

Supporting Awareness of Indirect Conflicts with Impact

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Abstract—Awareness has been largely studied in the field of CSCW research within software engineering. Many tools and techniques have been proposed and built in order to provide software developers and stakeholders with a greater sense of workspace and task awareness within their software projects. These techniques and tools have been largely focused on detecting *direct* conflicts which arise over a project’s life time or have created an exploratory ground for stakeholders to use as a means of resolving self discovered direct or indirect conflicts. However, detecting and providing pertinent information regarding *indirect* conflicts has been largely ignored partially due to their inherently larger complexity than direct conflicts. Indirect conflicts arise when changes in one software artifact affect another. In this paper, we present *Impact*, a new task awareness tool directly aimed at both detecting and presenting indirect conflicts which arise inside of a software project. *Impact* represents a first step towards the design and implementation of awareness tools that specifically address indirect conflicts in software projects. To describe *Impact*, we introduce previous indirect conflict awareness attempts, our design and implementation, as well as *Impact*’s potential through two evaluation studies.

I. INTRODUCTION

Awareness is characterized as “an understanding of the activities of others which provides a context for one’s own activities” [1]. The study of awareness and its tools has become an important topic of research in software engineering especially with the new importance of distributed work and collaboration. Awareness is generally associated with both technical and social dependencies that are created and evolve over a software project’s life time. The study of these dependencies has become the primary focus of most awareness related research. Task awareness has become the most prevalent field of awareness research to understand how developers cope with these technical and social dependencies.

Tools have been created to attempt to solve task awareness related issues with some success [2], [3], [4], [5]. However, these tools have been designed to solve task awareness related issues at the direct conflict level. Examples of direct conflict awareness include knowing when two or more developers are editing same artifact, finding expert knowledge of a particular file, and knowing which developers are working on which files. Meanwhile, task awareness related issues at the indirect conflict level continue to be an issue which is largely unsolved by most coordination mechanisms. Examples of indirect conflict awareness include having one’s own code effected by another

developer’s source code change or finding out who might be indirectly effected by one’s own code change. Previous interviews and surveys conducted with software developers have shown a pattern that developers of a software project view indirect conflict awareness as a high priority issue in their development [6], [7], [8], [9].

Indirect conflicts arising in source code are inherently difficult to resolve as most of the time, source code analysis must be performed in order to find relationships between technical objects which are harmed by changes. While some awareness tools have been created with these indirect conflicts primarily in mind [8], [10], most have only created an exploratory environment which is used by developers to solve conflicts which may arise. These tools were not designed to detect indirect conflicts that arise and alert developers to their presence inside the software system. Sarma et al. [11] has started to work directly on solving indirect conflicts, however, these products are not designed to handle internal structures of technical objects.

In this paper, we report on our research into supporting indirect conflicts and present the design, implementation, and evaluation of the tool *Impact*, a web based tool that aims at detecting indirect conflicts among developers and notifying the appropriate members involved in these conflicts. By leveraging technical relationships inherent of software projects with method call graphs [12] as well as detecting changes to these technical relationship through software configuration management (SCM) systems, *Impact* is able to detect indirect conflicts as well as alert developers involved in such conflicts in task awareness. While this paper outlines *Impact*’s specific implementation, its design is rather generic and can be implemented in similar indirect conflict awareness tools. *Impact* represents a first step towards the design and implementation of awareness tools which address indirect conflicts in software development.

The rest of this paper is organized as follows. First, we begin by discussing similar indirect conflict awareness tools which have partially solved the issues presented by this paper and how their designs can be applied to *Impact*. In the following section we describe a generic design and implementation of *Impact* as an awareness tool. We then discuss a preliminary evaluation of *Impact* followed by conclusions and future work.

II. RELATED WORK

Although there is an abundance of awareness tools developed in research today, only a handful have made an attempt to examine indirect conflicts. Here, we will outline three of the forefront projects in indirect conflicts and how these projects have influenced the decision making process in the design and implementation of *Impact*.

We first start with both Codebook [8] and Ariadne [10]. These projects produce an exploratory environment for developers to handle indirect conflicts. Exploratory pertains to the ability to solve self determined conflicts, meaning that once a developer discovers a conflict, they can use the tool as a type of lookup table to solve their issue. Codebook is a type of social developer network that relates developers to source code, issue repositories and other social media while Ariadne only looks at source code for developer to source code association. Through Codebook, developers become owners of source code artifacts. Both projects also use program dependency graphs [13] in order to relate technical artifacts to each other. These projects make use of method call graphs in order to determine which methods invoke others which forms the basis for linking source code artifacts creating a directed graph. While these projects can be great tools for solving indirect conflicts which may arise, by querying such directed graphs to view impacts of conflict creating code, they lack the ability to detect conflicts on their own.

