

Managing Literature Reviews Information through Visualization

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Abstract: Systematic Literature Review (SR) and Systematic Mappings (SM) are scientific literature review techniques that follow well-defined stages, according to a protocol previously elaborated. The goal is helping in finding evidence about a particular research topic and mapping a research area, respectively. Their steps are laborious and a computational support is essential to improve the quality of their conduction. Aiming to offer computational support to these types of reviews, the StArt (State of the Art through Systematic Review) tool was developed. Besides the expected functionalities, StArt generates studies score, uses information visualization and text mining techniques to facilitate the research area mapping and to identify the studies relevance. StArt has been developed through an incremental process by academics who adopt SR and SM. As the expectation is to have a tool that really aids the conduction of these types of reviews, new ideas are always investigated and make StArt different from other alternatives. Visualization and text mining techniques seems to be a powerful resource for facilitating data abstraction in the context of SRs and SMs, allowing the improvement of the review and the conclusions about it.

1 INTRODUCTION

The Systematic Literature Review process (SR or SM) has its origins in the medical area and its objective, according to Pai et al. (2004), is the creation of a complete and impartial summary about a given research topic following well defined and known procedures. Recently, this process is being adapted to the computer science area, particularly in Software Engineering (Kitchenahm, 2004). Some advantages of the SR usage are the coverage, the replicability and the reliability of its process. Besides systematizing the search for relevant studies, the SR predicts the organization and the analysis of the obtained results. However, the SR process is more laborious than the research conducted on an informal basis (Kitchenahm, 2004).

A previous activity to the SR should can be the Systematic Mapping (SM) which objective, according to Petersen et al. (2008), is to build a classification scheme and to structure a software engineering research area. Like a SR, SM is also a laborious activity and its process is similar to the SR process, with many repetitive steps. One of the main

differences between SR and SM is that the desired results of SMs are mainly quantitative but not qualitative and the studies should not be read in full. Despite this fact, quantitative data can also aid the summarization that should be provided by a SR.

Thus, considering that there are several steps to be executed and several documents to be managed, the computer support can aid the conformance to the SR and SM processes, enabling higher quality in their execution.

Since 2006 the Start tool (Montebelo et al, 2007) has been developed. In 2008 it was completely restructured and the new version was available (Zamboni et al., 2010) (Hernandes et al., 2010). This version gave full support to carry out SRs and currently, visualization and text mining resources are being added for easing data summarization since, in general, there is a lot of data for transforming into knowledge, which is a challenge. As mentioned by Burley (2010), information visualization is a valuable tool for knowledge integration activities and, in StArt, such views allow the researcher to find, in a simple way, information on the most important events, the evolution of the research topic by the academic community, and so on. This

information is very common in SM.

Another important contribution that has been reached with information visualization in StArt is the evaluation of the search strings quality. An important point in this kind of literature reviews is to find and ensure that the search strings bring all the relevant studies on the research topic. The Start tool provides a visualization of all the studies retrieved as well as their references. Hence, it is possible identifying for example, if a frequently cited reference was or was not retrieved by the search string.

Based on this context, the objective of this paper is to explore the contributions of information visualization for this kinds of literature reviews. Section 2 presents an overview of StArt functionalities and highlights some features that aid the control of the processes related to these kinds of literature reviews. Section 3 explains the visualization support provided by StArt and how it can be used to enhance the summarization of the investigated topic. Section 4 presents the support of text mining processing and Section 5 presents the conclusions and future work.

2 AN OVERVIEW OF THE StArt

Before explaining how information visualization and text mining processing help on identifying important information for SM and SRs, an overview of the main functionalities of StArt is presented below. As mentioned before, the processes of SR and SM have some repetitive steps and require discipline and systematic practice from the researcher. The information must be registered in an organized way, such that the expected results are reached, the process can be replicable and all the information can be packed.

Thus, StArt has been developed for providing automated support to as many steps as possible. Functionalities to ease data summarization were also implemented in the tool as the possibility to display data through visualization and Excel formatted reports, according to the researcher's needs.

As the SM process is a subset of the SR process, StArt was initially planned to support SRs and currently it is being adapted to also support SMs. Figure 1 illustrates the general process of SR, highlighting what is done with (left side) and without (right side) StArt support. As electronic scientific databases do not allow automated search of primary studies, steps 2, 3 and 4 must be executed without the support of the tool. They are: the

adjustment of search strings in search engines, which happens while the protocol is being defined and reviewed; the execution of these search strings after the protocol approval; and the exportation of the search result in a BibTex file, respectively. The step numbers used in this figure will be used in the explanation of the StArt functionalities.

The main functionalities of StArt are presented in the screen shot of Figure 2. At the left side there is the hierarchical directory tree with the SR process phases. At the right side, the information associated to the functionality selected on the left side is presented.

