Awareness Support in Global Software Development: A Systematic Review Based on the 3C Collaboration Model

Igor Steinmacher[1], Ana Paula Chaves[2], and Marco Aurelio Gerosa[3]

[1] Coordination of Informatics - Federal University of Technology - Parana, BR 369 - km 0,5 - CEP: 87301-006 - Caixa Postal: 271, Campo Mourao-PR - Brazil
igorfs@utfpr.edu.br
[2] System Analysis and Development - Faculdade Integrado de Campo Mourao Avenida Irmaos Pereira, 670 - CEP:87301-010 - Campo Mourao-PR - Brazil
anachaves@grupointegrado.br
[3] University of Sao Paulo (USP) Rua do Matao, 1010 - CEP 05508-090 - Sao Paulo - SP - Brazil
gerosa@ime.usp.br

Abstract. The developers' physical distribution in Global Software Development (GSD) imposes challenges related to awareness support during collaboration. In this paper, we present a systematic review of the literature that describes studies that improve awareness support in a GSD scenario, identifying which of the dimensions of the 3C model, namely communication, coordination, and cooperation, are supported by these studies. Results indicate that coordination is far the most explored dimension, while awareness support in communication is very poorly studied. The research also identified a high number of tools introduced in the GSD domain and some new research opportunities.

Keywords: Awareness, Global Software Development, 3C Collaboration Model, Communication, Coordination, Cooperation.

1 Introduction

The Software Development industry has been using the benefits brought by CSCW in order to obtain competitive advantages in terms of cost and quality using qualified professionals distributed from all around the world [50]. This new approach, called Global Software Development (GSD), is based on geographically dispersed teams working collaboratively in a software project. Besides its advantages, GSD brings new challenges such as contextual, cultural, organizational, geographical, temporal, and political differences [35]. With the increasing number of organizations adopting GSD, researches and related literature also increased [49,38]. Within these researches, there is a great number of studies related to awareness support in distributed development environments. This occurs because awareness is essential when teams are distributed and there is a need to collaborate in order to achieve a common goal.

G. Kolfschoten, T. Herrmann, and S. Lukosch (Eds.): CRIWG 2010, LNCS 6257, pp. 185-201, 2010.

In this paper, we report a systematic literature review on awareness support within the GSD scenario. Its purpose was to identify awareness studies that brought improvements to collaboration in GSD. For the purpose of analysis the improvements were classified into the three dimensions of the 3C Collaboration Model [27]. According to this model, commonly used in the CSCW literature, the collaboration is analyzed from the communication, coordination, and cooperation points of view. The systematic review also identified aspects upon which researchers have focused more intently, thus allowing analysis and identification of current challenges and opportunities for future works.

This paper is organized as following: in Section 2 we present the concepts of awareness and the 3C model; in Section 3 we present the systematic review, including its planning, conduction, and analysis; in Section 4 we classify and summarize the improvements and the opportunities identified on this review; and, in Section 5, we discuss our findings and the limitations of our review.

2 Awareness and the 3C Collaboration Model

Awareness was defined by Dourish and Belloti [18] as "an understanding of the activities of others, which provides a context for one's own activities." Its objective is to allow a group of people working collaboratively to realize how and which of their contributions are relevant to the group activities. Awareness is concerned to support activities that involve two or more individuals, resources or services, voluntarily or involuntarily involved in any collaborative activity.

In GSD environments, collaborative teams are geographically dispersed. Thus, physical, temporal, and cultural distances make the difficulty of providing awareness more evident. The participants of a collaborative work often do not know other participants in person, work in different timezones, do not speak the same language and do not share the same culture. These, among other factors, hinder the information sharing [10], increase the possibility of conflicts [53], and inhibits informal interaction [7] among team members.

The problems addressed by GSD affect communication, coordination, and cooperation among team members. This occurs due to the relationship between these elements and awareness. This relationship is reflected in the 3C collaboration model, which was originally proposed by Ellis et al.[21] and later extended by Fuks et al.[26]. This model defines collaboration as the union of communication, coordination, and cooperation efforts, as represented by Figure 1.

Communication generates commitments that are managed by coordination. Moreover, during communication people negotiate and make decisions. Coordination arranges task for cooperation, helps managing conflicts, and organizes people to prevent loss of communication and of cooperation efforts. Cooperation is the joint operation of members of the group in a shared space, seeking to execute tasks, and generate and manipulate cooperation objects. To obtain success, cooperation demands more communication, generating a cycle that indicates the iterative nature of collaboration. Awareness is the element that intermediates each of the 3Cs, offering feedback to users actions and giving them information about other participants of a collaborative work [27,26].

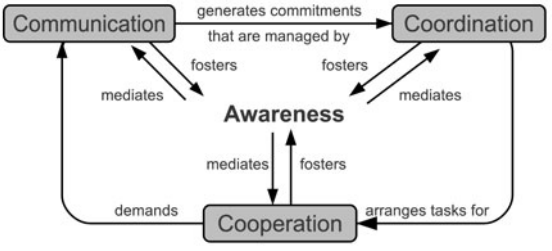

Fig. 1. 3C collaboration model proposed by [21] and adapted by [26]

The relationship among the 3Cs may be used as a guidance to analyze a groupware application domain. A chat, for example, which is a communication tool, requires communication (exchange of messages), coordination (access policies), and cooperation (logging and sharing). Therefore, despite their separation for analysis, there is a constant interplay between them. Figure 2 presents some applications positioned in the triangle formed by the 3 dimensions.

