Automated Tests of Computer-based Interlocking Systems

Developing a test case generator

MOHAMED BAKHIET

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Master’s Thesis at ICS
Supervisor: Olof Sundqvist
Examiner: Robert Lagerström
Abstract

Automated tests have become the most sought after method of testing in today’s market. Automating systems is generally found to be cheaper, faster and more reliable than manually operating them. For this reason many companies decide to make the switch over to this inexpensive yet efficient way of testing, only to realize that their costs have in fact gone up. The reasons for this could be poor planning, automating too much too soon or even automating unnecessary parts of the system. This study takes a closer look at the effects of automating tests used on interlocking systems. A tool has been developed as a part of the automated tests at Bombardier. The main function of the tool is to speed up the testing process by automatically generating test cases rather than having a worker write them down. The aim of this paper is to present this recently developed tool and show how its use significantly reduces testing time, costs and workload compared to the manual tests used today.

Keywords: Computer-based interlocking, test cases, test case generator, automation, manual tests.
Sammanfattning


Nyckelord: Förregling, datorställverk, testfall, genereringsverktyg, automatiserings, manuella tester
Acknowledgments

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I am very glad to have had the opportunity of working with my colleague, Mikael Krydzinski. The exchange of thoughts and ideas, as well as the great conversations between us made work a lot smoother and more enjoyable.

And finally of course, I have to thank my parents and the rest of my family for all the love and support. Their endless encouragement and constant optimism have always been the greatest source of motivation in my life.
## List of abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBI</td>
<td>Computer-Based Interlocking</td>
</tr>
<tr>
<td>GP</td>
<td>Generic product</td>
</tr>
<tr>
<td>GA</td>
<td>General application</td>
</tr>
<tr>
<td>Eurostat</td>
<td>Statistical office of the European Union</td>
</tr>
<tr>
<td>KTH</td>
<td>Royal Institute of Technology</td>
</tr>
<tr>
<td>RCS</td>
<td>Rail Control Solutions</td>
</tr>
</tbody>
</table>
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Chapter 1

Introduction

Transportation is increasingly becoming an indispensable part of our lives. The use of rail transportation is becoming all the more frequent due to its advantages. The most notable of these are reduced traffic congestion and pollution, a means for the less financially stable to travel and an increase in property values fostering economic development [1]. Over 405 billion passenger-kilometers were travelled in the European Union (except Bulgaria) during 2008 according to Eurostat [2]. Figure 1.1 shows the distances travelled by passenger trains in Sweden between 1990 and 2011 [3].

With the ever growing demands of rail transport it is highly crucial that safety performance undergoes continual improvement. This is achieved through thorough testing and verification of the railway system.

Figure 1.1. Passenger-kilometers travelled in Sweden [3]
1.1 Background

Train traffic and movement is controlled through railway signaling. A fundamental part of railway signaling is interlocking. Interlocking is defined as “the controlling of setting and releasing of ‘signals’ and ‘points’ to prevent unsafe conditions from arising...” [4]. Figure 1.2 is an illustration of how interlocking works [5]. As train 1 is given the green light, it is crucial that train 2 does not enter the intersection until train 1 has passed. Furthermore, it is important that the points are in the correct position in order for the train 1 to take the correct route. These objects are controlled through interlocking.

Interlocking was first introduced in England where engineer John Saxby received the first patent for it in 1856. During that time they used what is known today as mechanical interlocking, where an operator controls signals, points and other appliances through levers.

With the electronic age and advancements in technology, mechanical interlocking would largely be replaced by relay interlocking. Relay interlocking is an electrical system comprised of circuits made up of relays. An advantage with relay interlocking is that one signal box could replace numerous mechanical plants as they can cover larger areas. The main concern with relay interlocking is the maintenance cost over a longer period.

