

Fifty section explain the other modules that need to be done in this project to can view and evaluate the results of the fault injector.

Finally, in last section I do an overview analyses to my work, in general the operators and the constraints developed. I speak also in the work to be done in the next semester.

## 1.5 Management

In this section is described the planning of work developed in dissertation.

### 1.5.1 Meetings

In relation a meetings, the supervisor Raul Barbosa and me agreed that meet weekly was the best option. And the meetings were going on, with one or another change of schedule to reconcile with the other activities of both. In addition, I went to several general meeting of the project. Where could discuss concepts and the direction of the project with colleagues and teachers, among them: Raul Barbosa (supervisor), Henrique Madeira (co-supervisor), João Durães and João André Ferro.

### 1.5.2 Risks

The main-risks of execution of this project are:

- Equipment Failure
- Data lost
- Publication of similar research
- Personal issues interfere with progress
- Student loses interest
- Dispute between student and supervisor
- Supervisor takes excessive time to check final drafts
- Student wants to submit thesis without supervisor approval

The preventative measures and recovery measures can be seen at Appendix A.2.

### 1.5.3 Planning and Tracking

In Appendix A.1, is presented the gantt with the planning tasks to first and to second semester.

About the development of this project, I have used an *Agile Life Cycle* based in a *Incremental Model*.

What is the requirements of this project???

# 2 State of the Art

Nowadays, people use lot's of services based in cloud and lot's of companies choose to use them too. Using it, companies reduce the costs of IT infrastructure and people don't buy "physical storage" and don't care where are the data. The cloud service provide that the data is secure. But, like any system, the cloud have problems such as another computer systems, software and hardware faults. And the resilience of the cloud is an important characteristic.

The increased use of cloud is related with a low usage of many dedicated servers, lower voltage levels, reduce noise margins and increase clock rates.[1]

The cloud providers offers resources ready to deliver.[1]

With this work, I want to inject software faults and analyze how the system react to them.

A lot of studies show that the software faults[2] it's the main cause of computer failures.

About 44% of the software faults cannot be emulated.[3]

I had access to the application (executable only, not the source) of Robert Natella, called SAFE, that inject software faults, as I also have to do and I will describe it in next section.

## 2.1 SAFE by Robert Natella

Safe is an application to inject realistic software faults in programs written in C and C++. This tool uses MCPP as parser, to get the tree of code. The decision of use MCPP instead of GCC parser was a workaround for some of the shortcomings of the GCC's C preprocessor. After that, write some files, variations of original files (code with simple mutations) with operators applied. Robert Natella implemented thirteen operators in SAFE, same as João Durães,[4] but with the difference that Robert implemented at source code level, and João at binary level.

## 2.2 ODC Model

Orthogonal Defect Classification (ODC) Model is a framework developed by IBM, created to improve the level of technology available to assist the decisions of a software engineer, via measurement and analysis. ODC can be used to classifying and analyzing defects during software development.

essentially a classification of the defects. This model have eight categories:[5][6]

- **Function** - This defect affects significant capability, end-user features, product Application Programming Interface (API), interface with hardware architecture, or global structure(s). It would require a formal design change.

- **Checking** -
- **Assignment** -
- **Algorithm** -
- **Interface** -
- **Timing/serialization** -
- **Build/package/merge** -
- **Documentation** -

# 3 Research objectives and approach method

In this section are discussed the main aspects in study.

## 3.1 Cloud Computing

Three levels of Cloud Computing Service Models:

- **Infrastructure-as-a-Service (IaaS)** - as the name suggests, provides an computing infrastructure, such as virtual machines, firewalls, load balancers, IP addresses, virtual local area networks and others. Examples: Amazon EC2, Windows Azure.
- **Platform-as-a-Service (PaaS)** - provides an computing platform, normally includes operating system, programming language execution environment, database, web server and others. Examples: AWS Elastic Beanstalk, Windows Azure, Heroku.
- **Software-as-a-Service (SaaS)** - provides access to application softwares ofter referred as *on-demand self-service* sofwares. Use it without install, setup and run the application. Service provider do all things for you. Google Apps, Microsoft Office 365.

The cloud computing isn't free of external disturbances,[1] the most important are:

- Security attacks;
- Accidents;
- Power surges;
- Workload faults;
- Malfunction;
- Worms
- Distributed Denial of Service (DDOS) attacks.

