People and Computers XI

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Proceedings of HCI '96

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Contents

Preface: Maturing Nicely

With this volume, which contains all the submitted full papers selected for presentation at the conference and some of the invited papers of HCI'96, we are starting the second decade of annual conferences of the British HCI Group (A Specialist Group of the British Computer Society). This warrants a brief reflection on the state of the conference and the direction in which it is developing.

In their editorial for the proceedings HCI'85, Peter Johnson and Stephen Cook (1985) stated that:

> "the aim of the conference and the group was to bring together researchers, designers and users of computer systems to discuss and exchange views on the quality of user interfaces".

Growing attendance at the conferences and membership of the group over the past decade have affirmed the need for such a forum.

It is an indication of continuity in HCI research that of the contributors to the HCI'85 proceedings, 4 have a full paper in this volume (Jim Alty, Peter Johnson, John Long, and Alistair Sutcliffe), one is an HCI'96 keynote speaker (Alison Kidd) and 4 served as members of the HCI'96 Conference Committee 11 years on (Gilbert Cockton, Alan Dix, Harold Thimbleby and Bob Spence).

At the same time, the papers in this volume and the overall conference programme reflect a development of HCI which has taken place over the past decade. From a forum of researchers from a range of disciplines in 1985 (Psychology, Computer Science, Ergonomics/Human Factors and Electrical Engineering) exchanging views, the conference has moved to become a showcase of an established discipline at work. Methods and tools, which were the focus of the early years, have moved out into the hands of practitioners who are providing feedback on their applicability to a range of design problems. The industrial and short papers at HCI'96 provide many examples of this, and it is valuable feedback which not only leads to changes in the tools and methods themselves, but also helps to refine and consolidate the theoretical framework of HCI itself.

In their preface to the HCI'95 proceedings, Mark Kirby, Alan Dix & Janet Finlay (1995), identified the challenge that constantly emerging technologies posed to HCI. They suggest that, since new technologies require new approaches, HCI may be denied the opportunity to consolidate its knowledge into established principles, guidelines and tools. Work on relatively new technologies such as CSCW, multi- and hypermedia, which are is well represented in this volume, shows that existing HCI knowledge and tools can provide a good starting point to analyse and shape emerging technologies into usable and useful systems. At the same time, this work generates indeed new findings, methods and tools which need to be integrated in the disciplinary knowledge base.

HCI's focus has been extended from the user interface (screen displays and input/output devices) to a more holistic view which considers the user, the task to be performed, the system to be used for that purpose, in a particular environment. This holistic view can only be obtained through user involvement in the design process, and the papers by Caroline Axtell, Chris Clegg & Patrick Waterson, Simon Buckingham Shum et al. and Stephanie Wilson et al. cover research and application issues arising from user involvement.

This extension will not go far enough for Thomas Green (1995), who, in his invited paper at HCI'95, proposed a move on to "computerless HCI", a discipline which can be applied to any complex information-based artifact. The papers under Fundamental Design Issues in this volume aim to address more general principles such as style (Phil Gray & Steve Draper), games metaphors (Kostas Stathis & Marek Sergot) and the use of 3-D (Alistair Sutcliffe & Uma Patel), though there is still a preference for computer-based implementations to illustrate the principles. In the papers under Specific Design Issues, the system still takes centre stage. In our view, this does not signify lack of progress: the benefit of HCI research which leads to the development of systems for user groups such as visually impaired students (described in the paper by Carol Linehan & John McCarthy) is self-evident.

Rather than being an indication of conflicting developments, the fact that HCI research is able to develop its theory base and solve practical usability problems at the same time is, in our view, the mark of a discipline which is maturing nicely. HCI will continue to address both general and specific design problems, and these two strands should continue to inspire each other, rather than dispute each other's worth.

Another notable development is that, even though HCI'96 is the conference of the British HCI Group, it has become very much an international conference. The papers in this volume report HCI research conducted in Europe, US, Canada and Australia as well as the UK. The conference committee and the British HCI Group are extremely pleased at this development, which reflects a growth in the international reputation of the conference. It also seems to reflect strong international research collaboration in HCI, which is also encouraging. But, as Donald Day's paper reminds us, despite international research collaboration and globally marketed systems, HCI has yet to establish what usability may mean for cultures other than our own, 'Western' one.

