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Toro: A Web-based Tool to Search, Explore, Screen, Compare and Visualize Literature

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ABSTRACT

We present TORO (https://www.toro.ac.nz/), a web-based application that aims to simplify the time-consuming literature research process by providing an easy way of searching, exploring, screening, and comparing literature inside a visual paper graph. Unlike many automated tools, the user actively explores papers and constructs the graph. Users can add papers by searching across different publishers or pasting DOI links and bib-files. Users can analyse relations between papers in one view, look up common keywords, access paper details and categorize them easily. Expanding references allows exploring interesting streams of literature and performing search strategies like snowballing easily across platforms. To manage large numbers of papers and identify interesting work, users can define filters and highlighting criteria. We present our initial design and implementation and discuss the results of a preliminary user study with 18 researchers. The results indicate that TORO already helps researchers' exploration process and highlights opportunities for future work.

Keywords

Literature Search, Visualisation, Paper Graph, Web-based tool, Exploration.

INTRODUCTION

Searching, browsing, screening, and selecting papers are frequent tasks of researchers when exploring literature. However, performing these tasks is a time-consuming and cumbersome process. The researcher has to manually navigate different publisher websites to access all relevant information and compare papers individually. Common search strategies like snowballing are hard to perform without manually searching individual references due to limited links to references. Specifically, during the exploration process, where new topics or questions can emerge, it is hard to follow interesting streams of literature without losing track of already explored papers and to discover interesting relations between papers within traditional hierarchical lists.

Previous work focused on providing tools to discover related work in visual paper graphs or directly suggesting which paper to screen next (CitationGecko, 2018; Eitan et al., 2020; Howard et al., 2016; Open Knowledge Maps, 2018; Ros et al., 2017; Tim Wölfle, 2019; Yu & Menzies, 2019). However, these tools do not provide the user with full control about the exploration process. They suggest papers in a non-transparent way and do not allow expanding or filtering papers in a user-specified way, which hinders an active, dynamic and verifiable exploration process. While many tools have been proposed to support researchers performing a systematic literature review (SLR) and provide a uniform way of screening and selecting papers (Barn et al., 2014; Fabbri et al., 2016; Götz, 2018; Hinderks et al., 2020; Marchezan et al., 2019; Navarrete et al., 2018), they usually expect an already specified set of papers and follow a strict deterministic process. They do not provide the flexibility and a short iteration cycle required for a dynamic exploration process.

In this paper, we present TORO, a web-based tool tailored to the dynamic literature exploration process. The user can easily search and screen papers in a uniform way across different publishers and extract information that can help refining the exploration strategy (Figure 1). Using a visual paper graph, the user can quickly get an overview of a set of papers and discover interesting relations. The user has complete control of constructing the graph, can actively explore streams of interesting work according to user-specified criteria and is able to easily keep track of already explored papers. TORO can feed into the classic SLR process by supporting the user determining an initial set of keywords or papers that can then be used as a starting point to perform a traditional SLR. We explain how the individual features of TORO can help researchers within

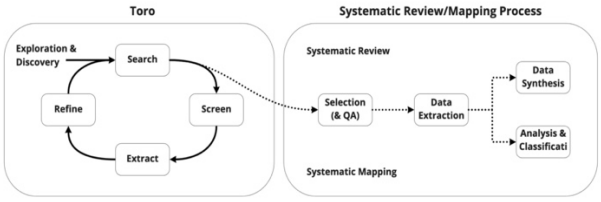

Figure 1. TORO focuses on the dynamic exploration process in which new streams of interesting literature are often discovered, and the search strategy changes. New information can be used to quickly refine the search. Collected literature and keywords can form the starting point for a classic linear SLR process.

the literature exploration process and discuss feedback from a preliminary user study providing insights into how TORO can be improved in the future.

