

Independent Verification and Validation (IV&V) Techniques for Object Oriented Software Systems

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Summary

This paper presents an Independent Verification and Validation (IV&V) framework for the emerging use of Object Oriented (OO) techniques for large-scale NASA systems. The paper is focused on use case analysis. IV&V is most beneficial if the analysis is performed during early phases of the software development. This paper presents IV&V framework with an emphasis on use case prioritization and use case complexity analysis techniques. A full report by authors [4] describes a complete set of suggested techniques for use case analysis.

1 Objectives

The shift from the traditional function-based development to OO development, while capable of providing advantages for the development and maintenance of a system, introduces a unique set of lifecycle risks. There is a need to develop techniques for mitigating such risks while improving the quality of the developer's products.

This research study proposes an IV&V framework for use cases based on the following steps:

1. Prioritize use cases by: rating stakeholders, rating use case, and finalizing, use case dependencies.
2. Prioritize use case packages based on the number of high priority use case grouped in that package.
3. Evaluate use case complexity using metrics.
4. Establish base value of system complexity based on use cases.
5. Finalize the prioritization of use case and develop use case priority list (UPL).
6. Select the group of use case high in the UPL.
7. Perform the analysis on the selected use cases, such as: System boundary analysis, Use case precision analysis, Analysis of use case element names, Evaluate sponsorship, Evaluating transition processes, and Evaluate testability.
8. Analyze adequacy of test cases in developer's plans. Develop off-nominal test cases for independent testing

2 Methods and Procedure

IV&V framework incorporates different techniques in a structured form. The framework consists of a schema, a set of techniques, and a set of metrics. The schema sets up the IV&V goals, and defines a set of constraints. The IV&V goals in the schema are to mitigate developer and IV&V related risks. These goals guide the application and development of a set of analysis steps and related metrics as described below. This framework will be enhanced based on the future work.

2.1 Prioritizing Use cases

Budget and staff resources can limit the level of IV&V analysis. During the process of validation and verification, the analyst should know which cases are more important so as to fully analyze them. A set of techniques that can prioritize use cases from a use case model would help reduce time and cost and improve quality.

2.1.1 Schema for prioritization

Two levels are used for prioritizing use cases as suggested in [1]. The first level determines which use cases are important to the success of the software. Input to this level consists of essential use case. The second level concentrates on which scenarios of each important use case needs to be identified and elaborated.

2.1.2 Use case prioritization technique

Moisiadis [1] bases this technique on two groups of actors: Stakeholders, System analyst. These stakeholders are given a rating based on the stakeholder's role, skill-level, and position in the organization etc. Then the use cases are rated for the actors based on: stakeholders rating, essential use case rating, business goals rating etc.

2.1.3 IV&V Customization

This technique can be adapted for the IV&V use by introducing specific actors: developers, customer, and IV&V analyst, and use case criteria: system criticality, and severity goals. In the final step, the IV&V analyst will rate the skills of developers and the maturity of the development process. After completing the prioritization analysis of use cases, use case packages are rated

based on the number of high priority use case grouped in that package.

2.2 Evaluating use case complexity

Complexity of a use case grows more than linearly with the number of its communications [2]. An IV&V analyst will perform the following activities:

1. Verify the scope of actors. It may have been defined too broadly if there were too many relationships between actors and use cases.
2. Verify generalization of actors. Use case notation provides actor generalization for describing the commonality of actor roles [3].

Marchesi [2] presents metrics for measuring complexity of use case based on communication between actors and use cases, where the number of use cases is measured as: $UCI = N_U$. IV&V plans to utilize these metrics as part of the framework.

2.2.1 Use case total communications metric

This metric is developed to measure overall number of communications regardless of extend, and use relationships and represented by the following equation.

$$UC2 = \sum_{i=1}^{N_U} [\sum_{k=1}^{N_A} [C_{ik}]]$$

2.2.2 Communications metric without redundant relationships

This metric eliminates redundancies in communication due to extend and use relationships. [2] defines a matrix $[D]$ that filters the extend relationship redundancies from $[C]$:

$$d_{ik} = c_{ik} - cs(i)k \quad \text{with } c0k = 0, \text{ for all } k$$

Matrix $[E]$ eliminates from $[D]$, the communication redundancies due to use relationship as:

$$e_{ik} = 0 \quad \text{if } d_{ik} = 0;$$

$$e_{ik} = 0 \quad \text{if } d_{ik} = 1; \text{ and } \exists k \in \nu(i) \text{ such that } d_{ik} = 1$$

$$e_{ik} = 1 \quad \text{if } d_{ik} = 1; \text{ and } \nexists k \in \nu(i) \text{ such that } d_{ik} = 1$$

where $\nu(i)$ vector holding the indexes of use cases.

The resulting metric removes redundancies due to extends and use relationship as:

$$UC3 = \sum_{i=1}^{N_U} [(\sum_{k=1}^{N_A} [e_{ik}])]^{k_U}$$

The value of the term k_U accounts for non-linearity must be great than 1. Communication inherited by all use cases extending or using other use cases is:

$$\text{Communication}_{All} = \text{summ}([C]) - \text{summ}([E])$$

Where $\text{summ}([C])$ and $\text{summ}([E])$ are sums of all elements of matrices $[C]$ and $[E]$.

2.2.3 Global complexity of use cases

This is an estimate of the global complexity of the system based on its use cases. The key com-

plexity measurement is the number of independent communications in terms of the metric $UC3$. This metric also needs to take into account the total number of use cases $UC1$ and the degree of communications extended or used. This is because a system with no 'extend' or 'use' relationship is less complex [2] than a system with same $UC3$ but more communications. This is accomplished by introducing the following metric: $UC4 = K_1 UCI^2 + UC3 + K_2 [\text{summ}([C]) - \text{summ}([E])]$, Coefficients k_1 and k_2 are computed empirically [2].

2.3 Develop Use case prioritization list

The IV&V analyst will establish base value of system complexity based on use cases, finalize the prioritization of use case and develop UPL, and select the group of use case high in this list.

2.4 IV&V analysis of use cases

Using UPL, the IV&V analyst will perform the analysis on the selected use cases, such as: system boundary analysis, use case precision analysis, analysis of use case element names, evaluate sponsorship, evaluating transition processes, evaluate testability, analyze adequacy of test cases in developer's plans, and develop off-nominal test cases for independent testing. Details of this analysis are available from the authors' NASA report [4].

3 Conclusions and Summary

This report presents an IV&V framework for OO software systems with use cases. It further builds on existing schema for use case prioritization techniques, and use case complexity analysis. The author plans to expand this framework to other software development phases such as: analysis and design that are based on the OO software specifications.

4 References

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