Software Requirements Risk and Maintainability

Norman F. Schneidewind
Naval Postgraduate School, USA

INTRODUCTION

In order to continue to make progress in software measurement, as it pertains to reliability and maintainability, there must be a shift in emphasis from design and code metrics to metrics that characterize the risk of making requirements changes. By doing so, the quality of delivered software can be improved because defects related to problems in requirements specifications will be identified early in the life cycle. An approach is described for identifying requirements change risk factors as predictors of reliability and maintainability problems. This approach can be generalized to other applications with numerical results that would vary according to application. An example is provided that consists of 24 space shuttle change requests, 19 risk factors, and the associated failures and software metrics.

In addition to the relationship between requirements and reliability and maintainability, there are the intermediate relationships between requirements and software metrics (e.g., size, complexity) and between metrics and reliability and maintainability. These relationships may interact to put the reliability and maintainability of the software at risk because the requirements changes may result in increases in the size and complexity of the software that may adversely affect reliability and maintainability.

BACKGROUND

Several projects have demonstrated the validity and applicability of applying metrics to identify fault prone software at the code level (Khoshgoftaar & Allen, 1998; Khoshgoftaar et al., 1996a, 1996b; Schneidewind, 2000). This approach is applied at the requirements level to allow for early detection of reliability and maintainability problems. Once high-risk areas of the software have been identified, they would be subject to detailed tracking throughout the development and maintenance process (Schneidewind, 1999).

Much of the research and literature in software metrics concerns the measurement of code characteristics (Nikora et al., 1998). This is satisfactory for evaluating product quality and process effectiveness once the code is written. However, if organizations use measurement plans that are limited to measuring code, the plans will be deficient in the following ways: incomplete, lack coverage (e.g., no requirements analysis and design), and start too late in the process. For a measurement plan to be effective, it must start with requirements and continue through to operation and maintenance. Since requirements characteristics directly affect code characteristics and hence reliability and maintainability, it is important to assess their impact on reliability and maintainability when requirements are specified. As will be shown, it is feasible to quantify the risks to reliability and maintainability of requirements changes — either new requirements or changes to existing requirements.

Once requirements attributes that portend high risk for the operational reliability and maintainability of the software are identified, it is possible to suggest changes in the development and maintenance process of the organization. To illustrate, a possible recommendation is that any requirements change to mission critical software — either new requirements or changes to existing requirements — would be subjected to a *quantitative* risk analysis. In addition to stating that a risk analysis would be performed, the policy would specify the risk factors to be analyzed (e.g., number of modifications of a requirement or *mod level*) and their threshold or critical values. The validity and applicability of identifying critical values of metrics to identify fault prone software at the code level have been demonstrated (Schneidewind, 2000). For example, on the space shuttle, rigorous inspections of requirements, design documentation, and code have contributed more to achieving high reliability and maintainability than any other process factor. The objective of these policy changes is to prevent the propagation of high-risk requirements through the various phases of software development and maintenance. The payoff to the organization would be to reduce the risk of mission critical software *not* meeting its reliability and maintainability goals during operation.

APPROACH TO ANALYZING REQUIREMENTS RISK

By retrospectively analyzing the relationship between requirements and reliability and maintainability, it is possible to identify those risk factors that are associated with

Table 1. Change request hierarchy

Change Requests (CRs)
- 1. No Discrepancy Reports (i.e., CRs with no DRs)
- 2. (Discrepancy Reports) or (Discrepancy Reports and Failures)
    - 2.1 No failures (i.e., CRs with DRs only)
    - 2.2 Failures (i.e., CRs with DRs and Failures)
        - 2.2.1 Pre-release failures
        - 2.2.2 Post-release failures

reliability and maintainability. In addition, risk factors are prioritized based on the degree to which the relationship is statistically significant. In order to quantify the effect of a requirements change, various risk factors were used, which are defined as the attribute of a requirement change that can induce adverse effects on reliability (e.g., failure incidence), maintainability (e.g., size and complexity of the code), and project management (e.g., personnel resources).

Table 1 shows the Change Request Hierarchy of the space shuttle, involving change requests (i.e., a request for a new requirement or modification of an existing requirement), discrepancy reports (i.e., DRs: reports that document deviations between specified and observed software behavior), and failures. In Table 1, Category 1 versus Category 2 was analyzed with respect to risk factors as discriminants of the categories.

Categorical Data Analysis

Using the null hypothesis, Ho: A risk factor is not a discriminator of reliability and maintainability versus the alternate hypothesis H_1: A risk factor is a discriminator of reliability and maintainability, categorical data analysis is used to test the hypothesis. A similar hypothesis was used to assess whether risk factors can serve as discriminators of metrics characteristics. Requirements, requirements risk factors, reliability, and metrics data from the space shuttle *"Three Engine Out"* software (abort sequence invoked when three engines are lost) were used to test the hypotheses.

Table 2. Definition of samples

Sample	**Size**
Total CRs	24
CRs with no DRs	14
CRs with (DRs only) or (DRs and Failures)	10
CRs with modules that caused failures	6
CRs can have multiple DRs, failures, and modules that caused failures. CR: Change Request. DR: Discrepancy Report.	

Table 2 shows the definition of the change request samples that were used in the analysis. Sample sizes are small due to the high reliability of the space shuttle software. However, sample size is one of the parameters accounted for in the statistical tests that produced statistically significant results in certain cases.

To minimize the effects of a large number of variables that interact in some cases, a statistical categorical data analysis was performed incrementally. Only one category of risk factor at a time was used to observe the effect of adding an additional risk factor on the ability to correctly classify change requests that have *No Discrepancy Reports* versus change requests that have ((*Discrepancy Reports Only*) *or* (*Discrepancy Reports and Failures*)). The Mann-Whitney test for difference in medians between categories was used because no assumption need be made about statistical distribution. In addition, some risk factors are ordinal scale quantities (e.g., modification level); thus, the median is an appropriate statistic to use.

RISK FACTORS

One of the software process problems of the NASA Space Shuttle Flight Software organization is to evaluate the risk of implementing requirements changes. These changes can affect the reliability and maintainability of the software. To assess the risk of change, the software development contractor uses a number of risk factors. The following are the definitions of the 4 out of 19 risk factors that were found to have a statistically significant relationship with reliability and maintainability. The names of the risk factors used in the analysis are given in quotation marks.