RELATED WORK

Systematic Review Approaches

The SLR is a complex and time-consuming task (Bowes et al., 2012). It is a common approach for literature reviews with many existing tools to support the systematic process (Barn et al., 2014; Fabbri et al., 2016; Götz, 2018; Hinderks et al., 2020; Kohl et al., 2018; Marchezan et al., 2019; Navarrete et al., 2018). It usually involves setting a research question, finding related works through keyword search and other methods, screening papers based on inclusion and exclusion criteria, and selection of relevant works (Kitchenham & Charters, 2007; Kitchenham & Brereton, 2013). Then, researchers analyse the selection of papers to achieve their predefined goal such as to answer their research question or to identify a specific effect of an intervention. There are many current tools that support the SLR process. Buhos is a web-based SLR tool that allows searching, collaborative screening, data extraction and reporting of papers. CloudSERA (Ruiz Rube et al., 2018), Covidence (Veritas Health Innovation, 2019) and StArt (Fabbri et al., 2013) provide similar collaborative functionality. Most of them emphasise on easing the complexity of the screening by allowing users to easily review paper titles and abstract and indicate whether to include or exclude the papers. In addition, many tools enable automated or semi-automated text mining of the pool of papers to aid with the analysis stages and display the results graphically. SLR-Tool (Fernández-Sáez et al., 2010) supports the SLR process along with refining searches within the documents through text mining, defining a classification schema to facilitate data synthesis, and exporting the results as tables and charts. SLuRp (Bowes et al., 2012) and SLRTool (Barn et al., 2014) provides similar functionality where it synthesizes qualitative data within the papers and displays analysed data in tabular and graphical format. The SLR Toolkit (Götz, 2018) generates analysis diagrams (i.e. bar charts, bubblematrix charts and pie charts) of taxonomy terms in the papers. Visual Text Mining (VTM) has been used to support SLR by mapping and clustering the papers based on text analysis. This was first introduced as a VTM tool (Malheiros et al., 2007). The Systematic Mapping Visual Text Mining tool (SM-VTM) (Felizardo et al., 2010) reduces the effort and time required to categorize and classify data in systematic mapping studies. These existing SLR tools mainly focus on the selection of primary studies for the SLR process based on a predefined set of papers. Which means that a predefined bibliography needs to be imported first, before using the tools to perform a strict systematic process to screen and select primary studies. In some cases the tools allow performing keyword searches on external publisher platforms to obtain this initial set. However, unlike TORO these tools are not designed to dynamically adjust the initial set, by using distinct search queries or browsing through their references and citations. In contrast to these tools, TORO focuses on the dynamic exploration process (Figure 1) to build up a bibliography or set of keywords that can form the starting point to perform the actual SLR process.

Search & Exploration Tools

Although the most common and reliable way to search for papers is through searching on literature databases, there are other methods to find relevant literature. The snowballing approach is one of such methods and it refers to using the references of papers to identify additional papers until no more relevant papers are found (Wohlin, 2014). Just as how Visual Text Mining can support the analysis of studies in the SLR, graphical visualization of citations and their references can help to support the snowballing approach. StArt (Fabbri et al., 2013) builds on visual text mining and snowballing concepts; It supports the visualisation of the relationship among the studies uploaded into StArt desktop application and their references which is useful for finding studies that were not retrieved in the literature review but referenced by other retrieved studies. Rayyan (Ouzzani et al., 2016) is a web and mobile app for systematic literature reviews where users first upload a citation file of studies searched from external databases. Users can then explore the citations through a similarity graph that clustered citations based on how similar they are based on title and abstract content and common authors. Connected Papers (Eitan et al., 2020) is an online tool that automatically finds related papers for a chosen paper and visualises it in a graph. It allows search and discovery of important papers and can help ensuring that users do not missed an important paper. Research Rabbit (Chandra et al., 2021) lets users search papers and expand references in list views. It furthermore allows discovering author networks, create and share collections, and collaborate with others. These tools provide new ways of discovering important related work and provide different concepts of presenting, managing and sharing them. Unlike these tools, we propose a tool that focuses on providing the user with a paper graph that allows the user to actively explore and follow interesting streams of literature in a visual way and according to customisable criteria.

