



Pós-Graduação em Ciência da Computação

Yguaratã Cerqueira Cavalcanti

**AN AUTOMATED APPROACH TO ASSIGN SOFTWARE CHANGE
REQUESTS**

Ph.D. Thesis



Federal University of Pernambuco
posgraduacao@cin.ufpe.br
www.cin.ufpe.br/~posgraduacao

RECIFE
2014



Federal University of Pernambuco
Center for Informatics
Graduate in Computer Science

Yguaratã Cerqueira Cavalcanti

**AN AUTOMATED APPROACH TO ASSIGN SOFTWARE CHANGE
REQUESTS**

*A Ph.D. Thesis presented to the Center for Informatics of
Federal University of Pernambuco in partial fulfillment of
the requirements for the degree of Philosophy Doctor in
Computer Science.*

Advisor: *Silvio Romero de Lemos Meira*
Co-Advisor: *Eduardo Santana de Almeida*

RECIFE
2014

Yguaratã Cerqueira Cavalcanti
An Automated Approach to Assign Software Change Requests/ Yguaratã Cerqueira
Cavalcanti. – RECIFE, 2014-
53 p. : il. (algumas color.) ; 30 cm.

Advisor Silvio Romero de Lemos Meira

Ph.D. Thesis – Universidade Federal de Pernambuco, 2014.

1. Palavra-chave1. 2. Palavra-chave2. I. Orientador. II. Universidade xxx. III.
Faculdade de xxx. IV. Título

CDU 02:141:005.7

Tese de doutorado apresentada por **Yguaratã Cerqueira Cavalcanti** ao programa de Pós-Graduação em Ciência da Computação do Centro de Informática da Universidade Federal de Pernambuco, sob o título **An Automated Approach to Assign Software Change Requests**, orientada pelo **Prof. Silvio Romero de Lemos Meira** e aprovada pela banca examinadora formada pelos professores:

Prof. André Luis de Medeiros Santos
Centro de Informática/UFPE

Prof. Alexandre Marcos Lins de Vasconcelos
Centro de Informática/UFPE

Prof. Christina von Flach Garcia Chavez
Departamento de Ciência da Computação/UFBA

Prof. Leonardo Gresta Paulino Murta
Instituto de Computação/UFF

Prof. Jones Oliveira de Albuquerque
Departamento de Estatística e Informática/UFRPE

*I dedicate this thesis to all my family, friends and professors
who gave me the necessary support to get here.*

Acknowledgements

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

*I have yet to see any problem, however complicated, which, when looked at
in the right way, did not become still more complicated.*

—POUL ANDERSON

Resumo

O gerenciamento eficiente de solicitações de mudança (SM) é fundamental para o sucesso das atividades de manutenção e evolução de software. Entretanto, a atribuição de SMs a desenvolvedores de software é um aspecto custoso desse gerenciamento, pois demanda tempo e requer conhecimento apropriado do projeto de software. Com o propósito de diminuir esse custo, várias pesquisas já propuseram métodos de atribuição automática de SMs. Embora representem avanços na área, existem vários fatores inerentes a atribuição de SMs que não são considerados nessas pesquisas e são essenciais para a automação.

Como demonstrado nesse trabalho, a atribuição automática deve, por exemplo, considerar a carga de trabalho, a experiência e o conhecimento dos desenvolvedores, a prioridade e a severidade das SMs, a afinidade dos desenvolvedores com os problemas descritos nas SMs, e até mesmo os relacionamentos interpessoais. Para tornar esse cenário ainda mais complexo, esses fatos podem variar de acordo com o projeto de software que está sendo desenvolvido. Assim, uma solução para o problema de atribuição de SMs depende de informações contextuais.

Assim, esse trabalho propõe, implementa e valida uma solução arquitetural sensível ao contexto para atribuição automática de SMs. Dado o aspecto contextual da solução, a arquitetura enfatiza a necessidade de considerar as diversas fontes de informações presentes na organização, assim como a necessidade de se desenvolver algoritmos que implementem diferentes estratégias de atribuição. A proposta e implementação dessa solução é embasada em resultados de duas pesquisas quantitativas: um estudo de mapeamento sistemático da literatura, e uma pesquisa de questionário com desenvolvedores de software. Esse último forneceu um conjunto de requisitos que a solução automatizada deve satisfazer para que as estratégias de atribuição sejam atendidas, enquanto o mapeamento da literatura identificou técnicas, algoritmos, e outros requisitos necessários a automação.

