Assessing the Economic Effects of V&V and IV&V Processes Using Simulation

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Abstract

There is a critical need for cost effective Verification and Validation (V&V) and Independent Verification and Validation (IV&V) on software development projects. The goal of this research is to create a flexible tool and methods that can be used to quantitatively assess the economic benefit of performing V&V and IV&V activities on software development projects and to optimize that benefit on a given project as well as across an organization's portfolio of projects. The Software Process Simulation tool we use is based on extensive research into Software Process Simulation Models (SPSMs) conducted at the Software Engineering Institute (SEI) by Watts Humphrey, Marc Kellner, Bill Curtis, and others.

1. Current Interests

My current research interests include: software process design, financial analysis of software engineering decisions, process simulation, global software development and value based software engineering. Specifically with respect to EDSER related topics, I am interested in: optimization, business case analysis, risk adjusted return on investment and options theory.

2. Past Work

Most of my past work relates to making economic and value-based decisions regarding software process improvements and product functionality. This work may be identified with two main themes as follows:

- Software Process Simulation – With a number of colleagues and students, we have developed a variety of software process simulation models for assessing the impact of tools, technologies, process improvements and process alternatives on software projects. We have utilized state-based, discrete event, and system dynamics methodologies.
- Value Based Software Engineering (VBSE) – With colleagues Stuart Faulk and Robert Harmon, we have developed a process and set of techniques for assessing the customer value associated with software products and features using both financial and strategic measures. Our VBSE process then drives the customer value information all the way through the development process.

3. Issue Statement

Optimizing the benefit of V&V and IV&V activities across the software development lifecycle and across projects.

Type of issue
Strategic, tactical, process, technical.

Context
All process and product types where rigorous V&V and IV&V are conducted.

Stakeholders
Customers, project managers, QA engineers and developers

Information needs
Project demographics regarding type of development, size, process and so forth. We also use data on project effort, schedule, productivity, defect injection and detection rates, as well as rework costs.

4. Proposed Approach

We plan to utilize Software Process Simulation models to predict the benefits and costs associated with a variety of V&V and IV&V activity combinations. The outcomes associated with each configuration will be presented in terms of overall project performance along the dimensions of development cost, product quality and project schedule. These results will be in the form of normal distributions.

Assumptions

Data are available and valid. Models can be built.

Process or Solution

We are using SPSMs to quantify the costs and benefits associated with V&V and IV&V practices enabling management to effectively allocate scarce resources for QA activities. In addition, SPSMs facilitate the analysis of V&V and IV&V activities of Software Development Processes by enabling checks and performance assessments.

Research Methods

We will analyze the output of the SPSMs using a variety of techniques including: utility functions, financial measures and data envelopment analysis (DEA) [17]. Analytic hierarchy process is also useful.

In order to determine which process configuration and set of techniques are preferred, we need to evaluate each alternative. Since there are multiple process measures of performance, a tradeoff may need to be made of one performance measure over another. Several methods for conducting this tradeoff are discussed below:

1. ***Comparison of performance measure differences using a utility function***. When running a simulation model, results are obtained for the AS-IS and TO-BE processes and the differences between the performance measures are obtained. If these differences show conflicting results where some performance measures worsen and others improve, a tradeoff by the decision-maker must be made. In this case, developing a utility function reflecting management's preferences can be a helpful way to assess the tradeoff and to reduce multiple performance measures down to one number. This overall measure can be checked for statistical significance and a decision can be taken.

2. ***Comparison of performance measure differences using financial measures such as Net Present Value [5]***. This approach is very similar to the approach using a utility function. Net present value or other financial measures are calculated using a certain kind of utility function where all performance measures are reduced to cash equivalents. The most difficult performance measure to reduce to a cash equivalent typically is schedule, because good estimates describing the dollar value associated with releasing the product earlier or later are difficult to obtain. Once the cash equivalents are determined a simple internal rate of return, net present value or risk adjusted rate of return calculation can be used.

3. ***Comparison of overall performance measure values using Data Envelopment Analysis (DEA) [2].*** DEA may be viewed as an optimization technique that finds an "efficient frontier", i.e., a select set of process configurations that are potentially the most efficient given the input set. DEA works like this: For any given configuration, the DEA program determines a set of objective function weights that is most favorable to the given configuration. Suppose the given configuration has one of the best (shortest) schedules, but more defects and higher costs than most of the other configurations. Hence, the given configuration would want the schedule parameter to be valued most in the objective function. The DEA program sets the weights for this objective function and then evaluates all other configurations according to this "schedule heavy" objective function. If the given configuration is the best using this objective function, it is held as a candidate for the optimal set. If another configuration beats the given configuration using the given configuration's objective function, the DEA program knows that the given configuration is sub-optimal and discards it. The DEA program evaluates all the configurations in this manner and determines an efficient frontier from which final selections can be made.