Shortly, the goals of the three phases are:

- Planning Phase, which consists of the protocol filling (Step 1 of Figure 1);
- Execution Phase, which is composed of Studies Identification (Steps 2, 3, 4, and 5 of Figure 1), Selection (Steps 6, 7, and 8 of Figure 1) and Extraction (Step 9 of Figure 1). In this phase the researcher should identify the studies, select them and extract the relevant information for answering the research question.
- Summarization Phase (Steps 10 and 11 of Figure 1), which corresponds to the analysis of the data extracted from each accepted study and the elaboration of a final report describing the state of the art. For this phase, StArt provides graphics, spreadsheets and data visualizations, aiming to make the researcher's tasks easier. Such options will be detailed in Section 4.

Following, each phase is detailed, exemplifying the support provided by the StArt tool.

2.1 Planning

In this phase StArt supports the SR Protocol elaboration (Step 1 of Figure 1) according to the attributes suggested by Kitchenham (2007). Some of the attributes are: research question definition; keywords that will be used for searching for studies; search engines; criteria for acceptance or rejection of studies; etc. There is a help message for each protocol attribute aiming to guide its filling. The protocol is stored in the tool and can be accessed and modified if necessary. It is worth noting that, to ensure the SR process conformance, the content of the protocol fields are reflected in later steps of the SR process. For example, when a search engine is chosen during the protocol filling, it is added under the Studies Identification of the Execution Phase, as shown in Figure 3. Similarly, each attribute inserted in the Information Extraction Form Attributes during the protocol filling becomes a field that must be

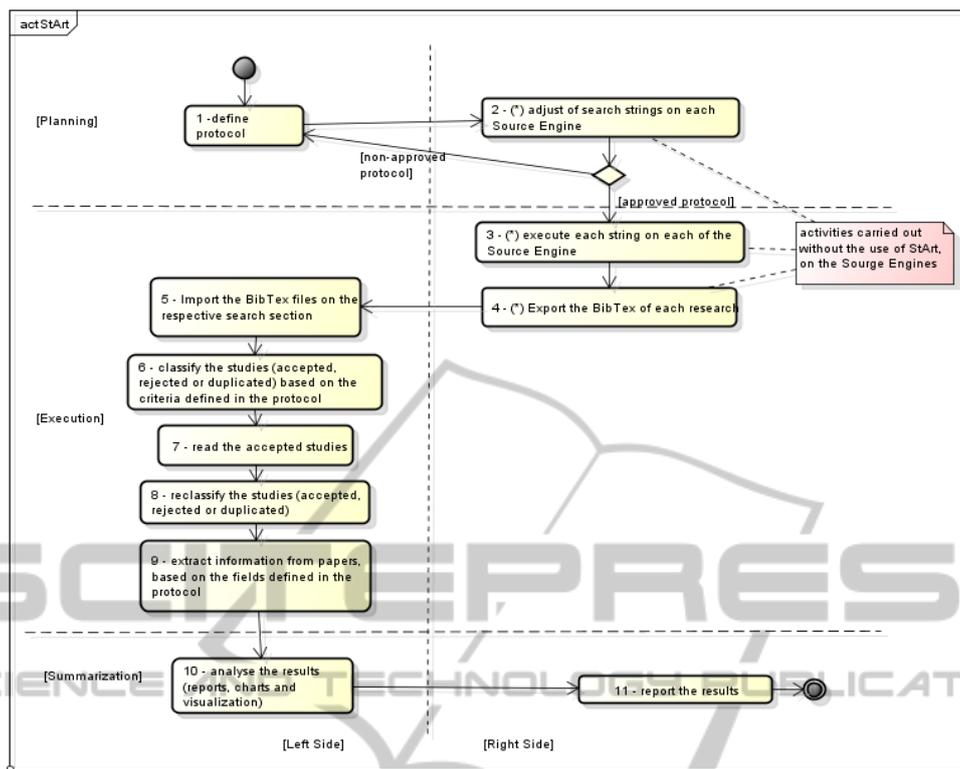


Figure 1: SLR steps: Left side – actions supported and Right side – actions not supported by StArt.

