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Revisiting Linus's law: Benefits and challenges of open source software peer review

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ABSTRACT

Open source projects leverage a large number of people to review products and improve code quality. Differences among participants are inevitable and important to this collaborative review process—participants with different expertise, experience, resources, and values approach the problems differently, increasing the likelihood of finding more bugs and fixing the particularly difficult ones. To understand the impacts of member differences on the open source software peer review process, we examined bug reports of Mozilla Firefox. These analyses show that the various types of member differences increase workload as well as frustration and conflicts. However, they facilitate situated learning, problem characterization, design review, and boundary spanning. We discuss implications for work performance and community engagement, and suggest several ways to leverage member differences in the open source software peer review process.

1. Introduction

"Given enough eyeballs, all bugs are shallow" (Raymond, 2001). Linus's law highlights the power of open source software (OSS) peer review. As a high-profile model of large-scale online collaboration, OSS development often involves globally dispersed experts, mostly volunteers, collaborating over the Internet to produce software with source code freely available. Peer review is one of the core collaborative practices of OSS development: distributed participants evaluate and test the released software products, and report any problems they discovered or experienced; others jointly analyze and identify software defects or deficiencies, and generate solutions for repairing or improving the software products.

Large diverse communities are considered paramount to OSS peer review processes. "More users find more bugs because adding more users adds more different ways of stressing the program. […] Each one approaches the task of bug characterization with aslightly different perceptual set and analytical toolkit, a different angle on the problem" (Raymond, 2001). Extensive studies on OSS have shown the existence of other dimensions of member differences, such as heterogeneous motivations (Feller et al., 2005; Roberts et al., 2006), different expertise in software engineering and usability (Twidale and Nichols, 2005), and divergent perspectives (Sandusky and Gasser, 2005). The advances of social media provide opportunities for engaging an even larger audience in OSS development, and these potential contributors are likely to differ at even wider dimensions (Begel et al., 2010; Storey et al., 2010). Thus, understanding the role of member differences in the collaboration and social processes of OSS peer review, and particularly how it may be better leveraged is important for enhancing the understanding of OSS and online large-scale collaboration. However, little research has directly addressed diverse characteristics of members; existing work is largely focused on differences caused by roles (e.g., Daniel et al., 2013), distance (e.g., Cataldo et al., 2006), or national cultures (e.g., Shachaf, 2008).

To enhance the understanding of the OSS peer review process, we focus on the differences of participants and their impacts on the process, building on our previous study that has identified and characterized the common activities constituting the OSS peer review process (Wang and Carroll, 2011). We are especially interested in the less discernable or quantifiable attributes (e.g., informational and value diversity) in the OSS development context, rather than more readily observable ones (e.g., tenure within the site and the community, roles, language) as other studies did. To unfold the impacts of various types of differences, we conducted a case study of OSS peer review processes in Mozilla Firefox, a high-profile OSS project involving massive number of participants with a wide range of attributes. We analyzed member interactions recorded in bug reports, the central space for Mozilla's peer review. Participants who contributed to bug reports are valuable assets for OSS projects to retain, as they are probably more motivated than the generic Firefox users because using bug tracking systems to report, analyze, and fix bugs require more efforts than simply using the browser.

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Our findings indicate that informational diversity and value diversity result in both benefits and challenges to the work-related processes of OSS peer review as well as the well-being of open source communities. We disentangle the member differences that are often confounded with the prevalent dichotomic view of core/periphery and developer/user in current large-scale online collaboration literature. Such efforts create opportunities to understand and support overlooked groups of community participants, including triagers and co-developers. We also suggest implications for designing socio-technical interventions to mitigate the negative effects and augment the positive impacts of member differences. Distinct from prior research aiming at converting peripheral participation into active contributions, our design proposals offer an alternative way to embrace, leverage, and support member differences in communities that thrive on diversity.

2. Related work

2.1. Open source software peer review

OSS peer review is widely believed to be remarkably benefiting from a large community – "many eyeballs" – of members with different perspectives (Raymond, 2001). In general, the OSS peer review process begins with one submitting a bug report to the bug tracking system—an application that helps developers keep track of reported defects or deficiencies of source code, design, and documents. Others examine the defect causes and request additional information to determine whether the bug should be fixed. Once a solution is reached, they then commit a change set (mostly a patch) to the current software product. Our earlier work (Wang and Carroll, 2011) has codified the process as consisting of four common activities, including submission (i.e., bug reporting), identification, solution, and evaluation. These activities were externalized and made available in bug reports. They serve similar purposes as individual reviews, review meetings, rework, and follow-up in traditional software review, respectively, but fundamentally rely on web-based technologies. In addition to bug tracking systems in which people record and comment on bugs and issues, version control systems manage and synchronize committed software changes, while communication tools such as mailing lists and Internet Relay Chat (IRC) enable developers to discuss bugs.