## 3.2 GCC Parser vs Bison vs Eclipse CDT

In the beginning of planning the basic software without any user interface, I needed to research the best applications, as the best way for using them to obtain panned results (fault injector). For that, I thought that I can use the same tools that I have used in Compilers course, Lex and Yacc

For parsing the code, analyze and modify it,

Finally I decided to use Eclipse CDT Plugin as standalone (only import libraries to project), because of my facilities in programming in Java Language, the maintainability of software, the low learning level than the developers need to modify it.

Problems with the rewriting of tree

Reflection

But I was forced to take decisions after that, for example, after create the tree of code, I can go through the tree in the recursive way or using *Visitor Pattern*.

Performance analyses

## 3.3 Applications to inject faults

The same applications that João Durães have collect information?

# 4 Fault Injector Development

| Fault Type | Description |
|---|---|
| MFC | Missing function call |
| MVIV | Missing variable initialization using a value |
| MVAV | Missing variable assignment using a value |
| MVAE | Missing variable assignment with an expression |
| MIA | Missing IF construct around statements |
| MIFS | Missing IF construct + statements |
| MIEB | Missing IF construct + statements + ELSE construct |
| MLAC | Missing AND in expression used as branch condition |
| MLOC | Missing OR in expression used as branch condition |
| MLPA | Missing small and localized part of the algorithm |
| WVAV | Wrong value assigned to variable |
| WPFV | Wrong variable used in parameter of function call |
| WAEP | Wrong arithmetic expression in function call parameter |
| | add another faults |

Table 1: *Faults.*

## 4.1 Generate derivations

I chose to use the most representative faults,[4] divided into missing, wrong and extraneous, specified individually further down:

Table of more representative faults of Durães

### 4.1.1 Fault Types - Missing:

- **MIFS** - if construct plus statements

  This operator is based in the remotion of one conditional if. To do that, I need to verify the constraints c02, c08 and c09.

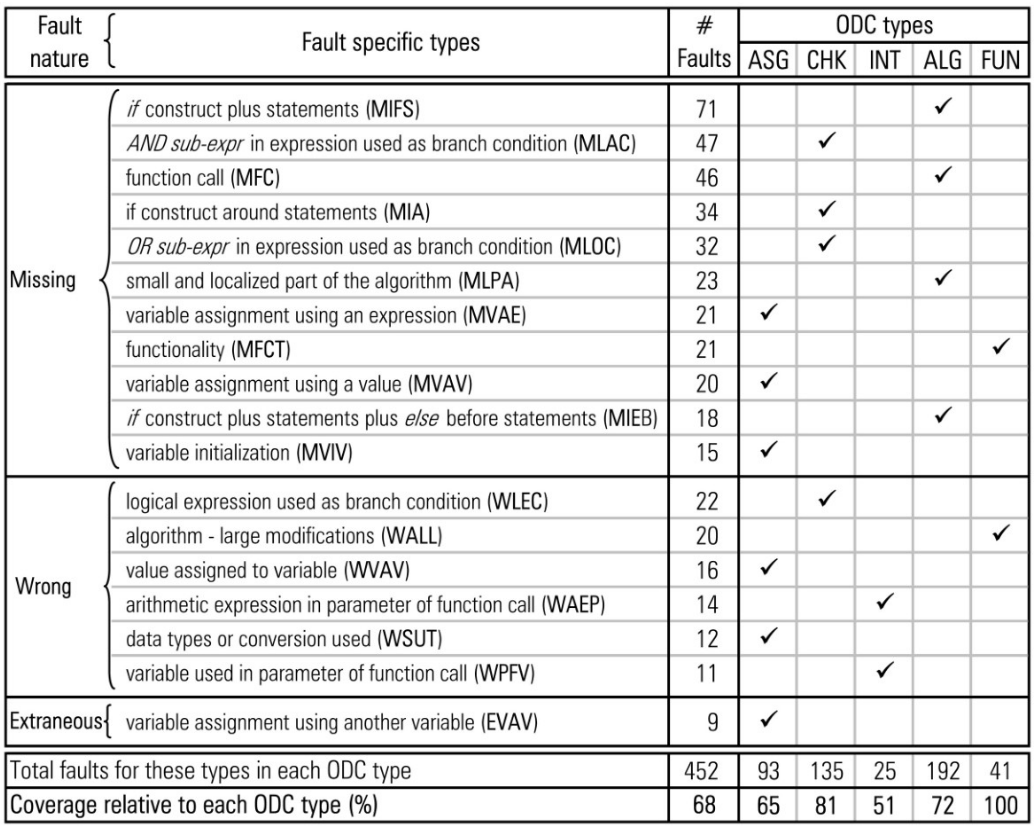
- **MLAC** - AND sub-expression in expression used as branch condition

