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Domain-Specific Languages: A Systematic Mapping Study

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ABSTRACT

Context: In this study we report on a Systematic Mapping Study (SMS) for Domain-Specific Languages (DSLs), based on an automatic search including primary studies from journals, conferences, and workshops during the period from 2006 until 2012.

Objective: The main objective of the described work was to perform an SMS on DSLs to better understand the DSL research field, identify research trends, and any possible open issues. The set of research questions was inspired by a DSL survey paper published in 2005.

Method: We conducted a SMS over 5 stages: defining research questions, conducting the search, screening, classifying, and data extraction. Our SMS included 1153 candidate primary studies from the ISI Web of Science and ACM Digital Library, 390 primary studies were classified after screening.

Results: This SMS discusses two main research questions: research space and trends/demographics of the literature within the field of DSLs. Both research questions are further subdivided into several research sub-questions. The results from the first research question clearly show that the DSL community focuses more on the development of new techniques/methods rather than investigating the integrations of DSLs with other software engineering processes or measuring the effectiveness of DSL approaches. Furthermore, there is a clear lack of evaluation research. Amongst different DSL development phases more attention is needed in regard to domain analysis, validation, and maintenance. The second research question revealed that the number of publications remains stable, and has not increased over the years. Top cited papers and venues are mentioned, as well as identifying the more active institutions carrying DSL research.

Conclusion: The statistical findings regarding research questions paint an interesting picture about the mainstreams of the DSL community, as well as open issues where researchers can improve their research in their future work.

1. Introduction

"*Domain-specific languages (DSLs) are languages tailored to a specific application domain. They offer substantial gains in expressiveness and ease of use compared with general-purpose programming languages in their domain of application [45].*" As such, DSLs [16,21,27,30,37,45,47,54] become an emerging popular area of research within the field of Software Engineering (SE), and one of the more important constituents of software development methodologies such as: Generative Programming [14], Product Lines [63], Software Factories [26], Language-Oriented Programming [62], and Model-Driven Engineering (MDE) [25,56–58]. On the other hand, research on DSLs has never become a truly independent research field with established research groups and long-lasting conferences/workshops. Despite some attempts to consolidate DSL research groups by organising USENIX Conferences on Domain-Specific Languages in 1997 and 1999, series of HICSS Minitracks on Domain-Specific Languages for Software Engineering in 2001–2003, IFIP Working Conference on Domain-Specific Languages in 2009 and 2011, and more recently SPLASH 2014 workshop on Domain-Specific Language Design and Implementation. More often DSL researchers have published their works either under broader communities such as programming language research (e.g., Symposium on Principles of Programming Languages; Conference on Programming Language Design and Implementation; Conference on Systems, Programming, Languages and Applications: Software for Humanity; Conference on Functional Programming; Symposium on Practical Aspects of Declarative Languages), or within specific application domains for which DSLs were developed (e.g., embedded systems, high-performance computing, electronic commerce, robotics). Furthermore, DSLs can

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be developed in more varied ways than General-Purpose Languages (GPLs). For example, during the design phase a new DSL can be based on already existing language (language exploitation pattern [45]), or designed from scratch without any relationship to an existing language (language invention pattern [45]). Whilst, independently from a design phase a DSL can be implemented by different approaches (e.g., interpreter, compiler, preprocessing, embedding, extensible compiler/interpreter, COTS, hybrid [45]), each having its own merits [36]. Due to the fact that research on DSLs is spreading into many software development methodologies, vast areas of application domains, and different development approaches, it is hard to obtain a complete knowledge of the DSL research field, and foreseen DSL research trends. Therefore, the main objective of the described work was to perform a Systematic Mapping Study (SMS) [31,52] on DSLs for better understanding the DSL research field, identifying research trends, and possible open issues.

Note that the term 'domain-specific language' has also been used within the MDE community as a synonym for a 'domain-specific modeling language' (DSML). On one hand, the differences between DSLs and DSMLs are not unbridgeable and many similarities in the designs and implementations of DSLs and DSMLs can be identified. As well as dissimilarities between the syntax descriptions used (grammars vs. metamodels) [50], and the semantic description immaturities of DSMLs compared to DSLs [9]. Thus, due to the aforementioned persisting differences between DSLs and DSMLs researchers have recently become more careful when using both terms. On the other hand modeling communities, and in particular domain-specific modeling communities, rarely cooperate with a programming language community. They have established their own set of conferences (e.g., Conference on Model Driven Engineering Languages and Systems; Domain-Specific Modeling Workshop) and journals (e.g., Journal of Software and Systems Modeling). Although, one of the goal of the Software Language Engineering (SLE) [35] series of conferences is to bring both communities together. SLE is a young engineering discipline with the aim of establishing systematic and rigorous approaches to the development, use, and maintenance of computer languages. However, SLE comprises general-purpose and domain-specific specification, modeling, and programming languages. Hence, its scope is much broader than DSLs. In this work we concentrated solely on grammar-based DSLs, which are intrinsically textual. We plan to perform similar SMS on DSMLs as future work. The main contributions of this paper are:

