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Artifact-based vs. human-perceived understandability and modifiability of refactored business processes: An experiment

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ABSTRACT

Business processes modeling has proven to be effective and reverse engineering techniques with which to recover business process models when they are missing or outmoded have therefore emerged. Regrettably, these techniques often lead to models with quality flaws and consequently to models with low levels of understandability and modifiability. Refactoring has been widely used to deal with such flaws, altering the internal structure of models while preserving their semantics. There are several studies concerning how understandability and modifiability are affected by refactoring in terms of several artifact-based measures. However, there is little evidence regarding how refactoring affects quality in terms of human-perceived measures. The goals of this paper are, therefore: to collect further empirical evidence about the influence of refactoring on understandability and modifiability of business process models and to investigate the correlation between artifact-based understandability and modifiability and human-perceived ones. The obtained results are not trivial and show that business process obtained by means of reverse engineering has recurrent quality flaws, and the understandability and modifiability of business process models cannot be assessed by using artifact-based measures only. Human-perceived measures need to be taken in to consideration in order to have a more accurate evaluation.

1. Introduction

Business process modeling allows us to understand the business activities that an organization carries out. Business process models provide a representation of an enterprise and depict the system functionality through the description of all its components and the interactions between them, in addition to describing the resources and goals involved (Weske, 2007). These models follow standard notations such as BPMN (*Business Process Modeling and Notation*) (OMG, 2011) in order to be understandable by stakeholders.

Business process modeling provides several benefits for both, enterprise management and software development. Despite all these benefits, some organizations have never carried out their own business process modeling, or it may be that their business process models are outdated and misaligned with regard to actual daily operation. It is for this reason that reverse engineering techniques have emerged in an attempt to retrieve business process models from existing source code or event logs (Di Francescomarino et al., 2009; R. Pérez-Castillo et al., 2011; Zou and Hung, 2006; Bianchi et al., 2000). Although reverse engineering is perceived as less error-prone and time-consuming than manual modeling, it often leads to some quality flaws that emerge as a consequence of the low abstraction level of the reconstructed models: redundancies (e.g., the same element is retrieved twice from two different elements in code); irrelevancy (e.g., an element that is not related to a business activity is abstracted from code); inconsistency (e.g., a business process element is retrieved in an isolated form and without some of the required relationships); and so forth.

Cutting-edge techniques like merging, mining, refactoring, re-use, among others, have been designed in recent years in an effort to deal with these quality problems (Dijkman et al., 2012). Refactoring in particular has been used by several authors in literature in the quest to improve the degree of quality in business process models. Refactoring techniques consist of changing the internal structure of business process models without altering or modifying their external behavior, and a

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refactoring operator therefore replaces some fragments with equivalent ones. Several refactoring operators with which to recognize refactoring opportunities and then apply different refactoring transformations have been proposed in literature (Dijkman et al., 2012; Weber et al., 2011; Dijkman et al., 2011; La Rosa et al., 2011; Leopold et al., 2010; Gambini et al., 2011; M. Fernández-Ropero et al., 2013). In addition, there is a proposal (La Rosa et al., 2011) especially designed to refactor business process models retrieved by means of reverse engineering.

The quality flaws mentioned have to be addressed in business process models, since these faults affect understandability and modifiability. These quality characteristics have proven to be two of the most challenging characteristics to consider in business processes (L. Sánchez-González et al., 2010; Reijers and Mendling, 2011). According to the international standard for the quality of software products ISO/IEC 25,010 (ISO/IEC, 2011), understandability represents the degree to which users recognize whether the product is appropriate for their needs. Modifiability, on the other hand, is the degree to which a business process model is effectively and efficiently modified without introducing defects or degrading performance. Business process models with adequate levels of quality make it possible to take advantage of the aforementioned benefits.

Since understandability and modifiability can be considered as extrinsic quality characteristics, they are difficult to evaluate without human intervention. Some studies such as (L. Sánchez-González et al., 2010; L. Sánchez-González et al., 2010) have analyzed the relationships between (i) certain intrinsic measures and indicators (e.g., size, connectivity, separability, density or depth) that can be directly quantified from business process models, and (ii) the gain in understandability and modifiability obtained after refactoring. For example, according to this kind of studies, it can be stated that a smaller business process model is theoretically more understandable. These “artifacts-based” studies are a means of assessing the understandability and modifiability of business process models before and after refactoring, without the time-consuming intervention of humans. Despite the fact that the authors of all the aforementioned works conducted empirical evaluations with students/practitioners to assess how metrics such as size affect the human beings‘ perceived understandability of process models, an in-depth assessment is necessary to demonstrate that these measures are really related to the perceived understandability and modifiability. Thus, the research questions that this paper addresses are:

1) Can refactoring improve the modifiability and understandability of business process models?
2) Is there a correlation between artifact-based measures and human-perceived ones?