A implementação da arquitetura segue uma estratégia de automação, também elaborada nesse trabalho, que possui dois componentes principais: um sistema especialista baseado em regras (SEBR); e um modelo de recuperação de informação (MRI) com técnicas de aprendizagem. Em nossa estratégia, esses dois componentes são executados alternadamente em momentos diferentes a fim de atribuir uma SM automaticamente. O SEBR processa regras simples e complexas, considerando informações contextuais do projeto de software e da organização que o desenvolve. O MRI é utilizado para fazer o casamento entre SMs e desenvolvedores de acordo com o histórico de atribuições.

Palavras-chave: Engenharia de Software, Manutenção e Evolução de Software, Gerenciamento de Solicitações de Mudança, Atribuição Automática de Solicitações de Mudança

Abstract

The efficient management of Change Requests (CRs) is fundamental for successful software maintenance; however the assignment of CRs to developers is an expensive aspects in this regard, due to the time and expertise demanded. To overcome this, researchers have proposed automated approaches for CR assignment. Although these proposals present advances to this topic, they do not consider many factors inherent to the assignments. Indeed, different complex factors may have influence on CR assignment, and most of them vary from one organization to another. For instance, developers' workload, CRs severity, interpersonal relationships, or developers know-how must be considered in the assignments. Actually, as we demonstrate in this work, CR assignment is a complex activity and automated approaches cannot rely on simplistic solutions. Ideally, it is necessary to consider and reason over contextual information in order to provide an effective automation.

In this regarding, this work proposes, implements, and validates a context-aware architecture to automate CR assignment. The architecture emphasizes the need for considering the different information available at the organization to provide a more context-aware solution to automated CR assignment. The development of such architecture is supported by evidence synthesized from two empirical studies: a survey with practitioners and a systematic mapping study. The survey provided us with a set of requirements that automated approaches should satisfy. In the mapping study, in turn, we figured out how state-of-the-art approaches are implemented in regarding to these requirements, concluding that many of them are not satisfied. In addition, new requirements were identified in this mapping study.

For the implementation of the proposed architecture, we developed a strategy to automate CR assignments which is based on two main components: a Rule-Based Expert System (RBES) and an Information Retrieval (IR) model. The strategy coordinately applies these two components in different steps to find the potential developer to a CR. The RBES takes care of the simple and complex rules necessary to consider contextual information in the assignments, e.g., to prevent assigning a CR to a busy or unavailable developer. Since these rules vary from one organization/project to another, the RBES facilitates their modification for different contexts. On the other hand, the IR model is useful to make use of the historical information of CR assignments to match CRs and developers.

Keywords: Software Engineering, Software Maintenance and Evolution, Change Request Management, Automatic Change Request Assignment

List of Figures

1.1	CR assignment.	24
1.2	Research methodology.	29

List of Tables

A.1	List of conferences on which the searches were performed.	51
A.2	List of journals in which the searches were performed.	52
A.3	Search string per Search Engine.	53

List of Acronyms

CCB	Change Control Board	
CR	Change Request.....	23
IR	Information Retrieval.....	27
RBES	Rule-Based Expert System.....	13

Contents

1	Introduction	23
1.1	Motivation (Why to Automate CR Assignment?)	24
1.2	Problem Statement	25
1.3	Overview of the Proposal	27
1.4	Research Methodology	28
1.5	Out of Scope	29
1.6	Statement of the Contributions	30
1.7	Organization of the Thesis	32
2	Background Chapter	35
2.1	Introduction	35
2.2	Section	36
2.2.1	Subsection	36
3	Development Chapter	39
3.1	Introduction	39
3.2	Section	40
3.2.1	Subsection	40
4	Conclusion	43
4.1	Introduction	43
4.2	Section	44
4.2.1	Subsection	44
	References	47
	Appendix	49
A	Mapping Study's Instruments	51

1

Introduction

Software maintenance starts as early as the first software artifacts are delivered, and is characterized by its high cost and slow speed of implementation ([IEEE Computer Society, 2014](#)). It has been stated that it is the most expensive activity of software development, taking up to 90% of the total costs ([EASTWOOD, 1993](#); [ERLIKH, 2000](#)). However, despite of the high cost, it is mandatory to ensure the success of the software project. [LEHMAN \(1980\)](#) argues, in his *Continuing Change* law of software evolution, that the modification of software is a fact of life for software systems if they are intended to remain useful. [BENNETT; RAJLICH \(2000\)](#) reinforced such an argument for the specific case of useful and successful software, where almost all of them have a common practice of stimulating user-generated Change Request (CR). Actually, software maintenance is driven by CRs reported by many stakeholders, such as developers, testers, team leaders, managers, and clients.