- **MFC** - function call

- **MIA** - if construct around statements

- **MLOC** - OR sub-expression in expression used as branch condition

- **MLPA** - small and localized part of the algorithm



| Fault nature | Fault specific types | # Faults | ODC types | | | | |
|---|---|---|---|---|---|---|---|
| | | | ASG | CHK | INT | ALG | FUN |
| Missing | *if* construct plus statements (MIFS) | 71 | | | | ✓ | |
| | *AND sub-expr* in expression used as branch condition (MLAC) | 47 | | ✓ | | | |
| | function call (MFC) | 46 | | | | ✓ | |
| | if construct around statements (MIA) | 34 | | ✓ | | | |
| | *OR sub-expr* in expression used as branch condition (MLOC) | 32 | | ✓ | | | |
| | small and localized part of the algorithm (MLPA) | 23 | | | | ✓ | |
| | variable assignment using an expression (MVAE) | 21 | ✓ | | | | |
| | functionality (MFCT) | 21 | | | | | ✓ |
| | variable assignment using a value (MVAV) | 20 | ✓ | | | | |
| | *if* construct plus statements plus *else* before statements (MIEB) | 18 | | | | ✓ | |
| | variable initialization (MVIV) | 15 | ✓ | | | | |
| Wrong | logical expression used as branch condition (WLEC) | 22 | | ✓ | | | |
| | algorithm - large modifications (WALL) | 20 | | | | | ✓ |
| | value assigned to variable (WVAV) | 16 | ✓ | | | | |
| | arithmetic expression in parameter of function call (WAEP) | 14 | | | ✓ | | |
| | data types or conversion used (WSUT) | 12 | ✓ | | | | |
| | variable used in parameter of function call (WPFV) | 11 | | | ✓ | | |
| Extraneous | variable assignment using another variable (EVAV) | 9 | ✓ | | | | |
| Total faults for these types in each ODC type | | 452 | 93 | 135 | 25 | 192 | 41 |
| Coverage relative to each ODC type (%) | | 68 | 65 | 81 | 51 | 72 | 100 |

Table 2: *Representativeness faults.*

- **MVAE** - variable assignment using an expression
- **MFCT** - functionality
- **MVAV** - variable assignment using an value
- **MIEB** - if construct plus statements plus else before statements
- **MVIV** - variable initialization

### 4.1.2 Fault Types - Wrong:

- **WLEC** - logical expression used as branch condition
- **WALL** - algorithm - large modifications
- **WVAV** - value assigned to variable
- **WAEP** - arithmetic expression in parameter of function call

- **WSUT** - data types or conversion used
- **WPFV** - variable used in parameter of function call

#### 4.1.3 Fault Types - Extraneous:

- **EVAV** - variable assignment using another variable

## 4.2 Constraints

The constraints defined below was specified by João Durães in ... .

| Constraints | Description |
|---|---|
| **C01** | Return value of the function **must not** being used |
| **C02** | Call **must not be** the only statement in the block |
| **C03** | Variable **must be** inside stack frame |
| **C04** | **Must be** the first assignment for that variable in the module |
| **C05** | Assignment **must not be** inside a loop |
| **C06** | Assignment **must not be** part of a for construct |
| **C07** | **Must not be** the first assignment for that variable in the module |
| **C08** | The if construct **must not be** associated to an else construct |
| **C09** | Statements **must not include more than** five statements and not include loops |
| **C10** | Statements are in the same block, **do not include more than** 5 stats. not loops |
| **C11** | There **must be** at least two variables in this module |

# 5 Work plan and implications

Built three separated modules:

- Generate the derivations of main code of selected programs;
- Verify and analyze the effect of produced faults;
- Compile the programs with injected faults, by using make file.

## 5.1 Analyze the effects

The fault injected results is equal to the real software faults?

## 5.2 Compile programs

Select five to ten programs to test.