Most studies related to the OSS peer review process were conducted from the software engineering perspective, deliberately modeling the information needs in bug report quality (Bettenburg et al., 2008a; Breu et al., 2010), inaccurate bug assignment (Jeong et al., 2009), efficiency and effectiveness of patch review (Rigby et al., 2008), and distribution of contributions in bug reporting and fixing (Mockus et al., 2002). Rigby et al. articulated stakeholders' involvement and their approaches for managing broadcast-based patch review (Rigby and Storey, 2011; Rigby et al., 2008). They also found that stakeholders interacted differently when discussing technical issues and when discussing the project scope.

With respect to the nature of a collaborative practice, much research effort related to OSS peer review has been devoted to explaining the coordination mechanisms (Yamauchi et al., 2000; Crowston and Scozzi, 2008; Sandusky and Gasser, 2005), negotiation (Sandusky and Gasser, 2005), leadership and governance (Fielding, 1999; Moon and Sproull, 2000), and the role of bug tracking systems (Bertram et al., 2010). Recent work by Ko and Chilana (2010) analyzed the reports of Mozilla contributors who reported problems but were never assigned problems to fix, indicating different competences of members in reporting bugs. Wang et al.'s analysis (Wang and Carroll, 2011) also showed large volume of bug reports failed to identify real bugs, increasing the cost of filtering them out. This study is to extend current understanding of OSS peer review by focusing on member differences of various attributes, particularly the impacts of these differences on the ways members interact and collaborate during the review process.

2.2. Diversity in collocated and distributed groups

Diversity is commonly defined as the differences of any attributes among individuals. As a complex construct, it has been studied in multiple disciplines, such as organizational behavior, sociology, and psychology. A complete review of this large body of literature is beyond the scope of this paper. However, regardless of variations between typologies, diversity can be of the readily visible attributes (e.g., gender, ethnicity, and age), of informational attributes (e.g., education, work experience, and knowledge), and of attitudes and values (e.g., whether members agree on what is important within the community and whether they have similar goals) (Van Knippenberg and Schippers, 2007; Jehn et al., 1999; Williams and O'Reilly, 1998). Diversity of an attribute can be further classified into three types—separation, variety, and disparity (Harrison and Klein, 2007). Separation refers to the differences in (lateral) position or opinion among members, primarily of value, belief, or attitude. Variety is the categorical differences, often unique or distinctive information, while disparity represents proportional differences along a continuum, mostly of socially valued assets or resources held among members. This conceptualization of diversity has important indication on the need of varying measurement when different types of diversity are being assessed.

Research on collaboration in collocated groups has a long history of analyzing diversity of various dimensions. Reviews and meta-analyses on this large volume of work suggested that the effects of diversity is contingent on the context: diversity can affect work processes, performance, and member identification in both positive and negative ways, and effects of the same diversity dimension may vary greatly across contexts (Harrison and Klein, 2007; Joshi and Roh, 2009). For instance, diverse perspectives tend to benefit work performance in short-term tasks, but these positive effects become much less significant in longer-term teams, and conflicts start to arise (Joshi and Roh, 2009). In general, a broad range of expertise and knowledge can enhance problem solving, decision-making, and even creativity and innovation, while differences of perspectives and values can result in dysfunctional group processes, conflicts, and poor performance (Milliken et al., 2003; Williams and O'Reilly, 1998; Van Knippenberg and Schippers, 2007). However, these studies were largely conducted in collocated groups in organizations or laboratory experiments.

A few other researchers looked into diversity in virtual teams. Shachaf (2008) explored the heterogeneity of national cultures of members from ad hoc global virtual teams at a corporation. The interviews showed such cultural diversity has positive influences on decision-making and negative influences on communication. Damian and Zowghi (2003) also focused on cultural diversity and found that it increased team members' difficulty in achieving common understanding of software requirements. Several chapters in Hinds and Kiesler (2002) discussed conflicts caused by differences of organizational cultures and informational diversity. However, such work still analyzed diversity in the settings in which group or organizational boundaries were clearly defined. There have been very few studies on volunteer-based large-scale online communities, such as OSS projects and Wikipedia, and therefore, they warrant additional examination.

Another theme of relevant research on virtual teams did not specifically analyze diversity but differences that were caused by distance, such as different information about remote contexts and different time zones. Unlike diversity literature focused on personal attributes, this body of work examined environmental factors, suggesting that dispersed locations led to conflicts (Cramton,