Mining Textual Data for Software Engineering Tasks

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***Abstract*—Software development artifacts produced during the development process are of different types. Some are structured such as the source code and execution traces while others are unstructured like source code comments, identifiers, bug reports, usage logs, etc. Such data embeds a significant knowledge about software projects that can help software developers make technical and business decisions.**

While the focus has been extensively on source code in the past, researchers have recently investigated the textual information (*e.g.*, identifiers and comments) contained in software artifacts or informal documentation (*e.g.*, StackOverflow, emails threads, change logs, bug reports, etc.) about the software systems. Automatic techniques and tools have been developed to generate and–or mine unstructured data to gain insight about the software development process or assist development teams in tasks like software traceability, feature/concept location, source code vocabulary normalization, bug localization, and summarization.

The tutorial will start with an introduction of textual information in source code and–or documentation. Next, we will present automatic techniques and tools to generate and mine unstructured data and discuss related challenges. We will also present examples of major software engineering tasks making use of unstructured data mining along with scenarios of their application and the most recent contributions relevant to each task. Specifically, we will focus on automatic source code vocabulary normalization, summarization, crash reports analysis for fault localisation. Finally, we will discuss with the audience the success and failures in achieving the full potential of such tasks in a software development context as well as possible improvements and research directions. The tutorial will provide novice with a common framework about major software engineering tasks leveraging textual information while for experts, the tutorial can be an interesting opportunity to discuss challenges, document the state of the art and practice, encourage cross-fertilization across various research areas ranging from mining software repositories to natural language processing and text retrieval, and to establish foreseeable collaborations between researchers.

I. Motivation

Software development projects knowledge is grounded in rich data. For example, source code, check-ins, bug reports, work items and test executions are recorded in software repositories such as version control systems (Git, Subversion, Mercurial, CVS) and issue-tracking systems (Bugzilla, JIRA, Trac), and the information about user experiences of interacting with software is typically stored in log files or informal documentation such as StackOverflow.

While there has been extensive research on static analysis of source code, recent studies have exploited textual information used in source code of software systems or trapped in informal documentation (*e.g.*, emails threads, StackOverflow posts, etc.). The purpose is to develop automatic software engineering techniques, gain insights and understand software projects, and support the decision-making process.

Major software engineering tasks have leveraged textual information. For example in the context of software traceability, researchers have made use of textual information to trace code to documents (*e.g.*, requirements) [1], [2], they also suggested lightweight techniques of linking code to documentation such as email threads [3] and StackOverflow [4], as well as tracing code examples to documentation [5]. Textual information have been also exploited in feature/concept location [6], [7], [8], source code vocabulary normalization [9], [10] and summarization of complex artifacts involving release notes [11], StackOverflow [12], and bug reports [13]. Such approaches have been developed with the aim of guiding developers and practitioners towards a better understanding of their software projects and the way they evolve.

While solutions provided for these engineering tasks demonstrated promising results, there are many challenges left concerned with mining textual information, using it in the development of the above-mentioned tasks, as well as integrating and adopting such solutions into software development processes.

The goals of this tutorial are to discuss the use of textual information, its related challenges and open-question, tools and techniques of mining such data as well as ways of integrating and exploiting them by major software engineering tasks to fully reap their benefits.

We invite both novice and experts to this tutorial that will be an opportunity to share tools, techniques, and experiences in the field. We also plan, after the presentation of the tutorial, to have a discussion and dissemination of the presented research by opening up a discussion and involving participants in sharing their opinions. We invite researchers and practitioners interested in improving, integrating, and adopting the use and mining of textual information in their software engineering tools and thus software development and maintenance activities. The tutorial encourages both academic researchers and industrial practitioners for an exchange of ideas and collaboration.

II. Topics

The tutorial will focus on the presentation of recent techniques and tools used to generate and mine textual information as well as software engineering tasks making use of such rich data.

The tutorial will explain, present, and discuss the following:

1) Textual information in source code and informal documentation;
2) Benefits of using textual information in software engineering tasks;
3) Recent tools and techniques used to generate and mine textual information;
4) Challenges related to mining textual information;
5) Major software engineering tasks using textual information;
6) Explain source code vocabulary normalization and how it makes use of textual information along with recent automatic approaches;
7) Present summarization software artifacts with recent automatic approaches in this area;
8) Explore bug localization, how it makes use of textual information, and how the instructors could improve it by leveraging text in crash reports;
9) Identification of open research challenges and possible solutions.

III. Contributors' Experience in the Area

Latifa Guerrouj preformed her past studies on context-aware source code vocabulary normalization. Vocabulary normalization aligns the vocabulary found in the source code with that found in other software artifacts (*e.g.*, test cases, requirements, specifications, design, etc). Latifa developed automatic context-aware source code vocabulary approaches by mining textual information in source code [14], [15], [16], [17], [18]. She also investigated the use of normalization in the context of feature location using textual information and dynamic analysis [19]. Recently, she suggested a new approach summarizing Android API classes and methods discussed in StackOverflow using n-grams language models and applying machine learning techniques [12]. Latifa is the co-organizer of the International Workshop on Software Analytics (SWAN'15). In this tutorial, she will make the focus on how text found in source code or information documentation can be mined and exploited in the context of engineering tasks namely source code vocabulary and summarization of software artefacts.