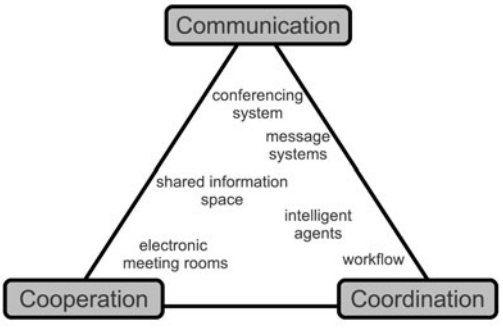

Fig. 2. Applications spread in the triangle formed by the 3C collaboration model [5]

The 3C collaboration model has often been used in the literature to classify collaborative tools [5,45,44]. Organizing collaborative tools according to this model facilitates the analysis since it allows one to realize the problems related to each dimension separately, to compose a complete solution [27]. Moreover, as they are interrelated concepts, dealing with them separately may reveal factors that otherwise would be forgotten.

In this paper, studies that improve awareness support in GSD were analyzed and categorized according to the 3C dimension they mainly support. We adopted the following criteria to classify the studies:

Communication: when the study brings improvements to the way messages and information are exchanged among people, reducing gaps, ambiguity, or the effort needed to understand, establish, or continue a conversation;

Coordination: when the study brings improvements to the support offered for people managing themselves, or being aware of the activities and its effects to the collaboration;
Cooperation: when the study brings improvements to the shared space or to the way users interact with shared artifacts synchronous or asynchronously.

3 Systematic Review

Kitchenham [40] summarizes the stages in a systematic review into three main phases: Planning the Review, Conducting the Review, and Reporting the Review. In this section, we present these three steps for our systematic review.

3.1 Review Planning

Review planning includes the identification of the review objective and the development of a protocol. The definition of a review protocol specifies the methods that will be used to undertake a systematic review and aims to reduce the possibility researcher bias [40]. This section summarizes our review protocol.

Formulating the research questions is the most important activity during protocol definition [40]. The research questions guide the systematic review. In our systematic review the research questions were:

Q1: What are the awareness studies carried out in order to improve the Global Software Development scenario?
Q2: Which of the 3Cs are these studies supporting?

The keywords were defined based on terms related to GSD and to awareness, as presented in Table 1.

Table 1. Keywords defined based on research questions

Reference	Category	Keywords
C1	Global Software Development	"Distributed software development", "Global software development", "Collaborative software development","Global software engineering", "Globally distributed work", "Collaborative software engineering", "Distributed development", "Distributed teams", "Global software teams", "Globally distributed development", "Geographically distributed software development", "Offshore software development", "Dispersed teams", "Virtual teams"
C2	Awareness	Awareness

Category C1 has more keywords and reflects the fact that GSD area is maturing, and there are many variations of the same term [49]. The three dimensions of the 3C collaboration model (communication, coordination, and cooperation) were not included in the query string, because there are studies related to awareness which might not explicitly present one of these words, however they can be classified according to them. The query string was defined as a combination of C1 and C2 using the logical connectors "AND" and "OR", as presented below:

(Awareness) AND ("Distributed software development" OR "Global software development" OR "Collaborative software development" OR "Global software engineering" OR "Globally distributed work" OR "Collaborative software engineering" OR "Distributed development" OR "Distributed teams" OR "Global software teams" OR "Globally distributed development" OR "Geographically distributed software development" OR "Offshore software development" OR "Dispersed teams" OR "virtual teams")

The query string defined was used to retrieve the candidate studies. The following search sources were used to obtain them:

- Science@Direct (http://www.sciencedirect.com);
- El Compendex (http://www.engineeringvillage.com);
- IEEE Digital Library (http://ieeexplore.ieee.org/); and
- ACM Digital Library (http://portal.acm.org).

After obtaining the studies by running the query string on the selected sources, papers were analyzed to check their relevance to this systematic review. The analysis was made in order to check if the study dealt with awareness on the GSD domain. It is worth noticing that only studies written in English and with online full paper available were considered.

The process used to include or exclude a study was based on [40,49] and followed the following steps. The first three steps were performed by two researchers, independently. When at least one of them included a paper as relevant, it was classified as a relevant study. All the steps were reviewed by a third – more experienced – researcher, responsible for checking the information generated.

1. The first analysis was made by reading papers titles, excluding those that were considered clearly irrelevant to the research questions.
2. The included studies were then analyzed based on the reading of papers abstracts and keywords, considering research questions.
3. Studies included in the previous step were further analyzed based on the reading of introduction, conclusion, and specific parts related to the contributions.
4. All studies selected so far were read by the researchers and documented on a proper form. Those studies which, despite addressing awareness issues, did not focus on GSD domain, were dismissed. We also discarded studies related to a same tool or environment, keeping just the most recent one. Papers included after this step were considered our primary studies.

