Reducing Risk by Segmentation

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ABSTRACT

The paper provides analysis of the various mechanisms through which the segmentation improves reliability and reduces technical risk and presents a classification of risk-reduction techniques based on segmentation. On the basis of theoretical arguments and examples, it is demonstrated that segmentation increases the tolerance of components to flaws causing local damage, reduces the rate of damage accumulation and damage escalation and reduces the hazard potential. The paper also demonstrates that segmentation essentially replaces a sudden failure on a macro-level with gradual deterioration of the system on a micro-level through non-critical failures. It is demonstrated that segmentation can even reduce the likelihood of a loss from opportunity bets and the likelihood of erroneous conclusion from imperfect tests. Finally, a comprehensive classification of methods and techniques for reducing risk, based on segmentation, has been proposed.

KEYWORDS

Generic Principles, Reliability Improvement, Risk Reduction, Segmentation, Technical Risk

1. INTRODUCTION

A systematic classification of generic methods for reducing technical risk is crucial to safe operation, to engineering designs and software, yet this very important topic has been overlooked in the reliability and risk literature. For many decades, the focus of reliability research has been primarily on reliability prediction instead of reliability improvement.

Work on formulating generic principles and methods for improving the reliability of engineering components and systems has already been done in (Todinov, 2007, 2015). The generic reliability improvement and risk reduction methods and principles are especially suited for developing new designs, with no failure history and with insufficiently researched failure mechanisms. The present paper contributes an important generic reliability improvement and risk reduction method referred to as ‘the segmentation method.’ Segmentation is the act of dividing an entity (assembly, system, process, task, time, etc.) into a number of distinct parts. Segmentation is often combined with its antipode - aggregation. Aggregation is the act of combining a number of distinct parts into a whole.

Reducing the variation of returns by segmenting and diversifying an investment portfolio into many non-correlated stocks is a well-documented technique for reducing financial risk by segmentation. With increasing the number of non-correlated stocks, the variance (volatility) of the portfolio, which is a measure of the risk associated with the portfolio returns, is reduced significantly (Teal and Hasan, 2002).

Micro-segmentation, aimed at improving the cyber security by isolating different applications and parts of computer networks has been discussed in (Mämmelä et al., 2016).

The struggle between the need of increasing efficiency and reducing the weight of components and systems and reliability is a constant source of technical and physical contradictions. In this
respect, the method of segmentation has been used as one of the principles for resolving technical contradictions in the development of TRIZ methodology for inventive problem solving (Altshuller, 1984, 1996, 1999). However, the formulated principle of segmentation was primarily formulated as a tool for generating inventive solutions by resolving technical or physical contradictions and not as a tool for reliability improvement and risk reduction. Some examples of patents using segmentation to improve reliability have indeed been listed in (Altshuller 1984, 1996, 2007), but no specific discussion has been provided related to the mechanisms through which segmentation actually works in increasing reliability. No discussion regarding the mechanisms through which segmentation works exist in more recent literature related to TRIZ (Terninko et al, 1998, Savransky, 2000; Orloff, 2006; Orloff, 2012; Rantanen and Domb, 2008; Gadd, 2011). The insufficient understanding why segmentation actually works does not allow reaching the full potential of this technique, particularly in the area of reliability improvement and risk reduction.

In addition, the segmentation as a problem-solving tool in TRIZ has been introduced in a rather narrow context: primarily as size segmentation or time segmentation. However, a physical division of the size is not the only instance when segmentation is present. Segmentation is also present when no physical division is done but additional boundaries with different properties are introduced in the homogeneous component. Such is the case of welding stiffening rings around an underwater pipeline, at regular intervals. The purpose of these rings is to restrict the eventual collapse of the pipeline between two welded rings, thereby minimising the extent of damage. Segmentation is present without the existence of a physical division of the whole object.

In addition, the TRIZ methodology does not consider a logical segmentation where no physical division exists yet the system is still segmented. In a logical segmentation of a computer network into several distinct parts for example, no reduction of size or complexity exists. In effect, during a logical segmentation, the barriers set between the different parts of the network increase complexity.

Essentially, the logical segmentation has been used as a very efficient problem-solving tool, long before the emergence of the TRIZ methodology and many other methodologies for creative problem solving. Segmentation is at the heart of one of the biggest inventions in mathematics - the differential and integral calculus. In determining the volume of an object with complex shape by double integration, for example, the volume is essentially converted into segments/slices with the same infinitesimal thickness and with cross-sectional area dependent on the position along one of the coordinate axes. In turn, the cross-sectional area of each slice is essentially converted into segments (multiple strips) with the same width and height dependent on the position of the strip along another coordinate axis. As a result, the evaluation of the complex volume is essentially reduced to two sequential summations (integrations) involving segments.

Another powerful problem-solving strategy based on segmentation has also been known for a long time - the divide-and-conquer strategy. This is a powerful strategy for solving seemingly intractable problems by combining segmentation and its antipode - aggregation.

The divide-and-conquer approach breaks a problem into simpler sub-problems for which solutions can be obtained with the available means. Next, the obtained solutions are aggregated (merged) until the solution of the initial problem is obtained. The divide-and-conquer approach is at the heart of the heapsort algorithm for sorting arrays of large size n, whose worst-case running time (unlike the worst-case running time of the quicksort algorithm) is always $O(n \ln n)$ (Sedgwick, 1992).

Segmentation combined with aggregation is also at the heart of the decomposition method for system reliability analysis (Todinov 2007) where the initial complex system is decomposed into simpler systems upon the condition of a single key component or several key components. The resultant systems can in turn be decomposed and so on, until trivial systems with simple solutions for their reliability are obtained. The system reliability of the initial system is obtained by aggregating (combining) the system reliabilities of the obtained trivial systems. Finally, segmentation of a complex task into multiple simpler manageable sub-tasks has always been a cornerstone in managing the execution of projects.
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