A serious attempt at both detecting and informing developers of indirect conflicts is the tool Palantir [11]. Palantir monitors developers activities in files with regards to class signatures. Once a developer changes the signature of a class, such as by modifying changes in name, parameters, or return values of public methods, any workspace of other developers which are using that class will be notified. Palantir utilizes a push-based event model [14] which seems to be a favored collection system among awareness tools. Sarma et al. [11] also developed a generic design for future indirect conflict awareness tools. However, Palantir falls short in its collection and distribution mechanisms. First, Palantir only considers "outside" appearance of technical objects, being their return types, parameters, etc. Secondly, Palantir only delivers detected conflicts to developers who are presently viewing or editing the indirect object while other developers who have used the modified class previously are not notified.

Impact is designed to address these limitations by extending this work in two directions: (1) the detection of indirect conflicts at an internal level of technical objects as opposed from object signatures, and (2) the dissemination of awareness information to all appropriate developers regardless of their current workspace activities. *Impact* is also designed around the successes these projects have had in the past with directed graphs as well as elements of collection, ownership, and distribution functionality.

III. IMPACT

This section will proceed to give an outlined detail of *Impact* in both its design and implementation. The design of

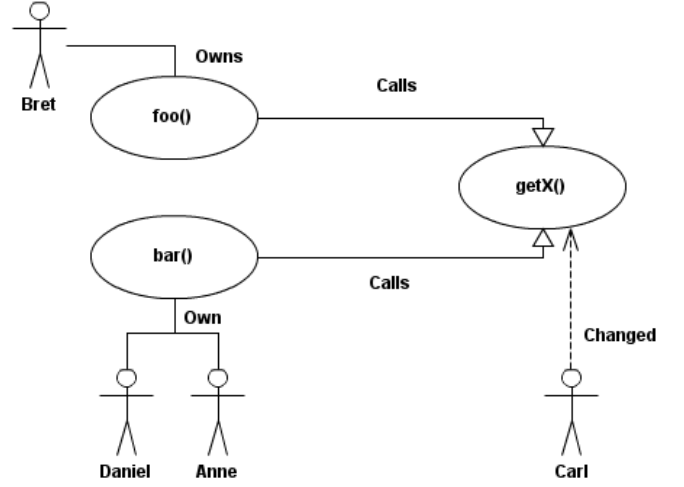


Fig. 1. Technical object directed graph with ownership

Impact was created to be a generic construct which can be applied to other indirect conflict awareness tools while the implementation is specific to the technical goals of *Impact*.

A. Design

Compared to tool design for direct conflicts, the major concern of indirect conflict tools is to relate technical objects to one another with a "uses" relationship. To say that object 1 uses object 2 is to infer a technical relationship between the two objects which can be used in part to detect indirect conflict that arise from modifying object 2. This kind of relationship is modeled based on directed graphs [13]. Each technical object is represented by node while each "uses" relationship is represented by a directed edge. This representation is used to indicate all indirect relationships within a software project.

While technical object relationships form the basis of indirect conflicts, communication between developers is the ultimate goal of resolving such conflicts. This being the case, developer ownership must be placed on the identified technical objects. With this ownership, we now infer relationships among developers based on their technical objects "uses" relationship. Developer A, who owns object 1, which uses object 2 owned by developer B, may be notified by a change to object 2's internal workings. Most, if not all, ownership information of technical objects can be extracted from a project's source code repository (CVS, Git, SVN, etc.).

Finally, the indirect conflict tool must be able to detect changes to the technical objects defined above and notify the appropriate owners to the conflict. Two approaches have been proposed for change gathering techniques: real time and commit time [14]. We propose the use of commit time information gathering as it avoids the issue of developers overwriting previous work or deleting modifications which would produce information for changes that no longer exist. However, the trade off is that indirect conflicts must be committed before detected, which results in conflicts being apart of the system before being able to be dealt with as opposed to catching

conflicts before they happen. At commit time, the tool must parse changed source code in relation to technical artifacts in the created directed graph detailed above. Where *Impact*'s design differs from that of Palantir's is that the object's entire body (method definition and internal body) is parsed at commit time to detect changes anywhere in the technical object. Once technical objects are found to be changed, appropriate owners of objects which use the changed object should be notified. In Figure 1, Carl changes method (technical object) 1, which effects methods 2 and 3 resulting in the alerting of developers Bret, Daniel, and Anne.

With this three step design: (i) creating directed graphs of technical objects, (ii) assigning ownership to those technical objects, and (iii) detecting changes within commit time and the notification of conflict information to appropriate owners, we believe a wide variety of indirect conflict awareness tools can be created or extended. The implementation of *Impact* described in the following section follows these three design guidelines.

B. Implementation

For *Impact*'s implementation, we decided to focus on methods as our selected technical objects to infer a directed graph from. The "uses" relationship described above for methods is method invocation. Thus, in our constructed directed graph, methods represent nodes and method invocations represent our directed edges. In order to construct this directed graph, abstract syntax trees (ASTs) are constructed from source files in the project. The ASTs allow us to construct method call graphs from which the directed graphs can be constructed.