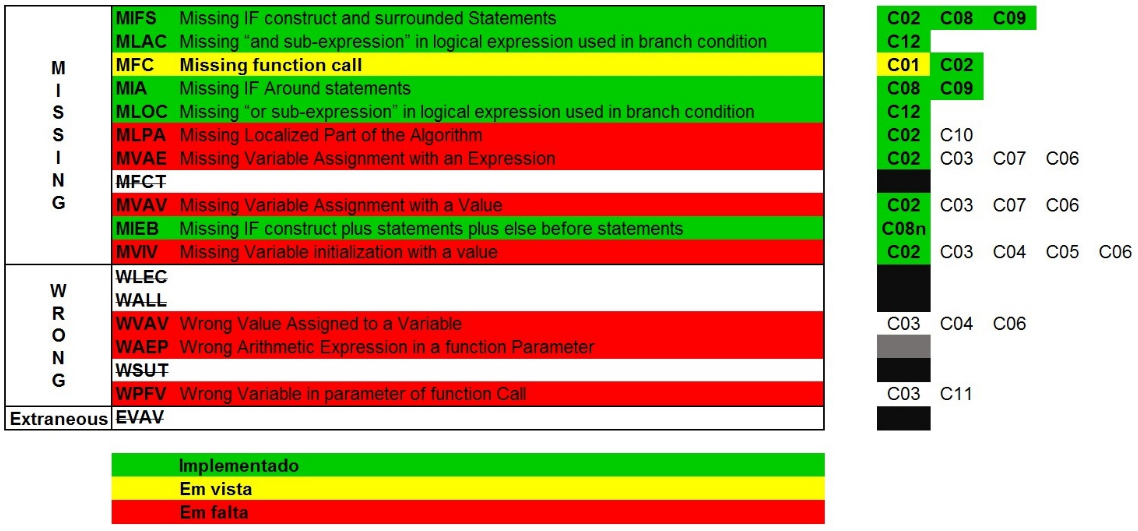
After the compilation and execution of the programs, the results need to be evaluate. For that, I will use the *CRASH Scale*:[7]

- **C**atastrophic
- **R**estart
- **A**bort
- **S**ilent
- **H**indering

# 6 Conclusion

## 6.1 Global Vision

In table 3, it's possible to understand the operators that was implemented in the first semestre of this dissertation. As can be seen, I have implemented five of thirteen operators that João Durães was especified.