The process of information extraction was based on obtaining information concerning the main contribution of the studies, thus allowing a categorization of the results. All papers were categorized based on the classification used in [38]. The categories used in our review were:

(i) case studies;
(ii) theoretical studies (also including conceptual/theoretical frameworks);

(iii) experiments;
(iv) tools (also including frameworks and architectures);
(v) literature reviews.

Additionally, studies were categorized according to which of the 3C dimensions the study was supporting. This categorization was made by identifying the dimensions supported and evaluating them from 0 to 3, according to the level of support the study presented:

3: Mainly supports (main focus of awareness study is on that dimension);
2: Also supports (the dimension is not the main focus, but it is also supported);
1: Indirectly supports (no focus, but brings indirect improvement);
0: Does not support (when no support or improvement is presented).

3.2 Review Conduction

The review was conducted according to the plan presented on the previous section. After executing the process defined in Section 3.1, a total of 42 primary studies were selected. More details about the process, the studies included and their classification can be found at http://www.igor.pro.br/awarenessRS/.

As can be observed in Table 2, confirming the observations of [49], the lack of standard terminology in GSD resulted in a large number of papers to start with, but only a few were selected. A high number of papers of unrelated areas (like computer networks, ubiquitous computing, e-learning, and psychology) also contributed to the large number of studies discarded at the beginning. After the title analysis, 143 papers (including duplicated ones) were selected; during the second analysis (based on abstract and keywords), 38 papers were dismissed; then, after the third selection (introduction and conclusion reading), we dismissed other 26 studies. During first and second analysis, we have also discarded 22 duplicated papers. Thus, we came to a number of 57 studies selected for an in-depth analysis.

In the deeper analysis, performed by reading the full papers, 15 papers were considered not relevant to the review or presented a same tool or environment (in this case only the latest study was considered). The main reason for dismissing papers at this step was that they were not presenting their contributions to the GSD domain area. In the next section, we present the results based on the data collected from these 42 papers selected as primary studies.

Table 2. Distribution of studies found

Source	Papers Found	Excluded per analysis step				Relevant Studies	Primary Studies Selected
		Title	Abstract, Keywords	Introduction, Conclusion	Repeated, Duplicated		
IEEE	37	11	4	6	2	14	**10**
ACM	325	256	20	9	5	35	**26**
Science Direct	229	203	9	10	2	5	**3**
El Compendex	86	64	5	1	13	3	**3**
Total	677	534	38	26	22	57	**42**

3.3 Review Report

Figure 3 shows the number of relevant studies by year, including the studies related to a same tool or environment to avoid any bias. The first conclusion is that the subject of awareness in GSD evidently is an area which was not widely studied until a few years ago, and that only recently appeared in a greater number of publications. As one can notice, the last three years present the greatest part of papers of our sample. It is important to highlight that the search was performed in early 2010, so it is possible that more studies could have been published in 2009 that have not been indexed to date.

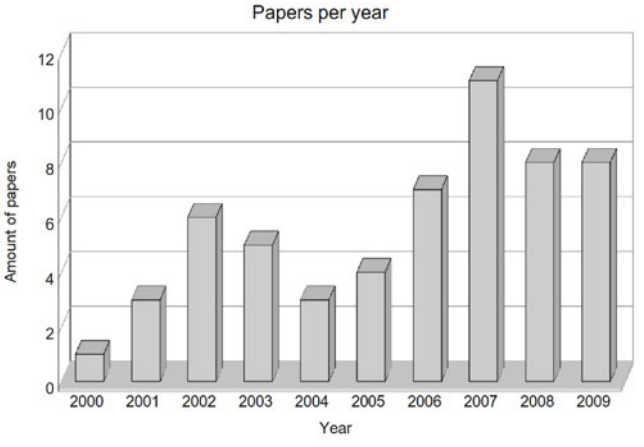

Fig. 3. Amount of relevant studies per year

Figure 4 presents the distribution of studies according to their categories. All studies were classified in, at least, one category. In this figure, the large number of tools presented in the literature may be noted. Out of a total of 42 primary studies, 33 studies (79%) presented a new tool. It is worth pointing out that 21 studies (64%) *only* presented a tool without any experimental analysis. Special attention should be given to one study [47] that presented a *tool* based on a proposed *theoretical study* and was further evaluated by an *experiment*.

The other 9 papers (not classified as tools) were categorized as case studies and/or theoretical studies. Five of them were classified only as theoretical studies: three [19,55,8] presented conceptual frameworks for awareness support; one study presented computer support interaction patterns for dispersed team members [54]; and the other one [31] brought an awareness analysis for Open Source communities.

Three papers were classified only as case studies: one [2] studied people work rhythm within a company, in order to find ways to make people aware of remote colleagues availability, providing a shared sense of time; and the other two [14,10] studied consequences of awareness gaps in broken code builds and communication, respectively. Only one study [9] was classified as both theoretical

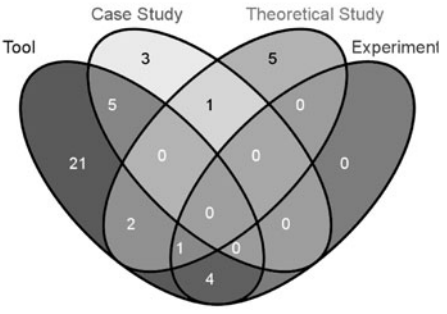

Fig. 4. Venn diagram for types of primary studies found

and case study. And, as one can notice, for this review no study was classified as literature review.