An alternative to relay interlocking is computer-based interlocking (CBI) whereby complex circuitry is replaced by software logic. This means that changes and modifications can be reprogrammed rather than having to rewire the system which saves time, money and resources. In fact, a study from the United States shows that the life-cycle cost of Computer-based interlocking is significantly less than that of relay-based interlocking over a 25 year period [6]. For this reason, among others, numerous interlocking systems around the world are being replaced by computer-based interlocking. In this thesis project CBI-systems will be tested.
1.2 Testing of CBI-systems

A potential benefit that could arise as a result of using computer-based interlocking is highly improved efficiency in testing and verification of the interlocking system. In a CBI-system that is used to control rail traffic there is a wide range of data. The data has a number of purposes such as describing the interlocking functionality and passing on signal information to the train. At Bombardier RCS, the company where this thesis project was conducted, tests on the CBI-system are carried out in a simulated environment before it can be operated in a station. When a customer is looking to purchase a CBI-system they provide the supplier with certain details such as signal and geographical information of a station. To ensure that the system satisfies all the customer requirements as well as safety and quality standards, the CBI-system needs to be tested and verified for a variety of different scenarios. Tests at Bombardier are today carried out manually whereby a worker will run each test against the CBI-system and verify that it passes. The greatest disadvantage with manual testing is that they are very time consuming. Since costs increase with time, running large tests can become expensive leading to a shortage of necessary testing. Manual tests can also be very demanding on the workers, causing stress, fatigue and inconsistencies.

1.3 Thesis project

Bombardier is currently working on automating a large number of manual tests through the use of test cases that represent different scenarios and their expected outcomes. Test cases are sent to a test engine that automatically runs all the tests to verify that the requirements are satisfied. Writing down these test cases is extremely time consuming as some tests may require thousands of different scenarios to be examined and verified. The main purpose of the thesis project is to find a solution that eliminates the undesired time consumption caused by the number of test cases. To address this, the following questions have to be asked:

- Is there a way to speed up the slow process?
- Will this solution make automated tests a feasible alternative to the manual testing methods used today?
- Should all manual tests be automated?
CHAPTER 1. INTRODUCTION

1.4 Objectives

The objectives of this project are to:

- Design and create a tool that automatically generates test cases that can be directly run against the CBI-system.
- Write a user-manual for the tool.
- Run automated tests using the tool and compare the results with those of manual tests in order to study the benefits of automation in terms of time and costs.
- Conduct interviews with test engineers to get a better understanding of their opinions regarding automation.

1.5 Delimitations

The project will span over a 20 week period and take place at Bombardier RCS in Stockholm. Since the automation of tests can influence a wide range of variables, the focus of this paper will lie on its effects on time, costs and workload. The tests and results illustrated in chapter 5 will be an ongoing process which spans beyond the end of the thesis period. For that reason results will only curtail to the first round of testing using the tool. Although regression testing will be discussed it will not be a part of the results.

1.6 Outline

The report is made up of nine chapters.

Chapter 1 gives some brief background information about rail transportation and its safety requirements. Then interlocking systems are shortly introduced and discussed.

Chapter 2 breaks up the project into different phases and mentions the work that was carried out during each one of them.

Chapter 3 starts off with some general information on automation and then goes into some of the advantages and disadvantages of automating tests.

Chapter 4 is a summary of the tool that was developed. The structure and functions of the tool are explained in detail.

Chapter 5 presents the tests performed as well as their results and analysis.
1.6. OUTLINE

Chapter 6 is the interview session conducted with the test engineers.

Chapter 7 discusses the feasibility of using automated tests over manual tests at the company as well as issues regarding the tool.

Chapter 8 gives a conclusion regarding the developed tool and the subject of automated versus manual tests.

Chapter 9 mentions some of the recommended future work after this project.
Chapter 2

Methodology

Figure 2.1. Phases of the thesis project

The entire thesis project mostly takes place at Bombardier RCS. The remainder of the work is completed at KTH. The phases of this project can be seen in figure 2.1.

The working process at KTH consists of two parts, start-up and presentation. The start-up phase mostly deals with agreements regarding the thesis work and other formalities between student, examiner and supervisor. Once the start-up phase is concluded, work at the company begins. The presentation, the last phase of the thesis project, is held after the work at the company is completed and presents the results and findings of the thesis project.

In the pre-study phase all the material and specifications of the company are studied and revised. This includes the programming languages they use, the data formats of the files and documents as well as standards and requirements.

The theory phase takes a closer look at the planning and structuring of the tool. Furthermore, different programming techniques are investigated in order to achieve a tool that is simple, efficient and adaptable. This phase is extremely crucial as it lays down the foundation of the tool.
The *implementation* phase is where the programming starts and the tool is developed. In this phase it is important to follow the steps and methods identified in the theory phase. After the development of the tool, a user manual is written with the aim of helping workers at Bombardier to acquaint themselves with the tool. The user manual is later be reviewed and updated before being approved.