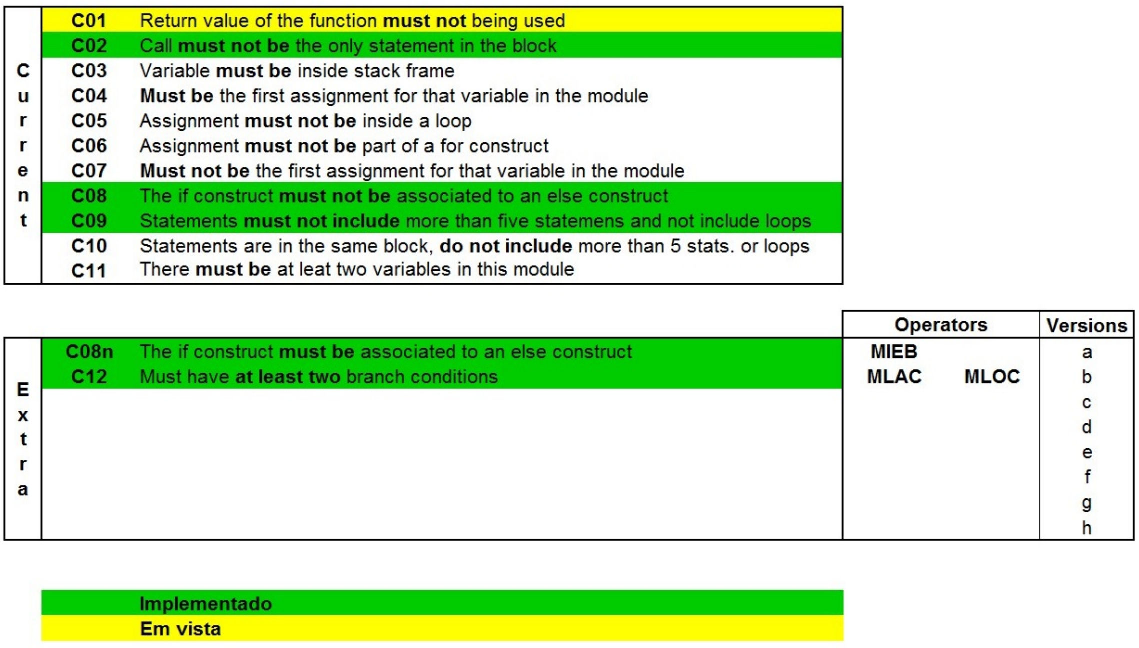


| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| MISSING | 🟩 | MIFS | Missing IF construct and surrounded Statements | C02 | C08 | C09 | | | |
| | 🟩 | MLAC | Missing "and sub-expression" in logical expression used in branch condition | C12 | | | | | |
| | 🟨 | MFC | **Missing function call** | C01 | C02 | | | | |
| | 🟩 | MIA | Missing IF Around statements | C08 | C09 | | | | |
| | 🟩 | MLOC | Missing "or sub-expression" in logical expression used in branch condition | C12 | | | | | |
| | 🟥 | MLPA | Missing Localized Part of the Algorithm | C02 | C10 | | | | |
| | 🟥 | MVAE | Missing Variable Assignment with an Expression | C02 | C03 | C07 | C06 | | |
| | | ~~MFCT~~ | | ■ | | | | | |
| | 🟥 | MVAV | Missing Variable Assignment with a Value | C02 | C03 | C07 | C06 | | |
| | 🟩 | MIEB | Missing IF construct plus statements plus else before statements | C08n | | | | | |
| | 🟥 | MVIV | Missing Variable initialization with a value | C02 | C03 | C04 | C05 | C06 | |
| WRONG | | ~~WLEC~~ | | ■ | | | | | |
| | | ~~WALL~~ | | ■ | | | | | |
| | 🟥 | WVAV | Wrong Value Assigned to a Variable | C03 | C04 | C06 | | | |
| | 🟥 | WAEP | Wrong Arithmetic Expression in a function Parameter | ▨ | | | | | |
| | | ~~WSUT~~ | | ■ | | | | | |
| | 🟥 | WPFV | Wrong Variable in parameter of function Call | C03 | C11 | | | | |
| Extraneous | | ~~EVAV~~ | | ■ | | | | | |

| | |
|---|---|
| 🟩 | **Implementado** |
| 🟨 | **Em vista** |
| 🟥 | **Em falta** |

Table 3: *Operators Status and related constraints.*

In table 4, can be seen also that I have implemented tree of eleven constraints related to the thirteen operators.



| | | |
|---|---|---|
| | 🟨 C01 | Return value of the function **must not** being used |
| | 🟩 C02 | Call **must not be** the only statement in the block |
| C | C03 | Variable **must be** inside stack frame |
| u | C04 | **Must be** the first assignment for that variable in the module |
| r | C05 | Assignment **must not be** inside a loop |
| r | C06 | Assignment **must not be** part of a for construct |
| e | C07 | **Must not be** the first assignment for that variable in the module |
| n | 🟩 C08 | The if construct **must not be** associated to an else construct |
| t | 🟩 C09 | Statements **must not include** more than five statemens and not include loops |
| | C10 | Statements are in the same block, **do not include** more than 5 stats. or loops |
| | C11 | There **must be** at leat two variables in this module |

| | | | **Operators** | | **Versions** |
|---|---|---|---|---|---|
| | 🟩 C08n | The if construct **must be** associated to an else construct | **MIEB** | | a |
| | 🟩 C12 | Must have **at least two** branch conditions | **MLAC** | **MLOC** | b |
| E | | | | | c |
| x | | | | | d |
| t | | | | | e |
| r | | | | | f |
| a | | | | | g |
| | | | | | h |