Figure 5 shows the classification of primary studies regarding the 3C collaboration model in two different analyses. The first analysis, depicted by Figure 5(a), is based on a Venn diagram representing the number of awareness studies that presented support (at any level) to each 3C-dimension. So, a first and clear conclusion that can be made is that communication is scarcely studied, presenting just 9 related studies and just 2 focusing *only* on communication. We can also see that a great focus is given to coordination and cooperation, as 40 out of 42 studies (95%) presented some support to one of these dimensions, and 21 (50%) support both dimensions concurrently.

Figure 5(b) presents the distribution of studies according to the 3C model and to the level of awareness support provided. It is clear that coordination is by far the main focus of awareness studies on GSD domain due to the number of studies that mainly support it (evaluated with 3 according to the scale presented in Section 2): a total of 28 studies out of 42 (67%). When we verify studies that support coordination evaluated with 3 or 2, this number grows to 35 (83%).

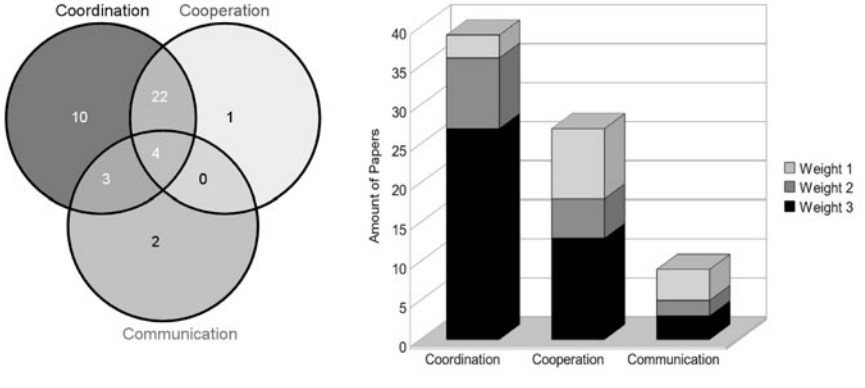

Fig. 5. (a) Venn diagram for 3C model classification; (b) Amount of studies evaluated according to 3C model

On the other hand we have communication, mainly supported by only 4 studies (9%). Additional details about the studies classified according to the 3C model dimensions can be found in the next section.

4 Studies Discussion and Classification

This section discusses the improvements and opportunities identified in this review. The open opportunities presented were raised according to the authors experience and based on the issues that frequently motivate GSD studies.

4.1 Communication

As it is possible to observe in Figure 5, awareness supporting communication is poorly explored within the GSD domain. Although many researchers use communication issues as motivation, only four awareness initiatives were classified as mainly supporting communication.

Three of these studies focused on providing the users with some kind of context for the conversation. Cheng et al. [11] presented a tool called Jazz, a collaborative distributed development environment that included communication facilities, such as a chat tool that allows developers to include links to transcripts of older chats, and team event notifications (e.g. code check-ins and check-outs from source control). Jacovi et al.[36] presented a tool that allows people to know what are the subjects being discussed on chats. Fitzpatrick [25] introduced a tickertape tool responsible for bringing CVS commit messages to members of a project, allowing them to start a private or a group chat within the context of the CVS message.

In the study presented by Calefato et al. [7] the Jazz environment was improved by presenting its integration with FriendFeed (a social network system), bringing personal interests to workspace and offering informal and social communication by using microblogs and forums within their development environment.

Some studied papers [29,37,55,32] presented limited means to allow communication on GSD environments (e.g. chats and forums) without any specific contribution to provide an easier or more effective communication in a GSD scenario.

According to [38], the software life cycle requires a great deal of communication using different tools and formats in order to avoid misunderstandings and delays. In order to avoid these problems and improve communication, awareness initiatives are needed to avoid ambiguity and misunderstandings, as cultural differences imply different vocabulary which may lead to mistakes. Using contextualized information and semantics extraction to improve communication can also be fruitful research areas. Privacy and security issues regarding access to sensitive user data [30] during communication is also a topic that should appear on awareness studies.

4.2 Coordination

Within a GSD environment, awareness is regarded as a means by which team members can become aware of the work of others that is interdependent with

their current tasks, therefore enabling better coordination of teams [14]. This maybe is the justification for why 38 out of 42 (90%) awareness studies present some level of support for coordination and 28 (67%) mainly support it.

In order to provide awareness for coordination, some studies focused on presenting information regarding the sequence of activities of an ongoing project. One example is the tool called TeamSCOPE [37], that presents a calendar of activities and a log relating artifacts and activities, allowing people to coordinate themselves. Godart et al. [29] introduces the tool ToxicFarm, which offers a workflow view, allowing one to be aware of the activities, their owners and their dependencies. Biuk-Aghai [4] presents a visualization approach that aims to support users in obtaining a greater understanding of structural and behavioral aspects of virtual collaboration, leading to increased awareness of the activities of the virtual team.