Once the directed graph is constructed, we must now assign ownership to our technical objects (methods) as per our design. To do this, we simply query the source code repository. In our case we used Git as the source code repository, so the command *git blame* is used for querying ownership information. (Most source code repositories have similar commands and functionality.) This command returns the source code authors per line which can be used to assign ownership to methods. If a method has 10 lines and developer A has written 3 while developer B has written 7, then ownership is assigned 30% and 70% respectively.

To detect changes to our technical objects (methods), we simply use a commit's *diff* which is a representation of all changes made inside a commit. We can use the lines changed in the *diff* to find methods that have been changed. This gives cause of potential indirect conflicts. We now find all methods in our directed graphs which invoke these changed methods. These are the final indirect conflicts.

Once the indirect conflicts have been found, we use the ownership information of our technical objects to send notifications to those developers involved in the indirect conflict. All owners of methods which invoke those that have been changed are alerted to the newly changed method. This can be seen in Figure 2, the user interface of *Impact*. Here, in an RSS type feed, the changing developer, time of change, changed method, invoking methods, and commit message are all displayed. This



Fig. 2. *Impact*'s RSS type information feed.

list is auto updating as new commits are pushed to the central git repository. The information provided also comes with a simple weight of the percent changed of changed method multiplied by ownership of the invoking method. This allows developers to filter through high and low changes affecting their own source code. Developers are now able to be alerted of detected indirect conflicts and solve them by communicating the developer who authored the change.

IV. EVALUATION

To fully evaluate both the generic design of detecting and resolving indirect conflicts as well as *Impact*, extensive testing and evaluation must be performed. However, we feel that a simple evaluation is first needed to assess the foundation of *Impact*'s design and claims about indirect conflicts at the method level.

We performed a user case study where we gave *Impact* to two small development teams composed of three developers. Each team was free to use *Impact* at their leisure during their development process, after which interviews were conducted with lead developers from each development team. The interviews were conducted after each team had used *Impact* for three weeks.

We asked lead developers to address two main concerns: do indirect conflicts pose a threat at the method level (e.g. method 1 has a bug because it invokes method 2 which has has its implementation changed recently), and did *Impact* help raise awareness and promote quicker conflict resolution for indirect conflicts. Our two interviews largely supported our expectation of indirect conflicts posing a serious threat to developers, especially in medium to large teams or projects as opposed to the small teams which they were apart of. It was also pointed out that method use can be a particularly large area for indirect conflicts to arise. However, it was noted that any technical object which is used as an interface to some data construct or methodology, database access for instance, can be a large potential issue for indirect conflicts. Interview response to *Impact* was also largely positive, as interviewees stated that *Impact* helped raise awareness among their teams

with what other developers are doing as well as the influence it has on their own work. However, *Impact* was shown to have information overload. It was suggested that while all method changes were being detected, not all are notification worthy. One developer suggested to only notify developers to indirect conflicts if the internal structure of a method changes due to modification to input parameters or output parameters. In other words, the boundaries of the technical objects (changing how a parameter is used inside the method, modifying the return result inside the method) seem to be more of interest than other internal workings. More complex inner workings of methods were also noted to be of interest to developers such as cyclomatic complexity, or time and space requirements.

These two studies have shown that our design and approach to detecting and alerting developers to indirect conflicts appear to be on the correct path. *Impact* as a tool has laid the foundations for future work in detecting indirect conflicts as well as notifying developers, although more thought must be given as to what constitutes a meaningful change inside our selected technical objects to avoid issues of information overload.

V. NEXT STEPS IN RESEARCH OF INDIRECT CONFLICTS

While *Impact* has laid the foundations for awareness tool construction aimed at resolving indirect conflicts, it has also raised questions in regards to levels of granularity in notification of indirect conflicts and the implied trade off between notifications and information overload. To address these problems, we plan to find industry expert opinion through interviews and surveys with experienced developers. From these interactions, we plan to answer some of the questions presented in this paper such as which technical objects concern developers with indirect conflicts, and what types of changes to these objects are cause for notification. We are also planning, through these expert opinions, to further the need for indirect conflict awareness tools by establishing that indirect conflicts are real world problems with harmful consequences. Further more, we plan to bring these opinions back to the realm of *Impact*, in combination with other academic works on balancing between notifications and information overload [15], to continue our development on this tool to further its life both as a research tool and a possible industry application.

VI. CONCLUSION AND FUTURE WORK

In this paper, we have presented the issues that arise from indirect conflicts in present awareness tools. We have proposed a generic design for the future development of awareness tools in regards to handling indirect conflicts. We have presented a prototype awareness tool, *Impact*, which was designed around our generic technical object approach. *Impact* was evaluated on a small scale, showing its future potential as well as highlighting its current weaknesses. Our preliminary evaluation has given us concrete insights into understanding awareness tools that specifically address indirect conflicts and has strengthened the need for further research towards notification and information overload (what makes a

change notification worthy), which has become the goal of our next step.

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