| | |
|---|---|
| 🟩 | **Implementado** |
| 🟨 | **Em vista** |

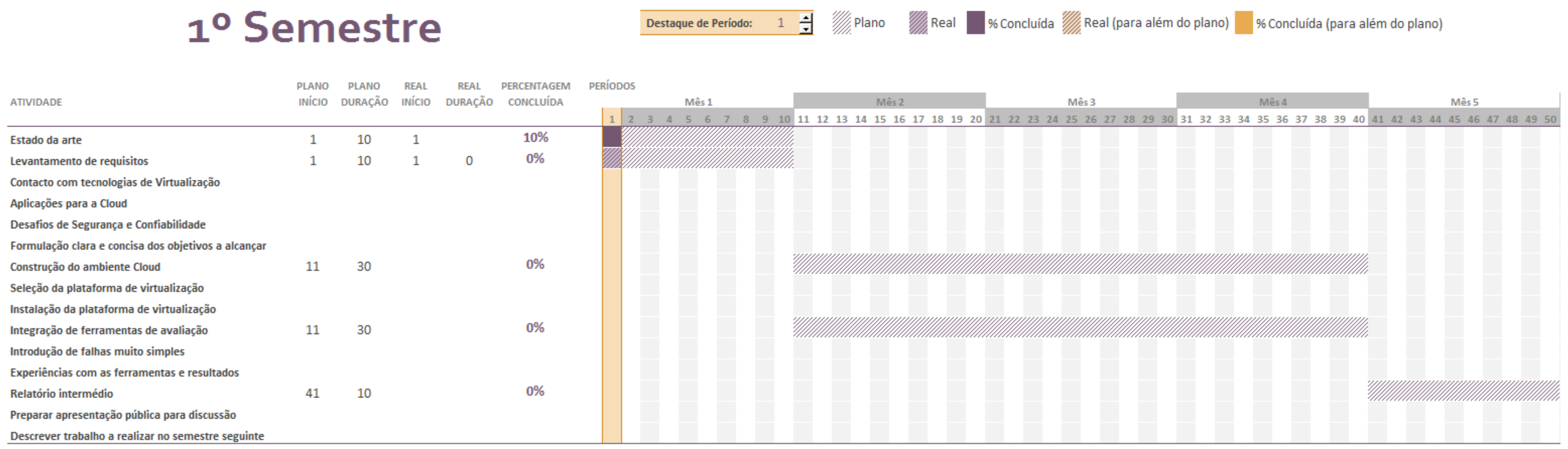
Table 4: *Constraints Status.*

## 6.2 Future Work

To the future, I plain to implement the other operators and constraints. And apply this software in testing of open source softwares that I will select.

## A Appendix

## A.1 Appendix A - Gantt diagrams



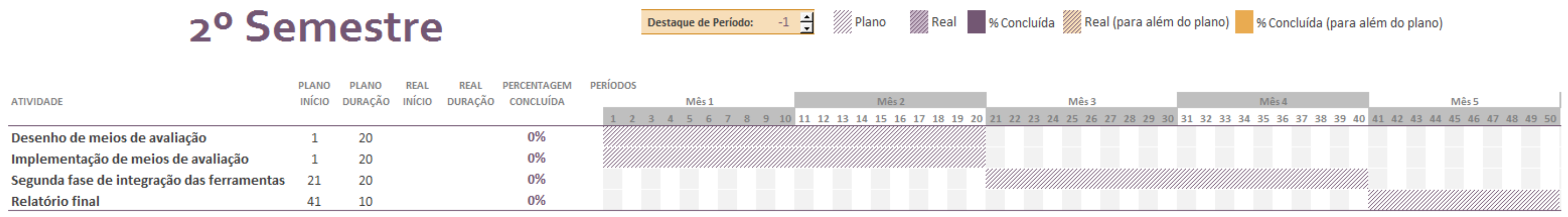
1º Semestre

Destaque de Período: 1

▨ Plano ▨ Real ■ % Concluída ▨ Real (para além do plano) ■ % Concluída (para além do plano)

| ATIVIDADE | PLANO INÍCIO | PLANO DURAÇÃO | REAL INÍCIO | REAL DURAÇÃO | PERCENTAGEM CONCLUÍDA |
|---|---|---|---|---|---|
| Estado da arte | 1 | 10 | 1 | | 10% |
| Levantamento de requisitos | 1 | 10 | 1 | 0 | 0% |
| Contacto com tecnologias de Virtualização | | | | | |
| Aplicações para a Cloud | | | | | |
| Desafios de Segurança e Confiabilidade | | | | | |
| Formulação clara e concisa dos objetivos a alcançar | | | | | |
| Construção do ambiente Cloud | 11 | 30 | | | 0% |
| Seleção da plataforma de virtualização | | | | | |
| Instalação da plataforma de virtualização | | | | | |
| Integração de ferramentas de avaliação | 11 | 30 | | | 0% |
| Introdução de falhas muito simples | | | | | |
| Experiências com as ferramentas e resultados | | | | | |
| Relatório intermédio | 41 | 10 | | | 0% |
| Preparar apresentação pública para discussão | | | | | |
| Descrever trabalho a realizar no semestre seguinte | | | | | |