In this context, the CR repositories play an important role in the maintenance and evolution process, being actually a focal point of communication and coordination for software projects ([BERTRAM et al., 2010](#)). Through a CR repository, the developers manage and coordinate the corrections and new features to be implemented in the software under development or maintenance. Moreover, the data stored in such repositories are a valuable source of information about the project, which can be used to assist in cost estimation, impact analysis, traceability, planning, expertise discovery, and software understanding ([CAVALCANTI et al., 2013](#)). Examples of these repositories are Mantis ([Mantis Bug Tracker, 2013](#)), Bugzilla ([BUGZILLA, 2013](#)), and Trac ([The Trac Project, 2013](#)).

Briefly, a CR describes a defect to be fixed, an adaptive or perfective change, or a new functionality to be implemented in a software system ([CAVALCANTI et al., 2013](#)). Each CR stores a variety of fields of free text and custom fields defined according to the necessity of each project. In Trac, for example, it has fields for summary and detailed description of a CR. In the same CR, it can be also recorded information about software version, dependencies with other CRs (such as CRs that are blocked, similar, or duplicate), the person who will be assigned to the CR, among other relevant information. Moreover, during the life cycle of a CR, different kinds of discussion take place through the comments that are inserted in it, such as fixing alternatives,

workarounds, and architectural decisions (BERTRAM et al., 2010).

1.1 Motivation (Why to Automate CR Assignment?)

Despite CR repositories claimed benefits to software maintenance and evolution, handling CRs is not cost-free. For example, when new CRs are reported they must be assigned to developers which have adequate expertise to address the request (ALJARAH et al., 2011; HOSSEINI; NGUYEN; GODFREY, 2012; KAGDI et al., 2012). Finding the appropriate developer is crucial for obtaining the lowest, economically feasible, fixing time (LUCCA; PENTA; GRADARA, 2002). Nevertheless, assigning CRs to developers is a labor-intensive and time consuming task (ANVIK, 2006; JEONG; KIM; ZIMMERMANN, 2009). Indeed, depending on the project being developed, the amount of CRs that are reported and need to be assigned can vary from dozens to hundreds per day (CAVALCANTI et al., 2013).

Figure 1.1 shows the activity of assigning CRs. At the top-left corner of the figure, there are the CRs which have been reported to the software project. At the bottom-left corner, there is a set of developers which could be assigned to those CRs. Then, at the center, the assignment of CRs is performed; the CRs and developers must be matched, and each developer should fix one or more CRs. Commonly, the matching is performed aiming at the shortest time and the highest quality for the CR fixing activities.

