Packaging Controlled Experiments Using an Evolutionary Approach Based on Ontology

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Abstract

A body of knowledge in Software Engineering requires experiments replications. The knowledge generated by a study is registered in the so-called lab package, which must be reviewed by an eventual research group with the intention to replicate it. However, researchers face difficulties reviewing the lab package, what leads to problems in share knowledge among research groups. Besides that, the lack of standardization is an obstacle to the integration of the knowledge from an isolated study in a common body of knowledge. In this sense, ontologies can be applied, since they can be seen as a standard that promotes the shared understanding of the experiment information structure. In this paper, we present a workflow to generate lab packages based on EXPEROntology, an ontology of controlled experiments domain. In addition, by means of lab packages instantiation, it is possible to evolve the ontology, in order to deal with new concepts that may appear in different lab packages. The iterative ontology evolution aims at achieve a standard that is able to accommodate different lab packages and, hence, facilitate to review and understand their content.

Keywords: Controlled Experiment, Experimental Software Engineering, Ontology, Knowledge Representation.

1. Introduction

Controlled Experiment in Software Engineering (SE) attempts to assess methods, techniques and tools applied on software development activities [5, 4]. By using a similar model of practitioners building software, subjects apply methods, techniques and tools under controlled environment, producing data that allow evaluating, measuring and comparing their performance under pre-defined conditions. The collected data set leads to conclusions that are meaningful on controlled conditions, considering the population from which subjects are representative. However, results from a single experiment cannot establish definitive facts about a phenomenon due to variations introduced by different system domains, personal background and experience and cultural environments [6, 21, 23, 27, 20]. Gaining insight into such variations requires running multiple independent studies on a topic [26, 20] – for example, varying the subjects profiles, the adopted procedures or even the experimental design help on establish knowledge about a topic [22, 20]. So, by executing multiple experiments that address these variations, researchers build knowledge on SE discipline, as well as help the practitioner understand how to build software systems better [4].

In this sense, the International Software Engineering Research Network (ISERN) was formed with researchers that promote SE research in an experimental context. According to the ISERN Manifesto [17], in order to build basic models and components on SE discipline, it is important to consider characteristics from specific environments, since each one imposes variations in the effects of technologies.

Replications of a study that investigates a technology by different research groups can deal with those execution variations, allowing to draw conclusions that reach a broader context and, thus, consolidating knowledge in SE. Replicate a study depends on the effective review of its lab package, to understand the adopted procedures and guarantee process conformance with the previous experiment [6, 28]. The description of a study – including the procedures, the results and conclusions – is registered in the lab package [26]. The lab package carries the knowledge to be transferred among researchers in order to enable replications and to report the experimental findings, aimed to contribute to the advance of the discipline and the application in industry.

However, knowledge sharing problems among research groups arise, such as difficulties in reviewing lab packages [26] and integrating this knowledge in a common body [18],
mostly because the lack of standardization of lab packages. Dealing with such problems minimizes the risk of an experiment being isolated. Noticing how those problems have influenced on replications, Mendonça et al. [20] presented the Framework for Improving the Replication of Experiments (FIRE). The FIRE suggests standardizing packages and evolving knowledge repositories in order to share knowledge, which should be available in a common body and also understandable to researchers willing to execute a replication.

In this direction, Garcia et al. [14] elaborated the $\text{EXPEROntology}$: an ontology of controlled experiments domain, with the purpose of formally describe concepts that compose a lab package. Ontologies have already been applied in Software Engineering aiming at the standardization of the concepts of a domain and knowledge reuse and share [12, 13, 2, 7, 3].

The packaging of information about a study can incorporate the ontology as a standard in order to deal with the complications in integrating and transferring the knowledge from experiments, considering that knowledge representation and sharing is a recurring application to which ontologies are designed for [15, 29]. According to Amaral and Travassos [1], packaging should be done phase by phase, throughout the experimental process [31]. So, in this context, it is proposed a workflow that suggests this packaging based on the concepts defined in $\text{EXPEROntology}$. And, since its definitions are not necessarily static, the ontology can absorb new concepts, as lab packages containing different sets of information are instantiated.

The remainder is organized as follows. In Section 2 is given an overview of replications importance and is presented the problem in knowledge sharing among research groups. With the purpose to address such problems, in Section 3 is argued about the use of an ontology to represent the knowledge from a study. In Section 4 is presented the proposed workflow that applies and evolves the ontology as a standard to lab packages. Finally, in Section 5, the contributions and future work directions are summarized.

2. Replications, Knowledge Transfer and Integration

Several issues involved in running an experiment present sources of variations that limit the generalization to apply the conclusions. The participants may be from different cultural environments or imposed to a different set of conditions during the execution [22, 20]. Therefore, in order to generalize the conclusions, these variations should be explored and dealt with in replications of the study.

