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The importance of socio-technical resources for software ecosystems management

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HIGHLIGHTS

- A survey on the relevance of socio-technical resources for SECOs based on literature.
- Expert opinion on the main roles, activities and artifacts in ecosystem platforms.
- Discussion of socio-technical resources in two real ecosystems, BPS Portal and GitHub.
- A second survey on the usefulness and ease of use of two real ecosystem platforms.
- The top 12 socio-technical resources evaluated in two real SECO platforms.

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ABSTRACT

Software Ecosystem (SECO) is often understood as a set of actors interacting among themselves and manipulating artifacts with the support of a common technology platform. Usually, SECO approaches can be designed as an environment whose component repository is gathering stakeholders as well as software products and components. By manipulating software artifacts, a technical network emerges from interactions made over the component repository in order to reuse artifacts, improving code quality, downloading, selling, buying etc. Although technical repositories are essential to store SECO's artifacts, the interaction among actors in an emerging social network is a key factor to strengthen the SECO's through increasing actor's participation, e.g., developing new software, reporting bugs, and communicating with suppliers. In the SECO context, both the internal and external actors keep the platform's components updated and documented, and even support requirements and suggestions for new releases and bug fixes. However, those repositories often lack resources to support actors' relationships and consequently to improve the reuse processes by stimulating actors' interactions, information exchange and better understanding on how artifacts are manipulated by actors. In this paper, we focused on investigating SECO as component repositories that include socio-technical resources. As such, we present a survey that allowed us to identify the relevance of each resource for a SECO based on component repositories, initially focused on the Brazilian scenario. This paper also describes the analysis of the data collected in that survey. Information of other

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SECO elements extracted from the data is also presented, e.g., the participants' profile and how they behave within a SECO. As an evolution of our research, a study for evaluating the availability and the use of such resources on top of two platforms was also conducted with experts in collaborative development in order to analyze the usage of the most relevant resources in real SECO's platforms. We concluded that socio-technical resources have aided collaboration in software development for SECO, coordination of teams based on more knowledge of actor's tasks and interactions, and monitoring of quality of SECOs' platforms through the orchestration of the contributions developed by external actors.

1. Introduction

Implementing software reuse can increase code quality, productivity and time-to-market since a component is not built from scratch—the same applies to other artifacts related to the software development, e.g., templates, documents and architecture. The traditional strategy of building isolated, monolithic systems within the organization is fading away in face of the component-based systems [1]. Those systems implement software reuse by developing software components to be integrated into the systems. The variability in a product depends on its potential components and can generate a product line. Product lines develop different versions of the same product according to the possible variability [2]. As an evolution of a product line, a Software Ecosystem (SECO) represents the extrapolation of organizational limits [3], facing a much larger set of elements such as social and business issues, orchestration of external actors, and management and monitoring of multiple software products and services. They implement many product lines at the same time focusing at technical, social and business dimensions of software development [4].

In order to support Software Reuse, a well-known and applied technique to help developers finding components consists of implementing a repository of reusable software artifacts. This type of repository stores components and related information, e.g., documents, architecture, source code etc. [1]. On top of such repositories, SECOs arise from the interactions among actors, i.e., developers and users (either internal or external). A SECO is created from a common technological platform focused on software products and services [2], contributing to explore the interorganizational reuse [2]. As a dynamic environment, it is important to boost actors' participation and artifacts' publishing, as well as community's discussion to maintain the SECO platform alive. As such, since an organization stops building software products isolated from other companies and starts seeking partnerships, opening business strategies go beyond organizational borders and encounter an ecosystem made up of various organizations [2]. Thus, it is relevant to study a SECO as a set of platforms, actors and artifacts/information within a software supply network [3,4]. In doing so, it is possible to analyze the evolution of SECO's software identifying potential investments in new releases or fixes, identify demands from the community. In addition, the role of external developer changes the traditional development management strategy. The keystone (i.e., organization that is responsible for the SECO platform) does not have complete control over an external developer. They can leave the SECO at any time (taking information with them) or enter (requesting information). This, it becomes a necessity to monitor the SECO in order to better understand its behavior and evolution. The keystone organization is mainly responsible for monitoring the SECO, evaluating it, making decisions, and taking actions [5].

In this scenario, the interactions among actors lack effective attention to encourage social relationships [6]. Due to different types of relationship among actors and artifacts like 'communicate with' and 'depends on', the existing networks are neither solely social nor technical; they include both actors and artifacts. Exploring socio-technical relationships can reveal information from the SECO that was too spread out to be organized, e.g., community's tendency and demands can be extracted after analyzing frequency of terms from the communications among actors. Those information contribute to the software development from the point of view of the keystone that can prioritize functions and bug fixes according to the community data; the developer that now have information of dependency relationships, e.g., helping to select a component; the user that can better understand the product based on the community's relationship information, e.g., information of use, reported problems, and technology dependency; and other benefits of comprehending how such elements are interacting and influencing each other. In turning the relationships in a SECO more explicit, its central platform and keystone can analyze the SECO as a set of integrated elements using the network drawn by the elements and its relationships, revealing new structural and influence information.

Aiming to support the social networks created from a SECO, it is important to provide social resources that foster actors' interaction and also include resources that allow software artifacts manipulation, i.e., the socio-technical resources. With the purpose of identifying the most relevant and suitable socio-technical resources for the SECO platform management, a survey was conducted with Brazilian experts in SECO, collaborative systems and distributed software development. This study allowed us to organize a set of social and technical resources presented in the literature as well as to analyze them in the context of an existing Brazilian government open source SECO—the Brazilian Public Software (BPS) Portal [7]. According to a broad systematic review on

SECO [5], BPS Portal is one of the Top 5 SECOs appearing in the literature and practice in the software industry in 2013. Additionally, Brazil was the sixth country in sales on the software market in 2001 [8], reflecting its importance for the global industry in the 21th century. Given the domestic market (excluding exportations), Brazil is the seventh in the world information technology market in 2015 [9]. Specifically in the software and services market, in 2015, Brazil is the eight nation in revenue of domestic market (2.4% of the world market), with 30.2% of growth from 2014 [9]. Therefore, the contributions of this paper concern not only the Brazilian scenario, but address worldwide problems considering the importance of this player in the global industry. The results of the survey on the relevance of socio-technical resources in SECOs contributes to the research community because the final ranking aids to extract resources that should be implemented on SECOs' platforms in order to bring business advantages and meet communities' demands. In addition, the ranking is based on experts' opinion and give rise to other features that are necessary to support interactions among different stakeholders that play in a SECO.

With the goal of analyzing the most relevant resources in real SECO's platforms, this paper presents another study for evaluating the availability and the use of such resources on top of two platforms was conducted with experts in collaborative development. This paper is an extended version of [10], published in the Proceedings of the 7th International Conference on Management of computational and collective intElligence in Digital EcoSystems (MEDES 2015). In [10], we presented a survey to evaluate the relevance of socio-technical resources identified in the literature and also in BPS Portal (the first study of our research). Background on SECO, socio-technical networks and software artifacts management were discussed. On the other hand, in this extended version, we included: (i) a discussion of two important SECOs, one from the Brazilian software industry scenario (BPS Portal) and another from the international software industry scenario (GitHub); and (ii) a second study of our research (survey) was planned and executed to evaluate the most relevant resources obtained in our first study [10] in those two abovementioned scenarios, regarding usefulness and ease of use, as well as to collect other missing resources used by the participants. The evaluation executed in this paper takes the findings of our first study published in the original paper and uses them as inputs for our second study, i.e., an exploratory study using real cases for SECO platform management. In other words, the extended work was built upon the results of the first study and those results were evaluated in the second study to explore how developers actually use them in two existing SECOs.