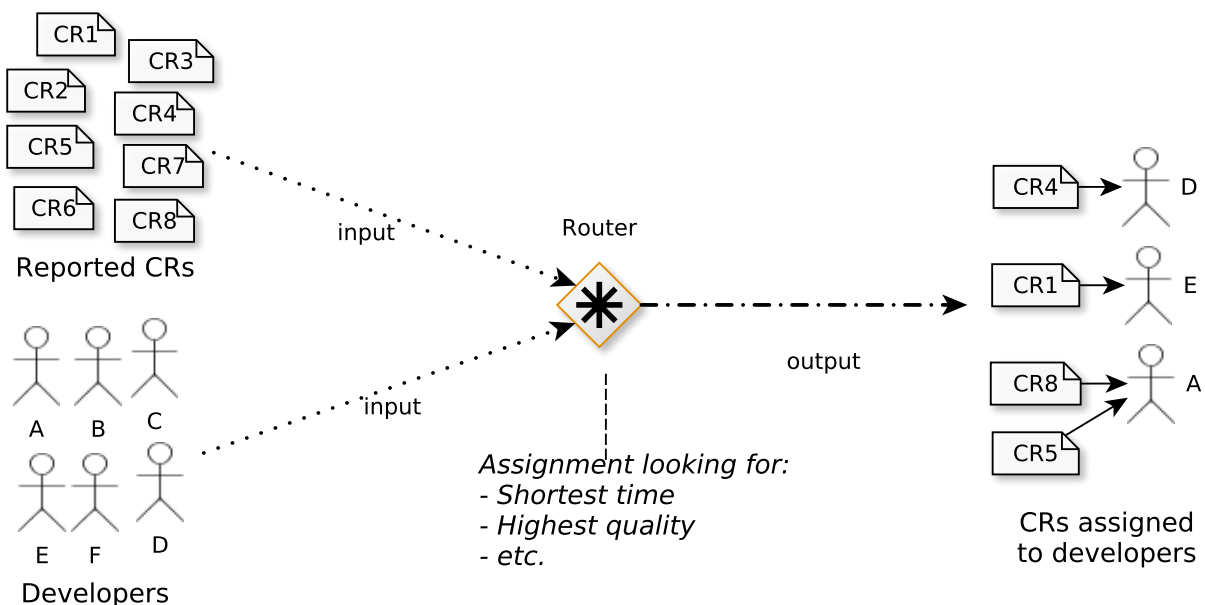


Figure 1.1: CR assignment. The router, which may be the CCB, project leaders, or managers, must match CRs and developers in order to obtain the shortest fixing and highest quality.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci

et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Nevertheless, by increasing the amount of reported CRs or the size of the development team, it is visible that the router becomes overloaded and the CR assignment becomes an intensive, error prone activity. It was confirmed by [JEONG; KIM; ZIMMERMANN \(2009\)](#), which identified that 37%-44% of the CRs in Mozilla and Eclipse projects did not reach the right developer in the first assignment. These CRs, in turn, had their fixing time delayed because they needed to be reassigned one or more times. Furthermore, if the CRs are not fixed by the appropriate developers, there is also the chance of introducing new defects during the CRs fixing.

In this context, we believe that it is necessary to develop methods and tools to automate the assignment of CRs and ensure that the CRs are being assigned to the appropriate developers. With these methods and tools, we could reduce the time needed to perform the assignments and, given that the appropriate developers are actually being selected, the quality and time for the CR fixing are also improved.

1.2 Problem Statement

As previously mentioned, software maintenance has been considered as the most costly aspect of software development ([IEEE Computer Society, 2014](#)). There is a myriad of reasons for this situation. One of them is the many changes that are required after software delivery due to poor documented and misunderstood requirements, or simply because “*the clients do not know what they want*” ([BROOKS, 1995](#)).

Another reason is the fact that a set of development activities must be inevitably performed in order to implement a change. For instance, for each change to be implemented it is

necessary to comprehend the existing software artifacts, modify the software's source code to implement the change, perform tests and verification, and deliver the new version of the software. Additionally, very often, the implementation of the change ends up by introducing new defects in the software.

A third reason is the management aspects of software maintenance. It is necessary to keep track of all these changes that are performed, generally considering different versions of the software and customers.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

1. Firstly, the approaches available in the literature were designed to perform autonomously. That is, the software analysts do not have the control of the approach; they cannot modify the approach's behavior. Without such control, in turn, the approach cannot be properly calibrated. As a consequence, if the approach's performance is not satisfactory, it is simply discarded.
2. Secondly, the reported values for accuracy of these approaches are still low. With low accuracy, the previous reason takes place. That is, as the approaches perform with low accuracy, and the software analysts do not have control over them, the approaches are simply discarded.

3. Finally, the third reason concerns the lack of contextual information in those approaches. As is well known, software development companies are dynamic: developers move from projects; developers are hired/fired; developers enter in vacation or take a day off; and developers have different experiences. This dynamic influences the assignment of CRs. Thus, contextual information is a necessity in automated approaches.

Based on this context, the main research question investigated by this thesis is:

Research question *Is it possible to develop a new approach for automated CR assignment with satisfactory accuracy, leveraging contextual information, and designed in order to put the software analysts in control of such approach?*

With the objective to answer this question, it is necessary to understand current approaches available in the literature, choose the correct technologies that could support dynamic environments and, mainly, understand the necessities of software analysts regarding a new approach for automated CR assignment. Thus, the goal of the work described in this thesis can be stated as:

Research objective *This work proposes an automated approach for CR assignment which uses Information Retrieval (IR) models, expert systems, and context-aware information in order to select the appropriate developers. The approach is supported by the state-of-the-art in the management of CRs as well as by the understanding of the aspects concerning the CR assignment activity itself.*

1.3 Overview of the Proposal

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci

et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

1.4 Research Methodology

This research design of this thesis is based on a multimethod approach ([HESSE-BIBER, 2010](#)). Such approach combines two or more quantitative (or qualitative) methods in a single study, such as a survey and an experiment ([HESSE-BIBER, 2010](#)). Multimethod must not be confused with mixed method. In this last, methods for both qualitative and quantitative types of research are applied in a single study. On the other hand, multimethod studies combine different methods for a single research type.