Another approach used to provide awareness to support coordination is gathering information on source code version management repository to make users aware of changes on artifacts that affect their work. Cook et al. [12] presents CAISE, a tool that notifies developers regarding dependent codes, user dependence and impacts of code changes, based on commits. FASTDash [3] is a visualization tool that seeks to improve activity awareness using a representation of the shared code (extracted from SVN/CVS) that highlights team members' current activities. Many other studies revealed that code repositories are a rich source of information for awareness generation [51,48,11,15,13,47].

Also using information from source code version management repository, but studying social network analysis techniques, De Souza et al.[16] introduces Ariadne, a tool that extracts information from code repositories and analyzes sociotechnical dependencies, thus helping to find coordination problems using social network visualization. Tesseract [52] and SmallBlue [20] are other tools that also present sociotechnical network analysis to improve awareness.

Expertise search is another mechanism studied to provide awareness to support coordination. Expertise Browser [43] is a tool to assist users in identifying experts for specific artifacts or tasks, making them aware of how experienced they are and the amount of experts for that artifact or task. SmallBlue [20] is an expertise search tool that can be used to identify experts, see dynamic profile information, and get information about the social distance to the experts; it supports someone to find the right people to work for a given task or area of interest. Minto [42] presents Emergent Expertise Locator, that uses emergent team information extracted from source code repositories to propose experts.

Cataldo et al. [8] study the coordination and propose a framework based on product features in order to support coordination within distributed environments, providing information about members activities and their relations with product features.

Most part of the studies that support coordination presented features based on historical information extracted from source code repositories, but, based on [47] it is also necessary to get recent information, once key information items used to gain awareness are the items that change on a daily, hourly or minute-by-minute basis,

according to [3]. Another open research topic is the social network coordination [14], trying to maintain awareness on the emerging and unplanned interactions that appear during the development cycle.

4.3 Cooperation

Activities within a GSD environment require awareness information to help distributed developers to edit shared artifacts, reducing negative impacts of distribution. In this sense, two studies [34,33] use code annotation to present changes being concurrently made by other developers in a shared artifact. Dekel and Herbsleb [17] also use code annotation to provide awareness on a tool called eMoose, that allows developers to write informal comments in the code, stores them in a central database, and spreads them to other developers using the annotated module.

A well explored way to provide awareness to support cooperation is warning and preventing conflicts on shared (cooperative) artifacts. Lighthouse [13] is a tool that captures code change events directly on developers workspace to avoid conflicts by keeping a shared and up-to-date UML design representation of the actual code. Estublier and Garcia [22] present a study based on cooperative policies to control concurrent engineering in order to avoid conflicts and propose awareness support considering different concurrent models. Palantìr [53] is another tool that supports cooperation by making users aware of direct or indirect conflicts on source code and helping them to reach a solution. Holmes and Walker [33] and Ignat [34] also proposed studies to avoid conflicts during cooperative handling of code artifacts.

A different awareness study is presented by Everitt et al. [23], who propose Designers' Outpost, a tool that allows users writing on Post-it notes and adding them to an electronic whiteboard, and organize information by physically moving Post-its around on the board. The tool provides synchronous remote cooperation and supports awareness regarding changes on the electronic whiteboard.

Despite the amount of studies presenting support to cooperation, it is an area that requires further development. One example is that there is no study presenting ways to suggest pieces of code to complete a given function or method based on similar codes extracted from other developers' code. Another possible opportunity is to focus on providing awareness support to cooperation in development phases other than coding; for example, present support to clients and analysts cooperate during requirement extraction and specification phases.

4.4 Summary

This subsection summarizes and classifies the awareness features of the studied tools. This classification was made to (i) further organize the high number of tools found on this review and (ii) provide a quick reference to GSD environment developers and researchers regarding which awareness features have already been investigated. Table 3 presents the references for the studies classified according to which 3C model dimensions they support. The table does not include frameworks or architectures [39,41,46,24,6].

Table 3. Identified awareness support for each 3C dimension

	Coordination	Cooperation	Communication
Conflict indication	[3] [13] [22] [53] [48] [51] [34]	[22] [34]	
Artifact change indication	[29] [37] [3] [11] [13] [15] [48]	[39] [15] [22] [53] [34]	
Activity control (workflow, logs, agenda, worklist)	[29] [37] [28] [25] [4] [51]		
Presence/status indication	[29] [37] [56] [11] [32] [28] [23]		
Context/subject-aware message exchange			[37] [11] [36] [28] [25]
Historical log		[37] [47] [22]	
Historic based expert search/recommendation	[47] [42] [43] [20]		
Social/socio-technical network	[16] [52] [51] [20]	[47] [16]	
Source code annotation		[17] [33] [34]	
Collaborative artifact synchronous handling		[13] [28] [23]	
Screen Sharing	[56] [11]	[11] [48]	
Informal/social communication			[7]

In addition to the analysis of opportunities made on each subsection of this section and the ones summarized in Table 3, it is possible to highlight other possible research topics that may be explored on all 3C dimensions. Firstly, we have not found studies dealing with awareness to overcome issues related to cultural, political, geographical differences, although this is frequently presented as motivation on GSD studies. Another research opportunity is the definition of policies to provide awareness within a GSD environment, maintaining the privacy of team members and organization as well as information security. Another opportunity that was very poorly explored on all three dimensions is to provide awareness not only to the coding phase, but also to the other software engineering phases. Several concepts and techniques already well investigated by the CSCW community in other contexts may be adapted or extended to the GSD domain.