The paper is organized as follows: Section 2 presents the background of this research from which our two surveys were prepared; Section 3 analyses some related work found in the literature; Section 4 discusses the first survey for evaluating socio-technical resources, including details on the planning and execution of a questionnaire with experts in SECO, collaborative systems and distributed software development, as well as the methodology and technique selected to analyze the collected data; Section 5 discusses the results of the analysis of socio-technical resources' relevance, including correlation among them and observations of some specific participants' profiles; Section 6 analyses the existing tool support for SECOs; Section 7 presents the second survey that we conducted with experts in the two widely used SECO platforms to evaluate the most relevant resources listed in Section 4; and Section 8 concludes the paper and points out future work.

2. Background

This section discusses the background for the main topics used in this study according to the related literature. An ad hoc search on the themes was executed on SECO and its definitions; on how an artifact is stored, manipulated and managed within a SECO; and on the role of socio-technical networks for emerging SECOs.

2.1. *Software ecosystems*

SECO can be described as a set of actors interacting with software products and services that are centered on a common technological platform [2]. As an organization no longer develops its own products in a "closed" environment (without external actors), it encounters an environment with several companies, suppliers and products that requires coping with openness of the organization's business and technologies [3]. Thus, the organization becomes more dependent on external partners, suppliers and tools, and all of that is out of its complete control. So, it is important to study not only the platform, but also a unit formed by the actors and artifacts' networks as a SECO [4].

Some actors' roles found in the literature are described in [5]: (i) *Keystone*—a team or company that is responsible for the platform management and interested in its improvement; (ii) *Dominator/Competitor*—individual or company interested in mining the keystone's power and attracting SECO members; (iii) *Supplier*—provides technological support or tools for the platform management; (iv) *Developer*—develops the software or components and make them available for the SECO (they might be external, or work for the keystone); and (v) *End user* (or *client*)—benefits from the SECO platform and are the source of new requirements. An example is the iPhone SECO where the keystone is Apple, a dominator is Google and a supplier is the company that produces hardware. Applications' developers and end users are spread over the world. iPhone SECO [10] was created in 2007, but the ecosystem growth affect the platform since it aggregates more and more members, applications are increasingly available, and the interactions among actors and artifacts are also diversified/multiplied [11].

2.2. *Artifacts management in SECO*

For the purpose of this paper, SECO's artifacts are software assets (i.e., software components, services and applications) as well as demands (i.e., organization's needs, or SECO community's requirements). Those artifacts are produced or acquired by a software organization and then stored and sold [7]. Once

they have been stored, their management involves improving methods to acquire, build and use them [12]. To support such tasks, a software asset base (repository, inventory or catalog) can be used to manage them throughout their lifecycle phases [13]. Software artifacts can be considered reusable artifacts too [14]. Reusable software artifacts might be created by the keystone's developers or brought in from outside the organization by external developers within the SECO. Usually, actors playing as keystone and developers manipulate and manage SECO's artifacts inside the organization. They communicate with the external actors, e.g., external developers and resellers that usually have less permission and access to the software asset base. Therefore, the roles of an actor can be differentiated by the type of artifact one manage and the scope (i.e., inside or outside the organization), e.g., actors like resellers that add value to the original product creating a new artifact that they can sell outside the SECO.

The development management strategy applied for demands is different from those applied for other artifacts. Usually, they cannot be negotiated, purchased or sold, but they can suffer interference from users, even though they are controlled by the keystone—in different levels of permissions, from private companies to open-source projects. In order to represent the artifacts, their information should be captured, stored and displayed at the repository. Besides, it becomes clearer that essential information on the projects is retained at the artifacts and its interactions with other SECO's elements.

2.3. *Socio-technical networks in SECO*

In general, networks are used to map elements and its relationships. Social networks represent the relations among people, such as communication, collaboration, or even virtual friendship. People share information through those relationships. On the other hand, there are artifacts being produced and exchanged through purchasing, downloading, collaboration etc., forming a technical network. Currently, the information exchanged and overall interactions among actors tend to be focused on the artifact [15], due to staff turnover and maintenance of organizational knowledge.

Thus, fostering visibility and relevance of software artifacts is a growing trend [16]. SECO deals with artifacts that flow in the actors' relationships, as well as from/to the common technological platform. Considering this scenario, it is possible to build up a socio-technical network to represent the SECO structure. The emerging network belongs to both social and technical perspectives, i.e., dealing with relationships between actors and artifacts. Social networks platforms (e.g., web sites) are frequently used to support those networks. The impact of such platforms motivates organizations and communities to interact through groups, profile pages (personal and commercial), among others, directly related to their specifics goals [17].

3. Related work

A search in the literature reveals some related work with similar goals and methods. Some papers recommend elements and resources, whereas others present and discuss basic functions and elements of existing SECOs, e.g., artifacts and actors related to the ones assessed in our work.

In [18], it is discussed that SECO's participants are connected to artifacts in such close way that they behave as 'first class citizens', although the role of participants is not deeply discussed. Those ideas corroborate the socio-technical network discussed in our work. As artifacts become part of the social network, it is necessary to study them as a unique network that reveals new relationships. The related work described in [19] lacks the discussion on the participant's roles. However, it focuses on extracting information from software projects repositories—this is the method applied for our second study described in Section 6. Those project repositories represent the SECO with its main elements, e.g., artifacts, actors and relationships. In [20], the focus is not on the artifacts, but on the actors. The context of social relationships is discussed, but not in the level where information and knowledge are present in the artifacts. The socio-technical network gives a structure in which it is possible to represent the flow of information among actors through the exchange of artifacts.

In [6,5], some empirical evidence on SECOs is gathered through a systematic literature review, including some reported case studies about SECOs. In those papers, different types of actors are listed and real SECOs are discussed. Our extended work in this paper is partially based on those findings and uses a survey as an instrument for collecting information. In Section 4, we explain that the respondents are experts in the field and represent the source of information, while [6,5] use published papers as their sources of information, configuring a systematic literature review.

A comparison of related work is shown in Table 1. Our work aims to discuss the mentioned topics, especially the ones that lack existing research initiatives. The related work discusses and focuses on the findings reported in the literature; our contribution is on the matching of those findings with the real experience reported by SECO users that are also experts in the field, so that we can understand the most relevant roles, artifacts and relationships. Therefore, we investigate the socio-technical network from the types of existing relationships and support the implementation of a socio-technical network from the prioritization of the resources to be implemented.

4. Survey with experts

The goal of this survey was to evaluate the relevance and suitability of socio-technical resources from the point of view of experts in SECO, collaborative systems and distributed software development. The sources used for specifying the set of items to be evaluated are the following:

1. The work about social networks presented in [18]. This paper considers social resources and interactions not only among actors, but also considering artifacts. Example of socio-technical resource extracted from this source: *the use of a profile page for users*;
2. The observation of BPS Portal version available at 2014, maintained by the Brazilian Federal Government. This is

Table 1 – Comparison with related work.