To effectively attend to the conditions variation, different research groups might execute replications in their own laboratory environment. Thereby, if obtained results confirm previous conclusions, it is demonstrated that they are applicable to a broad context. Conversely, if the results do not confirm the conclusions of the previous study, the influence of the variations can be identified and produce other relevant conclusions on the topic. Therefore, the knowledge about a technology can be consolidated across replications based in the study that investigates it. Besides, the selected variables to model the phenomenon or the adopted procedures in the realization may not be ideal. In this sense, similar replications, accomplished by the original experimenters or not, can build confidence in the procedure and the result [8].

Replicating a study, in a not completely independent way, depends on the effective review of its original execution, to understand the procedures and the experimental design of the previous study for process conformance sake [28], that is, to produce comparable results. The lab package is the tool that carries study information. Thus, replications can be encouraged with the availability of lab packages [26]. And, given the amount of effort required to conduct an experiment, it is reasonable to facilitate the reuse of experimental artifacts by providing a lab package [8]. From its review, researchers have access to how the previous study was conducted.

However, the review of lab packages by researchers presents difficulties [26], what can be considered an obstacle in knowledge transfer among research groups. Noticing knowledge transfer problems as barriers to the conduction of replications, Mendonça et al. [20] proposed the Framework for Improving the Replication of Experiments (FIRE), which is composed by the two cycles of activities, as illustrated in Figure 1. The internal cycle represents the execution of a study by a research group. The external cycle (inter-group) represents the activities whose purpose is to integrate the knowledge generated by running a study (internal cycle) in a common body of knowledge. In that sense, the lab package can be effectively reviewed by eventual replicators from a different research group aimed to set the experiment (replication) goals. One might observe in Figure 1 that create/evolve package influences the external activity share knowledge. Likewise, in the other point that the cycles intercept, understand lab packages is crucial to set experiment goals of a new replication.

It can be considered, therefore, that the lab package represents the output of the internal cycle carrying out information about an isolated study, and also the input of the internal cycle of a possible replication, considering that researchers should review and understand the original experiment lab package. So, with regard to share knowledge and favor better understanding of lab packages (in the external cycle), the way which the lab package information must be represented is important, what is endorsed by the activity of standardize packages.

In the other hand, activities of the external cycle of FIRE
also suggest to integrate the knowledge generated by an isolated study in a common body. This established body of knowledge may support decision making to practitioners in software development process [18] and the available lab packages should supply an experimental infrastructure to support future replications as well [26], whose results can sustain the progress of such body of knowledge. However, a major problem for this integration is the heterogeneity in the way that experiments are reported [18], which present different sets of information or level of details [9]. Accordingly to FIRE, to integrate the knowledge or to evolve knowledge repositories, it is necessary to standardize packages (see Figure 1). Indeed, Carver [9] highlights the importance of standardization to deal with this heterogeneity.

3. Ontologies as the Common Solution

Shull and his partners have pointed out that lab packages are important tools for supporting replications (easy-available designs and materials facilitate replications by reducing the amount of effort required from independent researchers), but well-designed lab packages are crucial for facilitating better and comparable replications [28]. Therefore, it must be promoted well-defined knowledge representation into the lab packages. Additionally, there is not a broadly adopted standard to lab packages. In this context, the EXPER Ontology was proposed to deal with the necessity of a established standard, that also eases the understanding of lab package information. With the purpose to apply EXPER Ontology, initially was proposed the instantiation of lab packages information based on EXPER Ontology concepts, according to the experimental process [31, 1]. To support this initial approach, the EXPER Ontology was implemented using OWL (Web Ontology Language) and, then, a tool was developed to instantiate the concepts [25]. However, during the tool validation, it was faced the lack of standardization problem, what leads to the difficulties in knowledge integration, as stated in Section 2.

Thus, not only the use of EXPER Ontology in packaging experiment data set should be considered, but also the current reporting practice, since it is usual lab packages con-
taining different sets of information. For example, details about treatments might be missing, becoming unable to apply ontology concepts straightly. So, it is necessary to deal with different sets of information to accommodate them according to EXPEROntology.

Despite problems found during instantiation using the tool [25], the ontology-based packaging proved itself to be appropriate, since the lab packages were generated in a format that makes explicit the meaning of the information represented, what enables machine processing – the ontology is expressed in a language with formal semantics [30]. However, considering the need for a standardization that complies with the inconsistency of published experiments [9], the EXPEROntology should address the different manners in which an experiment execution is registered. This suggests that the initial ontology should evolve, incorporating new concepts.

