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A methodology for the classification of quality of requirements using machine learning techniques

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ABSTRACT

Context: One of the most important factors in the development of a software project is the quality of their requirements. Erroneous requirements, if not detected early, may cause many serious problems, such as substantial additional costs, failure to meet the expected objectives and delays in delivery dates. For these reasons, great effort must be devoted in requirements engineering to ensure that the project's requirements results are of high quality. One of the aims of this discipline is the automatic processing of requirements for assessing their quality; this aim, however, results in a complex task because the quality of requirements depends mostly on the interpretation of experts and the necessities and demands of the project at hand.
Objective: The objective of this paper is to assess the quality of requirements automatically, emulating the assessment that a quality expert of a project would assess.
Method: The proposed methodology is based on the idea of learning based on standard metrics that represent the characteristics that an expert takes into consideration when deciding on the good or bad quality of requirements. Using machine learning techniques, a classifier is trained with requirements earlier classified by the expert, which then is used for classifying newly provided requirements.
Results: We present two approaches to represent the methodology with two situations of the problem in function of the requirement corpus learning balancing, obtaining different results in the accuracy and the efficiency in order to evaluate both representations. The paper demonstrates the reliability of the methodology by presenting a case study with requirements provided by the Requirements Working Group of the INCOSE organization.
Conclusions: A methodology that evaluates the quality of requirements written in natural language is presented in order to emulate the quality that the expert would provide for new requirements, with 86.1 of average in the accuracy.

1. Introduction

The development of any software project must be based on a high quality of requirements engineering process. Requirements engineering is a "systematic process of developing requirements through an iterative co-operative process of analyzing the problem, documenting the resulting observations in a variety of representation formats, and checking the accuracy of the understanding gained" [1]. Low quality of requirements can provoke errors during the development of a project, since they are considered to be the most costly to correct, if they are not detected on time.

Depending on the project, there could exist systems that need a large quantity of requirements and their specification could include different roles, such as: users or clients, design engineers, and development groups. For this reason, one of the approaches in Requirements Engineering is to establish standards and guides in order to facilitate the specification and improvement of quality of requirements. In [2] the authors "synthesized the different quantitative indicators of qualitative desirable properties of the requirements"; these properties are: verifiability, validability, modifiability, consistency, completeness, unambiguity, understandability, traceability, abstraction, precision and atomicity.

Although these characteristics are clearly defined, the quantification of the value of each characteristic for a requirement is a complex task. In this direction, various studies have been realized for the automatic calculation of these values, using quality metrics over the requirements and establishing quality levels for these requirements [2–4].

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However, one of the most decisive factors for the quality of requirement must be the evaluation of the involved domain experts, because their evaluation is strongly linked to the needs and necessities of the project. Today, the most widely used techniques for the analysis of requirements, that calculate quality metrics automatically, do not take into account the experts' interpretation of quality when they define the quality levels of the requirements, and they are, therefore, less flexible for adaptation at the needs of different projects.

In this work, we present a methodology for the evaluation of the quality of requirements in an automatic way, according to the quality criteria posed by the domain expert who uses this methodology. The objective of this methodology is the emulation of the prediction of the quality of new requirements that are entered in the system. In order to achieve this goal, the expert must contribute with an initial set of requirements that have been previously classified according to their quality and that have been chosen as appropriate for establishing the degree of exigency for the project. For each of the requirements in the given set, we extract metrics that quantify the value for the quality of the requirement. The methodology proposes the use of a Machine Learning technique, namely rule inference, for learning the value ranges for the metrics, as well as the way they are combined to result into the interpretation of requirements quality of the domain expert.

For the demonstration of the reliability of the proposed methodology, we examine a case study of a requirements system provided by the INCOSE's Requirements Working Group and we present two approaches of implementation of the methodology, obtaining different results in accuracy and efficiency in resolving problems.

2. State of the art

2.1. Machine learning techniques

In this paper, we use rule induction techniques which is part of the field of machine learning. The rule induction techniques receive as input a data set composed of the attribute group and a value of class. This set forms the set of learning examples. The purpose of the rule induction techniques is to generate a decision tree or a set of rules for determining the classification of new samples [5].

The reason to use these techniques is because they are robust against noise, caused by insufficient data or errors in both attributes and in the allocation class value. They have the ability to identify irrelevant attributes, as well as to detect discriminating, absent or empty attributes. Extracting rules of the results provided by these techniques allows easy interpretation, facilitating rule modification or elimination for a set [6].

The rule induction techniques used in this work are:

- *C 4.5:* A technique that generates rules from a previously generated decision tree [7].
- *PART:* This algorithm is a combination of C4.5 and RIPPER rule learning [8]. RIPPER implements a propositional rule learner that initially builds a rule set until all positive examples are covered and improves its fit to the training data through a pruning process over the set [9].
- *Boosting and Bagging:* these algorithms are a combination of homogeneous classifiers belonging to so-called "set of classifiers". Classifier sets aim to improve the accuracy of individual classifiers that are generated using machine learning algorithms [10]. Homogeneous classifiers are generated based on the same learning algorithms. In this paper the algorithms used are based on C4.5 and PART.

2.2. Management of requirements

Many of the errors in software development are caused by deficiencies in the elicitation, specification and analysis of requirements. These errors are the most expensive and most difficult to correct if they are not detected in the early phase of the project [11–15]. This demonstrates the importance of quality of requirements in the development of a project.

One of the phases in the requirement engineering process is specification. The specification of any requirement must be in a complete, consistent and correct form. To ensure that requirements comply with the quality metrics, there are several approaches based on conceptual modeling [16–18] in order to detect errors and provide a more formal specification improving the quality. But, the first step to perform the model is the specification of the requirement in natural language. Two advantages of this are: there is no limitation on the concepts that can be expressed; and sentences and grammatical structure provide means of tracing meaningful elements. [19].

Based on high quality requirements written in natural language, the conceptual models are performed with a good quality improving even more the final quality of the requirements.

In order to ensure the quality of requirement written in natural language, various books and articles have been published that the structure and quality metrics to be taken into account in each of the requirements [20–24]. International organizations, such as the IEEE and ISO, have issued several standards for specification of quality of requirements [25–27]. Moreover, Ivy F. Hooks published for NASA the "Guide for managing and writing requirements" [28] and the European Space Agency (ESA) has published a similar guide for the specification of requirements [29]. Finally, the International Council on Systems Engineering [30] dedicated to the development and progress of the systems engineering, published in 2012 another guide for writing quality of requirements [19].

Also with the aim of assisting in the creation and development of projects, there are software tools that allow the management of requirements [31–35].

The main features that provide the tools for the management of requirements are:

- Storage Management.
- Help is the specification.
- Traceability.
- Validation.
- Quality Management.

2.3. Automation in the quality assessment of requirements

Research in requirements engineering has led to current studies that assess in an automatic way the properties that affect the quality of the requirements by analyzing their language and composition. There are studies where attention is focused on the detection and evaluation of a single feature. Some papers detect ambiguities [36–39], inconsistencies [40] and conflicts [41].

In [42] authors present a set of automated analysis mechanisms to support the requirements engineers to detect and analyze modeling errors in contextual requirements models. They present a tool called Re-Context, which supports analysts by checking consistency and conflicts in the requirements models.

The work [43] presents a model-based requirements verification method, called NLtoSTD, to verify requirements documents. The method transforms natural language requirements into a State Transition Diagram that can help to detect and to eliminate ambiguities and incompleteness. The authors assess the approach