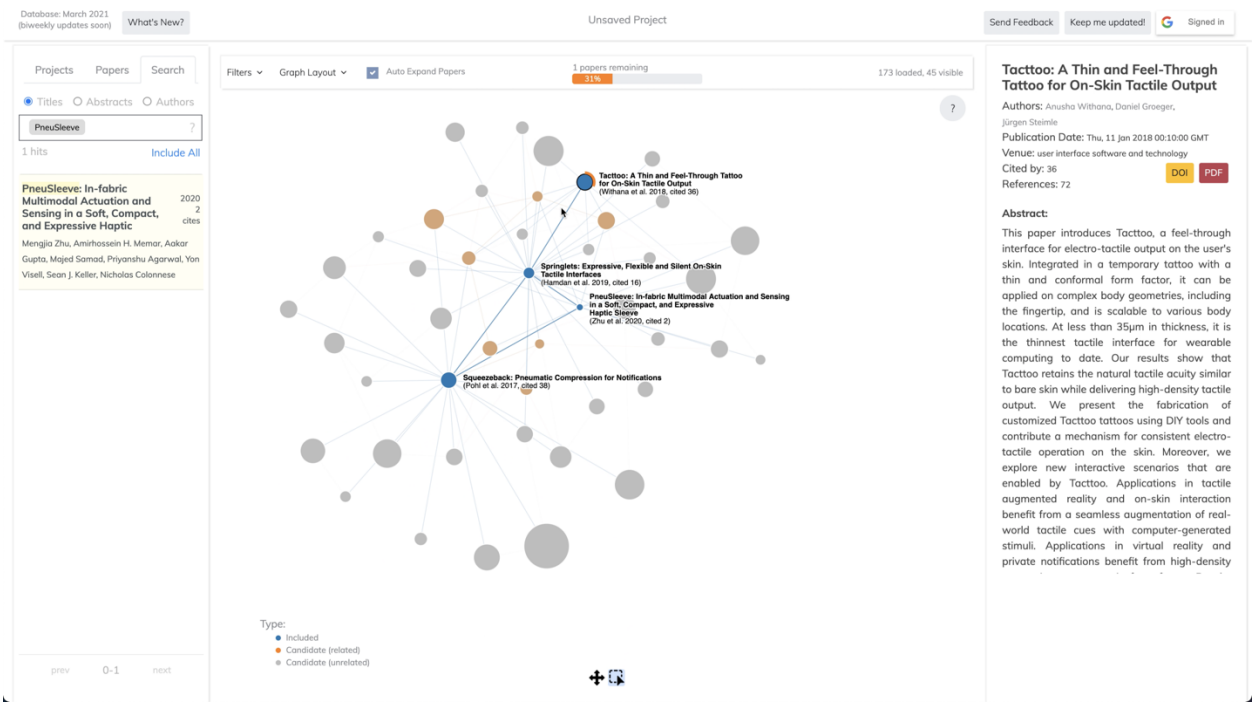

Figure 2. TORO's UI: On the left the user can import papers using keyword search, manage paper lists and projects. On the right the user can view details about selected papers. At the center the user can view and manipulate the visual paper graph. Papers are represented as circles. Connections indicate reference links. The size of the circles indicates the number of citations.

REQUIREMENTS

We conducted a focus group with 7 HCI researchers to identify users' requirements during the literature review process and inform the design of TORO. In three 3-minute sessions, participants were asked to write down as many thoughts for: 1) the ideal outcome of the literature reviewing process, 2) any questions that come to mind for a tool that could help with the literature reviewing process. 3) the most important things a tool should do to help with the literature reviewing process. After each session, the participants presented their thoughts and discussed them. We found that the researchers did not always want to follow an extensive systematic literature review process. Often their goal is to get a quick overview of the literature on a particular topic to understand it better, see if there was a gap in the literature, answer a question, or develop ideas by exploring new interesting streams of work. We summarise their challenges and requirements as follows:

- **Unified Search and Paper Access:** The researchers wanted to easily perform search queries across different publisher platforms. Apart from keyword-search, browsing through the references of papers was a common strategy. However, this would usually require manually searching for the references titles. Different publisher website formats impeded an easy navigation between papers.
- **Screening & Categorisation:** They wanted to screen papers more easily in a uniform way to quickly determine if a paper was interesting. Other than common metadata such as Title, Abstract, Authors and Citations, they wanted to view the relations between papers. Several participants wished to automatically cluster and categorise papers based on their topic. A typical problem was that they could easily come across a paper more than once, unnecessary increasing their screening time.
- **Information Extraction:** They wanted to easily extract information such as keywords to refine their search queries, export citations or .bib-files to reference managers, and share their results with colleagues.
- **Refining Search:** During the exploration process, they would often gather more information like new keywords they did not consider before. They wanted to easily go back and refine their search or follow individual streams of interesting literature as soon as they discover them.

TORO

TORO was designed to address these requirements and implements an interactive visual paper graph for a quick overview of the literature (Figure 2). The user can view the relations between papers, screen relevant information in one view, filter undesired papers, or expand on related ones to explore interesting streams of literature. The user is in full control of adding and removing papers in the graph.