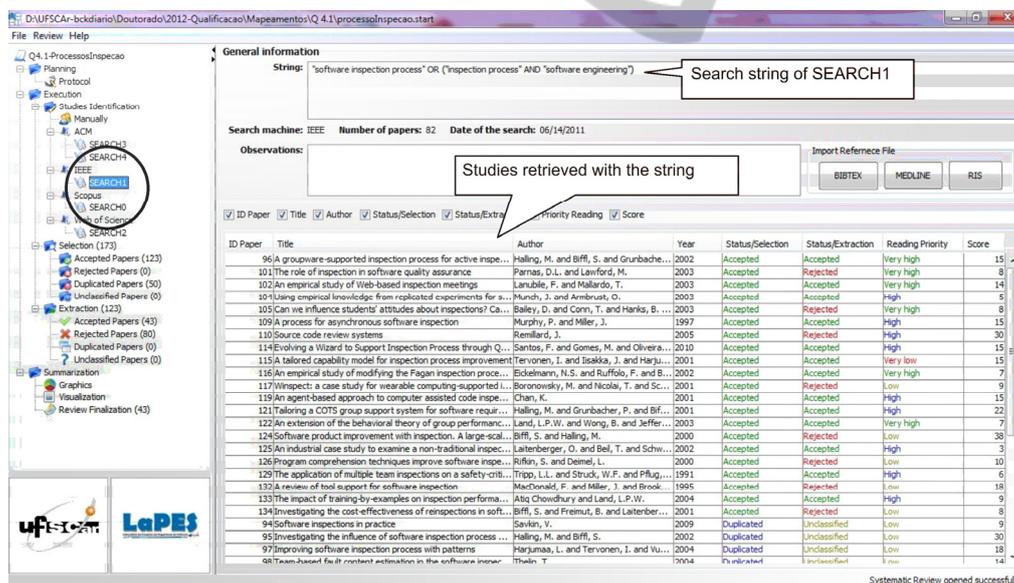


Figure 2: Overview of the StArt tool.

filled in during the Extraction Step (Step 9 of Figure 1), as shown in Figure 4.

2.2 Execution

This phase of the SR has three steps according to the

guidelines proposed by Kitchenham (2004) (2007). The first one is Studies Identification (Steps 2 to 5 of Figure 1). In this step, the researcher should adjust the search string using the keywords earlier defined in the protocol. After this step, the strings should be applied in each search engine, for example, IEEE, Scopus,

ACM, Springer and Web of Science. This action is not supported by the tool and the search results must be imported into StArt. As the studies are being imported into the tool, it assigns a score for each study according to the occurrences of the keywords defined in the protocol, in the studies title, abstract and keywords list. This score can be used, for example, to establish an order of reading once studies with higher scores should be more relevant to the SR. Also, if the studies with higher scores are not relevant to the research question, it is possible that the strings should be revisited and improved. The string definition is an important point to the success of SRs, and its quality can be accessed through visualization provide by StArt, which is explored and presented in Section 4.

The second step is Studies Selection (Step 6 of Figure 1). In this step, the researcher should use the inclusion and exclusion criteria, defined in the protocol, to classify the studies as accepted or rejected. Duplicated studies are automatically identified by the tool. When the study is accepted, the researcher can attribute to it a relevance level (Very High, High, Low or Very Low).

The third step is Extraction (Steps 7, 8 and 9 of Figure 2). At this step, the researcher must read the full version of each study “Accepted study”, elaborate a summary and fill in the Information Extraction Form of each study (Figure 4-B).

Aiming to facilitate this step, it is possible to link the studies full text file (e.g. PDF files) with their record in the tool.

2.3 Summarization

In this phase (Step 10 of Figure 2), StArt provides the following facilities:

- Easy access to the information of all studies accepted in Extraction Step. Comments and information extracted in previous steps can be accessed and copied to a text editor added in the tool. After collecting that information, the researcher can transfer this initial version of the summary to a more powerful text editor.
- Generation of charts that support a quantitative SR characterization. For example: the percentage of studies identified by each search engine, the percentage of studies accepted, rejected and duplicated in Extraction step, the times that each inclusion and exclusion criterion was used for classifying the studies as accepted or rejected (Figure 11). In fact, this kind of quantitative data is particularly relevant for Systematic Mappings (Petersen et al, 2008). In case the researcher

choose to do meta-analysis, carry out statistical tests or elaborate other charts, StArt can generate, among other reports, a spreadsheet that allows data manipulation outside the tool. These reports can be generated according to researchers’ needs, based on options that allow grouping data in different ways, (Figure 5-A), applying different filters (Figure 5-B) and choosing specific characteristics of the studies (Figure 5-C). Figure 5-D shows a preview of the report.

- Deal with a large volume of data to discover features, patterns and hidden trends through visualization. When an SR or SM process is finished, there is a large amount of data related to the research topic that can show trends in the evolution of the topic over time, which is interesting information to explain the state of the art. As mentioned before, the information visualization is a helpful tool for knowledge integration activities.

3 VISUALIZATION IN StArt

Considering the importance of quantitative data for both the SR and SM and the fact that information visualization explores the natural visual ability of humans aiming to facilitate information processing (Gershon, Eick, Card, 1998), StArt uses visualization to facilitate knowledge management about literature reviews. Using effective visual interfaces, it is possible to quickly manipulate large volumes of data to discover characteristics, patterns and hidden trends.

Based on visualization, for example, it is easier to realize how a specific research topic evolved over time. See Figure 6 where the researcher’s interest was to understand how the topic “traceability” was explored by the academic community, in relation to the question investigated in this example. It is easy to identify that in 2005 and 2006 there was only one study published; in 2007 and 2008 there were few additional studies, but in 2009, 2010 and 2011, the number of studies that mentioned the research topic was more significant than in the previous years.

To build this visualization, the researcher should select the following options (Figure 6): green rectangle representing an accepted study; part of the study title nearby the rectangle, the publication year as the grouping filter, and the Radial Graph as the visualization technique.

