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If You Want Your Research Done Right, Do You Have to Do It All Yourself? Developing Design Principles for Systematic Literature Search Systems

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Abstract. A review of existing knowledge builds the foundation of any research project. However, conducting a rigorous and systematic literature search that provides the required literature sample is a complex and tedious task. Existing technical solutions, like literature databases or scientific web search engines, provide only limited support for systematic literature searches, due to their narrow coverage, oversimplified user interfaces, or non-transparent search processes. In this paper, we report the first results of an ongoing design science research project focusing on how to design systematic literature search systems (SLSS) that effectively facilitate systematic literature searches. The meta-requirements and design principles derived in this paper provide a starting point for future research on SLSS. Our research results may also serve as blueprints for new SLSS that increase the comprehensiveness, precision, and reproducibility of systematic literature searches.

Keywords: Systematic literature searches · Design principles · Systematic literature search systems · Design science research

1 Introduction

Even though a review of literature is essential for any academic project [1] and all researchers like to find and use relevant literature, no one likes to search for it, perhaps, with the exception of librarians [2]. Conducting a rigorous literature search is often complex and time-consuming, especially for students and novice researchers [3,4]. However, identifying the literature to be analyzed determines the review's quality [5,6]. Carelessness during the search process will lead to an outdated, scattered, and irrelevant literature sample, which, eventually, reduces the quality of the research output [5]. A rigorous and systematic literature search is therefore a necessity for any high-quality research project [1,4]. To support reviewers, (i.e., researcher who is conducting a literature review) numerous approaches and guidelines exist. The proposed methods range from highly systematic approaches [7,8] to more traditional or narrative reviews [1,5,6,9]. Which method is best suited for a specific review depends on different aspects, such as the research question, available resources, and the topic under review [7,10]. Although there is no universal recipe for conducting literature reviews or searches [9], any high-quality literature review requires a systematic approach to some degree [1,3,7]. Unsystematic reviews tend to be subjective, give no justification why certain literature is selected, and are often based on a partial examination of the available literature, which might result inaccurate or even false findings [3,5]. Since it is difficult to draw a line between systematic and narrative reviews [7,10], in this paper we use the term 'systematic' synonymously for the degree to which a review follows a rigorous methodology.

Systematic literature searches are regarded as a complex task for different reasons. Due to the limited coverage, a literature search usually requires querying multiple literature databases, each with its own peculiarities (e.g., available features, search fields, and query syntax). This is even more of an issue when the topic under review is interdisciplinary. A good example is the information systems (IS) field, where scientific contributions are published in a wide variety of outlets (e.g., journals and conference proceedings), which are dispersed over numerous databases [4,11]. To address this issue, much research has been dedicated to investigating the applicability of alternative search systems. For instance, scientific web search engines (e.g., Google Scholar) were found to have a higher coverage of scientific outlets in comparison to individual literature databases, while being criticized for their oversimplified search interfaces, undocumented and fluctuating search indexes, and export limitations [12-14]. Another example are scientific meta-search engines, like EBSCO Discovery or ProQuest's Summon, which are described as efficient but are also found to have a limited coverage and inflexible search interfaces inapt for systematic searches [15,16]. However, unlike studies on existing search tools, research on developing new systematic literature search systems (SLSS) for the specific purpose of facilitating systematic literature searches is scare. Extant research focuses instead on, for instance, the design of retrieval systems with high user interaction [17], search systems with faceted or symbiotic interfaces [18,19], paper recommender tools [20,21], systems to support synthesis and analysis of research articles [22,23], meta-search engines for individual full-text articles [24,25], specialized web crawler for indexing research papers [26,27], and citation analysis tools for mining academics' social networks [28,29]. While all these efforts seek to assist researchers during the literature review process, systems or individual features for the specific purpose of conducting systematic, rigorous searches are not investigated. However, a deeper understanding of the design and effects of SLSS would provide not only new design knowledge on this class of systems but also insights into why existing systems fail to sufficiently aid reviewers and guidance on the construction of innovative systems that, eventually, increase efficiency and quality of systematic literature reviews.

To address the existing literature gap, we want to answer the following research question: How to design a SLSS that effectively facilitate systematic literature searches? To approach this question, we use the design science research (DSR) paradigm [30,31]. Our research method consists of multiple design cycles (DC) comprising artifact development, evaluation, and refinement. This paper focuses on the results of the second DC, containing a first set of design principles for SLSS along with their instantiation in form of a prototype web application. We thereby contribute to both research and practice by providing novel design knowledge that may serve as a starting point for future research on SLSS and guide the development of new information systems that aid reviewers in conducting rigorous, systematic literature searches.