In this direction, we propose a workflow, which includes the evolutionary approach to the lab packages instantiation using the EXPEROntology. As illustrated in Figure 2, the inputs of the workflow are the lab package to be instantiated and the EXPEROntology – the concepts described and their relationships are used as parameters to instantiate the lab package. Each phase of experimental process has its own goal and concepts defined in EXPEROntology. Following experimental process, the concepts are used as parameters to a mining process aimed to match corresponding information, which is initially presented without a standard. Thereby, it is possible to instantiate information in the OWL lab package.

To describe the workflow activities, the concepts defined to Planning and Definition phases in the ontology for Lab Packages are presented throughout the experimentation process, highlighted in the following. At first, the initial hypothesis of a controlled experiment is established. It is composed by the object of study, in agreement with a purpose, under a quality focus, and in a specific context. The Definition phase is the basis for the Planning phase and the initial hypothesis generates the hypotheses formalized. These hypotheses have null hypothesis and the alternative hypothesis, as attributes. From the hypothesis formalized, the experimenter defines the experiment variables – dependent and independent variables. During the planning phase s/he also defines the experiment objects: technologies to be studied (techniques, methods or tools) and artifacts (documents, tools or forms) to be used. Each subject has his/her profile recorded to characterize his/her background. Capturing the subject background aims at identifying possible influence on results. For instance, previous knowledge about experiment objects or domain application might influence the results obtained. The subjects’ profile must be considered to create the experimental design, which is built combining experiment objects, independent variables and subjects, in agreement with the hypothesis under investigation. In addition, the subjects’ profile must be considered in analysis. Based on the experimental design, an execution plan must be elaborated in order to describe the entire controlled environment to conduct the experiment.

For instance, conducting the mining process focusing on Definition phase, the concepts Purpose and Context are essential to compose the Initial Hypothesis (parameters to mining process). And considering the experiments published by De Lucia et al. [11] as data set (lab package), after mining process we obtained “Compare ER and UML class diagrams in data modeling” and “Academic” as information corresponding to Purpose and Context, respectively.

Additionally, the mining process might fail: or the mining do not match meaningful values to concepts; or do not match at all. This situation might be consequence of missing data in the lab package, what indicate to experimenters that s/he should handle during the activities of FIRE internal cycle. Also, this situation might be consequence of missing concept, i.e., the EXPEROntology have to be updated in order to evolve it. Considering the same experiment from the previous example [11], the researchers applied feedback questionnaires after tasks execution. The information of subject feedback analysis did not match properly to the concept Questionnaire, since Questionnaire concept is defined in the EXPEROntology to represent subject profile, and its relation with feedback analysis was missing. This mechanism of discover and insert missing concepts automatically is facilitated by the ontology formal description, which enables machine processing.

The instantiation of several lab packages following the proposed workflow allows capturing missing concepts and, consequently, evolve the EXPEROntology. This can be accomplished similarly as the tool validation, by using information extracted from published experiments [10], but only after a comprehensive review of the literature. As the lab packages are instantiated through the workflow, the ontology approximates to the semantic standard that allows to accommodate variations on lab packages, and thereby, the EXPEROntology evolution improves its application on packaging experiments as well.

5. Conclusions

In this paper we propose a workflow to apply and evolve the EXPEROntology to package controlled experiments in Software Engineering. The use of an ontology as a standard to instantiate experiment information was already implemented [25] aiming at improve the understanding of lab packages, since problems concerning their review by researchers were pointed out [26].

The validation of such approach has shown that its main
contribution is the creation of lab packages according to a structured and organized way that makes explicit and meaningful the represented information. Also, ontologies enable machine processing, since are expressed in a language that presents formal semantics [30]. As pointed out by Jedlitschka et al. [18], experiments reports in practice contain different sets of information, what produced the requirement to evolve the ontology, in order to accommodate variations on the sets of information that lab packages can present. This heterogeneity entangles the integration of the knowledge generated by each isolated study in a common body [18]. In this sense, the ExperOntology can be seen as a unifying model, in which lab packages are instantiated, therefore enabling integration. Also, create/evolve package activity proposed on FIRE (see Figure 1) suggests that the initial ontology should evolve, incorporating new concepts, what is addressed by the proposed approach. Consequently, a semantic standard that deal with the heterogeneity issue can be accomplished.

As input to the workflow we consider the lab package as the data set describing an experiment. In this sense, any experiment description might be used: for example, an experiment description found in literature. In this case, the workflow should be applied in parallel with a literature review, in order to apply the information extraction from papers describing experiments [10]. Through this mechanism, it is also possible to assess the new concepts being inserted.

References