Now, suppose that the researcher would like to identify appropriated places for submitting a study or for publishing results of a literature review. In this

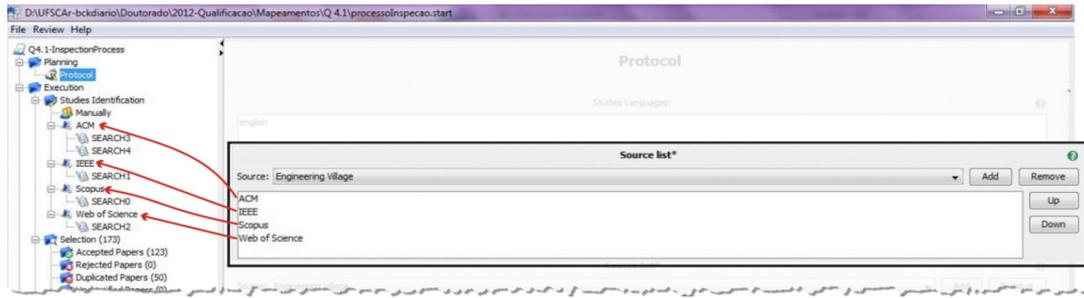


Figure 3: Search engines defined in the protocol are automatically inserted under Studies Identification.

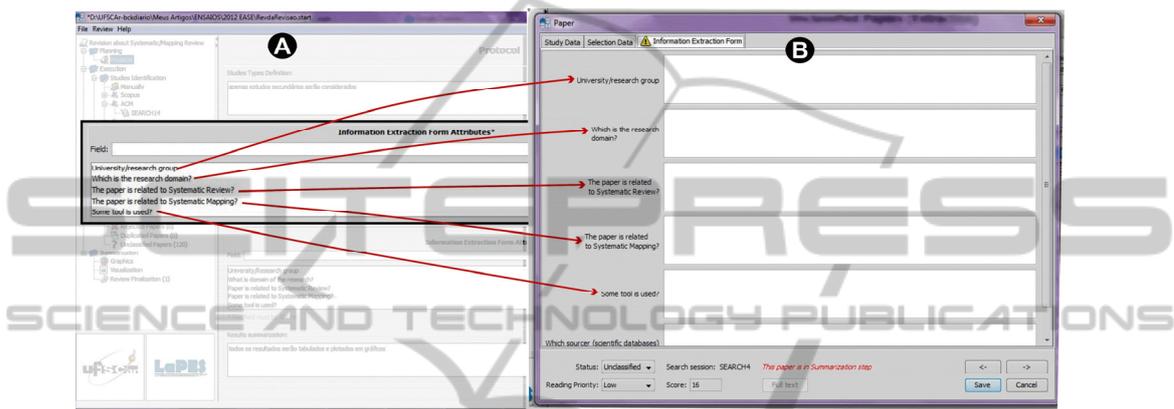


Figure 4: Relationship between attributes defined in the protocol and the form available during the Extraction step.

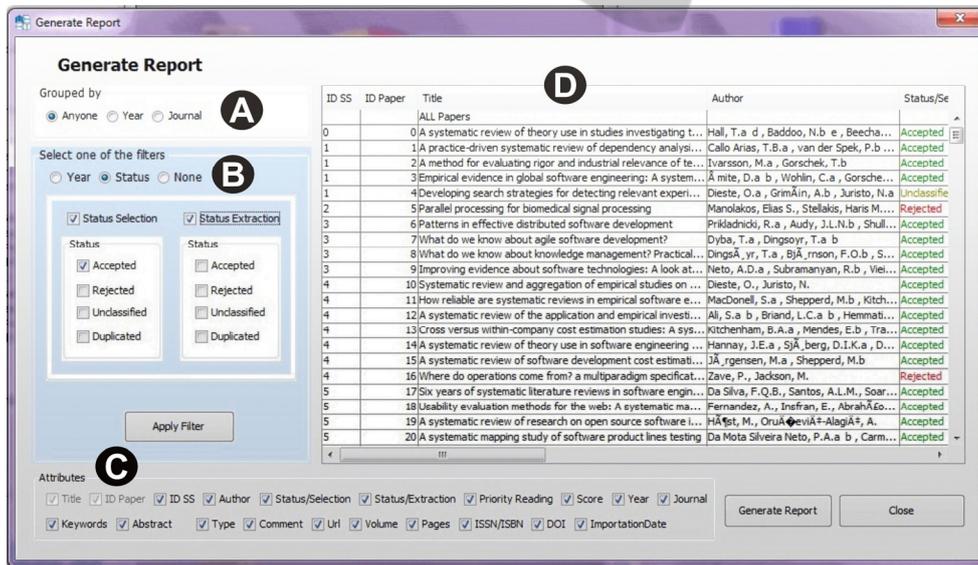


Figure 5: Options for specifying reports.

case he/she should select almost the same options mentioned before, exchanging year by place. This visualization (Figure 7), allows identifying the main discussion forums for the topic under investigation. Observe that some places have few studies related to “traceability”, while some others have have more

publications on this topic. Besides, the visualization type was Radial Graph and the studies titles were omitted.

