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Software reliability modeling based on ISO/IEC SQuaRE

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ABSTRACT

Context: The increasing dependence of our society on software driven systems has led Software Reliability to become a key factor as well as making it a highly active research area with hundreds of works being published every year. It would, however, appear that this activity is much more reduced as regards how to apply representative international standards on Product Quality to industrial environments, with just a few works on Standard Based software reliability modeling (SB-SRM). This is surprising given the relevance of such International Standards in industry.
Objective: To identify and analyze the existing works on the modeling of Software Reliability based on International Standards as the starting point for a reliability assessment proposal based on ISO/IEC-25000 "Software Product Quality Requirements and Evaluation" (SQuaRE) series.
Method: The work methodology is based on the guidelines provided in Evidence Based Software Engineering for Systematic Literature Reviews (SLR).
Results: A total of 1820 works were obtained as a result of the SLR search, more than 800 primary studies were selected after data filtering. After scrutiny, over thirty of those were thoroughly analyze, the results obtained show a very limited application of SB-SRM particularly to industrial environment.
Conclusion: Our analysis point to the complexity of the proposed models together with the difficulties involved in applying them to the management of engineering activities as a root cause to be considered for such limited application. The various stakeholder needs are also a point of paramount importance that should be better covered if the industrial applicability of the proposed models is to be increased.

1. Introduction

It is generally accepted that Reliability is a key factor in Software Quality since it quantifies failures and misbehavior. Also, on the economic point of view, high Reliability is desirable if the total costs of the software product are to be reduced. There are also other very important aspects such as customer dissatisfaction and loss of the manufacturer's prestige that can be traced to Software Product Reliability issues. It should not therefore currently be necessary to discuss the paramount importance of Software Reliability [1–4] in many sectors of industry and society since Software Reliability is the crucial factor as regards estimating both software quality and software cost [5]. According to Musa [6], "Reliability is probably the most important of the characteristics inherent in the concept Software Quality."

Developing performable ways in which to build reliable systems is therefore a real need, and knowing how to assess the actual reliability level of any software product is of no less importance. If this is to be achieved then it is necessary to develop models that are able to assess what level of reliability can be delivered by the software systems. This is the purpose of Software Reliability Modeling (SRM). However, if these models are to be effectively applied in day–to-day industrial practice then it is not only necessary for the proposed models to be sound, well founded and capable of being applied in an efficient, effective and economic manner, but also to be clearly valuable and profitable for the organization. International Standards play a central role in this issue since the objective demonstration of compliance with quality standards provides a means to demonstrate to client organizations that requirements are being achieved as well as generates better positioning in the market by means of increased customer satisfaction. Companies and organizations increasingly require their providers to comply with International Quality Standards.

Despite the above and the high research activity on Software Reliability there would appear to be very little activity in SRM based on Standards, which is surprising given the aforementioned relevance of International Standards in industry. In a previous work [7] we identified a potential lack of research as regards this point and the consequent need to conduct a Systematic Review on the basis of this result, along with the necessity to attain a better understanding of the applicability of SB-SRM to industry. This work is therefore the result of having searched for an answer to the question of how to apply

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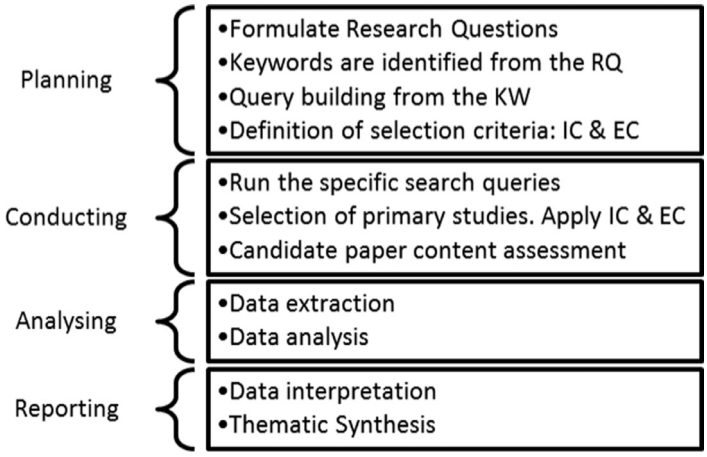

Fig. 1. Systematic Literature Review.