Figure 1: *First semester gantt.*



2º Semestre

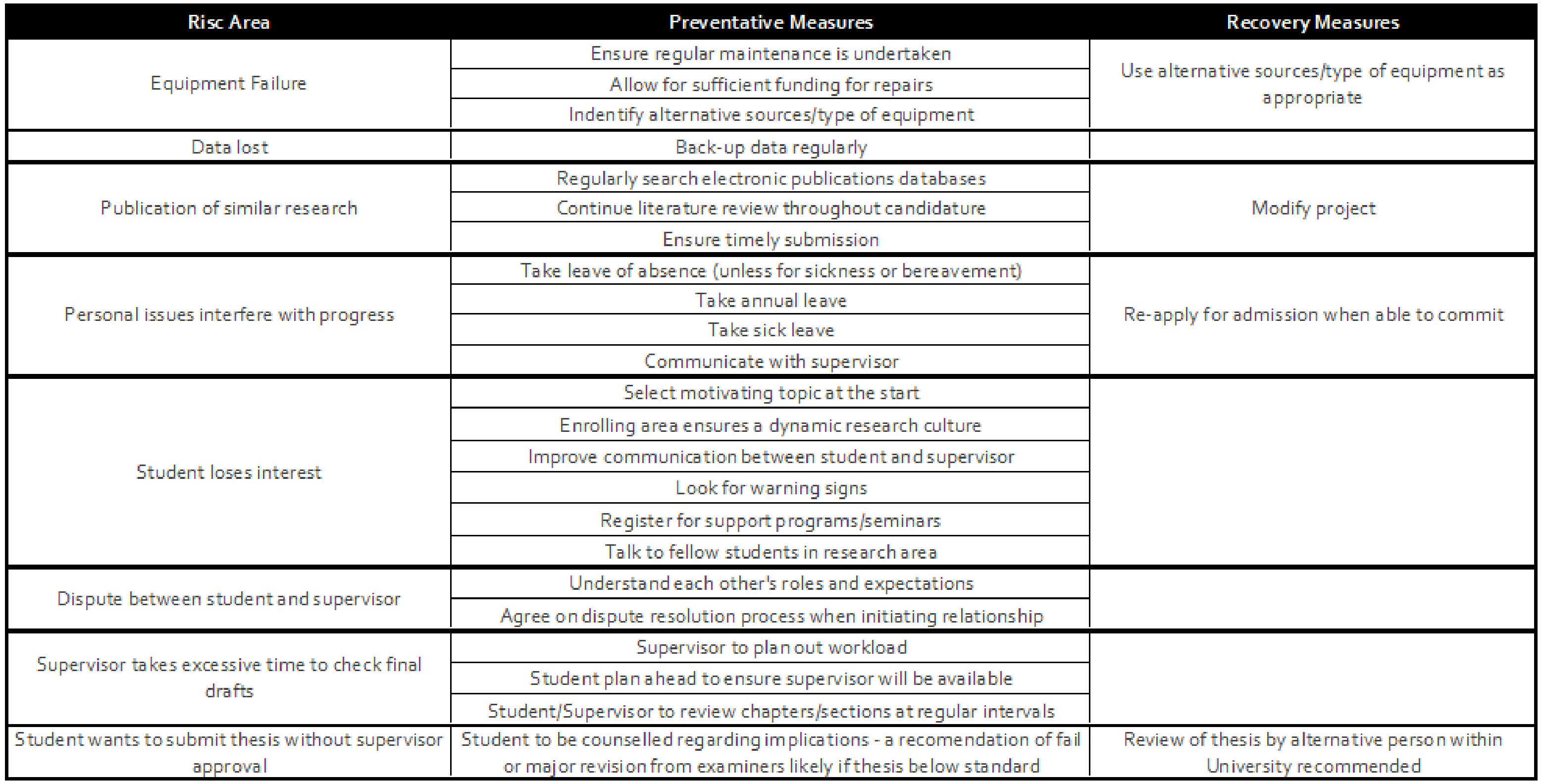
Destaque de Período: -1

▨ Plano ▨ Real ■ % Concluída ▨ Real (para além do plano) ■ % Concluída (para além do plano)

| ATIVIDADE | PLANO INÍCIO | PLANO DURAÇÃO | REAL INÍCIO | REAL DURAÇÃO | PERCENTAGEM CONCLUÍDA |
|---|---|---|---|---|---|
| Desenho de meios de avaliação | 1 | 20 | | | 0% |
| Implementação de meios de avaliação | 1 | 20 | | | 0% |
| Segunda fase de integração das ferramentas | 21 | 20 | | | 0% |
| Relatório final | 41 | 10 | | | 0% |