If the researcher wishes to merge both the previous analysis in one graph, it would be better to use a different visualization type. In this case the

Tree technique seems better, as shown in the screenshot of Figure 8. The researcher can expand the levels according to their need.

A double click on a selected study shows information (like authors, abstracts, etc) about it.

In addition to the features described above, visualization is also used to show the relationship among the studies recovered in literature review. This information allows evaluating the set of studies

and enhancing the search for them. This resource is better explained in next section.

4 TEXT MINING IN StArt

According to Dunne et al. (2012), the growing number of publications combined with increasingly

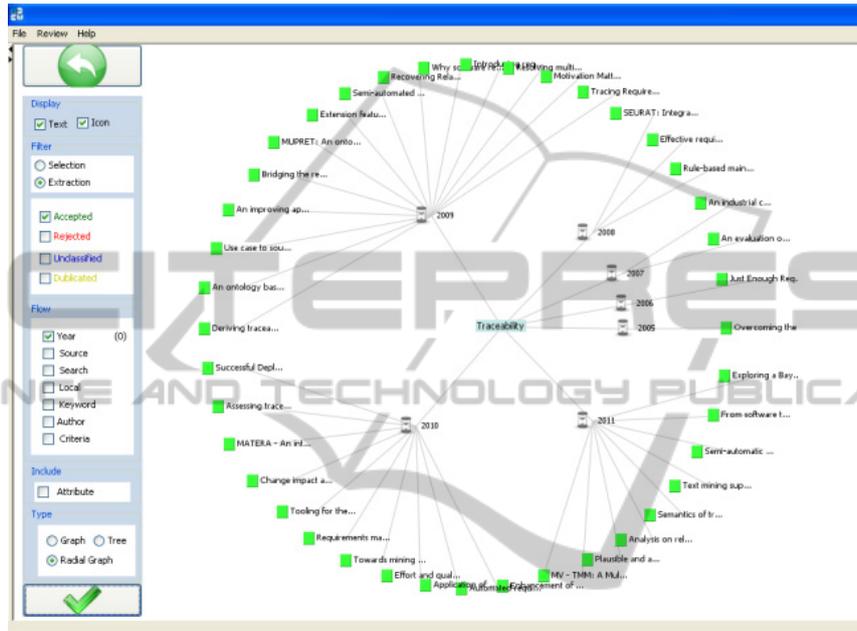


Figure 6: Visualization of publications on “traceability” over time.

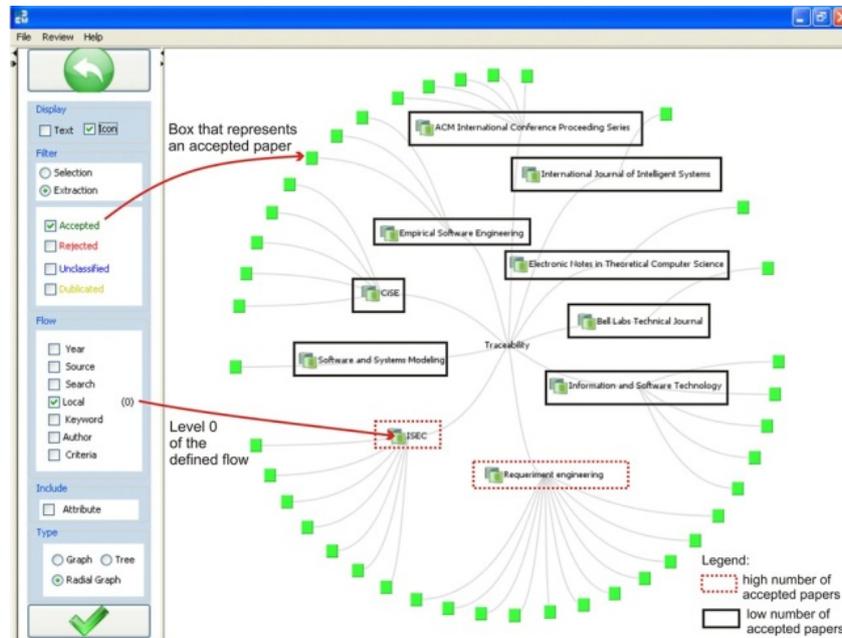


Figure 7: Visualization of places where “traceability” has been published.