Related work	Main related topics				
	Social network (actor and relationships)	Technical network (artifacts and relationships)	SECO elements (discussion on the structure)	Integration of socio-technical resources	Analysis of SECO's real cases
[6,5]	✓	–	✓	–	✓
[18]	✓	✓	Main focus: Artifacts	–	–
[19]	–	✓	–	–	✓
[20]	✓	–	Main focus: Actors	✓	–

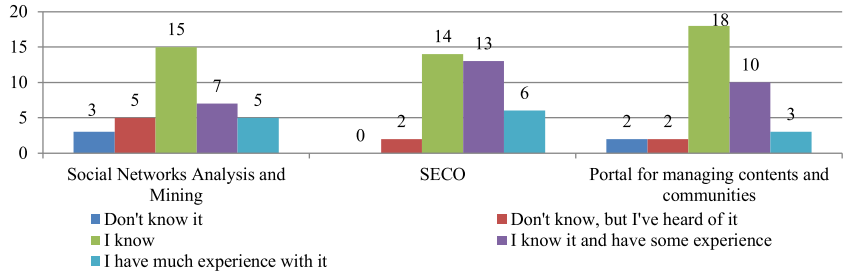

Fig. 1 – Participant's knowledge regarding the survey areas.

a catalogue of open source software projects available at a web portal. Software projects are organized by communities, allowing to obtain, discuss and evaluate software products and projects. Examples of socio-technical resources extracted from this source: *chat and community management*;

3. Items proposed in [21]. This paper identifies possible resources that are not covered by social networks, technical networks (and similar work from sources 1 and 2). It focuses on resources and mechanisms for social networks and requirements engineering. Example of socio-technical resource extracted from this source: *suggestion of demands*.

4.1. *Planning*

The survey consists of a questionnaire composed by three types of questions: (i) *characterizing questions*, for collecting participant's profile; (ii) *relevance degree*, for assessment of socio-technical resources in SECO; and (iii) *open field*, for general comments. The estimated time of response was 25 min. We previously ran a pilot study with four participants to improve the first version of the questionnaire as regards to its structure, questions and instructions. After some adjustments, we emailed the survey to potential participants from our sample.

Participants were chosen from personal indications of post-graduation professors related to software engineering known by the author and also from the program committees of two academic events in Brazil: WDDS/WDES (Workshop on Distributed Software Development, Software Ecosystems and Systems-of-Systems) 2014 and 2013; and SBSC (Brazilian Symposium on Collaborative Systems) 2013, 2012 and 2011. These events were chosen for treating the specific topics of this research and for being relevant in the Brazilian scenario.

This survey was initially planned to collect and analyze information on socio-technical resources of SECO in the Brazilian scenario, motivated by the fact that BPS Portal is one of the Top 5 SECOs appearing in the literature and practice [5]. Considering the goal of capturing the relevance of each item (socio-technical resource) to a SECO platform, we used a five-point scale, mapping according to the following: No importance; Neutral; Some importance; Important; and Very important. Also, participants were asked to qualify their experience degree regarding the following areas: *social networks analysis and mining*, *SECO* and *portals for managing contents and communities*. These data were useful to allow us to perform some analyses of participants' profiles versus socio-technical resources' relevance.

4.2. *Execution*

The survey was run from November 6th, 2014 to December 15th, 2014. We sent 99 invitations and 35 invitees responded the survey. The response rate (35.35%) is considered positive in studies like this (on-line surveys), according to a previous study focused on the adequacy of response rates to online and paper surveys [22]. This study compares the rate for paper-surveys and online-surveys with simulations of different arrangements for populations and response rates.

Table 2 and Fig. 1 summarize data regarding participants' profile, i.e., personal experience and knowledge in the areas of interest. Most participants had some experience in the survey's areas. They have significant experience and mostly work at the *public* and *academic* sectors. Fig. 2 presents the reported distribution of roles based on some multiple-choice options, but also considering others as informed by participants.

In Fig. 2, it is possible to observe that several participants chose multiple roles. The only role with no representation

Table 2 – Participant's profile.

Item	Result		
Workplace	Public companies	25	71.4%
	Private companies	3	8.6%
	Both	7	20.0%
	Academy	27	77.1%
	Industry	2	5.7%
	Both	6	17.2%
Experience on IT/software sector	0–5 years	3	8.6%
	5–10 years	5	14.3%
	10–15 years	9	25.7%
	15–20 years	10	28.6%
	20 years or above	8	22.8%
Academic degree	Bachelor degree	2	5.7%
	Master degree	12	34.3%
	Doctoral degree	21	60.0%

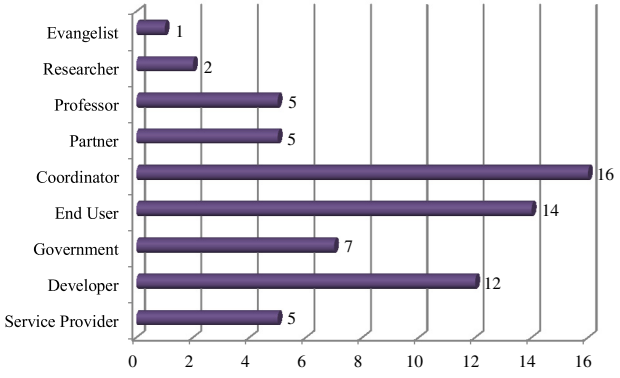

Fig. 2 – Participants' roles in the SECO they participate.

was "Software Sector". Beside the roles offered as options on the survey, three roles were suggested by some participants. They were included in the analysis: *Researcher*, *Evangelist* and *Professor*. According to the participant that considers himself an "Evangelist", this role consists of an organizational actor responsible for training and maintaining the community [23].

4.3. *Methodology for the analysis*

Once the survey execution was completed and the data were collected, some tasks to extract information were established. A formal methodology was not used, but the following steps were performed to analyze the data:

1. Data transformation and formatting;
2. Responses distribution;
3. "Resources-Resources" Correlation; and
4. "Specific Profile-Resources" Relations;

Most answers were collected through qualitative questions, such as "choosing related roles and artifacts manipulated by participants within a SECO". So, it was necessary to format the answers into a corresponding numeric scale. The Spearman correlation algorithm for calculating a correlation coefficient for ordinal scales was applied according to the relevance degree of all different socio-technical resources (*n* to *n*).

To calculate correlations, two tools were used: regular spreadsheets (*Microsoft Excel*) and *Action*.[1] *Action* is a Statistics software integrated to Excel that uses data to generate many statistical analyses and graphics. *Action* was chosen for being free software and supplying the Spearman correlation. For analyzing "specific profile-resources" relations, a subset was used, selecting the responses according to a specific participant's profile. We defined questions aligned with the survey's goals, as follows:

Q1. Are community's demands (i.e., requirements) necessary and relevant resources in a SECO?
Q2. What are the most correlated socio-technical resources?
Q3. What are the most correlated socio-technical resources to the community's demands resources?
Q4. What are the most relevant socio-technical resources in the opinion of the most experienced participants?
Q5. What are the most relevant resources in the opinion of the more knowledgeable participants, regarding the survey's areas?
Q6. What are the most relevant socio-technical resources in general?

5. Survey analysis

In this section, the main findings of the survey are discussed. For each socio-technical resource, a diagram for distribution of answers is presented (Fig. 5). In general, the only resource evaluated as not being so important, compared to the others, is the "User Profile Page". Conversely, this would be useful information for others who are interested in the user reputation or finding other data regarding a specific user.

The best evaluations were for "Artifacts Versioning", "Environment to Report Problems" and "Artifact Forum". This may indicate the need for a sort of 'place' to discuss and help SECO users, besides the artifacts version control. None of the resources had the majority of votes as being of

[1] Action Portal.
Available at <http://www.portalaction.com.br/ >.

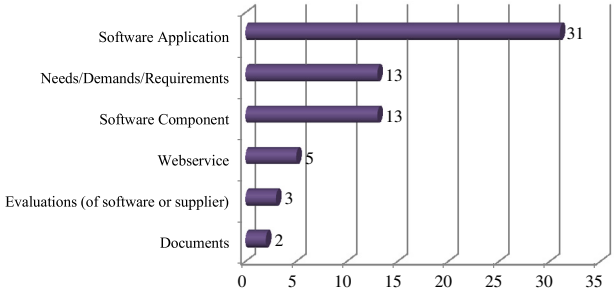

Fig. 3 – Artifacts manipulated by participants in a SECO.