5 Conclusion

In this paper, we presented a systematic review on the use of awareness to support GSD projects. It can be considered a starting point to establish issues upon which subsequent researches may be focused on or upon which developers may consider while designing GSD environments. The systematic review aims to present a fair evaluation of a research topic by using a trustworthy, rigorous, and auditable methodology, increasing the likelihood of detecting real effects that individual smaller studies are unable to detect [40].

We have presented our findings in two phases: in the first phase an initial quantitative data was presented, including number of studies per year, types of primary studies, and their classification according to the 3C model; in the second stage, we have analyzed and discussed the data extracted from the primary studies, enabling us to show some conclusions about the current state of art and practice of the awareness support in the GSD domain and the contributions

and challenges identified. In general, most part of the primary studies (79%) focuses on introducing a new tool with some awareness support to GSD. The main focus is given to studies gathering information from source code version management repositories, used to provide awareness, supporting both coordination and cooperation.

During this review we found a lack of studies and tools offering solutions that could provide awareness regarding recent (or real time) context. We did not find any study linking awareness in GSD and ubiquitous computing. Merging these areas should be a promising research topic, since awareness is already being discussed in ubiquitous computing for some time [1]. We also did not find any clue on how to use awareness regarding the physical location of a team member, for example, how to treat different cultures, national laws or organization restrictions. The closer study we found was a case study presented by Begole et al. [2], aiming on finding ways to coordinate teams in different timezones according to their temporal rhythmic activities patterns on a day-by-day and weekly basis.

In terms of the classification according to the 3C collaboration model, the main conclusion is that most of the literature focus on the support for coordination and the support for communication is very poorly explored, being a fruitful research topic. Coordination, even appearing as the main focus of awareness within the GSD area, still presents some opened opportunities like those presented in [47] and [14] and summarized in Section 4.2.

The approach of conducting a systematic review based on a collaboration model widely used by CSCW community may also be considered itself as a contribution, since it has not been yet used and may be adapted by others groupware researchers while conducting systematic reviews for other CSCW domains.

5.1 Limitations

Systematic review is a powerful method to search for primary studies within a given domain [40]. But as any other method, it also presents some limitations. This review may have missed some papers that address the use of awareness to support GSD, since we did not perform our search into every possible source. The four most relevant digital libraries were selected based on previous studies [38,49] and on the subject under review. The findings of this review may also have been affected as the classification is a human process and it is based on some criteria that could be considered subjective. In order to reduce this possible threat, this review involved two researchers cross checking each paper for inclusion, and a third researcher responsible for reviewing and discussing the information generated after each step.

References

1. Baldauf, M., Dustdar, S., Rosenberg, F.: A survey on context-aware systems. Int. J. Ad Hoc Ubiquitous Comput. 2(4), 263–277 (2007)
2. Begole, J., Tang, J.C., Smith, R.B., Yankelovich, N.: Work rhythms: analyzing visualizations of awareness histories of distributed groups. In: ACM Conf. on Computer-Supported Cooperative Work, pp. 334–343. ACM, New York (2002)