- an overview of DSL research since the DSL survey paper [45] was published 10 years ago identifying trends and gaps in DSL research,
- better classification on primary studies in the DSL research than presented in [49] by deriving more accurate conclusions,
- applying SMS to a broader field of DSLs, thus enhancing its usability,
- improving best practices on performing SMSs (e.g., keywording process would be better if replaced by taking into account survey papers within a research field and/or by contacting experts within that research field), and
- enhancing reliabilities of SMSs (e.g., classification of empirical or non-empirical research).

This paper is organised as follows. Related work on SMSs in general and within DSLs are discussed in Section 2. Description of research method, SMS planning and execution details are highlighted in Section 3. In Section 4, we report the results of performed SMS according to the research questions defined in Section 3. A discussion on threats to validity is presented in Section 5. Key findings and concluding remarks of SMS on DSLs with an outline for future work are summarised in Section 6.

2. Related work

A systematic review (SR) is a secondary study that reviews primary studies with the aim of synthesising evidence related to a specific research question. Several forms of SRs exists [31], depending on the depth of reviewing the primary studies (e.g., performing quality assessment of the primary studies), and on the specificities of research questions:

- Systematic literature review (SLR): "*A form of secondary study that uses a well-defined methodology to identify, analyse and interpret all available evidence related to a specific research question in a way that is unbiased and (to a degree) repeatable [31].*"
- Systematic mapping study (SMS): "*A broad review of primary studies in a specific topic area that aims to identify what evidence is available on the topic [31].*"
- Tertiary review (TR): "*which is a systematic review of systematic reviews [31].*"

Hence, SLRs are more driven by specific research questions (e.g., is one particular approach better than other), whilst research questions in SMS are of a higher-level (e.g., which empirical methods have been used, which research topics have been addressed). A further guideline as to whether to perform a SLR or a SMS is that the latter is more appropriate if it is discovered that very little evidence is likely to exist or that the topic is very broad [31]. Due to the broadness of DSLs, as discussed in Section 1, the emphasis in this work is on SMS for DSLs. A more detailed definition of SMS can be found in [52]: "*The main goal of systematic mapping studies is to provide an overview of a research area, and identifing the quantity and type of research and results available within it. Often one wants to map the frequencies of publication over time to see trends. A secondary goal can be to identify the forums in which research in the area has been published.*"

It is important to point out that both SLRs and SMSs have established rigorous methodologies [31] for performing such studies. Although, that methodology for SR in SE has recently attracted more attention, this young SE methodology still suffers from some infancy problems. Many of them are stated in [10,32,34,66]:

- usefulness of many SMSs is not as was expected (e.g., SMSs have not as yet been used by other researchers as a starting point for their research, SMSs benefit more researchers than practitioners),
- problems of classifying studies in a replicative manner, and
- classification of primary studies by inexperienced researchers.

Overall, we still need to obtain more experience in performing various SMSs by acquiring knowledge on how to perform and use them. Hopefully, this study will introduce an additional facet of knowledge towards gaining more experience with such studies.

By examining the literature on existing SMSs we noticed that many of them were performed on research topics with very little existing evidence. In an extreme case as little as 13 primary studies were identified and examined [5]. There is a clear trend in current SMSs towards selecting a research topic which is not too broad in nature. One possible reason might be that a SMS that needs to examine several hundred primary studies is even more time-consuming and challenging. On the other hand the usefulness of such SMSs is severely hampered due the narrowness of the research topic. We are convinced that SMSs would be of much greater use if they were applied to broader research topics. However, this previous claim can only be proved after such SMSs have indeed been performed on broader topics. This is also the aim of SMS in this paper. The only SMS we found with more than 1000 examined and classified primary studies was SMS on DSLs [49] but, this SMS [49] revealed most of the problems of current SMSs as previously mentioned and discussed in [10,66]. In particular, we didn't find that study [49] very useful as the authors classify the primary studies regarding a research focus with respect to keywords found in the primary studies and not to already-established