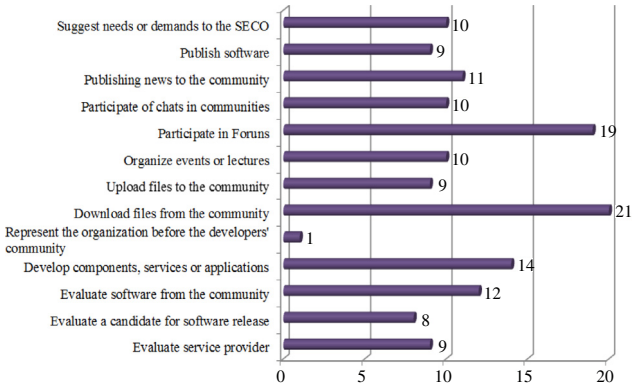

Fig. 4 – Activities performed by participants within a SECO.

"No importance" or "Neutral". For the other items, 21 were considered as "Important" and 13 as "Very Important".

The survey also collected data on how participants exchange information within the SECO by asking the types of artifacts they manipulate and the activities they execute. Fig. 3 displays the types of artifacts handled by the participants and also the number of votes. From six options, the majority of participant's votes (31 votes meaning 42.27%) works with "Software Applications ". It is possible to observe that artifacts such as "Documents" and "Evaluations" are less handled.

However, they are important to support software development processes. They also might be used to choose a software product or a component from the SECO, mainly when participants are looking at their evaluation and documentation. Perhaps, it happens due to the lack of appropriate support for organizing those types of artifacts.

It was questioned about what sort of activities the actors perform within the different SECOs they participated. Most participants use a SECO for downloading software, and attending or reading forums, though it is not possible to ensure that those are only end-users, since each participant chose many activities. Aside from the Evangelist's suggestion (only one vote), most activities stay on the range of 8–12 votes, as displayed in Fig. 4.

For Q1, resources containing the word "demand" were selected, resulting in the following socio-technical resources:

A. Information about SECO's needs and demands;
B. Negotiating SECO's needs/demands/requirements in order to prioritize new functionalities;
C. Recommendation of new demands for SECO, originated by mining the existing ones;
D. Rewards for members who identify and evaluate new demands; and
E. Demands registering.

These five socio-technical resources directly relate to community's demands, or requirements. This is important to identify resources that can foster innovation in a SECO. Fig. 6 illustrates the participants' votes regarding each resource (the percentile is shown beside the bar on the left hand side). None of these resources got "No importance" as an answer. In fact, for these resources, the highest concentration of responses was on "Important" and "Very Important". For *A*, *B* and *E*, the majority of participants judged them to be "Very Important" (A: 45.4%, B: 42.9% and E: 57.1%). For *C* and *D*, the responses were "Important" (C: 48.6% and D: 54.3%).

For Q2, a correlation matrix was generated from the Spearman correlation algorithm through *Action*. Fig. 7 presents the results. The correlation function works by assigning a correlation variable from −1 to +1 for each pair of resources. Table 3 (ordered by the highest correlation) describes the highest scores for a positive correlation coefficient regarding each resource. The resources marked with(1) were extracted from [18],(2) observed from [7],(3) adapted from the SECO's socio-technical approach of [21], and (4) for the ones suggested after running the pilot survey (see Section 3).

An overview of the results can be better visualized in a squared table view (Fig. 7). This type of view shows in each cell the correlation values of the corresponding row and column using a color range that varies from dark red (strong negative correlation), over white (no correlation), to dark blue (strong positive correlation). In our analysis, if two socio-technical resources, A and B, have strong positive correlations (i.e., responses for A also happen for B), the proportion is shown by the range between −1 and +1 (in the graphic case, it is from red to blue).

It means that the majority of participants who voted for the most relevant resources in the first column also voted in the same way for some resources in the second column. For example: the participants who voted for the positive relevance of "Software license information" also thought the same for "Negotiation of different acquisition ways, including licenses". We can find out that negotiating acquisition (including licenses) is important to have information about them available within the SECO. By analyzing each row, it is possible to see non-trivial correlations, e.g., the relation between "Documents download" (34) and "Socio-technical network mechanisms that consider actors and artifacts evaluation" (29). Perhaps, when choosing a document to download, participants would look at the evaluations of the actor who published it or the artifacts to which this document relates. Table 3 presents each resource at the left hand column and its most correlative resource at right hand column, resulted from the item with highest correlation value.

For Q3, the highest positive coefficient of each row corresponding to five socio-technical resources regarding demands was extracted from Fig. 7.

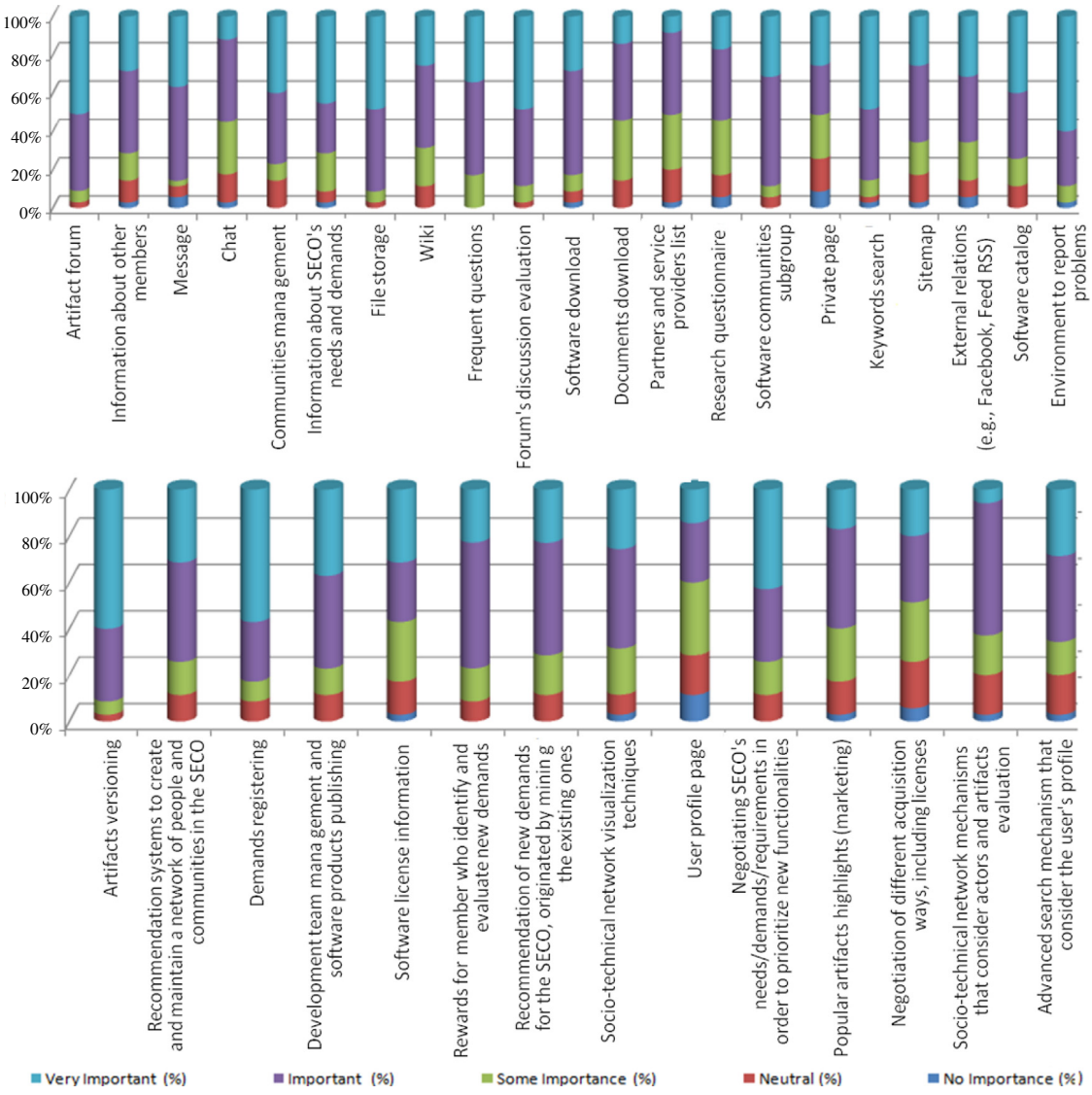

Fig. 5 – Distribution of participants' answers per socio-technical resource.