Figure 2: *Second semester gantt.*

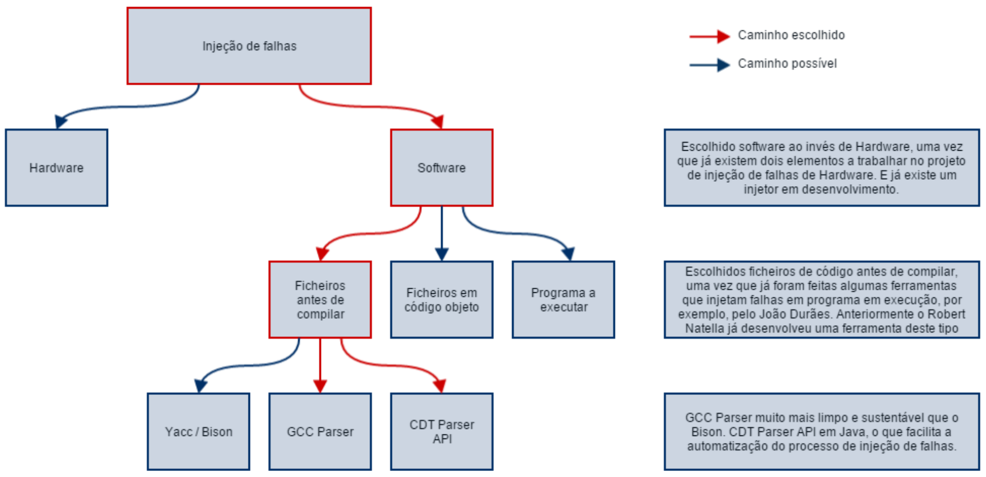
## A.2 Appendix B - Risks table



| Risc Area | Preventative Measures | Recovery Measures |
|---|---|---|
| Equipment Failure | Ensure regular maintenance is undertaken | Use alternative sources/type of equipment as appropriate |
| | Allow for sufficient funding for repairs | |
| | Indentify alternative sources/type of equipment | |
| Data lost | Back-up data regularly | |
| Publication of similar research | Regularly search electronic publications databases | Modify project |
| | Continue literature review throughout candidature | |
| | Ensure timely submission | |
| Personal issues interfere with progress | Take leave of absence (unless for sickness or bereavement) | Re-apply for admission when able to commit |
| | Take annual leave | |
| | Take sick leave | |
| | Communicate with supervisor | |
| Student loses interest | Select motivating topic at the start | |
| | Enrolling area ensures a dynamic research culture | |
| | Improve communication between student and supervisor | |
| | Look for warning signs | |
| | Register for support programs/seminars | |
| | Talk to fellow students in research area | |
| Dispute between student and supervisor | Understand each other's roles and expectations | |
| | Agree on dispute resolution process when initiating relationship | |
| Supervisor takes excessive time to check final drafts | Supervisor to plan out workload | |
| | Student plan ahead to ensure supervisor will be available | |
| | Student/Supervisor to review chapters/sections at regular intervals | |
| Student wants to submit thesis without supervisor approval | Student to be counselled regarding implications - a recomendation of fail or major revision from examiners likely if thesis below standard | Review of thesis by alternative person within University recommended |

Figure 3: *Risks.*

## A.3 Appendix C - Decision Tree



Escolhido software ao invés de Hardware, uma vez que já existem dois elementos a trabalhar no projeto de injeção de falhas de Hardware. E já existe um injetor em desenvolvimento.

Escolhidos ficheiros de código antes de compilar, uma vez que já foram feitas algumas ferramentas que injetam falhas em programa em execução, por exemplo, pelo João Durães. Anteriormente o Robert Natella já desenvolveu uma ferramenta deste tipo

GCC Parser muito mais limpo e sustentável que o Bison. CDT Parser API em Java, o que facilita a automatização do processo de injeção de falhas.

Figure 4: *Decision Tree.*

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