Software Product Reliability Modeling to industrial environments using representative international standards as a basis. To achieve this we first performed an SLR on SB-SRM in order to then integrate the results with the proposals from International Standards, all within the broader framework of Software Product Quality as a reference area in which the research is situated.

This paper provides two main contributions: firstly, it is the first systematic review of SB-SRM literature and secondly, it presents an innovative layout with which to model Software Reliability that integrates the needs of the different stakeholders in a simple but highly descriptive manner.

This paper is organized as follows. Section 2 presents the research work and the Systematic Review methodology as well as the framework chosen. Also in Section 2 Software Product Reliability is considered from the Quality Standards point of view. Section 3 shows the application of the SLR to the context of software reliability, along with the data extraction and results. Section 4 presents an analysis and a synthesis with the answers to our research questions. Section 5 presents a proposal to overcome the principal issues identified, as well as proof-of-concept which aim is shown the feasibility of the proposed approach. In Section 6 our main findings and threats to validity are discussed. Conclusions and further works are then summarized in Section 7.

2. Research description

2.1. Research methodology

As mentioned, this research is designed to follow the standard guidelines for SLR as specified in [8–12] and applied by previous SLRs in the Software Engineering area [13–15] from which valuable insight has also been obtained. A Systematic Literature Review is a process whose intention is to identify, extract and aggregate the best information from the available literature which, with the aim of mitigating bias, uses replicable methods to identify relevant studies and then to analyze those studies. This research methodology is outlined in Fig. 1.

The first stage comprises both a formulation of the problem and the establishment of a protocol that will drive the review. The objectives and the scope of the review are identified at this stage and are expressed by means of the Research Questions (RQ) from which keywords are derived. A Systematic Literature Review is driven by a very narrow research objective that is formalized by means of a short set of very specific research questions. It is also necessary to plan a search strategy by selecting which search sources will be used to find the primary studies. Inclusion Criteria (IC) and Exclusion Criteria (EC) are formalized in order to make it possible to include only primary studies that are relevant to answer the research question. These criteria must be straightforward to apply and, to mitigate each evaluator's bias, not require any interpretation.

The second stage is the data collection and evaluation process. This signifies searching for relevant papers that match the search string in each of the search sources selected. This is done by establishing the keywords and the particular search strings for each literature source. Once the search has been completed we can proceed to the Selection of the primary studies by applying the inclusion and exclusion criteria. The reviewers analyze the title and abstract in the search for terms and concepts that reflect the contribution of the paper. Once the selection phase has finished, the resulting works are analyzed to extract the data that is relevant to the research objectives. Finally, the overall process and outcomes are reported.

2.2. Research framework

This research falls into the knowledge area of Software Product Quality, and in this field the state-of–the-art is led by International Standard proposals such as those from ISO/IEC or IEEE and other like MIL-STD[1] or ECSS[2] for specific industrial environments. We have chosen the ISO/IEC 25000 "Software Product Quality Requirements and Evaluation" (SQuaRE) series of standards as a reference framework for this work. The rationale behind this selection is that the International Standards, and SQuaRE in particular, tackle the well-known lack of consensus and the variety of views on what Software Quality is bringing together the efforts of hundreds of volunteers representing varied viewpoints and interests but also SQuaRE is the most recent release on this field and then, arguably, offers the more mature proposal in the framework of Standard Based Software Product Quality.

In the SQuaRE proposal [16,17] the Quality of a system is understood as the degree to which the system satisfies the stated and implied needs of its various stakeholders. It is, thus, necessary to consider Quality from different stakeholder perspectives. The quality models provide a framework with which to collect stakeholder needs. Among the documents in the ISO/IEC standard the 25010 "Quality Model" defines a product quality model composed of eight characteristics which are further subdivided into sub-characteristics (Fig. 2). This model is understood as a structural model that SQuaRE defines as; "Quality model: defined set of characteristics, and of relationships

[1] United States defense standard, often called a military standard, "MIL-STD", "MIL-SPEC" or "MilSpecs".

[2] European Cooperation on Space Standardization.