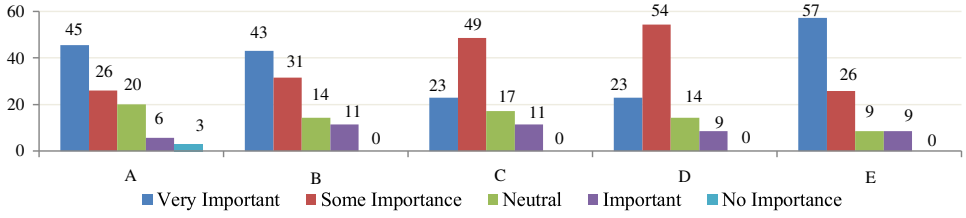

Fig. 6 – Socio-technical resources versus demands.

- Information about SECO needs and demands: **Development team management and software products publishing**;
- Negotiating SECO needs/demands/requirements in order to prioritize new functionalities: **User profile page**;
- Recommendation of new demands for the SECO, originated by mining the existing ones: **Chat**;
- Rewarding members that identify and evaluate new software demands for the SECO: **Demands registering**;
- Demands registering: **Rewards for member who identify and evaluate new demands**.

For Q4, answers from participants who had 20 or more years of experience were selected. From a total of eight participants, we extracted the most relevant options ("Very Important" and

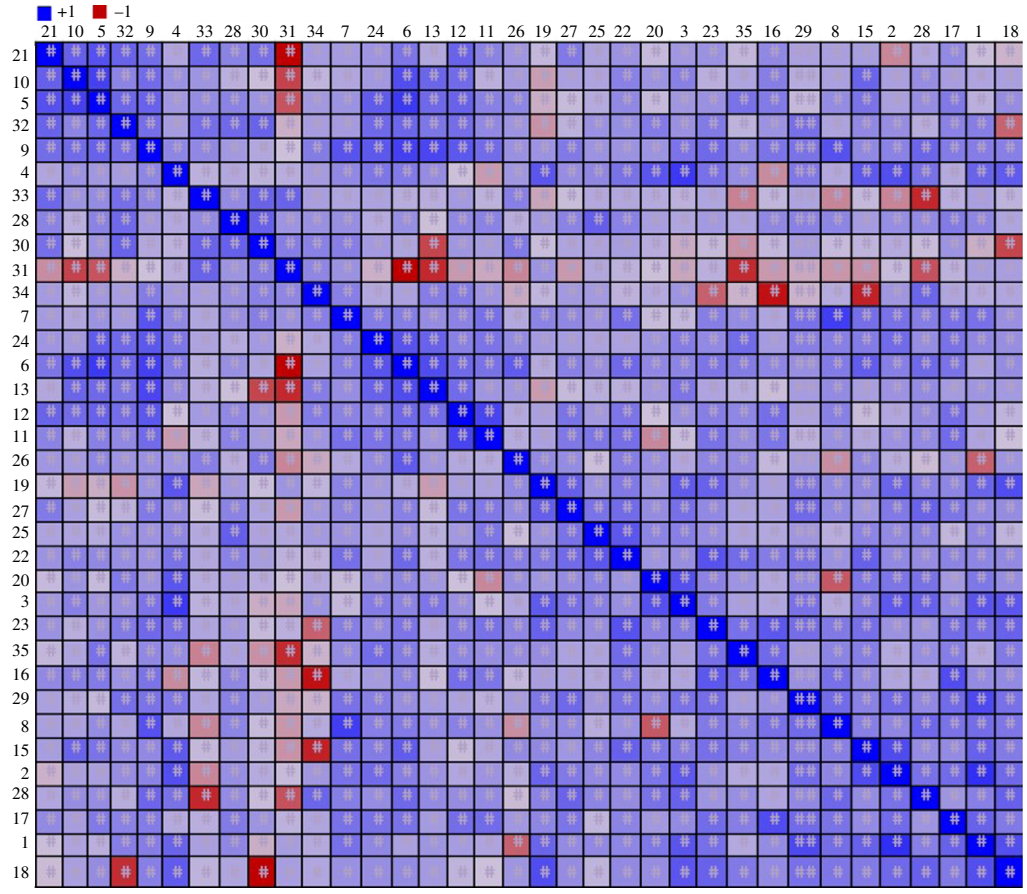

Fig. 7 – Socio-technical resources correlation matrix. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

"Important"). The result considered resources with more participants' votes (8 and 7 votes). The majority of resources (6 out of 8) is still technical resources (File storage; Software download; Artifacts versioning; Keyword search; Recommendation systems to create and maintain a network of people and communities in the SECO; and Forum's discussion evaluation). Nevertheless, participants also recognized "Environments to report problems" and "FAQ" as relevant resources. We may understand it as a problem in communicating and performing discussions regarding artifacts that could solve other developers' problems. In addition, "Recommendation systems to create and maintain a network of people and communities in the SECO" and "Forum's discussion evaluation" are the social resources recognized by the most experienced participants as the most relevant from the list of technical resources.

For answer Q5, all responses from the five more knowledgeable participants were selected, considering their level of knowledge in the survey's areas (social networks analysis and mining, SECO, and portals for managing contents and communities). For each participant, it was counted "Very Important" answers (top value in the survey's scale). From those resources, there is one concerning "demands" and another concerning the "social side", i.e., communication between actors ("Message"). The most relevant resources in their opinion are (ordered by the most relevant): *Artifacts versioning* (5 answers); *Message* (4 answers); *Demands registering* (4 answers); *Environment to report problems* (4 answers); and *Software download* (4 answers).

For Q6, a sample of the data was selected from participants who answered "Important" and "Very Important" together (80% or more). Those can be demands from the SECO community, listed in Table 4. From these results, it is possible to observe that the most relevant resources are focused on demands and social networks differently from the ones that are more commonly found in the literature, such as "Keyword Search" or "Documents download". They are identified as numbers 3, 4, 11 and 12 at Table 4.

6. Analysing tool support for SECO management

In the previous sections, the concepts found in the literature involving SECOs (e.g., participant's roles and activities, artifacts, and resources) were assessed according to experts in the field of SECO and related areas. This is a contribution to understand how those experts use and participate in their SECOs. Those socio-technical resources contribute to comprehend the functions and their relevance for users. The next step is to evaluate the main finding from the first study

Table 3 – Highest correlation for each socio-technical resource.

