The Influence Explorer

Lisa Tweedie, Bob Spence, Huw Dawkes and Hua Su

Department of Electrical and Electronic Engineering,
Imperial College of Science, Technology and Medicine
South Kensington , London, SW7 2BT
Tel: +44 171 594 6261
lisa.tweedie@ic.ac.uk

ABSTRACT

This paper illustrates the benefits, for a wide range of design activities, of Interactive Visualization Artifacts.

INTRODUCTION

In an extremely wide range of design tasks, of which electronic product design is an example, the designer is concerned with the *influence* of the **parameters** - whose values can be chosen - upon the **performances** which are of direct interest to the customer. Interactive visualization allows the fluent exploration of the effect of parameters upon performances and, thereby, the acquisition of insight, a valuable commodity in any design situation.

INFLUENCE PROBLEMS

In any design the performances of an artifact are determined by a set of parameters (Figure 1). Requirements are placed by a customer on the performances F_1, F_2....F_n (**F**). It is then the task of the designer to choose values of the individual parameters P_1,P_2..P_n (**P**) that will lead to a design that satisfies these requirements. There may easily be as many as 100 Ps and Fs of interest. Design is difficult, partly because each performance is determined by many parameters, partly because the relation between **P** and **F** is usually non-linear, and partly because the requirements may be difficult or impossible to satisfy. The greatest difficulty, however, arises because, whereas **F** can be directly calculated if **P** is known, *the reverse is not true.*

Even if a satisfactory parameter set is found, a further complication arises. Uncertainty is always present in the manufacturing process, so that each parameter is characterised, not by a single value, but by a nominal value and a tolerance range. This tolerance range defines the extent to which a parameter may randomly differ from the nominal value. Mindful that wider tolerances are usually associated with lower cost, one of the designer's tasks is to choose a tolerance range for each parameter so that, despite parameter variation within this range, as many mass-produced copies of the artifact pass the specification as possible. The fraction that pass is called the *yield.*

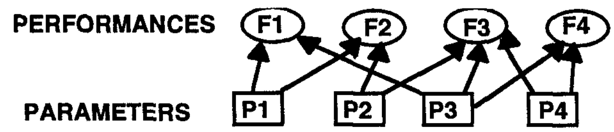


Figure 1: The Parameter -> Performance relationship

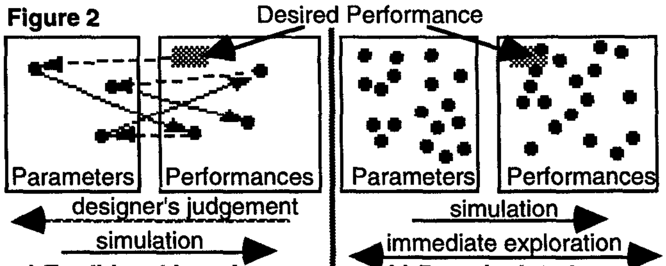
EXPLORATION AND PRE-CALCULATION

Any tool used for design must allow sufficient insight to enable design decisions (i.e. choices of **P**) to be made with confidence. To do this the designer will want to *explore the complex relationship between P and F*. Conventional design, illustrated in Figure 2a, involves many iterations, in one direction (right to left) based on a designer's estimate of the parameter values needed to achieve a desired performance and, in the other (left to right), simulation of the resulting performance. The *overwhelming* difficulty is that of estimating the **P** corresponding to a desired **F**. In the new approach (Figure 2b) parameter space is, first, widely sampled and simulated to provide an equally wide coverage of performance space. The resulting data allows the relationship between **P** and **F** *to be instantly explored in either direction*: the ability to select a region of **F** and immediately observe the corresponding **P** is especially valuable in gaining insight. The immediacy of the exploration also allows *the perceptual benefits of interactive visualization* to be realised.

THE INFLUENCE EXPLORER

The Influence Explorer incorporates this new approach, and is illustrated here by real data relevant to the design of a light bulb. Based on measurements, 4 stresses associated with the bulb are modelled as functions of 4 parameters (its physical dimensions) using Response Surface Methodology [1]. Parameter values within given (wide) ranges are randomly selected for 100 bulbs. The model is then used to calculate the associated performances (the 4 stresses). The data is displayed within the Influence Explorer (figure 3). Vertical scales relate to the four parameters (**P**) and the

Figure 2



a) Traditional iterative simulation

b) Precalculated simulation

horizontal scales on the left to the four performances (F). Histograms show their distributions. A given bulb is represented by one square on each histogram.

Many actions can be taken by the designer. For example in the early stages of exploration the designer may select a range on a scale. All the bulbs within that range will be highlighted on each of the other scales [2]. Another facility allows "main effects" to be judged. When a range is moved up and down a scale, a yellow circle is displayed on each of the other scales. This indicates the average of all the relevant lamps, allowing correlations and trade offs, so crucial to design, to be discovered. The selection of one square (i.e. one bulb) on one histogram highlights that same bulb on the other histograms, and numerical values can be examined. The line joining these squares (figure 3) can be displayed, allowing a number of bulbs to be compared (parallel co-ordinate plots [3]).