4. ***Analytic Hierarchy Process (AHP)[19], [20].*** When the comparison among alternatives contains few alternatives and many quantitative and qualitative criteria that must be compared, using analytic hierarchy process is a useful approach. Through a process of pair-wise comparisons the best alternative on each criteria is found and the relative weights associated with each criteria are assigned. The end result is a selection of the most preferred alternative based upon criteria.

Previous work

A variety of simulation approaches have been applied to software development activities [10], [13] and [14]. Discrete event simulation (DES) models of specific software processes have been reported in the literature [4], [6], and [18] among others. These models have been useful in predicting the cost and benefits associated with a number of different process changes and process variations. However, these models have not been built with the goal of application to IV&V projects.

The system dynamics (SD) paradigm (continuous system simulation) [1], [11], and [21] has also been used to represent portions of development and QA processes of the software development process. The SD models have the advantage of being able to effectively represent dynamic project concerns, such as worker motivation, and schedule pressure. However, these models assume that all work products flowing through the system are identical.

Other researchers have represented the software development process from the view of the developer using artificial intelligence based rules [12]. However, the level of detail captured by these representations, in our view, obscures the cost/ benefit performance picture.

Accordingly, we believe that DES models representing the software development process as distinct process steps, as would be found in a work break down structure, offers the best approach for modeling the performance of software development processes when the structure of the process is an important consideration in determining the costs and benefits associated with various process alternatives. Specifically, in order to evaluate different V&V and IV&V techniques, in different combinations on different projects, our experience indicates that the discrete event paradigm using stochastic simulation models is most appropriate.

In previous work, Raffo et al. developed a number of Software Process Simulation Models (SPSMs) to predict the impact of various quality assurance techniques in terms of cost, quality, and schedule [15][16][18] at a variety of organizations that develop commercial, government and military applications. This work has been based on extensive research into software process modeling conducted at the Software Engineering Institute (SEI) by Watts Humphrey, Marc Kellner, Bill Curtis, and others [3][7][8] and [9]. Raffo's research specifically focuses on determining the costs, benefits and return on investment (ROI) associated with implementing testing and inspection processes in various combinations throughout the process lifecycle. The result is an economic justification/ business case for process improvement efforts that managers can understand and use when setting budgets and trading-off among multiple process improvement activities.

Moreover, due to the extensive sensitivity or "What if" analyses that can be done while using simulation, not only can SPSMs be used to plan for the expected case, they can also be used to assess the impact of changes in development environment on IV&V (and V&V) techniques as well as determine ways to improve IV&V and V&V applications.

5. Results, Status, Prospects, and Needs

We are in the process of collecting data and building models. However, initial results assessing the performance of various V&V and IV&V configurations based on preliminary data look interesting and useful.

6. Open Issues

We are looking at approaches for how to optimize resources across projects. The key question is: How to compare the value of different projects?

7. References

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For a good overview of Software Process Simulation, see [10].

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8. Biography

Dr. Raffo is currently an Associate Professor at Portland State University. He has joint appointments in the School Business Administration (Information Systems and Supply & Logistics Management) and in the College of Engineering and Computer Science (Department of Computer Science). Dr. Raffo completed his Ph.D. at Carnegie Mellon University and the Software Engineering Institute (SEI). His research interests include: Software Process Design, Financial Analysis of Software Engineering Decisions, Process Simulation, Global Software Development and Value Based Software Engineering. Dr. Raffo has over thirty refereed publications in the field of software engineering and is co-Editor-in-Chief of the international journal of *Software Process: Improvement and Practice*. He has received research grants from the National Science Foundation (NSF), the Software Engineering Research Center (SERC), NASA, IBM, Tektronix, Motorola and Northrop-Grumman. Prior professional experience includes programming as well as managing software development and consulting projects at Arthur D. Little, Inc. Dr. Raffo teaches courses in Software Process Improvement, Software Process Modeling and Simulation, Systems Analysis and Design, and Statistical Process Control.