ID	Resource	Resource with highest correlation
1	Software license information[3]	Negotiation of different acquisition ways, including licenses (0.753)
2	Negotiation of different acquisition ways, including licenses[3]	Software license information (0.753)
3	Development team management and software products publishing[3]	Information about SECO needs and demands (0.705)
4	Information about SECO's needs and demands[2]	Development team management and Software products publishing (0.705)
5	Chat[2]	Subgroup (0.703)
6	Subgroup[2]	Chat (0.703)
7	Partners and service providers list[2]	User profile page (0.682)
8	User profile page[1]	Partners and service providers list (0.682)
9	Information about other members[2]	Research questionnaire (0.663)
10	Message[2]	Chat (0.661)
11	Sitemap[2]	Keyword search (0.644)
12	Keywords search[2]	Sitemap (0.644)
13	Private page[1]	Information about other members (0.636)
14	Socio-technical network visualization techniques[3]	Software license information (0.617)
15	Negotiating SECO's needs/demands/requirements in order to prioritize new functionalities[3]	Negotiationof different acquisition ways, including licenses (0.608)
16	Forum's discussion evaluation[3]	Advanced search mechanism that consider the user's profile (0.603)
17	Advanced search mechanism that consider the user's profile[3]	Forum's discussion evaluation (0.603)
18	Highlighted artifacts[3]	Software catalog (0.602)
19	Software catalog[2]	Highlighted artifacts (0.601)
20	Recommendation systems to create and maintain a network of people and communities in the SECO[3]	Development team management and software products publishing (0.585)
21	Artifact Forum[2]	Chat (0.577)
22	Demands registering[4]	Rewards for member who identify and evaluate new demands (0.573)
23	Rewards for member who identify and evaluate new demands[3]	Demands registering (0.573)
24	Research questionnaire[2]	Subgroup (0.563)
25	Artifacts versioning[4]	Demands registering (0.547)
26	External relations (e.g., Facebook, Feed RSS)[2]	Subgroup (0.525)
27	Environment to report problems[4]	Software catalog (0.509)
28	Wiki[2]	Artifacts versioning (0.508)
29	Socio-technical network mechanisms that consider actors and artifacts evaluation[3]	Highlighted artifacts (0.499)
30	FAQ[2]	Wiki (0.498)
31	Software download[2]	File Storage (0.483)
32	Communities management[1]	FAQ (0.483)
33	File storage[2]	Software download (0.483)
34	Documents download[2]	Socio-technical network mechanisms that consider actors and artifacts evaluation (0.474)
35	Recommendation of new demands to the SECO, originated by mining the existing ones[4]	Demands registering (0.442)

Table 4 – Most relevant socio-technical resources, considering VI (Very Important) and I (Important).

	Resource	I (%)	VI (%)	(I + VI) (%)
1	File storage	42.9	48.5	**91.4**
2	Artifacts versioning	31.4	60.0	**91.4**
3	Artifact Forum	40.0	51.0	**91.0**
4	Forum's discussion evaluation	57.1	31.5	**88.6**
5	Software download	40.0	48.5	**88.5**
6	Environment to report problems	28.6	59.9	**88.5**
7	Message	49.0	36.8	**85.8**
8	Keyword search	37.1	48.5	**85.6**
9	Frequent questions	48.6	34.3	**82.9**
10	Documents download	54.3	28.6	**82.9**
11	Demands registering	25.7	57.1	**82.8**
12	Rewards for member who identify and evaluate new demands	54.3	25.8	**80.1**

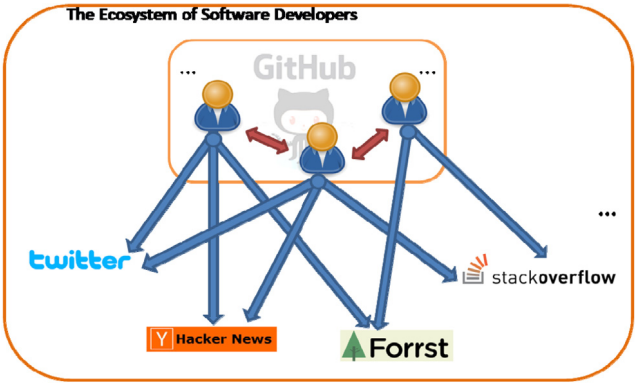

Fig. 8 – GitHub SECO.
***Source:* [22].**

(survey) on real examples from specific and popular SECOs as a novelty of our research in this paper.

Once we evaluate the relevance of socio-technical resources, it is useful to analyze how they are implemented and evolved in real ecosystems. A tool support for such variety of functions might not be in a unique platform, although this ideal scenario would benefit the users with the facilities of finding software related functionalities, as well as helping and having access to a social network for interactions. In order to evaluate the use of the most relevant socio-technical resources listed on Table 4 in real cases, a new survey was executed in the context of two SECO platforms based on tool support for software repositories. The study was focused on the Brazilian scenario. The SECO platforms used were GitHub[2] and the BPS Portal[3] because they are widely used in the Brazilian software industry. GitHub is a service for hosting and versioning software projects launched in 2008. It currently supports collaboration and social features, such as wiki, feeds, profile for members, and distributed development. GitHub is the main platform for software projects in the international scenario [24]. In 2014, Brazil was the eighth country in percentage of users in GitHub. In 2016, GitHub reported hosting more than 31 million repositories worldwide and over 15,000 accounts in Brazil. Fig. 8 represents part of GitHub SECO and associated social platforms that developers can use to seek better communication, technical help and other objectives.

BPS Portal is a Brazilian government initiative for sharing public software and promoting independency of suppliers [25]. There are more than 60 software solutions with their underlying communities. Despite being a Brazilian SECO platform, its services are available to other countries, such as Uruguay, Argentina, Portugal, Venezuela, Chile, and Paraguay. BPS Portal was developed using open source projects, such as: GitLab,[4] a version control system project; Colab,[5] a collaborative environment for managing communities; Mailmen,[6] a tool for managing electronic mail discussion and e-newsletter lists; and Noosfero[7] a web platform for social networks. All of them use GitHub for maintaining software repositories. BPS Portal provides services like software download, tutorials, forums etc. Any citizen can submit a software project to the portal in order to start an acceptance process. All software is free of charge and accessible for anyone. The portal was reformulated in 2015, then we considered the new version to prepare our second study (survey)—the version used to prepare the first survey as explained in Section 4.1 was the old one. BPS Portal was one of the Top 5 SECOs [5] and GitHub is one of the largest SECO joining technical repositories and social networks features. Both platforms consist of free open source software. An overview of whether the 35 socio-technical resources are present in both platforms is shown in Table 5. The analysis considered the platform and features used by the hosted projects. The observations follow the pattern as follows: **Y**: Yes, the resource is available; **N**: No, the resource is not available; and **PA**: the resource is partially available (it means that the platform provides no support to the functionality but it is offered through the extension of other platforms or other resources).

BPS Portal has 23 available resources, 9 were not found and 3 were considered partially available because it is possible to execute them through other resources, e.g., "Information about SECO's needs and demands" can be obtained using wiki and forums, even though there is no specific section for demands.

GitHub has 16 available resources, 13 were not found and 6 are partially available, e.g., "Subgroups" are formed considering issues that have messages, and then they show the lists of their participants. GitHub has many platforms in its SECO that complement its features, such as StackOverflow, Twitter, and HackNews [24]. The highlighted lines in Table 5 represent the resources considered as the most relevant ones from Table 4, being the target of our second study (survey) to analyze how they are implemented in real SECO platforms.

7. Survey focused on real SECO platforms

To evaluate how developers and experts in distributed and collaborative systems find and use socio-technical resources in real SECO platforms, we decided to analyze the most relevant ones identified in our previous survey (see Table 4), i.e., those highlighted in Table 5. This evaluation was performed using an online survey with a questionnaire aiming to collect information about the 12 items, and if they are easy to use and useful for the participants considering each platform (GitHub and BPS Portal). Question regarding participants' satisfaction with the functionalities and suggestions were also included. The goal was then to investigate the use of the most relevant resources in real SECO platforms in the Brazilian scenario.

[2] GitHub. Available at <https://github.com/ >.
[3] BPS Portal. Available at <https://softwarepublico.gov.br/social/ >(Portuguese only).
[4] GitLab. Available at <https://about.gitlab.com/ >.
[5] Colab. Available at <https://github.com/colab >.
[6] Mailmen.
Available at <https://www.gnu.org/software/mailman/ >.
[7] Noosfero. Available at <http://noosfero.org/ >.