3. Biehl, J.T., Czerwinski, M., Smith, G., Robertson, G.G.: Fastdash: a visual dashboard for fostering awareness in software teams. In: SIGCHI Conf. on Human Factors in Computing Systems, pp. 1313–1322. ACM, New York (2007)
4. Biuk-Aghai, R.P.: Visualizing structural and behavioural aspects of virtual collaboration. In: 10th IEEE International Workshops on Enabling Technologies, pp. 279–284. IEEE CS, Washington (2001)
5. Borghoff, U.M., Schlichter, J.H.: Computer-Supported Cooperative Work: Introduction to Distributed Applications. Springer, New York (2000)
6. Bouthier, C., Bitcheva, J., Canals, G.: A context-adaptive group awareness tool. In: Symposium on Applications and the Internet Workshops, pp. 238–241. IEEE CS, Washington (2005)
7. Calefato, F., Gendarmi, D., Lanubile, F.: Embedding social networking information into jazz to foster group awareness within distributed teams. In: 2nd International Workshop on Social Software Engineering and Applications, pp. 23–28. ACM, New York (2009)
8. Cataldo, M., Herbsleb, J.D.: End-to-end features as meta-entities for enabling coordination in geographically distributed software development. In: 2nd Workshop on Software Development Governance, pp. 21–26. IEEE CS, Washington (2009)
9. Cataldo, M., Wagstrom, P.A., Herbsleb, J.D., Carley, K.M.: Identification of coordination requirements: implications for the design of collaboration and awareness tools. In: 20th anniversary ACM Conf. on Computer-Supported Cooperative Work, pp. 353–362. ACM, New York (2006)
10. Chang, K.T., Ehrlich, K.: Out of sight but not out of mind?: Informal networks, communication and media use in global software teams. In: Conf. of the Center for Advanced Studies on Collaborative Research, pp. 86–97. ACM, New York (2007)
11. Cheng, L.T., Hupfer, S., Ross, S., Patterson, J.: Jazzing up eclipse with collaborative tools. In: OOPSLA Workshop on Eclipse Technology eXchange, pp. 45–49. ACM, New York (2003)
12. Cook, C., Churcher, N., Irwin, W.: Towards synchronous collaborative software engineering. In: 11th Asia-Pacific Software Engineering Conf, pp. 230–239. IEEE CS, Washington (2004)
13. da Silva, I.A., Chen, P.H., van der Westhuizen, C., Ripley, R.M., van der Hoek, A.: Lighthouse: coordination through emerging design. In: OOPSLA Workshop on Eclipse Technology eXchange, pp. 11–15. ACM, New York (2006)
14. Damian, D., Izquierdo, L., Singer, J., Kwan, I.: Awareness in the wild: Why communication breakdowns occur. In: 2nd IEEE International Global Software Engineering, pp. 81–90. IEEE CS, Washington (2007)
15. de Lucia, A., Fasano, F., Oliveto, R., Santonicola, D.: Improving context awareness in subversion through fine-grained versioning of java code. In: 9th International Workshop on Principles of Software Evolution, pp. 110–113. ACM, New York (2007)
16. de Souza, C.R., Quirk, S., Trainer, E., Redmiles, D.F.: Supporting collaborative software development through the visualization of socio-technical dependencies. In: ACM Conf. on Supporting Group Work, pp. 147–156. ACM, New York (2007)
17. Dekel, U., Herbsleb, J.: Pushing relevant artifact annotations in collaborative software development. In: ACM Conf. on Computer-Supported Cooperative Work, pp. 1–4. ACM, New York (2008)

18. Dourish, P., Belloti, V.: Awareness and coordination in shared workspaces. In: ACM Conf. on Computer-Supported Cooperative Work, pp. 107–114. ACM, New York (1992)
19. Dustdar, S., Gall, H.: Process awareness for distributed software development in virtual teams. In: 28th Euromicro Conf., pp. 244–250. IEEE CS, Washington (2002)
20. Ehrlich, K., Lin, C.Y., Griffiths-Fisher, V.: Searching for experts in the enterprise: combining text and social network analysis. In: ACM Conf. on Supporting Group Work, pp. 117–126. ACM, New York (2007)
21. Ellis, C., Gibbs, S., Rein, G.: Groupware: some issues and experiences. Commun. ACM 34(1), 30–58 (1991)
22. Estublier, J., Garcia, S.: Process model and awareness in SCM. In: 12th International Workshop on Software Configuration Management, pp. 59–74. ACM, New York (2005)
23. Everitt, K.M., Klemmer, S.R., Lee, R., Landay, J.A.: Two worlds apart: bridging the gap between physical and virtual media for distributed design collaboration. In: SIGCHI Conf. on Human Factors in Computing Systems, pp. 553–560. ACM, New York (2003)
24. Farshcian, B.A.: Integrating geographically distributed development teams through increased product awareness. Inf. Syst. 26(3), 123–141 (2001)
25. Fitzpatrick, G., Marshall, P., Phillips, A.: CVS integration with notification and chat: lightweight software team collaboration. In: 20th anniversary ACM Conf. on Computer-Supported Cooperative Work, pp. 49–58. ACM, New York (2006)
26. Fuks, H., Raposo, A., Gerosa, M., Pimentel, M., Lucena, C.: The 3c collaboration model. In: Kock, N. (ed.) The enciclopedia of e-Collaboration, pp. 637–644. Texas A&M International University, USA (2007)
27. Fuks, H., Raposo, A., Gerosa, M., Lucena, C.: Applying the 3C model to Groupware Development. Int. J. Cooperative Inf. Syst. 14(2-3), 299–328 (2005)
28. Geyer, W., Richter, H., Fuchs, L., Frauenhofer, T., Daijavad, S., Poltrock, S.: A team collaboration space supporting capture and access of virtual meetings. In: ACM Conf. on Supporting Group Work, pp. 188–196. ACM, New York (2001)
29. Godart, C., Molli, P., Oster, G., Perrin, O., Skaf-Molli, H., Ray, P., Rabhi, F.: The toxicfarm integrated cooperation framework for virtual teams. Distrib. Parallel Databases 15(1), 67–88 (2004)
30. Godefroid, P., Herbsleb, J.D., Jagadeesany, L.J., Li, D.: Ensuring privacy in presence awareness: an automated verification approach. In: ACM Conf. on Computer-Supported Cooperative Work, pp. 59–68. ACM, New York (2000)
31. Gutwin, C., Penner, R., Schneider, K.: Group awareness in distributed software development. In: ACM Conf. on Computer-Supported Cooperative Work, pp. 72–81. ACM, New York (2004)
32. Hansen, K.M., Damm, C.H.: Instant collaboration: using context-aware instant messaging for session management in distributed collaboration tools. In: 2nd NordCHI, pp. 279–282. ACM, New York (2002)
33. Holmes, R., Walker, R.J.: Promoting developer-specific awareness. In: International Workshop on Cooperative and Human Aspects of Software Engineering, pp. 61–64. ACM, New York (2008)
34. Ignat, C.L.: Annotation of concurrent changes in collaborative software development. In: 4th International Conf. on Intelligent Computer Communication and Processing, pp. 137–144. IEEE CS, Washington (2008)