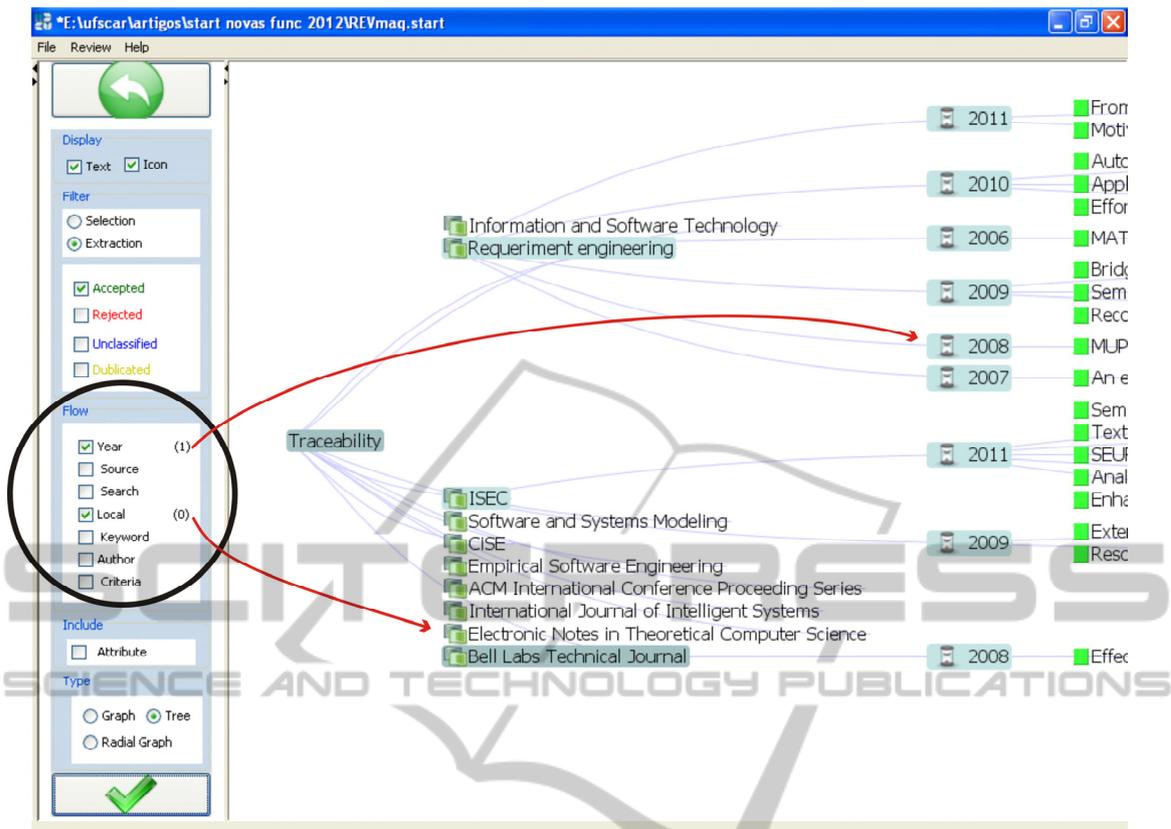


Figure 8: Visualization of places where “traceability” has been published according to the year.

cross-disciplinary sources makes it challenging to follow emerging research topics and identify key studies. It is even harder to begin exploring a new field without a starting set of references.

During the conduction of literature reviews many studies are retrieved from various search engines through search strings. Hence, the researcher must be careful not to leave out any studies that may be relevant. According to Boell and Cezec-Kecmanovic (2010), the usual problem of systematic reviews is that the more inclusive the search strategy, the more irrelevant studies will be retrieved; the more precise and specific the search strategy, the more relevant studies will be missed.

In order to help minimizing this problem, StArt provides support to identify the references of each study retrieved by the search strings. This support allows knowing if there are studies not retrieved, but referenced.

As the search engines generally do not provide the list of references from each study, this information is obtained by reading and extracting the references of the PDF files of the retrieved studies. Every time a PDF file is linked to a study, StArt searches the references in the PDF file. Aiming to

identify information like authors, publication place and title, regular expressions are used to identify the bibliographic reference template that was used (APA, Harvard, IEEE, etc.). To determine which study is related to another one, the similarity between the titles of the studies is calculated using the text mining algorithm proposed by Salton (1989). The result of this process is shown through visualization as presented in Figure 9. The study in the centre of the figure was not retrieved in the literature review, but is referenced by five studies that were retrieved.

This functionality is especially useful during the execution of pilot literature reviews, which should be conducted for adjusting the protocol and the search strings, as suggested by Kitchenham (2007). If there are studies not found but referenced many times, the researcher should verify, for example, if the keywords of these studies should be considered in the protocol and search strings. If so, a new search applying these new keywords must be performed aiming to find relevant studies that were missed.

Start also offers the functionality for detecting which of the studies imported into the tool are similar. The similarity is calculated based on the

abstracts through Vector Processing Model (Salton, Allan, 1994). The result of this processing is shown in a table as presented in Figure 10. This table provides a list of similar studies and their respective similarity grade in relation to a study previously selected

This list of similar studies can be used, for example: (i) to define the next study to be analyzed; (ii) to facilitate comparison between similar studies and (iii) to make the inclusion and exclusion of studies easier – studies with a high level of similarity to an excluded study tend to be also excluded.

Other researches use text mining in the context of SR or SM, but it is not available in tools that support the whole SR or SM processes.

Malheiros et al. (2007) proposed the use of a visualization tool, named PEx, to support the first step of studies selection. PEx has a module that processes the abstract of the primary studies, eliminates stopwords, calculates the terms frequency and, based on this result, displays clusters of studies to facilitate their analysis.