Benjamin Fung has over 80 refereed publications that span the prestigious research venues of data mining, text mining, assembly code mining, authorship analysis, and building engineering. For example, he suggested techniques to analyze topics and authors in chat logs for crime investigation [20], automatic subject-based semantic document clustering for digital forensic investigations [21], unified data mining solution for authorship analysis in anonymous textual communications [22]. Additionally, he proposed mining criminal networks from unstructured text documents [23] and chat logs [24]. Among the teachings of Bejamin related to this tutorial, we state the data mining course (GLIS 691) at McGill University.

David Lo research work focuses on software engineering and data mining. He investigates how techniques from these two research areas could benefit and complement each other. In the software engineering area, his research includes software specification mining/protocol inference, mining software repositories, program analysis, software testing and automated debugging. In the data mining area, he works on frequent pattern mining, discriminative pattern mining, and social network mining. David contributed to the analysis of software text with the aim of aiding software developers in performing their various tasks. Examples of his works relevant to this tutorial involve enhanced techniques making use of text version for bug localization [25], a large scale investigation of issue trackers from GitHub [26], accurate information retrieval-based bug localization based on bug reports [27], interactive fault localization leveraging simple user feedback [28], automatic duplicate bug report detection with a combination of information retrieval and topic modeling [29]. David is the co-organizer of the first International Workshop on Machine Learning and Information Retrieval for Software Evolution (MALIR-SE) collocated with ASE 2013. He was tutor of the *Data Analytics for Automated Software Engineering* course given at the 13th Estonian Summer School on Computer and System Science and the keynote speaker of the International Workshop on Mining Unstructured Data (MUD 2010).

Foutse Khomh leads the SoftWare Analytics and Technologies (SWAT) Lab that applies analytic techniques to empower development teams with insightful and actionable information about their activities. SWAT team also build tools to assess

and improve the quality of software systems. Early models and tools proposed by SWAT members are already being used in the industry. Among his research works related to this workshop, we state the ones on challenges and issues of mining crash reports [30], tracking back the history of commits in low-tech reviewing environments [31], supplementary bug fixes vs. re-opened bugs [32], improving bug localization using correlations in crash reports [33], classifying field crash reports for fixing bugs: A case study of Mozilla Firefox [34], and a text-based approach to classify change requests [35]. He was tutor for the Canadian Summer School on Practical Analyses of Software Engineering Data (PASED) in 2011, which introduced participants to different empirical software engineering techniques including text mining. Foutse co-founded the International Workshop on Release Engineering (RELENG) in 2013 and has been co-organizing it since then. In this tutorial, Foutse will show his recent work on using crash reports for the improvement of bug localization and identify highly impactful bugs.

Abdelwahab Hamou-Lhadj lead the Software Behaviour Analysis (SBA) Research Lab where he investigates techniques and tools to help software analysts understand and analyze the behaviour of complex software systems with the primary goal of enhancing maintenance, security, and addressing performance problems. He looks at software from the ecosystem perspective. The outcome of his research is to help with a variety of applications: software comprehension, software maintenance and evolution, performance analysis, anomaly detection, software compliance and certification, etc. Among his contributions relevant to this tutorial, we state the works on mining telecom system logs to facilitate debugging tasks [36], exploiting text mining techniques in analysis of execution traces [37], feature location in practice specifically for debugging aircraft simulation systems [38], as well as automatic bug reproduction using crash traces and directed model checking [39].

IV. Goals and Expected Results

This tutorial targets both novice and experts working in the field of software maintenance and evolution, interested in the analysis of software text, its mining, and its practical use in the context of software engineering tasks. For experts, it will provide an informal interactive forum to exchange ideas and experiences, streamline research making use of textual information, identify some common ground of their work, and share lessons and challenges, thereby articulating a vision for the future of software engineering.

The intended outcomes of this tutorial are:

1) Make clear (for novice) what is textual information and techniques of its mining;
2) Explore the different contemporary software engineering techniques making use of textual data;
3) Stimulate discussions, interest, and understanding in integrating textual info in software engineering tasks and software development process;
4) Bridging the gap between the theory and practice by bringing together researchers and practitioners interested in analysing software text for software engineering tasks;
5) Discuss challenges, experiences, lessons, and explore the different possible strategies to overcome the challenges faced and towards promising solutions to essential problems;
6) Build a common framework of major automatic approaches making use of textual information;
7) Advance the state of the art and practice in software engineering;

V. Outline

1) Introduction about software text and tools to generate and mine such data by David Lo.
2) Exploration of major software engineering tasks making use of textual data by Benjamin Fung.
3) Presentation of source code vocabulary normalization along with examples of recent published automatic source code vocabulary normalization approaches by Latifa Guerrouj.
4) Presentation of summarization of software artifacts along with examples of recent published automatic summarization approach by Latifa Guerrouj.
5) Presentation of bug localization with an example of most recent automatic approach in this area by Abdelwahab Hamou-Lhadj.
6) Exploration of recent ways to improve bug localization using crash reports and to identify impactful bugs by Foutse Khomh.
7) Summary and recap of the tutorial by all the presenters.