2 Research Method

Following DSR guidelines [30-32], our research method comprises multiple DC. The first DC was informed by initial requirements from the application domain. We identified problems and opportunities through a requirements workshop with seven researchers from the IS field. Furthermore, we reviewed extant research on information retrieval systems and investigated existing artifacts in the application domain. Based on our insights a first prototype application was developed and afterwards evaluated through an expert review with five IS researchers and developers. The results of the expert review demonstrated the technical feasibility of the prototype and showed a necessity for further refinements (e.g., improvements of the search process and usability). Building on the knowledge elicited from the first DC, the goal of the second DC was to develop a first set design principles for SLSS. Design principles serve as an abstract blueprint for the construction of design products or methods [32]. The principles developed in this paper can be classified as materiality oriented design principles [33]. These principles describe the shape and features of an artifact rather than the intended use of the artifact (i.e., action oriented design principles) [33], similar to principles of form and function [30,32]. However, before design principles can be developed, a clear understanding of the purpose of a design artifact in form of meta-requirements is required [30,32]. In the literature search context, meta-requirements should reflect the acknowledged quality criteria for the search process and its results. To expand our initial understanding of the meta-requirements for SLSS, we conducted a systematic literature review of literature review guidelines. Following Webster, Watson [1], we searched the eight top IS journals (AIS Senior Scholar's Basket) and a special issue of the Communications of the AIS (Vol. 37, 2015) on literature reviews. The eight basket journals were selected due to their high methodical rigor and diversity [34], which makes them most likely to publish or reference the acknowledged review guidelines we were looking for. To identify such guidelines and review articles referencing them, we searched in titles, abstracts, and keywords using the broad query 'literature AND review*'. From the resulting in 266 articles, 57 articles were either literature review guidelines or review articles referencing at least one guideline in their method section, which were also included (backward search). This way we wer able to identify a total of 25 literature review guidelines. After coding all requirements related to either the literature search procedure or its results, we aggregated them incrementally into meta-requirements, as presented in section 3. In the second step, we derived five design principles for SLSS by reflecting on the design knowledge acquired through the first DC and on the insights from our literature review of review guidelines (see section 4). In the third step, we instantiated the developed design principles by refining the existing prototype web application. This allowed us to investigate potential implementations of the derived design principles and provide a first proof-of-concept [35] (see section 5). Finally, we conducted a naturalistic ex-post evaluation of the prototype implementation through nine semi-structured expert interviews. The experts were researchers from the IS field with high expertise on the literature review process. The interview transcripts were analyzed using an iterative coding process to assess the utility, necessity, and sufficiency of the instantiated design principles. The interview results are briefly discussed in section 6.

3 SLSS Meta-Requirements

Our review of literature review guidelines shows that, despite their different approaches, there is a common understanding in the IS community on criteria that constitute a good literature search. The following three meta-requirements synthesize this understanding.

Comprehensiveness (MR1) of a literature review describes the degree to which all relevant literature on the investigated topic is covered. The main goal of literature reviews is to find the existing body of knowledge. A fragmented literature sample can lead to a partial view on a topic [3,5] and increases the chance that individual biased articles effect the integrity of an entire review [3,36]. A comprehensive overview of extant research is, thus, essential for finding and justifying research gaps [3]. The only way to achieve a comprehensive literature review is a comprehensive literature sample [5]. However, comprehensiveness usually does not equal completeness. Compiling a complete literature sample is usually either inefficient or even impossible [6,37]. Review guidelines therefore suggest "a good or reasonable coverage" [37, p. 246].

Precision (MR2) describes the fraction of documents in a result set that is relevant to the reviewer. Manually identifying relevant documents form a large result set is one of the most time-consuming tasks during a review [37], especially, when applying an iterative search and review approach [6,9]. Because reviewers' resources are usually limited [7], guidelines recommend the definition of explicit inclusion and exclusion criteria that pre-filter search results. These criteria include selecting appropriate databases (database-centered strategies) or outlets (outlet-centered strategies) as well as parameters like keywords or authors [3,7,10]. However, a more precise search is also more restrictive and more likely to exclude relevant research contributions [37]. A good literature search is therefore both precise enough to exclude as many irrelevant articles as possible and comprehensive enough to include all vital contributions [5].

