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Comparison of Design Models: A Systematic Mapping Study

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Context: Model comparison plays a central role in many software engineering activities. However, a comprehensive understanding about the state-of-the-art is still required. *Goal*: This paper aims at classifying and performing a thematic analysis of the current literature. *Method*: For this, we have followed well-established empirical guidelines to define and perform a systematic mapping study. *Results*: Some studies (14 out of 40) provide generic model comparison techniques, rather than specific ones for UML diagrams. *Conclusion*: Fine-grained techniques are still required to support ever-present and complex model comparison tasks during the evolution of design models.

Keywords: Model comparison; model matching; mapping study, model similarity.

1. Introduction

Model Driven-Engineering (MDE) is a model-centric approach where developers focus on elaborating, maintaining, and evolving design models at different levels [1]. In this context, model comparison plays a central role, e.g. finding overlapping parts between the evolving design models [2]. For this reason, both academia and industry have proposed several model comparison techniques, such as MADMatch [3], UMLDiff [4] and DSMDiff [5].

Unfortunately, model comparison is still considered a time-consuming and error-prone task until now; mainly, because the contemporary techniques are far from providing a precise and large-scale computation in synchronizing and matching models. To overcome this problem, a comprehensive understanding about the state-of-the-art is pivotal for identifying the current research gaps. This paper, therefore, aims at performing a systematic mapping study, following the guidelines described in [6], to characterize previously published model comparison approaches, creating a "big picture view" on the study performed. Next, we briefly present the study methodology, and the main results obtained.

2. Study Methodology

We have performed a Systematic Mapping Study (SMS) to investigate previous approaches following five steps: (1) definition of research questions; (2) elaboration of a search strategy; (3) description of inclusion and exclusion criteria for paper's selection; (4) establishment of the data to be extracted; and (5) execute the methodological study.

2.1. *Definition of research questions*

Table 1 presents the defined research questions investigated. These questions guided the discussion about previously published approaches about design model comparison.

Table 1. Research questions.

Research questions	Motivation
RQ1: What are the types of diagrams addressed by comparison techniques?	Find out the types of diagrams that comparison techniques support.
RQ2: Which empirical strategies are used to evaluate the comparison techniques?	Check the empirical strategies used to evaluate the comparison techniques.

2.2. *Search strategy*

We restricted the search for studies in the major search engines: IEEE Digital Library, Science Direct, Digital ACM Library, Scopus, Google Scholar and Springer Link. In addiction, we defined terms to form Search Strings for performing searches in the main digital libraries. Then, we developed various combinations of Search Strings. However, we present the strings that returned the most accurate results in search engines as follows:

((Diagram OR Design OR Model OR Structure) AND (comparison OR matching OR differencing OR match))

2.3. *Inclusion and exclusion criteria*

First, the search was limited to studies published in electronic digital libraries from newspapers or journals, educational institutions, international conferences, Master and PhD thesis. Secondly, we only considered approaches written in English and papers proposing model comparison.

For approach exclusion, we have applied the following criteria: (1) papers and studies which do not focus on model comparison; (2) duplicated studies returned by different search engines; and (3) papers and works that focus in low-level comparison (XML, source code and text).

2.4. *Extracted data*

We extracted (1) implicit data of inclusion and exclusion criteria: publication date, publication fora, and search engine; (2) basic attributes of studies: main author and title; and, finally, (3) information related to research questions:

Diagrams (RQ1): the set of diagrams elicited from collected studies: Component-and-Connector (CC), Generic (GD), Meta-Models (MM), Business Process Models (BPM), Use Case Diagram (UC), Class Diagram (CD), Sequence Diagram (SD), Activity Diagram (AD), Statechart Diagram (SCD), UML Profile (UP), and Any UML Diagram (AUD).

Research method categories (*RQ2)*: we classified the selected papers in five categories proposed by [6]: (1) *evaluation research* uses empirical strategies to assess proposed works; (2) *solution proposal* suggests novel solutions based or not on previous approaches; (3) *validation research* used for evaluating techniques, which have not been widely adopted in industry; (4) *philosophical papers* propose new and revolutionary research to address some aspects of model comparison; and (5) *opinion papers* discuss problems based on author's previous experiences.