VI. Target audience

This tutorial is intended for both novice and experts, academics and industrial practitioners. It will provide participants with an understanding of software text, techniques to mine it from source code or documentation, and ways of adopting and integrating it in major engineering tasks. Additionally, novice will be able to understand engineering tasks such as vocabulary normalization, bug localization, and summarization and how they exploit textual data to fully reap their benefits. The tutorial will show scenarios of the presented approaches and how they can help to guide developers during their tasks as well as to improve software maintenance and evolution. We will also discuss the limitations and challenges of the most recent related techniques and how these issues can be addressed and mitigated. Participants are encouraged to talk about their recent works related to the tutorial (if any) and share their experiences and major faced challenges. Experts will be there to guide and provide them with feedback.

VII. Format

We propose to have a half day tutorial consisting of (1) an introduction to textual data, tools for mining textual data and major software engineering tasks leveraging textual data

(1 hour presentation by David Lo and Benjamin Fung); (2) a presentation of source code vocabulary normalization and summarization techniques with concrete examples (1 hour presentation by Latifa Guerrouj); (3) a presentation of text mining techniques for bug localization using crash reports and execution traces (1 hour presentation by Foutse Khomh and Abdelwahab Hamou-Lhadj). At the end of the lectures there will be a 45 minutes discussion with the audience followed by a summary and recap of the session by the presenters. The material needed for this tutorial is 1 projector and 1 flipchart on which participants will write questions for the final discussion.

We encourage discussions so as to develop an in-depth understanding of the presented topics for novice. Experts are invited to enrich the discussions by providing opinions and moderating a discussion on the state-of-the-art and state-of-the-practice of software engineering tasks making use of textual data.

VIII. Acknowledgement

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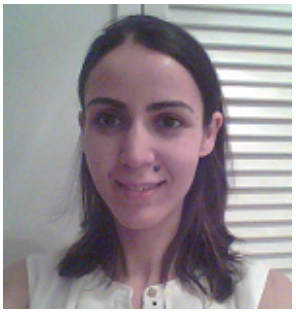
IX. Contributors' biography



Latifa Guerrouj is a Postdoctoral Research Fellow at McGill University, Canada. She received her Ph.D. from the Department of Computing and Software Engineering (DGIGL) of École Polytechnique de Montréal, Canada. Her research work/interests involves empirical software engineering, software analytics, data mining, and big data software engineering. Latifa is serving as an organizing and program committee member for several international conferences and workshops including ICSME'16, ICSME'15, SANER'15, MSR'15/14/13.

Benjamin C. M. Fung is an Associate Professor of Information Studies (SIS) at McGill University and a Research Scientist in the National Cyber-Forensics and Training Alliance Canada (NCFTA Canada). He received a Ph.D. degree in computing science from Simon Fraser University in 2007. Dr. Fung has over 80 refereed publications that span the prestigious research forums of data mining, privacy protection, cyber forensics, services computing, and building engineering. His data mining works in crime investigation and authorship analysis have been reported by media worldwide. Dr. Fung is a licensed professional engineer in software engineering, and is currently affiliated with the Data Mining and Security Lab at SIS.

David Lo is an Assistant Professor in the School of Information Systems at Singapore Management University. He received his PhD from School of Computing, National University of Singapore in 2008. Before that, he was studying at School of Computer Engineering, Nanyang Technological University and graduated with a B.Eng (Hons I) in 2004. David works in the intersection of software engineering and data mining. His research interests include dynamic program analysis, specification mining, and pattern mining. Lo received a PhD in computer science from the National University of Singapore. He is a member of the IEEE and the ACM.

Foutse khomh is an Assistant Professor at the École Polytechnique de Montréal, where he heads the SWAT Lab on software analytics and cloud engineering research (http://swat.polymtl.ca/). Prior to this position he was a Research Fellow at Queen's University (Canada), working with the Software Reengineering Research Group and the NSERC/RIM Industrial Research Chair in Software Engineering of Ultra Large Scale Systems. He received his Ph.D in Software Engineering from the University of Montreal in 2010, under the supervision of Yann-Gaël Guéhéneuc. His main research interest is in the field of empirical software engineering, with an emphasis on developing techniques and tools to improve software quality. Over the years, he has applied many text mining techniques to solve multiple software engineering problems. He co-founded the International Workshop on Release Engineering (http://releng.polymtl.ca) and was one of the editors of the first special issue on Release Engineering in the IEEE Software magazine.

Abdelwahab Hamou-Lhadj is a tenured Associate Professor in ECE, Concordia University. His research interests include software modeling, software behavior analysis, software maintenance and evolution, anomaly detection systems. He holds a Ph.D. degree in Computer Science from the University of Ottawa (2005). He is a Licensed Professional Engineer in Quebec, and a long- lasting member of IEEE and ACM.

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