Regular attendees of the HCI conferences and others in possession of past proceedings will note that we start the second decade of conferences with a new publisher: HCI proceedings are now published by Springer-Verlag London. We are looking forward to as fruitful a collaboration with Springer as we have had over the last 10 years with Cambridge University Press (CUP). We, on behalf of everyone involved in the last decade of HCI conferences, wish to thank CUP for having published the proceedings on those 10 occasions.

Finally some thought about the selection of papers to be included in the proceedings from those that were submitted. All submitted papers were refereed by 2–3 reviewers (all HCI researchers and practitioners) and a member of the conference committee — the lists of committee members and reviewers appears immediately after this Preface. We, the editors, would like to express our gratitude to all the reviewers for finding the time in to undertake the reviews, and for providing us with candid and thoughtful feedback which made the selection of the final 23 papers from 60 submissions easier.* In the few cases where there was disagreement between the reviewers' reports, the final decision on a paper was made by the Technical Programme Chairs. Perhaps more importantly, constructive feedback helped many of the authors to produce the final version you find in this volume.

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London, June 1996

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*For those fascinated by statistics and who have noticed that there are in fact 24 papers in this proceedings, the extra one — the paper by Victoria Bellotti — is one of the invited papers.

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Fundamental Design Issues

Towards the Total Quality Interface — Applying Taguchi TQM Techniques within the LUCID Method

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Juran defines quality as being 'fit for purpose or use'. It follows clearly from this that an effective interface is an essential ingredient in a quality software product. Whilst the discipline of Human Computer Interaction is maturing quickly, there still remains only limited support for *designing in* quality rather than *evaluating it afterwards*. In this paper the authors present the results of a pilot study within the first stage in the development of the LUCID (Logical User Centred Interface Design) method which attempts to integrate a number of human factor tools within a quality framework. Particularly they focus on the phases which adopt the Taguchi Method for designing quality into products and processes. By adopting such techniques within a practical example, the authors demonstrate how the use of a scientific experimental design strategy, together with conventional statistical tools can assist the selection of the optimum user interface.

Keywords: Taguchi, user centred design, interface design, total quality management.

1 Introduction

1.1 Aims

Designing, maintaining and operating complex computer systems has become a major task both for computer specialists and for the users of their systems. At the same time computers have become so pervasive in every day life that failure or malfunction of software systems can increasingly be life threatening. There have been a number of recent cases where under situations of stress computer users have misunderstood computer output or been unable to operate software successfully. Juran (1979) defines quality as being 'fit for purpose or use'. Clearly there are still cases where the software product is not fit for the purpose.

Whilst Hartson & Boehm-Davis (1993) in a review of user interface development processes and methodologies, recognize that "in one sense considerable progress has been made" they also identify a number of specific key research areas where there remains the need for 'real breakthroughs'. In terms of iterative methodologies Hartson & Boehm-Davis (1993, p.109) state that:

1. "research in the area of formative evaluation needs to focus on iterative evaluation techniques that, in fact, lead to a convergence on a good or at least an improved design"

2. "there is especially a need for techniques that can assign credit and blame, pinpointing why user performance is not up to expected levels in terms of specific interface flaws and shortcomings".

The objective of this paper is to investigate the application of the Taguchi method derived from the philosophy of Total Quality Management within the context of human computer interface design. In order to address issues such as those identified by Hartson & Boehm-Davis, the method suggested proposes to exploit the systems and tools developed recently for rapid prototyping but follows an entirely different philosophy and practical approach.

1.2 Iterative Prototyping

It is widely recognized that the process of determining user requirements for information systems is plagued with uncertainty, ambiguity and inconsistency. In current approaches to rapid prototyping an iterative approach is adopted through the construction of software prototypes for proposed systems. The general procedure followed has been to use rapid prototyping with incremental change based around continuous studies of the prototypes in use in authentic tasks. Often prototyping approaches include a parallel design phase in which several alternatives are explored at the same time. Detailed user interface design often involves prototyping the interface with reference to guidelines and check lists such as those suggested by McGinley & Hunter (1992), Mayhew (1992), or Whiteside et al. (1988). One issue which makes interface design so difficult is the extremely large number of variables (design factors) which effect the resultant usability. Prototyping, in whatever form, as currently practised will identify some, but not all, of these variables. There is limited formality in identifying and investigating how each individual variable alters the end product.

1.3 Usability Engineering

Hewett (1986) emphasizes that interactive systems should be designed iteratively and distinguishes between formative and summative methods for interface evaluation.