Table 5 – Socio-technical resources in GitHub and BPS Portal.

ID	Resource	GitHub	BPS
1	Software license information	N	Y
2	Negotiation of different acquisition ways, including licenses	N	N
3	Development team management and software products publishing	Y	Y
4	Information about SECO's needs and demands	PA	PA
5	Chat	N	N
6	Subgroup	PA	Y
7	Partners and service providers list	N	Y
8	User profile page	Y	Y
9	Information about other members	Y	Y
10	**Message**	**Y**	**Y**
11	Sitemap	PA	Y
12	**Keywords search**	**Y**	**Y**
13	Private page	Y	Y
14	Socio-technical network visualization techniques	PA	N
15	Negotiating SECO's needs/demands/requirements in order to prioritize new functionalities	PA	PA
16	**Forum's discussion evaluation**	**N**	**Y**
17	Advanced search mechanism that consider the user's profile	N	N
18	Highlighted artifacts	N	Y
19	Software catalog	Y	Y
20	Recommendation systems to create and maintain a network of people and communities in the SECO	N	N
21	**Artifact forum**	**Y**	**Y**
22	**Demands registering**	**PA**	**PA**
23	**Rewards for member who identify and evaluate new demands**	**N**	**N**
24	Research questionnaire	N	Y
25	**Artifacts versioning**	**Y**	**Y**
26	External relations (e.g., Facebook, Feed RSS)	Y	N
27	**Environment to report problems**	**Y**	**Y**
28	Wiki	Y	Y
29	Socio-technical network mechanisms that consider actors and artifacts evaluation	N	N
30	**Frequent questions**	**N**	**Y**
31	**Software download**	**Y**	**Y**
32	Communities management	Y	Y
33	**File storage**	**Y**	**Y**
34	**Documents download**	**Y**	**Y**
35	Recommendation of new demands to the SECO, originated by mining the existing ones	N	N

7.1. *Planning*

The survey was divided in 3 sections: (i) *characterizing questions*, capturing participant's experiences; (ii) *usefulness and easiness of use for each resource*, assessment of the top 12 most relevant socio-technical resources in two SECOs' platforms; and (iii) *satisfaction with platforms*, capturing if the platform provides the resource as the participant needs it, and if there is another indispensable resource in this context that has not been found. We included questions for general comments.

Based on Goal-Question-Metric (GQM) method [26], the goal is described as follows:

Analyze: the use of socio-technical resources in SECOs' platforms that host software projects

Purpose: to evaluate the presence, satisfaction, usefulness and easy to use

Focus: the difficulties and benefits

Viewpoint: software developers and researchers

Context: software development with software repositories and social networks

The next step of the GQM method was to derive questions, resulting in the questions bellow:

- Qa: Are the resources listed easy to use?
  - Scale: 5-point scale from *totally agree* to *totally disagree*, and an option for *Not Found*. **Mandatory**.
- Qb: Are the resources listed useful?
  - Scale: 5-point scale from *totally agree* to *totally disagree*, and an option for *Not Found*. **Mandatory**.
- Qc: Do you participate in other similar SECOs? If so, which ones?
  - Scale: *Yes* or *No*. **Mandatory**;
  - Qc1: If so, what resources do you use to improve socialization in SECOs?
    - *Free text*. **Optional**.
- Qd: What other resources are indispensable in the same context?
  - *Free text*. **Mandatory**.
- Qe: Do the features offered by the platform support the execution of the resources?
  - Scale: 3-point scale: *Yes*, *No* or *Partially*.
  - Qe1: Comments on the support. *Free text*. **Optional**.
- Qf: General comments. *Free text*. **Optional**.
- Qg: How much time did you take to evaluate all listed resources?
  - Answer was requested in two steps: time was captured before initiating the resources evaluation and after the last comment question.

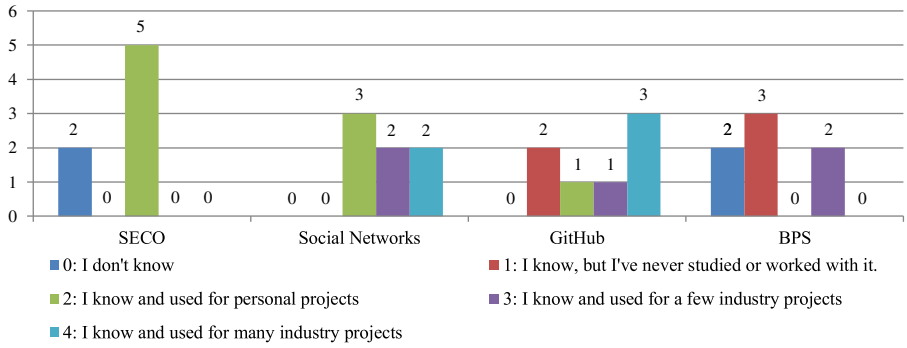

Fig. 9 – Knowledge and experience with the survey's areas and SECOs' platforms.

Table 6 – Participants' profile.

Item	Result		
Workplace	Academy	4	57.1%
	Industry	0	0%
	Both	3	42.9%
Academic degree	Bachelor student	1	14.3%
	Bachelor degree	1	14.3%
	Master student	4	57.1%
	Master degree	0	0%
	Doctoral student	1	14.3%
	Doctoral degree	0	0%

Once the goals and questions were derived, the next task was to define the metrics. As this survey has a qualitative nature and is based on experts' perceptions and experience, quantifiable metrics was not suitable. Before answering the questions, some instruction and a brief contextualization about SECO, social networks and the selected platforms were presented. Participants were requested to use the SECOs' platforms, mainly looking for the socio-technical resources from our list. It was suggested to explore the platforms' software repository and communities without necessarily having to create a user account.

7.2. *Execution and analysis*

One participant performed a pilot that was run to improve the questionnaire's structure and questions. Participants were invited to this survey based on indications of research groups of the Graduation School of Computer Science and Systems Engineering (PESC/COPPE) and also from a research group of Graduation School of Informatics (IM/NCE) specialized in distributed and collaborative systems, social computing and social network analysis and mining, both at the Federal University of Rio de Janeiro, Brazil. The answers were provided through an electronic questionnaire—the link was sent along with the invitation to the participants' email addresses. The pilot was executed for 2 days and captured some errors in the questionnaire's structure. The survey itself was executed in February-March, 2016, involving seven participants. The average time for responding the questionnaire was 17 min (from the end of characterization until the last comment). The participants' profile is presented on Table 6 and Fig. 9.

The participants were balanced between *academy* and both *academy and industry*. Most of them are Master students and one is Doctoral student. Two participants did not know about SECO, but all of them did receive a brief explanation before starting to answer the questionnaire. Five out of seven participants had previous knowledge and used SECOs' platforms in industrial projects. For social networks, the distribution is smoother, resulting in participants with all kinds of experience: academic, industrial, and personal. Most of them knew about GitHub compared to BPS Portal, although they were requested to use both platforms for the purpose of answering the questions.

For **Qa** (Are the resources listed easy to use?), the only resource that received a *totally disagree* was "Message". A participant did not find two resources: "Rewards for members who identify and evaluate new demands" and "Message". In the first case, both platforms have no specific resource for that. So, participants who found that resource probably associated with indirect rewards that are consequences of participating in forums and suggestions, e.g., gaining popularity, or the possibility to register a positive evaluation for a forum's message. Regarding the resource "Message", both platforms offer such resource. If the participant did not find such popular feature, it might not be highlighted as it should be. The distribution of answers is shown in Fig. 10.