Felizardo et al. (2011) continued the research

cited above presenting the VTM (Visual Text Mining) tool which supports studies selection. Like Malheiros et al. (2007), the result of text mining processes is shown by different visualization techniques which help applying the inclusion and exclusion criteria previously inserted in VTM tool.

It is important to notice that the focus of these studies is the studies selection step. On the other hand, in Start, visualization and text mining are currently being used to support the search string definition and the SR or SM Summarization phase.

5 CONCLUSIONS AND FUTURE WORK

This paper explored the use of visualization for making easier the interpretation of data provided by Systematic Literature Review and Systematic Mapping. This visualization is available in StArt, which also supports the steps of SR and SM processes. As these processes are laborious, posses

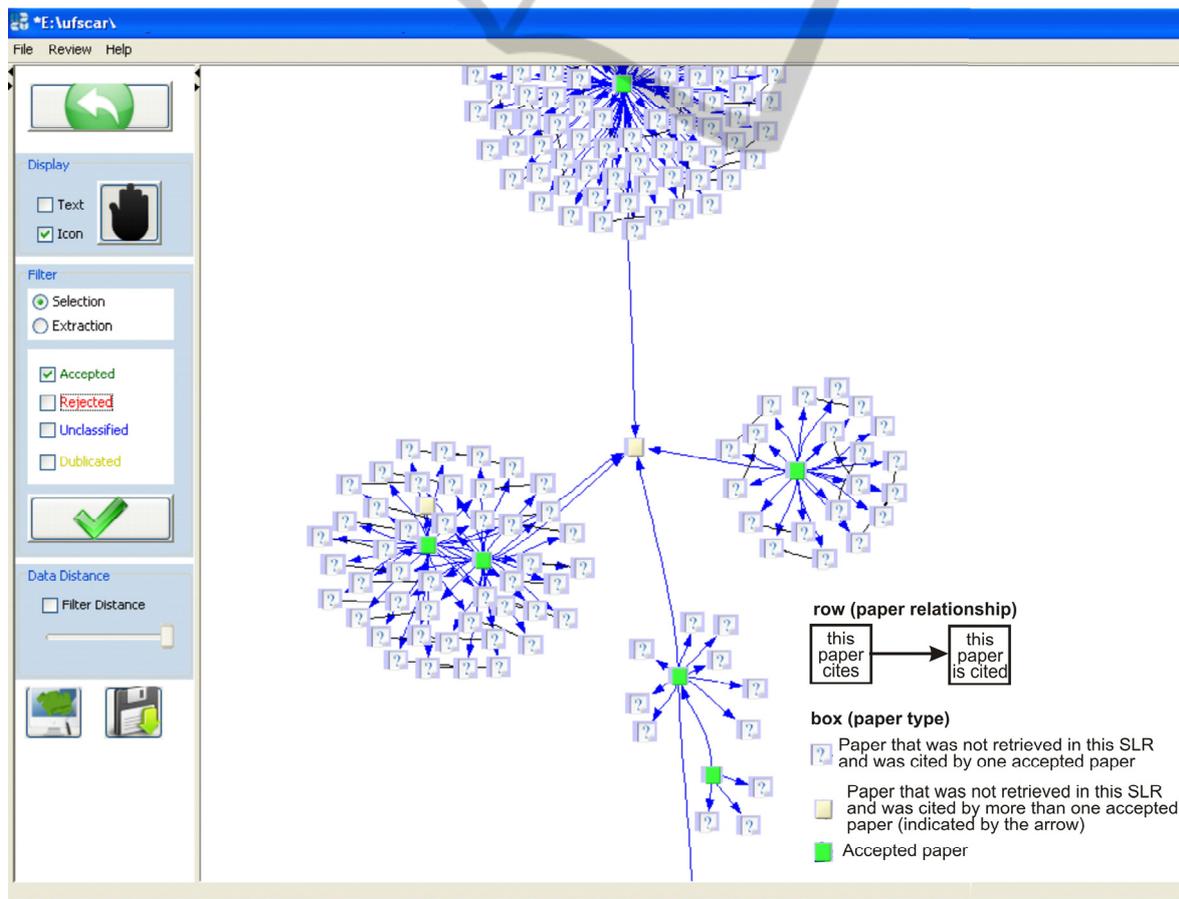


Figure 9: Relationship among the studies uploaded into StArt and their references.