Nielsen (1993) describes a life cycle of usability engineering within which usability inspection techniques are adopted. Usability inspection methods are now being widely adopted in large software development organizations. Microsoft and other companies are known to have embraced heuristic evaluation and other inspection methods in recent years (Nielsen, 1995). Heuristic evaluation is the most informal method and involves having usability specialists judge whether each dialogue element follows established usability principles. Other inspection methods include Cognitive Walkthroughs (Wharton et al., 1994), Pluralistic Walkthroughs (Bias, 1994), Feature Inspection (McGinley & Hunter, 1992), Consistency Inspection (Wixon et al., 1994) and Standards Inspection (Wixon et al., 1994). There is evidence, however (Dillon et al., 1993; Smith & Dunckley, 1995), within the mainstream software development community that whilst awareness of such methods is increasing, their adoption remains largely superficial. Whilst usability engineering and inspection methods, if adopted, have been shown to enhance usability, they do not ensure the production of the most usable interface.

1.4 Taguchi Methods and LUCID

The Taguchi approach presented here provides a semi-formal method for interface design and selection, and can be integrated into a range of current approaches. Implemented as part of the developing LUCID methodology it can be used at the early stages of software design, when it would involve brainstorming between users and designers, refinement of ideas, and the selection of alternative design options. Through the use of such a method the designer has a much higher degree of certainty that the interface developed is the most usable one possible, rather than the most usable one met so far.

2 Taguchi Design Method

Taguchi methods were developed by Genichi Taguchi in Japan and their use has spread to both the USA and Europe where, through the use of experimental design, aspects of quality can be pushed back from inspection to design. Taguchi aims to shift resources to the creative design process rather than relying on inspection methods to ensure quality.

Taguchi's ideas for TQM fall into two principal, and related, areas known as the *loss function* and *off-line quality control* (Dale & Plunkett, 1990). The majority of the applications of Taguchi methods are within production control where he defines the quality of a product to be 'the loss imparted to society from the time the product is shipped'. Among the losses, Taguchi includes consumers' dissatisfaction, warranty costs, loss of reputation and loss of market share. In order to investigate quality a quality characteristic (e.g. strength) is identified and losses occur not only when a product is out of a permissible range for the quality characteristic, but when it deviates from its target value. Quality, as defined by Taguchi, is achieved by minimizing deviation rather than mere conformance to specification. As a result emphasis is given to off-line quality control. Here we are concerned with the process of optimizing production processes and product factors (such as the quality of materials, or the temperature of production) in such a way as to minimize item to item variation in the product and performance. Underlying the Taguchi method is the concept that quality is affected by two types of factor: internal or control factors (such as materials) which can be controlled easily and external noise factors (such as maintenance of equipment) which cannot be controlled easily.

The search for the optimum production process often involves conducting a number of experiments where each of the control factors are systematically changed. Taguchi developed a number of tools to enable engineers and designers to improve processes and products. The technique for systematic investigation of conditions is based on the Factorial design method first introduced by Fisher in the 1920's and extensively applied in agrarian and social sciences. However the Taguchi method drastically reduces the number of experiments which have to be carried out by providing a framework for design and also a simplified analysis of results which makes the Factorial design accessible to non-statisticians. In many situations full factorial analysis will involve many experiments. Three factors each with two possible values, or levels, would involve only 2^3, or eight, experiments but fifteen two level factors would involve 32,768 experiments. By using fractional factorial experiments, identified through the use of orthogonal arrays, the number of experiments can be drastically reduced. In the case of fifteen two level factors only sixteen experiments would be necessary. Through statistical analysis techniques the optimum situation (any one of the 32,768 options) could be determined. Full details of the Taguchi process can be found elsewhere (Taguchi, 1986) but we may summarize the standard Taguchi procedure as follows:

2.1 Design and Conduct Experiments

Taguchi experiments are designed according to strict rules. The basic concept is for the design team to agree on the quality characteristic which would be a yardstick for measuring the performance of the product or process under study. The team then identifies the input factors in the development of the product which are considered to influence the quality characteristic of the output. The design of the experiments will be based on the selection of an appropriate orthogonal array. Experiments are then conducted to determine values of the quality characteristic associated with the factor levels determined from the orthogonal array.

Orthogonal arrays are a set of tables devised by Taguchi and are used to determine the minimum number of experiments (in our case prototype interfaces) and their input conditions. The term orthogonal is used in the sense that the arrays are both balanced and ensure independence. Orthogonal arrays are the foundation of the experimental design and are essential to the Taguchi technique. The orthogonal arrays are efficient at obtaining small amounts of data which can then be translated into meaningful and verifiable conclusions.