The final phase at the company is the *testing* phase. Tests are run over a two month period where the tool is extensively used to generate test cases for three different tests.
Chapter 3

Automation

Automation, in general, implies operating, acting or self-regulating, independently, without human intervention [7]

We currently live in a world where the demand for automation is exponentially increasing. Automation has significantly changed the way we perform tasks whether it be in our homes, schools or places of work. In fact, automation has become so crucial that it is now applicable in all walks of life such as:

- Infrastructure
- Transportation
- Military
- Health care
- Banking
- Sports
- Education
- Manufacturing

The question is, “Why has it become such a fundamental need?”
3.1 Why automation?

There are numerous reasons as to why automation is desired. Figure 3.1 illustrates a few of those reasons [8]. People are always looking for added comforts; businesses are continuously trying to increase revenue and organizations constantly need to improve their services. Lately, with the advancements made in software technology, companies have become all the more interested in automating different parts of their work. One of these parts is the testing process.

3.2 Automating tests

Automating tests is something companies, large and small, find extremely attractive to their business. If carefully planned and appropriately executed, companies can improve the quality of their tests while reducing costs simultaneously. In this thesis project, a closer study of how automated tests affect testing time, costs and worker performance is investigated.
3.2. AUTOMATING TESTS

3.2.1 Effect on time and costs

Tests are usually automated to save time, but sometimes running manual tests will be the faster option. This is frequently the case when running a rather small test. Since automated tests often require a longer preparation time, they don’t actually save any time unless they are large enough. Because of this preparation time, it’s not uncommon to have manual tests running quicker than automated ones during the first round of testing. However, as tests always need to be repeated, usually in the form of regression testing, automated tests do tend to pay off with time, see figure 3.2.

The cost of automation when it comes to testing is almost directly linked to the testing time. Time is money, and if the automated tests fail to achieve a decrease in time consumption, it will be noticed in the return of investment (ROI). However as stated in [9], it is important to remember that most automated tests don’t actually pay off until the next project.

3.2.2 Effect on workers

People have always been fascinated by automation; partly because the concept itself is rather intriguing, but mostly because of the added luxuries it provides them with. A great benefit of automation today is the level of safety it brings to both the work and the workers. The authors of paper [10] study how automation can benefit workers and in turn the work being carried out. But like most things in life, there

![Figure 3.2. Time for automated and manual tests](image)
can be consequences to this. Their findings are illustrated in figure 3.3, which lists the major advantages and disadvantages of automation on workers.

Advantages vs Disadvantages
- Elimination of human error
- Lower fatigue factor
- Reduced workload
- Increased stability
- Reduced stress
- Manual skills deteriorate
- Less awareness over system
- Less understanding of situation

Figure 3.3. Advantages and disadvantages of automation on workers [10]
Chapter 4

Test case generator

4.1 Approach

Before starting to develop the test case generator, it is important to decide how the whole project should be approached. Issues regarding the purpose, structure and functionality of the tool have to be addressed. The available input data and the desired output data have to be discussed, as well as data formats, programming language and much more.

4.1.1 Purpose of tool

The main function of the tool is to extract information from various input data and use it to generate files containing test cases as shown in figure 4.1. Input data is largely generated through an in-house program at Bombardier. Test cases are then set up in the tool and finally generated into the desired file format. These generated files will at a later stage be used to run automated tests against the CBI-system to verify that it is functioning correctly.

![Figure 4.1. Overview of the tool](image-url)
4.1.2 Tool language

The tool was built using Python. Although a number of programming languages could be used to create the tool, Python presents a number of benefits that made it seem like the most suitable option. The advantages that Python offer are [11]:

- Free and open source
- Easy to use
- Powerful
- Object-oriented
- Runs on most operative systems
4.2 Tool implementation

4.2.1 Architecture

When designing the structure, it is important to factor in qualities that make the tool both simple and efficient for the user. Separating the script and functions into modules makes the development of the tool easier and increases its maintainability. The structure of the tool can be seen in figure 4.2.

