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Considerations of the Software Metric-based Methodology for Software Reliability Assessment in Digital I&C Systems

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1. Introduction

Analog I&C systems have been replaced by digital I&C systems because the digital systems have many potential benefits to nuclear power plants in terms of operational and safety performance. For example, digital systems are essentially free of drifts, have higher data handling and storage capabilities, and provide improved performance by accuracy and computational capabilities. In addition, analog replacement parts become more difficult to obtain since they are obsolete and discontinued. There are, however, challenges to the introduction of digital technology into the nuclear power plants because digital systems are more complex than analog systems and their operation and failure modes are different. Especially, software, which can be the core of functionality in the digital systems, does not wear out physically like hardware and its failure modes are not yet defined clearly. Thus, some researches to develop the methodology for software reliability assessment are still proceeding in the safety-critical areas such as nuclear system, aerospace and medical devices [1]. Among them, software metric-based methodology has been considered for the digital I&C systems of Korean nuclear power plants. Advantages and limitations of that methodology are identified and requirements for its application to the digital I&C systems are considered in this study.

2. Software Metric-based Methodology

In this section the software metric-based methodology to assess the software reliability quantitatively is reviewed. Recently, this method has been developed by UMD(University of Maryland), which was sponsored by NRC(Nuclear Regulatory Commission) [2].

2.1 Approach

The software metric-based approach uses software metrics gathered in the software development process to predict the software reliability. Software metrics are a set of software engineering measures from which the software reliability can be predicted. For instance, “Line of Code” which assesses the physical size of a code is one of the software engineering measures. On the one hand, IEEE computer society has considered the measures as an indicator of the software reliability, and has published the standard dictionary of software engineering measures for producing reliable software from experts’ research and experience in the software engineering fields. Later, LLNL (Lawrence Livermore National Laboratory) reviewed recent software engineering literature including IEEE standard to identify the proper software engineering measures in measuring the software reliability [3]. So, they found 78 measures for the software reliability and then made a set of ranking criteria to rank them. Although they identified the top-ranked measures, they didn’t investigate the relationship between the measures and the software reliability.

In fact, UMD’s method is based on the LLNL’s prior research. Considering structural category and importance of each measure, UMD reselected 30 software engineering measures from a pool of 78 software engineering measures identified by LLNL. The ranking of these 30 measures was performed by aggregating experts’ opinions based on the ranking criteria.

Table 1. Ranking criteria and definition

Ranking Criteria	Definition
Cost	Estimates the effort required to implement and use the measure
Benefit	Estimates the avoidance of costs that would be incurred if the measure was not used
Validation	Determines how extensively the measure has been validated
Credibility	Rates the measure in terms of its documented goals
Experience	Rates the commercial experience in using the measure
Repeatability	Repeated application by the same or different people results in similar results
Relevance to Reliability	Scores the level at which the measure is relevant to software reliability prediction

2.2 Top-ranked measures

As a result, top-3 ranked measures were obtained as shown in Table 2. The selected measures were categorized by the software development phase such as requirement, design, implementation, and testing since all measures are not applicable to each phase and their importance is significantly different in each phase. Detailed application and implementation of each measure are described in IEEE standard 982.1 [4].

Table 2. Top-3 ranked measures phase by phase

Phase	Top-3 Ranked Measures
Requirements	Fault density, Requirements specification change requests, Error distribution
Design	Design defect density, Fault density, Cyclomatic complexity
Implementation	Code defect density, Design defect density, Cyclomatic complexity
Testing	Failure rate, Code defect density, Mean time to failure

2.3 Reliability Prediction System

Additionally, UMD defined a concept of reliability prediction system(RePS), which is a complete set of measures by which software reliability can be predicted. The concept of RePS was introduced to investigate the relation between the selected measures and the software reliability because the measures themselves don't reflect the reliability directly. The RePS is composed of a root measure and several support measures, and constructed the software reliability prediction from them. Currently, several RePSs were respectively constructed from each high-ranked measure, not all measures, because it is practically difficult task to combine the root measure and the support measures.

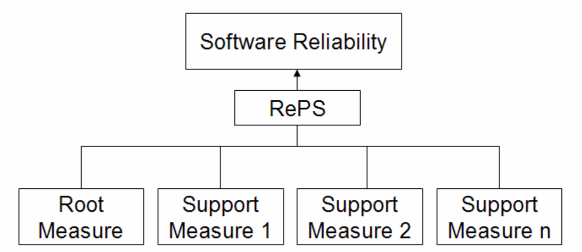

Figure 1. Simple structure of RePS

3. Advantages, Limitations and Requirements for Application

Main advantage of this metric-based methodology is that it is relatively easy to gain the measures, which are results of the mature software development process. Also, it can be easily included into the probabilistic safety assessment of nuclear power plants as a final goal. However, it has some limitations. The reliability is a property of product, not of the software development process, and the reliability constructed from the measures in each phase can be different in operation phase of the software. Because the measures were chosen by experts' opinion, some measures for the reliability might be modified and deleted or new ones can be added as the software development continues. In fact, in the revised version of IEEE standard 982.1 [5], the measure "Defect density" was modified for generalization and simplicity and some measures such as "Error distribution", "Cyclomatic complexity" were deleted because of correctness and difficulty in implementation.

To apply UMD's method to the digital I&C systems of Korean nuclear power plants, the following should be required. First of all, failure data from operating experience relating to the software should be collected. So, it can be determined if the RePS constructed from the measures is valid for predicting the software reliability. Second, because top-ranked measures are different according to each phase of the software development process, this method should be simultaneously performed with development of the software which will be used in digital I&C systems. After the release of final software version, RePS might be constructed from the measures of only testing phase and then actual reliability value can be different. Third, before applying it to the actual system, the measures for the reliability should be updated because the measures selected by IEEE computer society as indicators of the reliability might be modified and added as the software development continues.

4. Conclusions

The software metric-based methodology performed by UMD is a latest analytic and systematic approach for predicting the software reliability although it is difficult to quantitatively estimate the accuracy of the reliability prediction. In this study, the advantages and limitations of the methodology were identified and requirements for its application to the digital I&C systems were drawn from them.

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