Reproducibility (MR3) defines the degree to which results of a literature review can be reproduced. A good literature search follows an approach that is reliable (i.e., results do not vary over time) and allows to communicate and justify each process step [4,5]. Hence, one major precondition for reproducibility of literature searches is transparency of the search process [6]. A transparent search process enables reviewers to be explicit about how a literature sample was compiled, including queried data sources (e.g., databases or outlets) and exclusion and inclusion criteria [3,6,7]. A reproducible literature search is more reliable [7,36] and contributes to the credibility of a review [3,4]. Fellow researchers are enabled to assess the exhaustiveness of a literature sample and are encouraged to use and extend a review [4,11]. Furthermore, a reproducible and well documented search process allows to refine previous search steps and increases the chance of publication [1,6].

4 SLSS Design Principles

[DP1] Multi-sourcing: A SLSS needs the ability to access and combine multiple data sources. To address MR1, a comprehensive search has to cover all sources that might contain literature relevant to the topic under review [5,6] and is not limited to one set of journals or geographic region [1]. In the IS field, like most interdisciplinary fields, there is no central literature database. IS related research is published in over 800 outlets [38], which are spread over numerous databases (e.g., ProQuest and AISeL) [5,9]. Even scientific search engines, like Microsoft Academic or Google Scholar, offer only limited coverage [12,13]. Thus, to provide a reasonable coverage for a comprehensive literature search, SLSS must access and merge (without overlaps) data from multiple sources, when either building their own catalogue or querying on behalf of reviewers.

[DP2] Flexibility: A SLSS must be flexible enough to support reviewers' individual search strategies. Reviewers require the ability to formulate search requests that balance the trade-off between comprehensiveness (MR1) and precision (MR2). Since this trade-off is unique for each search, providing the freedom to implement strategies and constraints (i.e., exclusion and inclusion criteria) appropriate for a review's goals and limitations is vital for any search tool [9,37]. Furthermore, a fit between an SLSS's functionality and the researchers' needs will not only lead to a higher task performance but also increases usage acceptance of the system [39].

[DP3] Transformation: A SLSS needs the ability to translate search requests into data-source-specific queries. Increasing comprehensiveness by searching multiple data sources with one request requires multiple queries, due to lack of database standards [9]. Most literature databases have their own request format (e.g., syntax, parameters and wildcards), catalog style (e.g., outlet names), and restrictions (e.g., number of terms or Boolean expressions). Ignoring such peculiarities can lead to unexpected results during a cross-database search [9], and eventually decreases its comprehensiveness, precision, and reproducibility. Hence, SLSS must transform reviewers' requests to take peculiarities of queried data source into account, either for indexing or querying purposes.

[DP4] Transparency: A SLSS must provide transparent information on the search process. Detailed information on how the search results were produced (e.g., queried data sources and outlets, applied parameters) enables reviewers to understand the comprehensiveness of their search and, if necessary, to either extend the search to increase comprehensiveness or document gaps to increase reproducibility [3,4,37]. For instance, the undocumented catalogue of web search engines makes it impossible to determine which sources were searched [12-14], whereas a transparent search tool provides ample information on where and how the presented results were attained.

[DP5] Reliability: A SLSS must produce similar search results for identical search requests. Unpredictable search algorithms or search catalogue with high content fluctuation, like Google Scholar [12,14], will lead to unique search results depending on when the search is performed or by whom [13], no matter how thoroughly the search process is described. To provide reproducible search results (MR3), SLSS not only have to provide a transparent search process but also a stable environment (i.e., catalogues and search algorithms) to replicate results when following this process.

5 Instantiation of the SLSS Design Principles

This section gives a brief overview on the instantiation of the five SLSS design principles in form of LitSonar (http://litsonar.com), a prototype web application designed to support systematic literature searches. For an extensive description of the prototype and its development process we refer to Sturm et al. [40]. LitSonar provides unified access to multiple literature databases by utilizing the meta-search approach and, thus, addressing DP1. Reviewers' search requests are dispatched to up to six curated databases containing IS-related literature (e.g., ProQuest and EBSCOhost). By utilizing curated data sources, LitSonar passes their catalogues' stability on to the reviewer, which contributes to the reliability of the search results (DP5). LitSonar's user interface provides two novel features for entering search requests to increase precision (DP2), besides typical filters, like time-span or articles types. First, a flexible keyword editor lets reviewers define complex nested query structures of any depth using graphical elements, instead of the usual "expert mode" (i.e., a single text field), as most databases provide for complex requests. Second, a data-source-selection-form allows reviewers to either select multiple databases directly (database-centered) or compile a list of journals and conferences (outlet-centered). In the latter case, reviewers can choose from individual outlets and predefined lists of outlets based on journal and conference rankings. LitSonar automatically identifies appropriate databases, so that all selected outlets in the specified timeframe are covered.