35. Ivcek, M., Galinac, T.: Aspects of quality assurance in global software development organization. In: 31st International Convention MIPRO, pp. 150–155 (2008)
36. Jacovi, M., Soroka, V., Ur, S.: Why do we ReachOut?: functions of a semi-persistent peer support tool. In: ACM Conf. on Supporting Group Work, pp. 161–169. ACM, New York (2003)
37. Jang, C.Y., Steinfield, C., Pfaff, B.: Virtual team awareness and groupware support: An evaluation of the teamscope system. Int. J. Hum.–Comput. Stud. 56(1), 109–126 (2002)
38. Jimenez, M., Piattini, M., Vizcaño, A.: Challenges and improvements in distributed software development: A systematic review. Adv. Softw. Eng., 1–14 (2009)
39. Kirsch-Pinheiro, M., de Lima, J.V., Borges, M.R.S.: A framework for awareness support in groupware systems. Comput. Ind. 52(1), 47–57 (2003)
40. Kitchenham, B.: Procedures for performing systematic reviews. Technical Report TR/SE-0401, Keele University and NICTA (2004)
41. Mangan, M., Borges, M., Werner, C.: A middleware to increase awareness in distributed software development workspaces. In: 10th Brazilian Symposium on Multimedia and the Web 2nd Latin American Web Congress, pp. 62–64. IEEE CS, Washington (2004)
42. Minto, S., Murphy, G.C.: Recommending emergent teams. In: 4th International Workshop on Mining Software Repositories, p. 5. IEEE CS, Washington (2007)
43. Mockus, A., Herbsleb, J.D.: Expertise browser: a quantitative approach to identifying expertise. In: 24th International Conf. on Software Engineering, pp. 503–512. ACM, New York (2002)
44. Muhammad, A., Enríquez, A.M.M., Decouchant, D.: Awareness and coordination for web cooperative authoring. In: Szczepaniak, P.S., Kacprzyk, J., Niewiadomski, A. (eds.) AWIC 2005. LNCS (LNAI), vol. 3528, pp. 327–333. Springer, Heidelberg (2005)
45. Neale, D.C., Carroll, J.M., Rosson, M.B.: Evaluating computer-supported cooperative work: models and frameworks. In: ACM Conf. on Computer-Supported Cooperative Work, pp. 112–121. ACM, New York (2004)
46. Nutter, D., Boldyreff, C.: Historical awareness support and its evaluation in collaborative software engineering. In: 12th IEEE International Workshop on Enabling Technologies, pp. 171–176. IEEE CS, Washington (2003)
47. Omoronyia, I., Ferguson, J., Roper, M., Wood, M.: Using developer activity data to enhance awareness during collaborative software development. Comput. Supported Coop. Work 18(5-6), 509–558 (2009)
48. O'Reilly, C., Bustard, D., Morrow, P.: The war room command console: shared visualizations for inclusive team coordination. In: ACM Symposium on Software Visualization, pp. 57–65. ACM, New York (2005)
49. Prikladnicki, R., Damian, D., Audy, J.L.N.: Patterns of evolution in the practice of distributed software development in wholly owned subsidiaries: A preliminary capability model. In: IEEE International Conf. on Global Software Engineering, pp. 99–108. IEEE CS, Washington (2008)
50. Robinson, M., Kalakota, R.: Offshore Outsourcing: Business Models, ROI and Best Practices. Mivar Press, Georgia (2004)
51. Sarma, A., van der Hoek, A.: Towards awareness in the large. In: IEEE International Conf. on Global Software Engineering, pp. 127–131. IEEE CS, Washington (2006)

52. Sarma, A., Maccherone, L., Wagstrom, P., Herbsleb, J.: Tesseract: Interactive visual exploration of socio-technical relationships in software development. In: 31st International Conf. on Software Engineering, pp. 23–33. IEEE CS, Washington (2009)
53. Sarma, A., Redmiles, D., van der Hoek, A.: Empirical evidence of the benefits of workspace awareness in software configuration management. In: 16th ACM SIGSOFT International Symposium on Foundations of Software Engineering, pp. 113–123. ACM, New York (2008)
54. Schümmer, T., Lukosch, S.: The absent participant: more patterns for group awareness. In: Conf. on Pattern Languages of Programs, pp. 1–14. ACM, New York (2006)
55. Storey, M.A.D., Čubranić, D., German, D.M.: On the use of visualization to support awareness of human activities in software development: a survey and a framework. In: ACM Symposium on Software Visualization, pp. 193–202. ACM, New York (2005)
56. Tee, K., Greenberg, S., Gutwin, C.: Artifact awareness through screen sharing for distributed groups. Int. J. Hum–Comput. Stud. 67(9), 677–702 (2009)