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Sustainability analysis and ease of learning in artifact-based requirements engineering: The newest member of the family of studies (It's a girl!)

Birgit Penzenstadler

California State University, Long Beach, United States

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ABSTRACT

Context: Artifact-based requirements engineering promises to deliver results of high quality while allowing for flexibility in the development process and the project settings. Tailored for analyzing sustainability, it can offer tangible insights on potential benefits and risks of a system under development. However, as of now there is still relatively little empirical evidence available that would prove this quality, flexibility, and insight potential. Previous studies, specifically on the first two characteristics, differ in their socio-economic contexts and make the findings hard to generalize.

Objective: Our goal is to investigate the advantages and limitations in the application of artifact-based requirements engineering by new, inexperienced requirements engineers to extend our family of studies. In addition, the secondary goal is to evaluate the suitability of the sustainability analysis artifact for a sustainability analysis of the system planned for development.

Method: We report on a new member in a family of studies with 20 participants for evaluating artifact models in a sustainability application context. We use a graduate block course as case. Our data collection is performed via survey at the end of the course, based on the same instrument used in previous studies, and extended with a new section on evaluating the suitability of a particular artifact for sustainability analysis.

Results: Both from the quantitative and the qualitative feedback, the results indicate that the students have benefitted from the artifact-based approach to analyzing sustainability in requirements engineering. Usability, syntactic and semantic quality were all rated high and the rationales were positive, as was the feedback on the sustainability analysis artifact.

Conclusion: The results contribute to a reliable database on artifact-oriented requirements engineering and strengthen our confidence in the general benefits of artifact-orientation. Relating the old and new data provides some more insight into the trajectory of the wider transfer of artifact-based requirements engineering into practice.

1. Introduction

Requirements Engineering (RE) is a challenging field in software and systems development due to its inherently complex and interdisciplinary nature, and it is crucially important for the development success [1]. Zave defined:

> "Requirements Engineering is the branch of software engineering concerned with the real-world goals for, functions of, and constraints on software systems. It is also concerned with the relationship of these factors to precise specifications of software behavior, and to their evolution over time and across software families." [2]

Artifact-based requirements engineering is one approach to gather and document requirements in ways that are accessible for different types of stakeholders. Artifact-orientation emphasizes the results rather than dictating a strict development process [3]. This approach can ease some of the challenges arising from the mentioned complexity and interdisciplinarity.

Diomidis Spinellis recently stated in an IEEE Software Magazine editorial [4] that software developers have a social responsibility for the systems they develop. This challenge deserves more attention by software engineering research as well as by practitioners. A similar claim was stated earlier in the Karlskrona Manifesto for Sustainability Design [5], which proposed nine principles to better address sustainability challenges during software system development. These principles center around the ideas that sustainability is systemic, multidimensional and interdisciplinary. It transcends the software's purpose, is multi-level, and multi-opportunity. It involves multiple timescales, is not zero-sum, and system visibility is a necessary precondition and enabler for sustainability design [6].

E-mail address: birgit.penzenstadler@csulb.edu.

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These principles are being addressed by the Requirements Engineering for Sustainability (RE4S) approach in previous work from the author of this article. The RE4S approach uses artifact-based requirements engineering to emphasize sustainability analysis during the activities of that development phase. The artifacts are built on an earlier reference artifact model for domain-independent requirements engineering (AMDiRE) [7].

So far, there is comparatively little empirical evaluation of artifact-based requirements engineering, in terms of families of study with comparable data, that would allow for wider conclusions [8]. There is a need for evaluation of adequateness, ease of use, as well as syntactic and semantic quality [9]. For AMDiRE, we started a family of related studies to provide empirical evidence for the benefits of artifact-oriented requirements engineering. The aim of this paper is to expand that family by introducing a new family member that evaluates the adapted artifact model used in the RE4S approach.

1.1. Research gap and approach

There is a need for more studies adding to an already existing family of studies (see [10,11]) and thereby contributing to a larger reliable database, as Perry et al. [9], Sjøberg et al. [12] and Condori-Fernandez et al. [13] state the need for more empirical evidence in software engineering, and, more specifically, requirements engineering.