![Figure 4.2. Structure of the tool](image-url)
4.2.2 Functionality

<table>
<thead>
<tr>
<th>Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readers</td>
<td>Extract data from <em>input data files</em></td>
</tr>
<tr>
<td>Converters</td>
<td>Convert <em>input data files</em> into desired formats</td>
</tr>
<tr>
<td>Writers</td>
<td>Create and structure <em>generated files</em></td>
</tr>
<tr>
<td>Data reader</td>
<td>Links all the readers</td>
</tr>
<tr>
<td>Data converter</td>
<td>Links all the converters</td>
</tr>
<tr>
<td>Data writers</td>
<td>Links all the writers</td>
</tr>
<tr>
<td>Data storage</td>
<td>Stores extracted data from readers in dictionaries</td>
</tr>
<tr>
<td>Utilities</td>
<td>Additional module used to extract specific data</td>
</tr>
<tr>
<td>Temp.test storage</td>
<td>Temporarily stores output data until data is written</td>
</tr>
<tr>
<td>Test framework</td>
<td>Links the data modules to GP main</td>
</tr>
<tr>
<td>GP main</td>
<td>Contains all functions from the data modules used to</td>
</tr>
<tr>
<td></td>
<td>create tests</td>
</tr>
<tr>
<td>GA main (optional)</td>
<td>Contains specific functions for customary tests</td>
</tr>
<tr>
<td>Custom script</td>
<td>Generates tests based on input data and defined rules</td>
</tr>
</tbody>
</table>

*Table 4.1. Module description*

The different modules and all of their functions are described in table 4.1. The *custom script* is used to execute the tool. This is usually done through *GP main*. However, if a tester needs to add some of their own functions to the test, they can do so by adding them to the *GA main*. The tool will in this case be executed through the *GA main*. The execution process is shown in figure 4.3.
4.2. TOOL IMPLEMENTATION

Figure 4.3. Execution of the tool

4.2.3 Documentation

A user manual was written after the development of the tool. The manual contains the necessary information for an employee to run and try out the available functions. The user manual was revised and updated a number of times, and is now ready to be released. Hopes are that the tool will be available at offices abroad soon.
Chapter 5

Empirics

5.1 Tests

Three sets of automated tests were conducted on a current project using the tool. Each test is divided into three parts.

The first part looks at the characteristics of the test. That is the number of test scenarios that are tested, the number test cases, how many of them failed and the success rate of the whole test. A failed test case implies that our expected value is different to that of the CBI-system.

The second part compares tests run with and without the tool in a simulator. This allows us to see how much time can be saved simply by using the tool as opposed to writing down the test cases one by one. The reason why a simulator was used as opposed to the real system is that only the preparation time differs between these two testing methods. Furthermore, the benefits of simulated tests are that they run much faster than real-time tests, and they are applicable where certain real-life situations cannot be tested. Preparation time for the tests without the tool were estimated by writing down a hundred test cases, measuring the time it took and then calculating the estimated time it would take to write down all test cases. This was done as it would have taken too long to write down all test cases for each test.

The third part compares automated tests using the tool with manual testing. These parts of the tests were run on the real-time CBI-system. Here, time between manual and automated tests are compared. Testing time for the manual tests were estimated by highly experienced test engineers at the company. The reason for this was that the project is still ongoing and as such, manual tests have still not been completed.

Although the estimated values have to be treated as possible sources of error, it is important to note that the best case scenario was taken for each test. Therefore, it unlikely that these values will affect the outcome of the analysis let alone our conclusions.
5.1.1 Test A: Occupy and release

The occupying and releasing of track circuits detects the movement of the train. Tests were carried out to ensure that the occupation and release of the track circuits were running properly. Test A consisted of 7782 test cases.

5.1.2 Test B: Approach locking

When a signal wants to display STOP there needs to be a sufficient braking distance for the train to stop safely. If this distance is too short the signal must allow the train to pass. This is known as Approach locking. 10815 test cases were tested in Test B.

5.1.3 Test C: Level crossings

Level crossings are intersections where railways and roads meet. Level crossings have been sites of major accidents in the past, and therefore it is vital that they be tested carefully. In test C, 12 level crossings were tested. This was the largest of all three tests with a combined total of 75837 test cases.

