A System Model for Managing Requirement Traceability Matrices via Statistical Artifact Change Analysis

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1. Introduction and Motivation

The system Requirement Traceability Matrix (RTM) is primarily used for ensuring that all requirements are fulfilled by the system artifact deliverables and the management of change to deliverables with respect to impact on other systems. In the systems engineering and system of systems (SoS) engineering landscapes, the RTM is a tool that is useful at time of creation, but requires constant maintenance in a frequently changing landscape to maintain the original level of validity. The dynamic nature of systems and SoS engineering landscapes requires that a RTM be constantly regenerated in order to maintain this original level of accuracy. However, in highly complex and rapidly changing systems, this becomes an unrealistic proposition. The motivation of our research is the development of a system model which will statistically determine the dependability of the RTM based on the types of changes that have taken place since the most recent generation of the RTM, thereby providing a level of dependability to change management groups working with systems and SoS developers.

2. Advancement to State-of-Art

The current state of Systems and SoS Engineering relies on generated RTMs for analysis of overlap between requirements and system artifact deliverables to identify the impact of change to the system. It is difficult, expensive, and effort-intensive to maintain and especially predict the dependability of RTMs. As a result, the RTM in use can be outdated with its dependability unknown to change management groups, which can introduce additional change risk to the system or SoS development and evolution. This risk is accumulated as more changes are introduced while the system RTM is not updated.

In our research, we have performed a proof-of-concept study in analyzing the change patterns of more than sixty top-level requirements over three large scale open source software systems (Gantt, jHotDraw, and ReactOS). The analysis is taking place over at least three adjacent versions and includes a greater than 3 year commit history. All three systems have full release versions available and have active user communities which have become the main sources of requirement and system implementation changes.

Based on this knowledge and having a valid trace at a point in time $t = 0$, we will examine changes mined from the respective CVS repositories over at least one subsequent ($t = 1$) or previous ($t = -1$) version of the system source code. Identifying the changes in code, changes in the RTMs, and the types of changes that have taken place will allow us to model the impact of specific types of implementation changes over time to the RTM of a given system. The collected changes will be identified as a specific taxonomy of change that will be available for classifying of types of system implementation change and the further analysis of the impact of different types of system changes to the RTM. After collecting trace data from the multiple versions of multiple projects, as well as the collected information regarding changes that have taken place and been translated to the proper change taxonomy, our approach aims to build a statistical model of the impact of changes over time to the RTM based on each type of system changes. The advancement to the state-of-the-art will be the ability to statistically predict the dependability of the RTM based on the types and number of changes observed during the system evolution, thereby allowing for an empirical evaluation of the RTM for validity based on the changes proposed, thus reducing the risk of changes in a highly dynamic or complex system.

While examining existing results and identifying the known impacts of change on RTMs, we can speculate that there will be a value to knowing not only the individual change that take place after an RTM is generated, but also the order and dependency of the changes and the various types of changes. The statistical model of dependability will be able to evolve over time by differing types and combinations of changes to the RTM for any given set of requirements and system artifact deliverables.

3. Potential Impact on Systems Engineering

After examining the types and availability of trace data, based on our proof-of-concept study we envision that this research will positively impact the domain of systems engineering at many levels. As the taxonomy of changes can be modified for the scope under investigation, it is essentially a scalable solution that will be applicable and useful for requirement traceability management from the scope of individual system to the SoS.

Specific impacts include:

- A comprehensive understanding of the types of changes which impact a system the most. The taxonomy of change will classify the types of system implementation changes. While all changes impact a system, some will undoubtedly impact the system more than others. The knowledge of the level of impact associated with change types will be beneficial to system or SoS change management during development and evolution.
- A systematic vision on the impact of system changes to the RTM. While an RTM may exist within the parameters of acceptable validity before a change is introduced, it will be possible to predict the impact of the next change to the RTM validity, thereby proactively driving regeneration of the RTM if required. This will reduce the effort to having a valid RTM as well as reduce the speculation of RTM validity at any given time.
- Knowledge of RTM dependability. The RTM is assumed to be correct at a time $t = 0$. Based on the number and types of changes that have been applied since $t = 0$, what is the dependability of the RTM while being used to manage future change?