When applying a multimethod approach, the triangulation is used to consolidate the results from the different methods, considering, however, that the same research question(s) was/were investigated in these methods. As a consequence, the triangulation of methods enhances the conclusions and completeness of the study, bringing more credibility to the research findings ([HESSE-BIBER, 2010](#)). Figure 1.2 shows the multimethod research design applied in

this thesis.

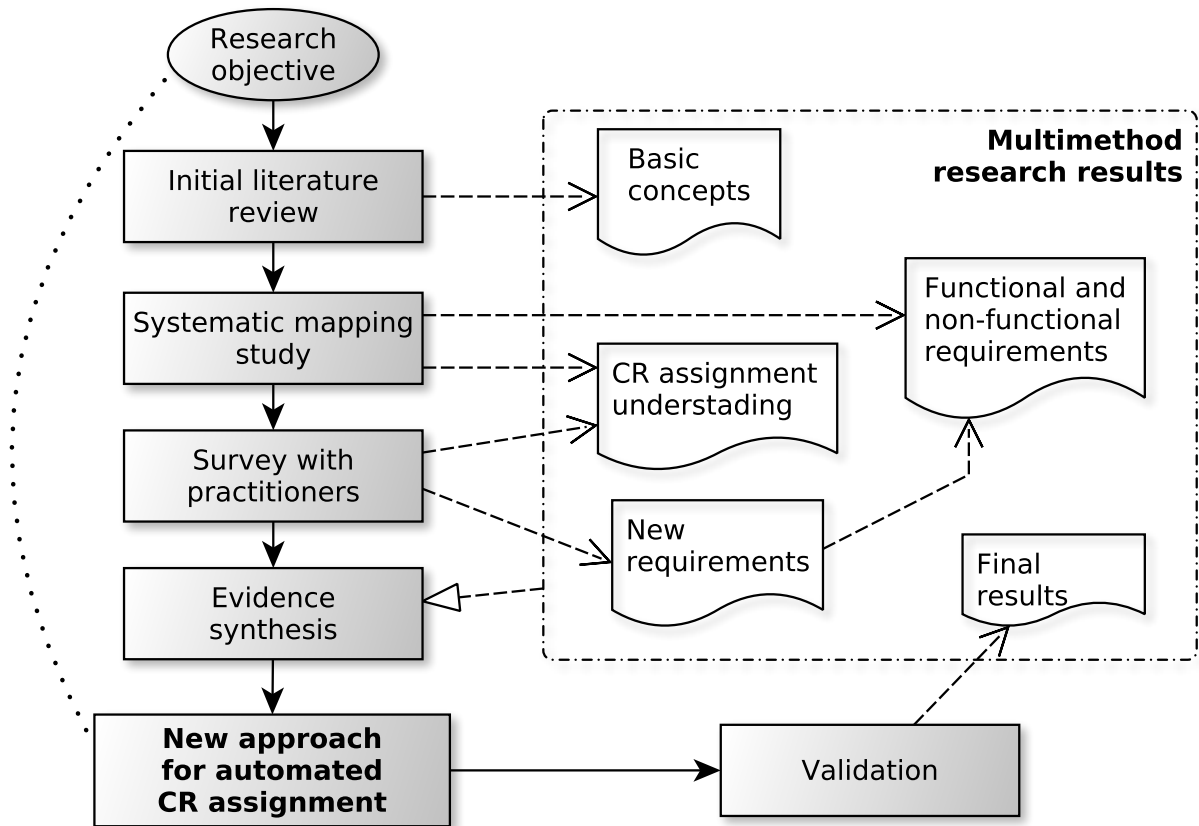


Figure 1.2: The research methodology applied for this thesis.

The design started by stating the research objective, which we defined in Section 1.2, and performing the initial literature review. This last provided the basic concepts and understanding of the area. Then, a systematic mapping study and a questionnaire-based survey were conducted. These two gathered detailed information on our research topic. Indeed, both of them were used to understand the key aspects of CR assignment and identify the set of requirements to automate the assignments. In the evidence synthesis step, these results were detailed and organized in order to formulate the approach to automate CR assignments, which was constructed in the next step. Finally, the research design states the validation of the proposed approach.

1.5 Out of Scope

As the proposed approach is part of a broader context, a set of related aspects will be left out of its scope. Thus, the following topics are not directly addressed in this thesis:

1. **Tools for CR management.** We are addressing a specific aspect of CR management, which is the CR assignment activity. Thus, it is out of scope of this thesis to provide a complete solution for CR management. Instead, we are planning to implement standalone software which will be able to integrate with the most well known tools for

CR management, such as Mantis, Bugzilla, and Trac, providing a service to leverage the automation of CR assignments.