Paper Graph

The interactive paper graph displays papers as circles. The connections between the circles indicate reference and citation links between the papers. When hovering the

mouse cursor over a circle, more detailed information is shown directly in the graph, including the title, main author, publication year, and number of citations. Papers that are linked are placed closer to each other in the graph. A cluster of circles therefore indicates high connectivity between the corresponding papers. The more citations a paper has, the bigger the corresponding circle size. By default, the graph distinguishes between: 1) *Included Papers*, papers the researcher has marked as Interesting, coloured in blue. 2) *Excluded Papers*, papers marked as uninteresting and not shown in the graph, also preventing screening the papers twice. 3) *Candidate Papers*, papers the researcher has yet not been marked as interesting or uninteresting, coloured in gray. The user can choose to highlight Candidate Papers related to the Included Papers in orange. This helps to identify which papers may be screened next.

Adding Papers

The user can add papers to the graph in different ways. The user can paste or drop various content into the graph such as text, links, .bib-files, or reference manager items from Mendeley and Zotero (currently supported and tested under MacOS 10.15.7, Safari, Opera, Chrome, Firefox). As long as the DOI is available and the paper found in the database, it is added immediately to the graph. This allows users to quickly start the exploration process based on a known set of one or multiple papers. As an alternative, the user can perform search queries in the TORO paper database by using the search field on the left side bar. The user can add individual search result items by clicking on them. Papers manually added to the graph as described before, will be automatically marked as interesting (i.e. Included Papers) and show up as blue circles on the graph (see Figure 1).

Screen Papers & View Relations

The tool provides several ways to screen papers to assess if they are interesting to the researcher. While the graph shows a quick overview of the relations between multiple papers and for example, shows works that influenced impactful papers by following the links from papers represented by large circles (with high citation counts), the user can also view meta information about papers in the right sidebar. Upon hovering or selecting a single paper, information like the title, authors, publication date, venue, citation count, reference count, and abstract are displayed on the right sidebar. The sidebar also provides the DOI link to the original publisher website and provides PDF access if available. Upon selecting multiple papers, the user can obtain meta information commonly shared by a group of papers, like the most frequent authors or most frequent keywords. This allows a quick discovery of new terms to refine the search string.

Expanding Linked Papers

TORO enables exploration of the citations and references of a paper in one view using the paper graph. By default, the citations and references (linked papers) of an Included Paper are automatically loaded and shown as gray circles (Expanded view). The user can deactivate the auto-expand functionality and manually expand or collapse Included Papers by triggering a context menu with a right click on a paper. This way citation graphs can be easily explored.

Categorizing & Tagging Papers

After screening a paper, users can mark and categorise Candidate Papers into interesting and uninteresting ones. The user can right-click a circle to trigger the context-menu and either select Include or Exclude. When selecting Include, the paper is treated as interesting, marked in blue and will remain in the graph regardless of the filtering options. If Exclude is selected, the paper will be removed from the graph and not appear again. Excluded papers can still be accessed in the Excluded Papers list on the left sidebar, and users can 'undo the exclusion' when desired. Upon a right-click, the tagging feature is shown and allows assigning new or existing tags to papers. A tag is composed of a tag label and a colour, allowing easily categorizing papers of interest. The colouring function allows quickly access groups of tagged papers visually in the graph. Papers can be assigned to multiple tags. Papers linked to a certain tag can be selected by clicking the tag on the legend. When browsing through papers, researchers often come across papers that are interesting but are not necessarily helpful working towards the main goal they are pursuing. Tagging can act as a bookmark for later use. In a similar way users can use the *Include In* feature to quickly add selected papers to a different project/graph.

Define Filters

When exploring new literature, researchers often encounter a large amount of papers. It is almost infeasible to screen papers with a few thousand citations; the visualisation in the graph becomes too obscured and the value of the graph view diminishes. Therefore, TORO implements filtering features to manage large amounts of papers. Users can shrink the amount of displayed papers to a desired scope using various filtering options including a required minimum citation count, required title or abstract keywords, venues, and more. These filter settings remain in place even if the user decides to expand more linked papers. Using the filter settings, users can decide to only view paper references or citations in the graph. This allows common search strategies like targeted forward and backward snowballing to be easily performed within the tool.

Exporting Papers

A selected group of papers can be exported as a .bib file and added to a reference manager or Overleaf. The user selects a group of papers, triggers the right-click context menu and chooses the Export option. Subsequently, a .bib-file is collated and downloaded as file from the browser.