Firstly the design team has to identify the number of key input factors and the settings or levels of these factors which they want to test. For example it could be decided to investigate an input factor at high, medium and low settings, representing three levels. Frequently just two levels, high and low would be used. When the factors and levels are agreed the orthogonal array can be selected, assigning the factors to columns and determining the conditions for individual experiments. Figure 1 illustrates the first two orthogonal arrays, the L_4 array which would deal with up to

Column	$L_4(2^3)$		
Condition	1	2	3
1	1	1	1
2	1	2	1
3	2	1	2
4	2	2	1

Column	$L_8(2^7)$						
Condition	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Figure 1: Orthogonal arrays.

three factors and the L_8 array which can cope with up to 7 factors. The orthogonal arrays are systematically named as $L_A(B^C)$ where A is the maximum number of experiments, B is the number of levels and C is the number of factors or columns.

Some factors in the design can influence each other and may not be independent. The Taguchi method enables the design study to investigate both the input factors and the suspected interactions between the factors. Taguchi provides a number of tools for dealing with interactions. The interaction between two factors is assigned a column in the orthogonal array. This means that every interaction which is included in the study takes up column space and may mean a larger orthogonal array will be required with an increased number of experiments. The correct columns must be assigned to the interactions, otherwise the results will not be reliable. The orthogonal arrays are independent — every column covers one factor and has the same number of occurrences of each level as every other column. This ensures that any differences in the results are only due to the change of factors. Orthogonal arrays are balanced because there are always an equal number of occurrences of each level in every column. The number of columns dictates the number of single factors or interactions which can be investigated. An $L_8(2^7)$ can deal with seven factors or four factors and three interactions

2.2 Analyse the Results Using ANOVA to Determine Optimum Conditions

The main effects are evaluated and their influence determined quantitatively. This gives the optimum condition and the factorial effects as shown below in the pilot study. ANOVA is performed on the results to identify the relative strengths of the factors. Multiple runs can be carried out and the results analysed and the signal to noise ratios (S/N) calculated. The S/N ratio represents a concept developed by Taguchi as an estimate of the relative strengths of the effects of the system factors vs. the noise in the environment.

2.3 Run a Confirmatory Test Using the Optimum Conditions

A further test of the optimum conditions must be made to confirm the performance.

3 Applying Taguchi Methods to Interface Design

Taguchi techniques have not previously been applied to the development of information systems although they have been applied to the solution of specific software problems, for example by Turton (1994) to genetic algorithms and by Khaw et al. (1993) to optimize the design of neural nets. The Taguchi Method for interface design offers:

1. A disciplined way of developing a user interface.
2. A way of investigating development problems.
3. A cost effective way of investigating alternative interface designs.

In commercial prototyping approaches there is a tendency to develop a prototype interface which may not have all the functionality required, so that the software developer adjusts aspects of the design, usually one at a time, until an apparently acceptable design is achieved. The decision to stop prototyping may be based not only on the design itself, but also on project cost and budget pressures. The rationale behind the proposed method outlined here is to develop a more systematic and rigorous procedure for developing and optimizing user interfaces. The Taguchi approach to interface design is an evolutionary technique which emphasizes the design rather than the iterative testing of the interface. It should produce robust interfaces with inherent reliability characteristics. The Taguchi method is an evolutionary approach because the factors and levels selected can be adjusted after testing / trialling and the system tuned and re-tested. The analysis of the results should provide the following information:

What is the optimum interface design?
What factors and associated levels give the optimum design?
What is the expected quality characteristic (usability metric) for the optimum interface?

In terms of the terminology used in Taguchi techniques it is necessary for us to discuss the role of both the factors and quality characteristics. Central to the approach we adopt here is the fact that within interface design there are an extremely large number of design factors. Indeed at the start of the design process there is an infinite space of design options. However, at particular stages within a prototyping process the design space, although still large, will be restricted. At this stage it will be possible to determine a range of factors, with their respective levels, for example the choice of interaction object (radio button or push button), colour of screen and nesting level of menus. In terms of the quality characteristic the interface designer again has a far wider choice. In production control applications the quality characteristics are limited in number and far more obvious to identify (e.g. strength). The quality characteristics for a user interface can be far more numerous and less clear. They will, however, relate to usability metrics and quantitative user satisfaction levels. This paper presents the results of a preliminary investigation of the application of the Taguchi method to interface prototyping