2. **Software maintenance process.** Software maintenance involves a set of activities aiming at implementing modifications in some software project. These activities must be coordinated through a process so that the maintenance can be successful. In Chapter 2, we discuss some of these processes. However, in this thesis, we are not concerned with the maintenance process itself. Actually, it should be transparent in our approach to automate CR assignment. Thus, it is out of scope of this thesis to provide any process assessment for software maintenance beyond the activity of CR assignment.
3. **IR models.** Many models for IR have been proposed for different objectives, including the CR assignment itself. However, due to the broad availability of these models, it is out of scope of this thesis to develop a new one. Instead, the IR models with better performance, identified through the systematic mapping study, were chosen to be integrated in our approach;
4. **Rule-based expert systems.** Similar to IR models, rule-based expert systems have a long history of development. Thus, our approach does not intend to develop a whole new system with this purpose. Actually, we integrated in our approach the Drools¹ expert system, which is a mature tool that can be easily manipulated;
5. **Mathematical formulations on NP-Complete problems.** We understand that the problem of assigning CRs to software developers is in the broad category of *assignment problems*, which is well known to be NP-Complete. Thus, could be formulated as such. However, the mathematical formulations of the CR assignment problem is out of scope of this thesis. As well as finding an optimal solution on the context of NP-Complete problems is also out of scope. The main reason for this is the human factors and context variables that are involved in the assignment of CRs, which make this problem hard to be computable. A mathematical formulation of the CR assignment problem is provided by RAHMAN; RUHE; ZIMMERMANN (2009).

1.6 Statement of the Contributions

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec

¹<http://www.jboss.org/drools/>

luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

1. An overview of the software maintenance concepts and processes, with emphasis on the importance of CR management aspects;
2. A survey performed with practitioners from a large organization, in order to understand the aspects of the CR assignment activity. Published in the *17th International Conference on Evaluation and Assessment in Software Engineering (EASE'2013)* ([CAVALCANTI et al., 2013](#));
3. A replication of the previous survey in two more organizations;
4. A systematic mapping study performed to understand the challenges and opportunities of CR management, as well as to identify research gaps and the road ahead. Accepted for publication in the *Journal of Software: Evolution and Process* ([CAVALCANTI et al., 2013](#));
5. The definition of the functional and non-functional requirements that are required to effectively automate CR assignment, which takes as input the systematic mapping study and the survey;
6. The definition of an approach that satisfies the identified requirements to automate the CR assignment activity;
7. The realization of the proposed approach's architecture, in which we described the methods and techniques used for the implementation, as well as the components that have to be built and the third party components that should be assembled together in order to provide a service for automated CR assignment; and
8. The evaluation of the proposed approach, performed as an offline experiment simulating a real context.

1.7 Organization of the Thesis

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetur. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum

dolor sed augue. Nulla nec lacus.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetur odio sem sed wisi.