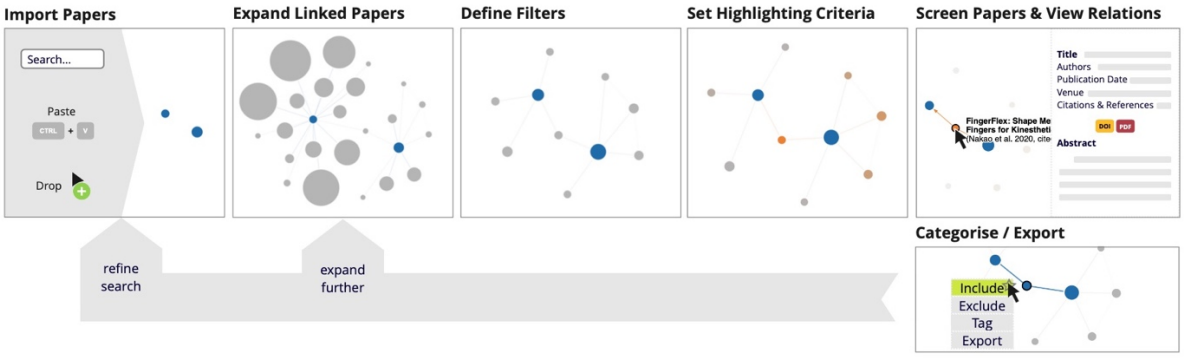

Figure 1. TORO Example Workflow: (1) User starts by searching keywords, pasting or dropping DOIs in the graph to import papers. (2) User expands the imported papers with a double-click to view all papers linked via references. (3) User reduces the number of papers to screen by filtering out irrelevant papers, not matching a given set of keywords. (4) User selects highlighting unscreened papers by their text-similarity to the imported papers. (5) User starts screening the most highlighted paper by hovering it and viewing title and abstract. (6) User right clicks and selects Include to add the paper to the set of interesting papers. Highlighting is recalculated and the user can decide to screen & include more papers, import additional papers, or expand the newly added paper.

IMPLEMENTATION

The TORO user interface is implemented in HTML5, Javascript and CSS. The user interface can run on web browsers from mobile or desktop devices without installation. We utilize the open source CSS framework called bootstrap to create a responsive page layout. To implement the paper graphic view, we leverage a visualization library called D3.js. It allows us to bind dynamic data to a Document Object Model (DOM) and then apply data-driven transformations to create an interactive SVG graphics with smooth transitions and interaction.

The back-end contains a Python-based REST API server which accepts the user interface requests and queries the Microsoft Academic Graph (MAG) databases for responses. The MAG database The MAG is a heterogeneous graph comprised of over 250 million publication entities and related authors, institutions, venues and fields of study. MAG has very good coverage across different domains with a slight bias towards technical disciplines. The database is released by Microsoft research team bi-weekly. MAG is a large heterogeneous graph and mainly consists of six types of entities, including publications, authors, affiliations, venues (journals and conferences), fields of study, and events (specific conference instances). Relations between these entities (e.g., citation and authorship) are stored in auxiliary tables. To store the MAG, we make use of the Mongodb, a cross-platform document-oriented database. Currently, the backend is hosted on a Google cloud server with the Ubuntu 20.04 image.

PRELIMINARY USER STUDY

In a preliminary user study, we wanted to explore the usability of TORO and gather initial feedback on various features which would help us improve the tool. We recruited 18 HCI students and researchers (7 female, 11 male) to use TORO over two weeks during their regular research activities. The participants covered different levels of research expertise including undergraduate students, PhD students, and associate professors. The average time involved in research activities was M=4.28 (SD=3.16, min=1, max=10) years. 11 of them had experience conducting systematic literature reviews. Before the study, they watched an introduction video to TORO explaining the different features. After two weeks, participants were asked to fill a qualitative questionnaire asking about TORO's individual features, opportunities to improve the tool, challenges, and whether they could achieve their goals. Furthermore, the System Usability Score (SUS) was used to assess the usability of the system in its current form.

Results and Discussion

All participants used the tool according to their own needs over the two weeks. The duration of use per participant ranged from 2 to 75 minutes, and the mean duration of use was M=23.71 minutes (SD=22.48). Each participant used the tool four times on average (M=4.22, SD=2.96, min=1, max=11). During the two weeks, participants used the tool for different goals. The most frequently-stated goal (9 of 18 participants) was performing a literature review and finding related papers to a specific work (P17, P2, P4, P13) or topic (P4, P3, P18, P17). Other participants stated goals such as trying to answer a question (P18), using the tool for ideation (P6, P11), comparing papers (P13, P16) and organizing papers (P6), understanding a topic and identifying research gaps (P10). Two participants highlighted that they were particularly interested in finding links and understanding relationships between cited and referenced papers (P9, P14). The overall feedback was positive with some users being very enthusiastic about the tool. Participants tended to agree that they could achieve their goal(s) using the tool (M=3.78, SD=.73, 1 highly disagree to 5 highly agree). 12 of the 18 participants stated that the graph visualization, especially the citation and