After receiving a reviewer's request, LitSonar transforms it into database-specific search queries, including the translation of syntax and parameter values (e.g., outlet names) to match the respective format (DP3). During this process, the semantic of queries is altered only with the reviewer's knowledge and consent to keep the search process transparent (DP4) and reliable (DP5). After dispatching the requests to the queried data source, returned results are presented in a homogenous, deduplicated list. Reviewers can browse through the list, download articles, compose individual result lists, and export article references. Additionally, LitSonar provides extensive reports on the coverage of literature databases and outlets to increase transparency of the search process (DP4). The database report shows which databases were searched and how many results per database were found. If a selected database could not be searched, an explicit warning is presented. In that case database-specific search query are provided, along with instructions on how to proceed manually. LitSonar also provides an outlet coverage report, if the reviewer restricted the search to certain outlets. This report gives detailed information about each selected outlet by listing the searched time periods and highlighting gaps in coverage. This information enables reviewers to assess and communicate the exhaustiveness of the conducted search and, if necessary, manually complement the results.

6 Qualitative Evaluation and Next Steps

The evaluation of LitSonar through expert interviews underline reviewers' need for SLSS. The manual search process is described as complex, time-consuming, and errorprone. Furthermore, we find a fit between LitSonar and the task of systematically searching literature. The interviewed experts express strong intent to use the system. Using the system is expected to have a positive outcome on performance in form of a higher comprehensiveness and efficiency of the search process, which contributes to the quality of literature reviews. These findings indicate the technical feasibility and utility of our prototype implementation and, thus, also give evidence for the relevance of our five design principles. Another interesting finding from the evaluation of LitSonar is that the interview experts mentioned a lack of support from the prototype during the early stages of a systematic literature search (e.g., for identifying relevant search keywords). It was also mentioned that these activities are probably not fully automatable and therefore difficult to implement. This is in line with Levy, Ellis [5], who describe identifying the right keywords as a creative process and a classic cold-start problem. Often several search and analysis cycles are necessary to refine naïve search terms into a complete set of relevant keywords [5]. This finding raises the question of whether SLSS can support the entire systematic literature search process, or even the broader question of what are the limitations of SLSS. To answer these questions, further research is necessary.

In conclusion, we learn that the SLSS design principles and their instantiation are technically feasible and carry the potential to facilitate systematic literature searches. However, to rigorously examine the utility and relevance of the designed artifact and thereby make a valuable contribution to the design knowledge base, LitSonar must be studied directly in the application domain [30,31]. The results from our qualitative evaluation demonstrate that LitSonar reaches a sufficient level of maturity allowing us to subject the prototype to a large-scale field test. Building on the output of the previous two DC, the next steps of our research incorporate a third DC of artifact refinement and evaluation. To evaluate LitSonar's impact on the efficiency and quality of the search process and the acceptance of the artifact by users from the application domain, the prototype will be rigorously examined in a quantitative evaluation. The evaluation will be conducted in course of a large-scale field test at two German universities, allowing us to study LitSonar directly in the application domain. Students and researchers will have open access to the system. The data collection method will include both data logs and a voluntarily questionnaire. Besides completing the third DC, the quantitative evaluation will contribute to the DSR knowledge base. Studying LitSonar in its environment allows us to assess whether the SLSS design principles adequately address the prevailing challenges and improve the application domain as intended by DSR.

The contributions of this paper are twofold. We contribute to research by identifying an initial set of meta-requirements through a systematic literature review, deriving design principles for SLSS, and providing first evidence for their utility. This paper can serve as knowledge repository and starting point for future research on SLSS. Fellow researchers might use the presented design knowledge to explore its relevance in different contexts (i.e., research areas) or develop novel evaluation instruments to measure the suitability of systematic literature search solutions. We also contribute to practice by providing meta-requirements and blueprints (i.e., design principles) for SLSS that facilitate the systematic search process. Developers can use this knowledge to create innovative search systems or add systematic search features to existing solutions. Our research results could help to increase comprehensiveness, precision, and reproducibility of future systematic literature searches and, eventually, have a positive effect on the overall quality of literature reviews.

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