2.5. *Execution*

We followed four steps to collect the primary studies: *First results (SP1)*: find electronic papers using the search string; *Duplicates Removed (SP2)*: remove repeated studies; *Preselection (SP3)*: remove papers that do not match with established requirements and research questions; and *Selected Studies (SP4)*: we analysed all selected studies in the previous step and then applied the exclusion criteria aforementioned. Table 2 shows the results obtained in each sub-phase. A final list of selected studies can be found in [10].

Table 2. Studies obtained in each step.

Steps	IEEE	Scopus	Springer link	Google scholar	ACM	Science direct	Total
SP1	270	461	891	427	49	483	2581
SP2	268	321	787	392	45	476	2289
SP3	41	49	87	93	20	9	299
SP4	7	2	2	23	6	0	40

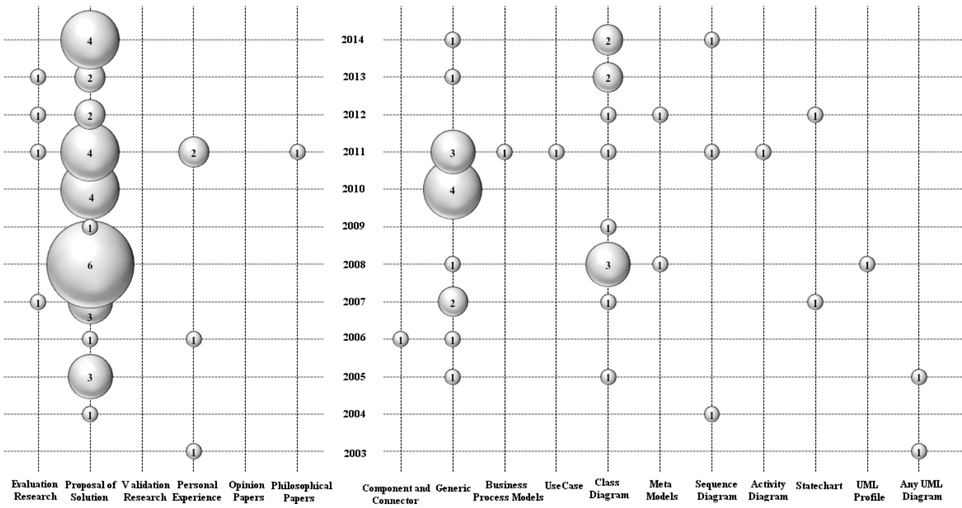

Fig. 1. Publications by year.

3. Results

Figure 1 presents a general overview of the main research questions, i.e. RQ1 (diagram types) and RQ2 (methodology). There are at least three main observed aspects: (1) production in 2009 was the most unproductive year (just 1 article produced). Additionally, we perceived a frequent amount of rises and falls regarding the number of publications every three years; (2) majority of approaches (77,5%, 31 of 40 papers) are Proposal of Solution. Concentration of proposals for model comparisons suggests that there are new emerging approaches for model comparison. In addiction, the approaches do not complement each other due to the frequent emerging proposals produced within the same year; and (3) the majority of the approaches (14 approaches) focused on generic diagrams, i.e. those diagrams that are more abstract and consider similar attributes to compare the diagrams. In the same dimension, we noted that the number of non-UML-based comparison techniques (53%) outnumbers the UML-based ones (48%). This is associated to the current challenge of developing fine-grained comparison techniques covering the details of UML diagrams. Moreover, model comparison is well known to be a NP-complete problem [7], i.e. hard to develop an algorithm that computes it in an acceptable execution time.

4. Conclusion

We have observed that there is no widely adopted model comparison technique [8]. Thus, the study showed the majority of studies focusing on generic diagrams. In [9], the author claims that generic tools are not enough to produce high-quality evaluations. Therefore, fine-grained techniques are still required to support ever-present complex model comparison tasks. In addition, given the diversity of modeling notations and diagrams, it would be challenging to produce a generic approach to address specific comparison problems. Finally, model comparison is not a trivial task to deal with. Rather, it may be still characterized as a time-consuming and error-prone task.

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