In **Qb** (Are the resources listed useful?), only the first resource was not found. It might be an inconsistency, or the participant might have found it by looking further. The resources receiving *totally agree* as the majority of votes are: "File storage", "Artifacts versioning", "Software download", and "Environment to report problems". Those are the core functions for SECOs' platforms based on software repositories. In addition, the resources with majority of votes as *totally agree* were: "File Storage", "Artifacts versioning", "Software download", "Environment to report problems", "Keyword search", and "Documents download".

There was no answer like *disagree* or *totally disagree* to the usefulness of the socio-technical resources. The ones related to demands (i.e., demands, requirements and needs) and social networks, such as "Demands registering", and resources related to forums and rewards, were also well positioned in the voting. The distribution is shown in Fig. 11.

Regarding participation in similar SECOs (**Qc** and **Qc1**), five participants mentioned that they did not use other SECOs'

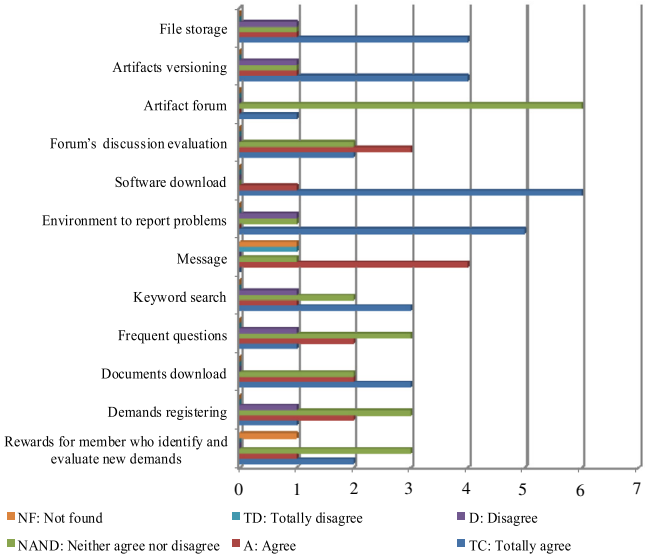

Fig. 10 – Evaluation of resources for *Qa* (easy to use) in both SECOs', platforms.

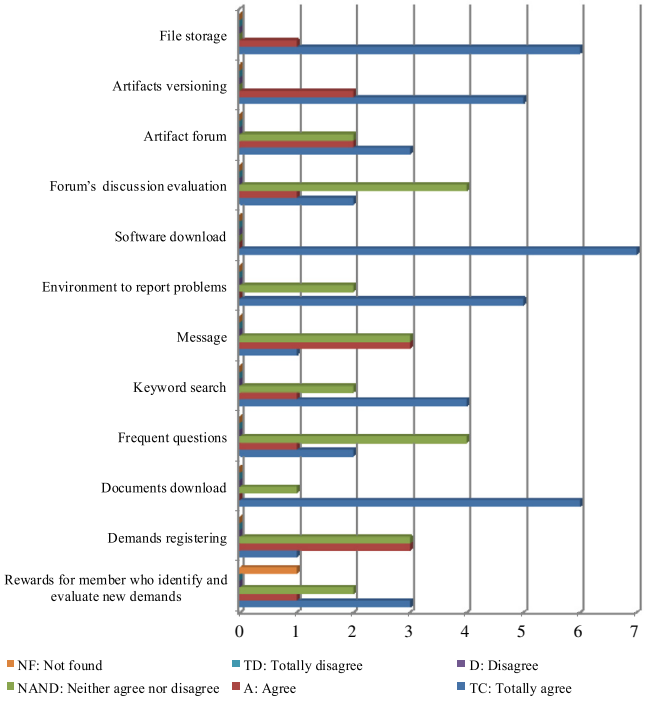

Fig. 11 – Resources evaluation for *Qb* (usefulness) in both SECO platforms.

platforms for the same purposes, and two said yes—one cited Tiger e Kanbam, and the other one cited BitBuckect (similar to GitHub), Trello (for monitoring tasks) and LinkedIn (for professional contacts).

Regarding other indispensable socio-technical resources (*Qd*), participants mentioned the following items:

- LinkedIn/Professional contacts with people from the same area (two);
- Google Hangout/communication (one);
- Trello/task management (one);
- Resources to facilitate monitoring and coordination (one);
- API that allows to create an environment for continuous integration (one);
- Visual representations and social indications that can improve the analysis of developers and software aspects (one);
- Mechanisms for perception of collaborative activities in such platforms (one).

Table 7 – GitHub's and BPS Portal's support.

SECO	Yes	No	Partially
GitHub	6	0	1
BPS	2	1	4

From those suggestions, we observed that communication, monitoring and information about collaborators are the main aspects that those SECOs' platforms did not have covered. The participants use many SECOs' platforms for very specific purposes, since they cannot find a platform with all the social resources for the collaboration they need.

For **Qe** (GitHub's and BPS Portal's support), the results are presented in Table 7. In **Qe1** (optional comments), two answers were registered: (i) *both platforms support the socio-technical resources. They have tools like FAQ or guides to aid newcomers' insertion and community's maintenance*; and (ii) *BPS might not be a trusted source. In all the projects I participated in (to implement an application), I had problems with imprecise or incorrect documentation*. Finally, in the *free comments* section, one participant suggested that BPS Portal should provide a search mechanism by programming languages.

8. Final considerations

Social and technical elements need to work together in order to better establish and maintain a network where technical artifacts and actors interact closer and more collaboratively; this is important for the understanding of the SECO relationships. Technical aspect has been already treated in SECO through component repositories. To offer support for SECO relationships, a set of socio-technical resources to be considered in a SECO platform were investigated. We also observed an example of a Brazilian SECO (BPS Portal).

In order to evaluate the relevance of some socio-technical resources for SECOs' platforms, the experts' opinions were captured through an initial study—first survey. The participants were chosen from the program committees of events related to the target areas of the survey, such as SECO, collaborative systems and distributed software development. 35 out of 99 invitees (35.35%) answered the survey. Our goal was to capture the participants' profile, what activities they perform and what types of artifact they manipulate. Also, some questions were included to determine the experience and types of SECO they participate. From the data analysis, the most relevant resources were selected according to different questions. The methodology applied in this survey has a few limitations, such as: (i) our ad hoc observations of BPS Portal may have neglected some important socio-technical resources; (ii) the answers represent opinions of a sample of experts and the questions are subjective and qualitative; (iii) the response rate of 35.35%; and (iv) the invitees were Brazilians since this work consisted of a first round of the survey, motivated by the fact that BPS Portal is one of the Top 5 SECOs appearing in the literature and practice [5]. As future work, we intend to re-execute this survey with an international sample.

Next, a second study – also a survey – was executed to analyze the most relevant socio-technical resources in two real SECO's platforms focused on software repositories and collaboration: GitHub and BPS Portal (new released version). Participants were users and professionals in software development, collaboration, social networks, and social computing. From this study, it was possible to evaluate the overall support provided by each platform and an indication of how easy to use and useful each resource is. We concluded that socio-technical resources have aided collaboration in software development for SECO, coordination of teams based on more knowledge of actor's tasks and interactions, and monitoring of quality of SECOs' platforms through the orchestration of the contributions developed by external actors. The limitations of this second survey are the restricted number of participants, and the limitations from the first one as well.

Some future work and opportunities were identified from this work, such as: (i) execute the survey for capturing the socio-technical relevance with the international community; (ii) execute survey with real platforms including more cases and with a large number of participants; (iii) investigate how demands are managed in real SECO's cases; and (iv) apply more sophisticated statistics analysis methods.

Finally, we concluded that our analysis contributes to better understand how socio-technical resources are realized by some SECO's participants, and what activities different stakeholders perform within a SECO's platform. We also include as a contribution the findings of evaluations of whether (and how) those resources are being used in popular SECOs' platforms.

Acknowledgments

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