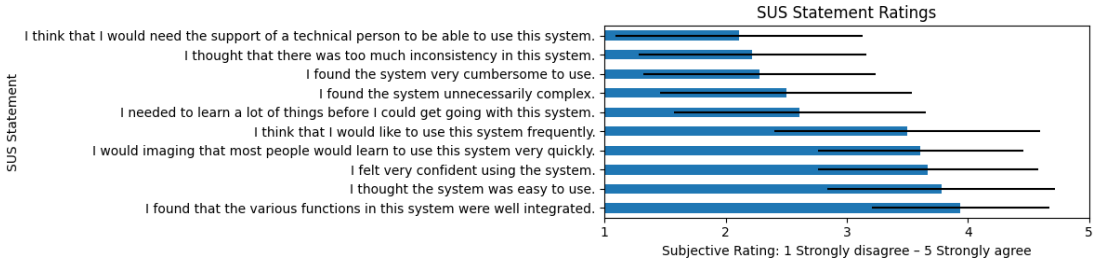

Figure 1. Subjective ratings of individual SUS statements.

reference links displayed by visual connections, were most beneficial to achieving their goals. *"Usually in my internet browser, I can only look through papers one by one. [..] [Using TORO] I could see all Related papers and citation relationships upon one click. I simply have to hover my mouse on the node to learn if this related paper is helpful."* (P10). *"I just put files into it and find some interesting co-related works"* (P6). 11 out of 18 stated they were able to find new literature that was interesting to them. Three of seven who answered they did not discover new and interesting literature said either that they did not use the tool very much (P8, P17), or had "already designed their search independently" (P14).

Using the graph to arrange and organize papers: While several users were asking for closer integration with reference managers such as Mendeley, Zotero, EndNote, and ReadCube as their preferred way of organising and annotating papers (P8, P10, P12, P18), several users also saw the potential to manually organize and annotate papers in the two-dimensional paper graph itself (P10, P5, P11). Several participants imagined using the graph to visualize relations between other instances, such as between authors and institutions. With respect to this, annotation and commenting features were also suggested to review and manage papers better in the future.

More Control through Filters: Participants found the filtering functionality useful but suggested additional filtering features such as filtering by document type (journal/conference), year range and language. A few users reported situations where they still wanted to go through many papers systematically (+100). A suggestion was to incrementally add small chunks of papers to handle many new ones (P10).

Paper Search Results: Participants highly appreciated the integrated cross-publisher-platform search functionality. However, several stated they would still prefer to rely on Google Scholar. Participants suggested improving search result relevance by citation count and being able to apply filters.

Performance and Usability: The System Usability Score was 66.94 out of 100, which is interpreted as "OK" with a trend to "GOOD" usability. As the subjective rating indicates in Figure 4, while most users found various functions well-integrated and disagreed that they would require help from a technical person, some felt they had to learn a lot of things before they could get going with the system. Several participants stated that learning the diverse functionalities before being able to start with the tool was still time consuming (P1, P16, P13, P8, P3). A future "on-boarding" feature that takes the user through examples was suggested. Participants tended to agree that they would use the system frequently (M=3.5, SD=1.1), however saw opportunities to increase the performance of searching and loading papers to improve the usability (P5, P6, P11). Several participants saw the opportunity to further develop the tool to support systematic reviews (P4, P3, P13). To do so, we see the need to allow adding papers that are not part of the database, e.g. results from external search engines, and providing more transparency about the completeness of the database.

CONCLUSION & FUTURE WORK

In this paper we presented TORO a new web-based tool to support research in performing the dynamic literature exploration process. We explained the different features of TORO and how they help to address the different challenges that researchers face during frequent exploration tasks. Our preliminary user study showed that TORO can help researchers achieving their goals to get a quick overview about related work, quickly view relationships between them and explore interesting streams of work. From user feedback we see potential in improving our tool by expanding existing functions like filtering, adding new features as arranging individual papers in the graph and improving the overall performance and usability. In the future we plan to conduct further studies to evaluate our tool regarding speed and performance regarding the discovery of relevant work compared to researchers' conventional exploration processes.

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