5.2 Results

The results were divided into three tables for each set of tests. The first table gives the characteristics of the test, i.e. how many test cases were executed and their success rate etc. The second table looks at the simulated tests and indicates the time differences between tests run with and without the tool. The third table shows the different outcomes regarding time of automated and manual tests.
5.2. RESULTS

5.2.1 Results for Test A

<table>
<thead>
<tr>
<th>Number of scenarios</th>
<th>Number of test cases</th>
<th>Number of failed cases</th>
<th>Success rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>166</td>
<td>7782</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5.1. Properties of Test A

<table>
<thead>
<tr>
<th>Simulated tests</th>
<th>Prep time (h)</th>
<th>Total time (h:m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With tool</td>
<td>16</td>
<td>16:29</td>
</tr>
<tr>
<td>Without tool</td>
<td>43</td>
<td>43:29</td>
</tr>
</tbody>
</table>

Table 5.2. Simulated tests for Test A

<table>
<thead>
<tr>
<th>Real-time tests</th>
<th>Total time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated</td>
<td>19</td>
</tr>
<tr>
<td>Manual</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 5.3. Real-time tests for Test A
5.2.2 Results for Test B

<table>
<thead>
<tr>
<th>Number of scenarios</th>
<th>Number of test cases</th>
<th>Number of failed cases</th>
<th>Success rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>129</td>
<td>10815</td>
<td>758</td>
<td>93</td>
</tr>
</tbody>
</table>

Table 5.4. Properties of Test B

<table>
<thead>
<tr>
<th>Simulated tests</th>
<th>Prep time (h)</th>
<th>Total time (h:m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With tool</td>
<td>24</td>
<td>24:47</td>
</tr>
<tr>
<td>Without tool</td>
<td>60</td>
<td>60:47</td>
</tr>
</tbody>
</table>

Table 5.5. Simulated tests for Test B

<table>
<thead>
<tr>
<th>Real-time tests</th>
<th>Total time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated</td>
<td>25</td>
</tr>
<tr>
<td>Manual</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 5.6. Real-time tests for Test B
5.2. RESULTS

5.2.3 Results for Test C

<table>
<thead>
<tr>
<th>Number of scenarios</th>
<th>Number of test cases</th>
<th>Number of failed cases</th>
<th>Success rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>112</td>
<td>75837</td>
<td>4280</td>
<td>94</td>
</tr>
</tbody>
</table>

Table 5.7. Properties of Test C

<table>
<thead>
<tr>
<th>Simulated tests</th>
<th>Prep time (h)</th>
<th>Total time (h:m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With tool</td>
<td>40</td>
<td>46:52</td>
</tr>
<tr>
<td>Without tool</td>
<td>421</td>
<td>427:52</td>
</tr>
</tbody>
</table>

Table 5.8. Simulated tests for Test C

<table>
<thead>
<tr>
<th>Real-time tests</th>
<th>Total time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated</td>
<td>41</td>
</tr>
<tr>
<td>Manual</td>
<td>240</td>
</tr>
</tbody>
</table>

Table 5.9. Real-time tests for Test C

Cost savings using automated tests

Table 5.10 shows the cost savings in testing time when using automated tests as opposed to manual tests. So 20 %, for example, would indicate that the cost of the automated test is 20 % less than that of the manual cost. The savings are only in relation to the cost of testing, therefore these cost savings are directly derived from the difference in testing time for each test.

<table>
<thead>
<tr>
<th>Test</th>
<th>Cost savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test A</td>
<td>21</td>
</tr>
<tr>
<td>Test B</td>
<td>7</td>
</tr>
<tr>
<td>Test C</td>
<td>83</td>
</tr>
</tbody>
</table>

Table 5.10. Cost savings for each test
5.3 Analysis

The results in each set of tests show how significant the use of the tool can be when it comes to automated tests. As this is an ongoing test process; the failed test cases detected using the tool are still being investigated and corrected. On a positive note, all failed test cases investigated so far have shown to be faults made in the projections, rather than the tool. The use of simulated tests highly increases the speed of testing, which if relied upon alone can save the company thousands or even millions depending on the size of the project. However, with safety being so crucial it is required that real-time tests be run on the CBI-system as well. In this case the main benefit of using simulated tests would be to detect possible errors in the system and then investigating them with tests on the CBI-system. This saves a lot of time, and in return money, as corrections to the system are made at an earlier stage. Furthermore, the verification process is improved since all test cases can be tested and examined. This cannot be done using manual testing methods if the tests are very large.

The tables at the end of each test show how automated tests affect time and costs. The results from Test A and Test B do not show a significant difference in time and costs between manual and automated tests. That is because the tests are relatively small; meaning that the majority of time spent in automated tests is for preparation rather than execution. However, in Test C, which is much larger than A and B, we clearly see the how much time and money can be saved on automated tests. This is because once preparation of the test is over; the computer does the rest of the work automatically, allowing the workers to shift attentions elsewhere. As these tests are run on a server, they can be left over night and investigated the next day. So where an employee puts in six hours of effective work a day using manual testing methods, the same test can effectively run on the server the full twenty-four hours. Since the amount of working hours per employee decreases with automated tests, the costs to perform them also decrease.