ID SS	ID Paper	Title	Authors	Year	Score	Similarity (%)
0	11	Integrated and tool-supported teaching of testing, d...	Ahrendt, W., Bubel, R., Hähnle, R.	2009	197	26,89
0	17	TLtoSQL: Rapid post-mortem verification using temp...	Drusinsky, D.a b	2009	266	20,47
0	46	Axiom-Based Transformations: Optimisation and Tes...	Bagge, A.H., Haveraaen, M.	2009	172	18,28
0	39	Automating expert-defined tests: A suitable approac...	Connolly, D.a , Mc Caffery, F.b , Keenan, F.a	2009	170	10,39
0	37	Multithreaded testing of program interfaces	Mutilin, V.S.	2009	161	10,1
0	10	UnitCheck: Unit testing and model checking combined	Kebrt, M., Šerý, O.	2009	147	9,76
0	38	Automatic Generation of Runtime Failure Detectors f...	Pezzè, M.a b , Wuttke, J.b	2009	331	9,32
0	0	Using hybrid algorithm for Pareto efficient multi-obje...	Yoo, S., Harman, M.	2010	216	9,18
0	40	A general testability theory	Rodríguez, I.	2009	94	8,96
0	27	Computerized procedure system for the APR1400 si...	Hong, J.-H., Lee, M.-S., Hwang, D.-H.	2009	440	8,76
0	41	Design tests: An approach to programmatically chec...	Brunet, J., Guerrero, D., Figueiredo, J.	2009	332	7,61
0	23	Performance testing of mobile applications at the uni...	Kim, H.a , Choi, B.a , Wong, W.E.b	2009	272	7,12
0	44	Developing acceptance tests from existing document...	Connolly, D., Keenan, F., McCaffery, F.	2009	263	7,02
0	6	Quality of code can be planned and automatically co...	Bugayenko, Y.	2009	194	6,77
0	34	Test data generation for derived types in C program	Wang, Z.a , Yu, X.a , Sun, T.a , Pu, G.a , D...	2009	287	6,62
0	35	GenUTest: A unit test and mock aspect generation tool	Pasternak, B.a , Tyszberowicz, S.b , Yehud...	2009	374	6,61
0	28	The axioms strike back: Testing with concepts and a...	Helene, A., Valentin, B., Haveraaen, D.M.	2009	249	6,46
0	45	An empirical study of testing file-system-dependent ...	Marri, M.R.a , Xie, T.a , Tillmann, N.b , De ...	2009	140	6,06
0	21	Incremental development of model transformation c...	Küster, J.M., Gschwind, T., Zimmermann, O.	2009	177	5,99
0	36	Automated software testing for matlab	Eddins, S.L.	2009	147	5,93
0	4	JavaCOP: Declarative pluggable types for java	Markstrum, S.a , Marino, D.b , Esquivel, M...	2010	334	5,57
0	48	Design pattern density defined	Riehle, D.	2009	207	5,54
0	7	Design pattern density defined	Riehle, D.	2009	189	5,52
0	26	An empirical study of incorporating cost into test suit...	Smith, A.M.a , Kapfhammer, G.M.b	2009	270	5,44
0	30	Unit test support for java via reflection and annotati...	Proulx, V.K., Jossey, W.	2009	224	5,41
0	18	Unit testing approaches for BPEL: A systematic review	Zakaria, Z.a , Atan, R.b , Ghani, A.A.A.b , ...	2009	283	5,36
0	2	Understanding tools and practices for distributed pai...	Schümmer, T.a , Lukosch, S.b	2010	178	5,3

Status: Search session: SEARCH0 *This paper is in Extraction step*

Reading Priority: Score: 198

Figure 10: List of similar studies in relation to a selected study – the similarity grade is highlighted.

many repetitive steps and require that all information is packed, the availability of computational support is relevant.

Although there are some tools that have been used by researchers to aid the conduction of literature reviews, most of them are reference manager. Some examples are JabRef (jabref.sourceforge.net), EndNote (www.endnote.com), ProCite (www.procite.com), Reference Manager (www.refman.com), RefWorks (www.refworks.com) and Zotero (www.zotero.org). Only SLR tool (Fernández-Sáez, Genero, Romero, 2010) focuses on SR process (Kitchenham, 2007). However, it works only on the English or Spanish versions of the Windows operating system.

As StArt is closely associated to the SR and SM processes, it provides many facilities that make easier the conduction of these types of reviews. Some characteristics that differentiate it from the other tools are the score, which is calculated automatically and can give insights on the paper relevance; different types of data visualization that can aid to map the research area; extraction of the references of the studies gathered in the review, that

allows evaluating the adequacy of search strings and improving the quality of the whole activity; and other facilities that make the conduction of the process more manageable.

Considering the importance of packing the SRs or SMs data, StArt saves all data in a “.start” file which allows conducting a review in sessions and sharing a review with another researcher. In addition, as StArt provides a simple text editor for writing an initial summary of the state of the art, this summary is also packed. StArt is being continuously evolved and tested. The tool was also evaluated from the perspective of its usefulness and ease of use, according to the TAM model, which found that the tool is useful to users and can be easily used by researchers (Hernandes et al, 2010).

As future work, it is planned to continue the development of StArt emphasizing the analysis related to Systematic Mappings. This objective has already initiated with the addition of visualization, but there are other features that can enhance its support for SM. Besides, it is planned some experimental studies that aim to establish a strategy to improve search strings based on the references of

the collected studies and also to explore the tool as a support to conduct meta reviews.

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