

ABSTRACT OF PAPER FOR THE ANNUAL RELIABILITY AND
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TOPIC “R&M Cost vs. Benefit Tradeoffs”

**Towards Cost-Effective Reliability
through Visualization of the Reliability Option Space**

(Author information omitted for purposes of “blind” review)

Problem addressed

In planning a complex system’s development there can be many options to improve its reliability. Typically their sum total cost far exceeds the budget available, so it is necessary to select judiciously from among them. Reliability models can be employed to calculate the cost and reliability implications of a candidate selection. However, there will typically be many – very many – such candidate selections. Consider for example the development of a piece of advanced technology: there are many ways to improve its reliability: build it from high-quality components, educate and train the assembly team, employ computer based design aids, perform design-time analyses, conduct reviews, inspections and tests, build in protection from possible environmental hazards, use redundancy to achieve a fault-tolerant design, etc. Each of these presents in turn a series of further choices (e.g., of which parts to make from high quality components, of which tests to perform).

In a technology development representative of our problem area there were 36 individual options, so the number of possible selections from such was 2^{36} (more than 10^{10}). Other studies of ours have involved even greater numbers of choices, with correspondingly larger option spaces. We employ heuristic search techniques to explore reliability cost-benefit spaces. The results of these machine-conducted searches then have to be presented back to the expert designers to assist them in their decision making. This is where we made use of *visualization*. The aim of this is to support those expert designers in two key ways:

1. **Understanding the overall cost-benefit trade space.** That is, understanding how much reliability can be attained for a given level of expenditure, and how much additional reliability can be had for a modest increase in expenditure.

2. **Understanding the contribution of individual options.** That is, understanding when an individual option (e.g., a test) contributes cost-effectively to the overall reliability (and, by implication, understanding when it is *not* cost-effective!).

Visualization of the overall cost-benefit tradeoff profile provides guidance on what it costs to attain various levels of reliability. Visualization of the effects of individual options within the cost-benefit space provides guidance on the utility of those individual options. The net result is that expert human designers can make cost and benefit informed decisions on attainment of reliability.

The approach is demonstrated on data drawn from planning the developments of advanced technologies.

Work to be described

The full paper will describe the visualizations we use – how we calculate them, how we present them, and how we interpret them.

An example of visualization of the overall cost-benefit trade space is shown in Fig. 1 (next page). The visualization plots a large number (many thousands) of option selections. Each such selection has been evaluated by our reliability model to yield estimates of its cost and benefit (expected attainment of objectives for the technology application in question). The resulting selection is plotted on the chart. Its position along the horizontal axis is determined by its cost estimate (the cost scale increases from right to left). Its position along the vertical axis is determined by its benefit estimate (the benefit scale increases from bottom to top). The black cloud is formed from the plotted points corresponding to many thousands of such option selections. The upper left boundary of this cloud represents the “optimal” frontier (referred to as the “Pareto front” in the optimization literature). From this plot is easy to discern the

relationship between increasing the expenditure and getting increased reliability in return. Designers can and do use this information to guide them as to what overall

development of complex and novel technologies. They have been applied to technology studies conducted over the past year. The paper will illustrate the approach with

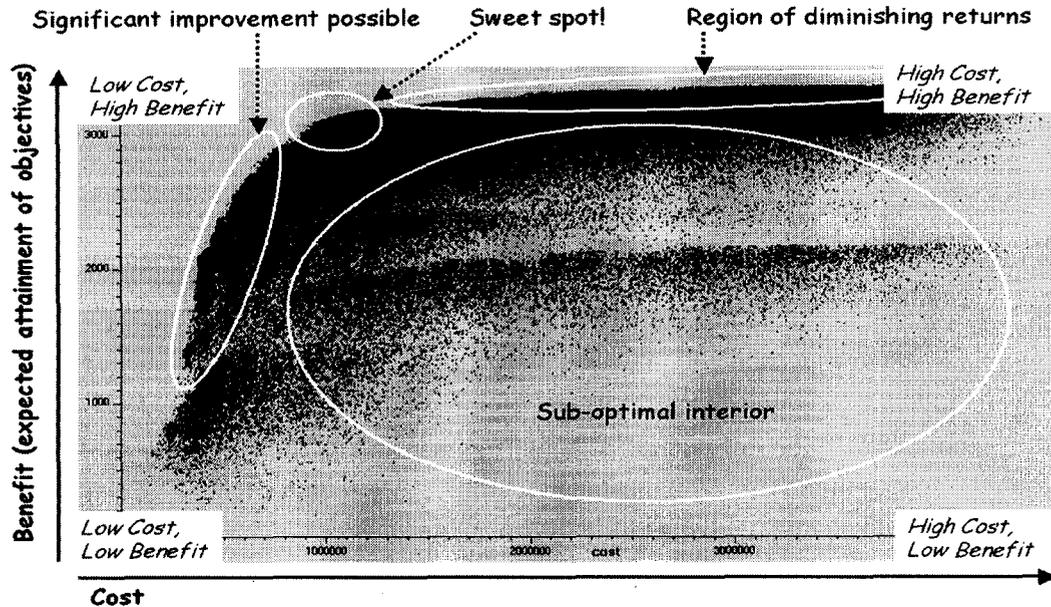


Figure 1. Visualization of the overall cost-benefit reliability option space

levels of expenditure to aim for in their planning.

Further visualizations give insight into the contributions of individual options within this overall space. A fragmentary example is shown in Figure 2. This is the same points as plotted in Fig. 1, but with the points corresponding to selections in which a particular option occurs colored white instead of black (in the interests of brevity, only the top portion of the plot is shown here). From this plot it is evident that the option in question contributes to optimal solutions only in the expensive region. Thus the expert designers would know to use this option if they sought an ultra-reliable design, say, but not otherwise. These kind of visualizations have proven useful to guide designers in understanding the benefits that individual options convey, and gauging the opportune times to apply them.

The status of the work is that implementations already exist of all the visualization capabilities we will describe. These have been incorporated within the software support that we have developed to aid experts in planning the

examples drawn from these studies.

Problem Results

The results of this visualization approach helps expert designers in making cost-benefit informed decisions concerning the reliability of the systems whose development they are planning. To be employed, the approach requires only that there exists:

- a choice of options for achieving reliability, and
- a means to calculate the cost and benefit (reliability) of a selection from among those options.

These results thus have broad applicability.

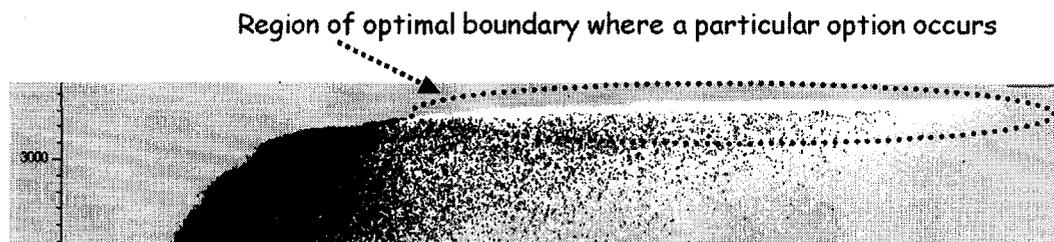


Figure 2. Visualization of the effect of an individual option