It is also important to note that these results are based on one round of testing. When one takes regression testing and final verification tests into account, the potential savings in time and money will become even greater. These are all benefits brought about by using automated testing with the help of the tool, and they are benefits highly sought after by companies today.
Chapter 6

Interviews

In order to get a better understanding of what automating tests means to the workers performing them, interviews were conducted with three test engineers currently working at Bombardier. The engineers were all asked the same questions regarding the advantages and disadvantages of automated testing as well as its future application.

Test engineer 1

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the advantages of automated testing?</td>
<td>I think automating tests can help us a lot. As a test engineer, I highly value exploratory testing. Automating tests could potentially earn us 70-80% more time to perform exploratory tests.</td>
</tr>
<tr>
<td>Are there any disadvantages with automated testing?</td>
<td>My fear when it comes to automation is that companies will use it as an excuse to win contracts. By promising potential customers that they can deliver products faster than their competitors, business owners may decide to test everything automatically leaving us testers very little time to run our own tests.</td>
</tr>
<tr>
<td>Can automated tests completely replace manual tests?</td>
<td>I don’t believe that all tests can be automated in the future. New scenarios are constantly being presented, and you need the experience and understanding of the manual testers in order to deal with these issues in the best possible manner.</td>
</tr>
</tbody>
</table>

Table 6.1. Interview with test engineer 1
### Test engineer 2

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the advantages of automated testing?</td>
<td>The main benefit of automation is of course that a large number of tests can be run in a relatively short space of time, saving the company a lot of money. On a personal note, automated tests would be greatly appreciated since they could be used to run simple tests such as object tests. In these tests we have to make sure that all objects such as signals and points are working as they should, i.e. do objects position themselves in the right position, display the right indication etc... This is usually a tiresome and dull process, so having these tests run automatically would be a huge relief.</td>
</tr>
<tr>
<td>Are there any disadvantages with automated testing?</td>
<td>The obvious disadvantage with automated tests is probably a loss in understanding of the whole test and its meaning. However, one disadvantage that would be common for every project is that every station has its own special test cases. This means that a lot of additional preparation has to be made at the beginning of each project. This is also problematic since test scripts become a lot more complex.</td>
</tr>
<tr>
<td>Can automated tests completely replace manual tests?</td>
<td>As I mentioned with the disadvantages, every station is unique which leads to an increased preparation time and a more complex test script. Therefore, automating them would yield greater costs and more work. So even if all tests can be automated in the future, it would not be an optimal solution.</td>
</tr>
</tbody>
</table>

*Table 6.2. Interview with test engineer 2*
## Test engineer 3

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the advantages of automated testing?</td>
<td>There are a number of benefits brought about by automating tests. We could for example easily replace a great portion of the traditionally performed tests such as object tests. When a new version of the system is delivered to us for testing, the push of a button is enough to run all regression testing. Because of this we do not have to waste time and effort evaluating which tests that need to be run over and over again.</td>
</tr>
<tr>
<td>Are there any disadvantages with automated testing?</td>
<td>A disadvantage of automating tests is that one can easily lose sight of the importance of the tests and rather focus on the number of tests that are run. The management team is often interested in numbers, and presenting large numbers is not difficult. What these large numbers mean on the other hand is usually overlooked. Also, as a manual tester you use your knowledge to draw certain conclusions regarding the tests that need to be run. With automated tests this is not the case, rather all tests are run 'blindly'. A third disadvantage is that automated tests cannot question the grounds upon which certain scenarios are tested, while a manual tester may use their experience to find faults within these grounds.</td>
</tr>
<tr>
<td>Can automated tests completely replace manual tests?</td>
<td>From the two previous answers it is clear that there are advantages as well as disadvantages to automation. It is extremely important to know when a test suite should be run automatically and when it should be run manually. Therefore, it is always best to combine manual and automatic testing in order to perform faster and higher quality tests.</td>
</tr>
</tbody>
</table>

*Table 6.3. Interview with test engineer 3*
Chapter 7

Discussion

The developing of the test case generator for automated tests in CBI systems is the first of its kind at Bombardier. The tool is very simple yet extremely effective in its cause. From the tests in chapter 5 it is clear that the use of automated tests saves time and decreases costs. In chapter 6 it is also clear that test engineers would greatly appreciate the use of automated tests instead of a large number of the manual tests. While all of these points are positive, it is important that a few issues be noted and discussed.