2

Background Chapter

2.1 Introduction

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea

dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

2.2 Section

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

2.2.1 Subsection

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat

a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

3

Development Chapter

3.1 Introduction

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea

dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

3.2 Section

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

3.2.1 Subsection

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat

a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

4

Conclusion

4.1 Introduction

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea

dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

4.2 Section

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

4.2.1 Subsection

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat

a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

References

- ALJARAH, I. et al. Selecting discriminating terms for bug assignment: a formal analysis. In: INTERNATIONAL CONFERENCE ON PREDICTIVE MODELS IN SOFTWARE ENGINEERING, 7. **Proceedings...** [S.l.: s.n.], 2011. p.12.
- ANVIK, J. Automating bug report assignment. In: SOFTWARE ENGINEERING (ICSE'06), 28. **Proceedings...** [S.l.: s.n.], 2006. p.937–940.
- BENNETT, K. H.; RAJLICH, V. T. Software maintenance and evolution: a roadmap. In: CONFERENCE ON THE FUTURE OF SOFTWARE ENGINEERING (ICSE'00), New York, NY, USA. **Proceedings...** ACM Press, 2000. p.73–87.
- BERTRAM, D. et al. Communication, collaboration, and bugs: the social nature of issue tracking in small, colocated teams. In: ACM CONFERENCE ON COMPUTER SUPPORTED COOPERATIVE WORK (CSCW'2010), 2010. **Proceedings...** ACM, 2010. p.291–300.
- BROOKS, F. P. **The Mythical Man-Month**: essays on software engineering. [S.l.]: Addison-Wesley, 1995.
- BUGZILLA. URL: <https://www.bugzilla.org>.
- CAVALCANTI, Y. C. et al. The bug report duplication problem: an exploratory study. **Software Quality Journal**, [S.l.], v.21, p.36–66, 2013. Online first on 2011.
- CAVALCANTI, Y. C. et al. Towards Understanding Software Change Request Assignment: a survey with practitioners. In: Proceedings of the 17th International Conference on Evaluation and Assessment in Software Engineering (EASE'2013). **Anais...** [S.l.: s.n.], 2013. p.195–206.
- CAVALCANTI, Y. C. et al. Challenges and Opportunities for Software Change Request Repositories: a systematic mapping study. **Journal of Software: Evolution and Process**, [S.l.], 2013. Online first.
- EASTWOOD, A. Firm fires shots at legacy systems. **Computing Canada**, [S.l.], v.19, n.2, p.17, 1993.
- ERLIKH, L. Leveraging Legacy System Dollars for E-Business. **IT Professional**, Piscataway, NJ, USA, v.2, n.3, p.17–23, 2000.
- HESSE-BIBER, S. N. **Mixed Methods Research - Mixing Theory and Practice**. [S.l.]: The Guilford Press, 2010.
- HOSSEINI, H.; NGUYEN, R.; GODFREY, M. W. A Market-Based Bug Allocation Mechanism Using Predictive Bug Lifetimes. In: EUROPEAN CONFERENCE ON SOFTWARE MAINTENANCE AND REENGINEERING (CSMR'2012), 16. **Proceedings...** [S.l.: s.n.], 2012. p.149–158.
- BOURQUE, P.; DUPUIS, R. (Ed.). **Software Engineering Body of Knowledge (SWEBOK)**. EUA: IEEE Press, 2014.

- JEONG, G.; KIM, S.; ZIMMERMANN, T. Improving bug triage with bug tossing graphs. In: EUROPEAN SOFTWARE ENGINEERING CONFERENCE AND THE ACM SIGSOFT SYMPOSIUM ON THE FOUNDATIONS OF SOFTWARE ENGINEERING (ESEC/FSE'2009), 7. **Proceedings...** [S.l.: s.n.], 2009. p.111–120.
- KAGDI, H. et al. Assigning change requests to software developers. **Journal of Software: Evolution and Process**, [S.l.], v.24, n.1, p.3–33, 2012.
- LEHMAN, M. Programs, life cycles, and laws of software evolution. **Proceedings of the IEEE**, [S.l.], v.68, n.9, p.1060 – 1076, sept. 1980.
- LUCCA, G. A. D.; PENTA, M. D.; GRADARA, S. An Approach to Classify Software Maintenance Requests. In: IEEE INTERNATIONAL CONFERENCE ON SOFTWARE MAINTENANCE (ICSM'02), 18. **Proceedings...** IEEE Computer Society, 2002. p.93–.
- Mantis Bug Tracker. URL: <https://www.mantisbt.org>.
- RAHMAN, M. M.; RUHE, G.; ZIMMERMANN, T. Optimized assignment of developers for fixing bugs an initial evaluation for eclipse projects. In: INTERNATIONAL SYMPOSIUM ON EMPIRICAL SOFTWARE ENGINEERING AND MEASUREMENT (ESEM'2009), 2009. **Proceedings...** [S.l.: s.n.], 2009. p.439–442.
- The Trac Project. URL: <https://trac.edgewall.org>.

Appendix

A

Mapping Study's Instruments

Table A.1: List of conferences on which the searches were performed.

Acronym	Conference
APSEC	Asia Pacific Software Engineering Conference
ASE	IEEE/ACM International Conference on Automated Software Engineering
CSMR	European Conference on Software Maintenance and Reengineering
ESEC	European Software Engineering Conference
ESEM	International Symposium on Empirical Software Management and Measurement
ICSE	International Conference on Software Engineering
ICSM	International Conference on Software Maintenance
ICST	International Conference on Software Testing
InfoVis	IEEE Information Visualization Conference
KDD	ACM SIGKDD International Conference on Knowledge Discovery and Data Mining
MSR	Working Conference on Mining Software Repositories
OOPSLA	Object-Oriented Programming, Systems, Languages and Applications
QSIC	International Conference On Quality Software
SAC	ACM Symposium on Applied Computing
SEAA	EUROMICRO Conference on Software Engineering and Advanced Applications
SEDE	19th International Conference on Software Engineering and Data Engineering
SEKE	International Conference on Software Engineering and Knowledge Engineering

Table A.2: List of journals in which the searches were performed.