In order to answer to them the paper reports the results of an experiment, involving 65 students, aimed at investigating the relationship between the artifact-based and human-perceived understandability and modifiability of business process models. The contribution of this paper is twofold:

1) The collection of empirical evidence that refactored business process models are better understood and easier to modify, while on the other, the time spent performing the understandability and modifiability tasks decreases with refactored models. Effectiveness and efficiency are therefore improved by using refactoring.
2) The evidence of the existence of a relationship between artifact-based measures related to the understandability and modifiability assessment (such as size, connectivity, separability, density and depth) and human-perceived ones. The correlation between artifact-based and human-perceived understandability and modifiability is negative with regard to size and depth, as previous works propose (e.g., the greater the size, the worse the understandability). Connectivity and density, meanwhile, have a positive correlation, while separability has a negative correlation, thus contradicting previous assumptions (L. Sánchez-González et al., 2010; Mendling et al., 2007). Nonetheless, the degree of correlation is weak and it is, therefore, impossible to draw strong conclusions.

The remainder of this paper is organized as follows: Section 1 presents the background by summarizing some related works. The subsequent sections present an in-depth empirical study carried out by means of a controlled experiment with the objective of obtaining some insights into the effect of refactoring on business process models, especially those retrieved by using reverse engineering. The experiment is based on the formal protocol with which to conduct and report empirical research in software engineering proposed by Jedlitschka et al. (2008). In accordance with this protocol, Section 3 shows how the experiment was planned and provides all the information needed to replicate it. The execution of the experiment is described in Section 4, while Section 5 sets out the entire data analysis, the discussion of which is provided in Section 6. Finally, Section 7 presents the conclusions drawn, along with future steps to be taken.

2. Background

Business process modeling and management have proven to be of great benefit enterprise modeling, as well for and software development. Several reverse engineering techniques with which to support business process recovery (Normantas and Vasilecas, 2013) have therefore emerged. However, these techniques imply the abstraction of information, and semantics are very often lost (Canfora et al., 2011); as a consequence, retrieved business process models frequently have quality faults such as missing or non-relevant elements, fine-grained elements, uncertainties and ambiguities (M. Fernández-Ropero et al., 2013). Fixing quality faults and improving business process models are topics that have been discussed by several authors in the last few years. Dijkman et al. (2012) provide several techniques such as merging, mining, refactoring or re-use, with refactoring being the technique most widely used by authors in literature. For instance, Weber et al. (2011) collect a catalogue of process model *smells* for the identification of refactoring opportunities. Dijkman et al. (2011) contribute by showing a technique that is based on metrics with which to detect refactoring opportunities. Similarly, La Rosa et al. (2011) identify patterns for the reduction of model complexity using means that include compacting, compositing, and merging. Dumas et al. (2011) and Ekanayake et al. (2012), meanwhile, focus on the detection of duplicate fragments (also called *clones*). Other authors, like Leopold et al. (2012), focus on the refactoring of activity labels in a business process model, following a verb-object style. Pittke et al. (2013) also focus on labels through the definition of a mechanism that can be used to identify synonym and homonym labels in model repositories. In an effort to retain relevant information, other approaches such as Smirnov et al. (2012,2011), Polyvyanyy et al. (2010), Smirnov (2012) pay attention to the identification of coarse-grained activities by means of business process abstraction, omitting anything that is insignificant. Conforti et al. (2014) focus on both discovering sub-processes in BPMN models and interrupting and non-interrupting boundary events and activity markers.

All of the above approaches are intended to be used with business process models discovered by employing mining process, e.g., using event logs as also occur in van der Aalst (2012) or by hand (Indulska et al., 2009). Other authors, such as M. Fernández-Ropero et al. (2013), Pérez-Castillo et al. (2014), and Caivano (2005), Caivano et al. (2001), attempt to identify and address quality challenges in business process models retrieved by means of reverse engineering. They define a technique and framework, IBUPROFEN, with which to refactor business process models specifically retrieved by using reverse engineering, in line with the BPMN notation. Their proposal allows different refactoring operators to be applied, considering their behavior: maximization of relevant elements, fine-grained