The designer can set a specification on the performances and a secondary specification can then be placed on the parameters, indicating a tolerance region (as shown in the lower panel). The crosses represent those bulbs that satisfy both specifications. The squares with dots represent those bulbs which satisfy the tolerance region but not the performance specification. These same bulbs are represented on the performance histograms in black (if they fail one requirement) and grey (if they fail two). It is these bulbs that cause a lower manufacturing yield. The same colour coding is used on the parameter histograms. This gives a simple indication of why the remaining bulbs fail to meet the tolerance region specification.

When a reasonable tolerance region has been found the designer can "zoom in". This recalculates the histograms using the tolerance region as the new parameter ranges for the model. In this way a more accurate understanding of the yield can be gained.

CONCLUSIONS

Initial responses from industrial designers have confirmed the potential value of the Influence Explorer.

ACKNOWLEDGEMENTS

We thank John Nelder and Aarnout Brombacher. This work is funded in part by EPSRC UK and Philips Research. The Influence Explorer was implemented in C by Huw Dawkes.

REFERENCES

[1] Su H., Nelder J. and Spence R. (1994)"Philips Light Bulb Design" Info. Engineering Section Report 94/6 Imperial College

[2] Tweedie L. , Spence R., Williams D. and Bhogal R. (1994)*"The Attribute Explorer"* Video Proceedings CHI'94 Boston, April 24th - 28th , ACM Press

[3] Wegman, E.J. (1990) *"Hyperdimensional analysis using parallel co-ordinates"* Journal of the American Statistical Association, 85, 411, Theory and Methods, pp.664-675

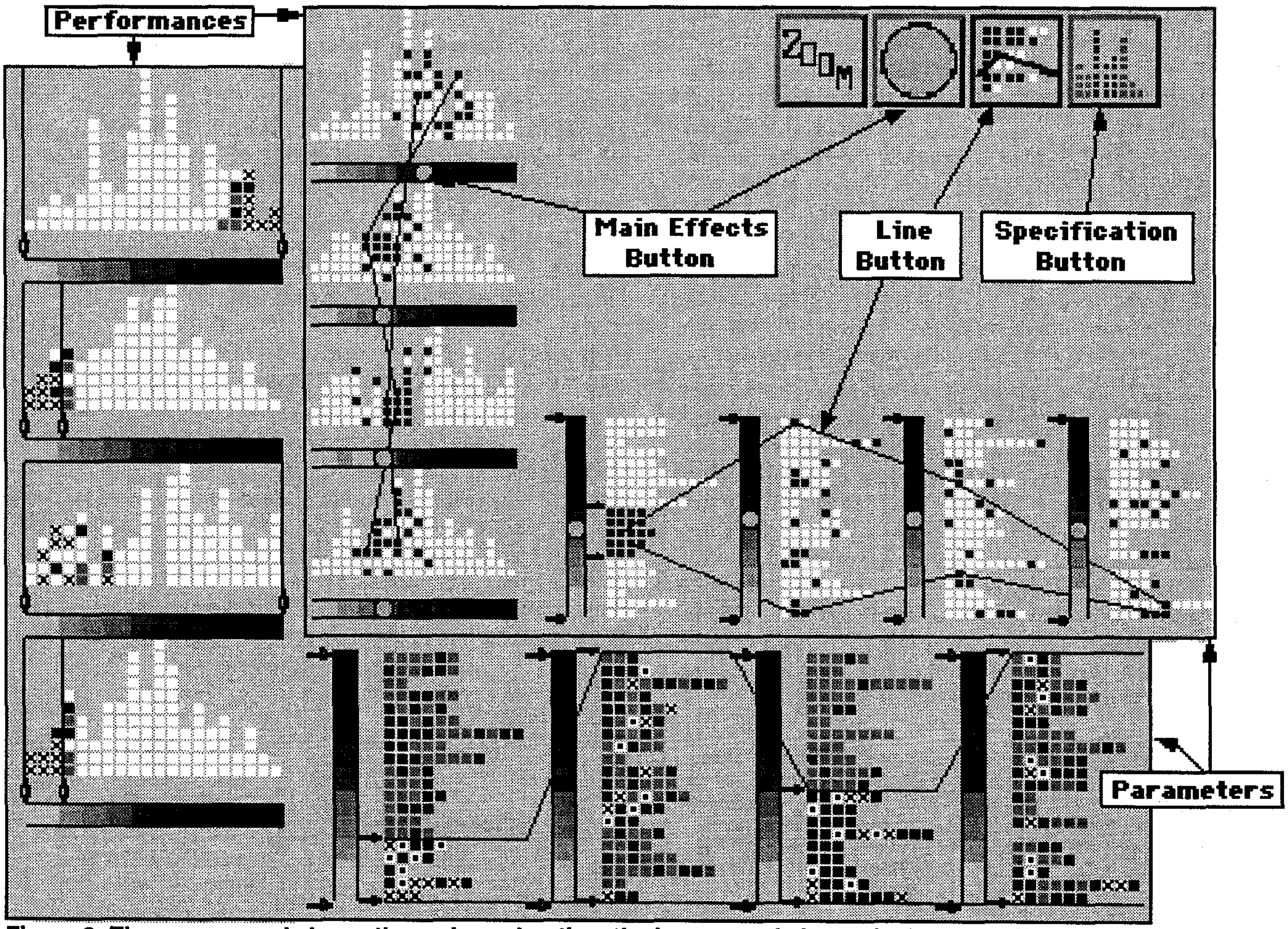


Figure 3: The upper panel shows the early exploration, the lower panel shows the later specification stages.