Journal title
ACM Transactions on Software Engineering and Methodology
Automated Software Engineering
Elsevier Information and Software Technology
Elsevier Journal of Systems and Software
Empirical Software Engineering
IEEE Software
IEEE Computer
IEEE Transactions on Software Engineering
International Journal of Software Engineering and Knowledge Engineering
Journal of Software: Evolution and Process
Software Quality Journal
Journal of Software
Software Practice and Experience Journal

Table A.3: Search string per Search Engine.

Search Engine	Search String
Google Scholar	bug report OR track OR triage “change request” issue track OR request OR software OR “modification request” OR “defect track” OR “software issue” repositories maintenance evolution
ACM Portal	Abstract: "bug report" or Abstract:"change request" or Abstract:"bug track" or Abstract:"issue track" or Abstract:"defect track" or Abstract:"bug triage" or Abstract: "software issue" or Abstract: "issue request" or Abstract: "modification request") and (Abstract:software or Abstract:maintenance or Abstract:repositories or Abstract:repository
IEEEExplorer (1)	(((((((((("Abstract": "bug report") OR "Abstract": "change request") OR "Abstract": "bug track") OR "Abstract": "software issue") OR "Abstract": "issue request") OR "Abstract": "modification request") OR "Abstract": "issue track") OR "Abstract": "defect track") OR "Abstract": "bug triage") AND "Abstract": software)
IEEEExplorer (2)	(((((((((("Abstract": "bug report") OR "Abstract": "change request") OR "Abstract": "bug track") OR "Abstract": "software issue") OR "Abstract": "issue request") OR "Abstract": "modification request") OR "Abstract": "issue track") OR "Abstract": "defect track") OR "Abstract": "bug triage") AND "Abstract": maintenance)
IEEEExplorer (3)	(((((((((("Abstract": "bug report") OR "Abstract": "change request") OR "Abstract": "bug track") OR "Abstract": "software issue") OR "Abstract": "issue request") OR "Abstract": "modification request") OR "Abstract": "issue track") OR "Abstract": "defect track") OR "Abstract": "bug triage") AND "Abstract": repositories)
IEEEExplorer	(((((((((("Abstract": "bug report") OR "Abstract": "change request") OR "Abstract": "bug track") OR "Abstract": "software issue") OR "Abstract": "issue request") OR "Abstract": "modification request") OR "Abstract": "issue track") OR "Abstract": "defect track") OR "Abstract": "bug triage") AND "Abstract": repository)
Citeseer Library	(abstract: "bug report" OR abstract:"change request" OR abstract:"bug track" OR abstract:"issue track" OR abstract:"defect track" OR abstract:"bug triage" OR abstract: "software issue" OR abstract: "issue request" OR abstract: "modification request") AND (abstract:software OR abstract:maintenance OR abstract:repositories OR abstract:repository)
Elsevier	("bug report" OR "change request" OR "bug track" OR "issue track" OR "defect track" OR "bug triage" OR "software issue" OR "issue request" OR "modification request") AND (software OR maintenance OR repositories OR repository)
Scirus	("bug report" OR "change request" OR "bug track" OR "issue track" OR "defect track" OR "bug triage" OR "software issue" OR "issue request" OR "modification request") AND (software maintenance OR repositories OR repository) ANDNOT (medical OR aerospace)
ScienceDirect	("bug report" OR "change request" OR "bug track" OR "issue track" OR "defect track" OR "bug triage" OR "issue request" OR "modification request") AND LIMIT-TO(topics, "software")
Scopus	("bug report" OR "change request" OR "bug track" OR "issue track" OR "defect track" OR "bug triage" OR "software issue" OR "issue request" OR "modification request") AND (software maintenance OR repositories OR repository)
Wiley	("bug report" OR "change request" OR "bug track" OR "issue track" OR "defect track" OR "bug triage" OR "software issue" OR "issue request" OR "modification request") AND (software maintenance OR repositories OR repository)
ISI Web of Knowledge	("bug report" OR "change request" OR "bug track" OR "issue track" OR "defect track" OR "bug triage" OR "software issue" OR "issue request" OR "modification request") AND (software maintenance OR repositories OR repository) ANDNOT (medical OR aerospace)
SpringerLink	("bug report" OR "change request" OR "bug track" OR "issue track" OR "defect track" OR "bug triage" OR "software issue" OR "issue request" OR "modification request") AND (software maintenance OR repositories OR repository) ANDNOT (medical OR aerospace)