- Although the tool can be updated to accommodate certain modifications, there is always a certain degree to these modifications that can be handled with relative ease. However, should the in-house file formats for example drastically change, it might mean that the readers need to undergo significant changes or be completely rewritten. These changes would of course cost the company time and resources.

- When it comes to the use of automated tests it is important that some of the consequences mentioned in chapter 3 be discussed. Firstly, manual skills may deteriorate as the use of manual testing will greatly decrease. More importantly, there may become a decrease in awareness to what the system is doing from the employee’s side. This could potentially lead to workers not understanding the situations that are essential to these tests.

Addressing these issues helps determining whether the automation of these tests is feasible.

- With regard to the tool, it is fair to say that drastic changes to file formats used today are highly unlikely, especially over a short period of time. And even if that becomes the case, seeing the benefits brought about by using the tool suggests it would be worth it in the long run.

- Worker issues that may arise as a result of automation can be solved or significantly reduced with the right approach. While it is true that workers may lose
understanding of the system with automated tests, a solution to that would be that they are tasked with the monitoring of these tests. This allows them to stay in touch with the systems and its functionality as well as mentally remain active without having to exert a lot of effort. It would also give them the skill set required to intervene should an automated test fail.
Chapter 8

Conclusion

The development of the test case generator has been a valuable experience in grasping and practicing the concept of automation, as well as understanding how production and testing may be carried out at a company. Results indicate that automated tests of CBI-systems through the use of the tool can bring about a lot of positive changes. The time and resources that are saved can be used to widen the scope of tests performed, and hence speed up system verification and increase safety margins. Alternatively, saved time and resources may be of use for other purposes within the company. The listed benefits of the test case generator in this project are:

- A decrease in time and resource consumption
- Costs are significantly reduced
- Less work load for the employees
- More time for exploratory testing

In addition to these benefits it must be mentioned that the lead time of the CBI-system will decrease since testing can be performed a lot quicker. This means that the end product will be delivered to the customer faster, hopefully leaving them satisfied and eager to return for future business. With the tool soon being released and potentially becoming available at other offices, the future seems bright for automated tests and the newly developed test case generator.
Chapter 9

Future work

Future work that revolves around this thesis project can be divided into two parts. The first part concerns to the tool that has been developed and its functions. The second part focuses on the use of automated tests, how they can be implemented and the how the whole testing process can possibly be improved.

Future work with the tool

In regard to the tool there is still some work that needs to be carried out before it can be officially released.

First of all, the tests that have been conducted need to be finalized. The errors found are currently under investigation. Until we are certain that none of the errors are brought about as a result of faults in the tool, it is not possible verify whether it is functioning correctly. It is also important to remember that faults may not affect the the current project, rather they may appear in future projects where different functions are used for testing. Should faults in the tool be detected, they can then be dealt with accordingly.

Secondly, the types of input data recognized by the tool are still limited. By expanding the tool through the addition of new readers, more information can be extracted giving workers a wider range of automatic testing. It would be recommended that these readers only be added when the desired input data is to be used in a test. Adding a lot of readers without using them in the testing process increases the chance of having faults go unnoticed.

Finally, more effort should be put in to make sure that the tool is as maintainable as possible. The reason for this is that maintenance costs can become quite expensive, sometimes overshadowing the benefits of the software in the first place. Paper [12] discusses factors that affect software maintainability and the work that needs to be carried out in order to ensure that the developed tool is highly maintainable.
CHAPTER 9. FUTURE WORK

Future work with automated tests

From the interviews in chapter 6, it is quite clear that the test engineers at the company value automated tests. However, the testers are also unanimous in their view that there should be a fine balance between manual and automated tests. So rather than consuming resources in an effort to automate all tests, time should be spent trying to identify, which tests that should be automated and how they can be improved. An example of this would be improving the layout of the customer specifications. If the specifications delivered to the company are structured in a consistent manner whereby all the relevant information is available to run the test, the workers can simply create a reader that directly extracts information from the customer specification and runs it as a test. This would significantly lower the preparation time for each test making automated tests even faster and cheaper.
Bibliography