Extending a family of studies can happen in two ways. Either researchers perform replication studies that investigate the exact same research questions using the same instruments, as performed in [11] for our family of studies. Or researchers perform studies that use the same instruments but in a different evaluation context to look at related research questions and phenomena, as performed in the study at hand.

1.2. Research goal

Motivated by the experience in practice with industry (as in [10,11]), we wanted to get feedback on how easy it is to learn artifact-based requirements engineering for inexperienced requirements engineers. In addition, we wanted to get qualitative feedback on a particular artifact for sustainability analysis. The setting of this study is not with industry practitioners but with graduate students. This setting allowed for getting feedback on the feasibility of the sustainability analysis diagram before transferring it to practice and evaluating it with practitioners.

1.3. Contribution

In this article, we present two contributions to a larger empirical database on artifact-based RE.

- A new member in a family of studies for evaluating requirements engineering artifact models that relies on the same questionnaire as instrument. The results give insights with regard to the adequateness of artifact-based RE for requirements engineers in training.
- An evaluation of the suitability of the artifact "sustainability analysis diagram" for the sustainability analysis of systems. First indicators strengthen our confidence of its feasibility for practice.

These contributions aid in analyzing sustainability in all its dimensions, including the environmental one that is often referred to as 'green'. More specifically, the artifact model used in this particular study was dedicatedly developed for supporting sustainability analysis during requirements engineering.

Analyzing the suitability of the sustainability analysis artifact together with the usability, semantic and syntactic quality of the artifact model allowed for a more encompassing data gathering. Furthermore, the additional research question aligned well with the overall objective of the family of studies. It would have been possible to report on the two contributions in two separate articles and split the presented data but that seemed like slicing to the author.

1.4. Outline

The remainder of this article introduces the related work on artifact-oriented requirements engineering, requirements engineering and sustainability, empirical studies in requirements engineering as well as the background on the domain-independent artifact model and the requirements engineering for sustainability approach used as foundation for the study at hand in Section 2. We introduce the research questions and the study design in Section 3 and present the results in Section 4. The evaluation of validity is described in Section 5, and we conclude with a summary, relation to existing evidence, lessons learned, limitations, and future work in Section 6.

2. Foundation and related work

In the following, we introduce the fundamentals and related work. Due to the fact of this study being a member of a family of studies, there will be an overlap with the related work and foundations presented in the earlier studies [10,11] but adapted to families of studies as opposed to direct replication. Furthermore, we extended with the specific underlying artifact model used in this study and the sustainability analysis background.

2.1. Related work

The related work for this article includes artifact-based requirements engineering, requirements engineering for sustainability, and empirical studies in requirements engineering.

2.1.1. Artifact-oriented requirements engineering

The focus in artifact-orientation lies on *what* to create rather than on *how* to create it [3].

> The basic idea of artifact orientation consists in defining a reference model of all relevant artifacts and their dependencies while leaving open the way of their creation [3].

In RE, there exist several artifact models, such as the one by Berenbach et al. [14, chap. 2], who describes RE artifact modeling with the key components to be a measurable reference model and respective process guidelines.

Artifact models for RE range across different levels of detail: from providing tool support by capturing the basic concepts of the domain in detail data models to very generic checklists as given at the example of the Volère Requirements Specification Template[1].

Artifact orientation remains a paradigm with various interpretations and manifestations in practice. To tackle the problem of a blurry terminology and to foster the discussions about this paradigm, we introduced a meta model for artifact-based RE in [3]. This meta model defines the basic concepts of artifact-based RE, i.e. which elements are necessary to define an artifact (structure, content), or how an artifact relates to further software process concepts like "method" or "role". This supports the systematic creation of artifact-based RE approaches covering all elements of software processes. Thus, the meta model facilitates the integration and customization of an artifact-based RE as part of a software process.

2.1.2. Requirements engineering and sustainability

The first work to specifically address sustainability analysis of the application domain and in relation to the software system under development within requirements engineering is Mahaux et al. [15], who

[1] http://www.volere.co.uk/template.htm.