Developing the optimum help system using the LUCID method

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ABSTRACT In this paper the authors describe the application of the Logical User Centred Interface Design (LUCID) method to the development of a Windows based help system. LUCID is a participative method which, through the integration of Taguchi techniques from the domain of total quality management, attempts not only to develop usable human-computer interfaces, but to identify the optimum, or most usable, interface. An outline of the method together with detailed results from the first commercial implementation are presented. The method is shown to provide powerful support to the optimisation of a commercial on-line help system.

KEY WORDS: usability, evaluation, prototypes, design methods, Taguchi

1 INTRODUCTION

In a review of user interface development processes and methodologies, Hartson and Boehm-Davis (1993) recognise that although *'in one sense considerable progress has been made'* they identify a number of key specific research areas where there remains the need for *'real breakthroughs'*. In terms of methodologies for interface design Hartson and Boehm-Davis (1993, p109) state that:

- *'research in the area of formative evaluation needs to focus on interactive evaluation*

techniques that, in fact, lead to convergence on a good or at least an improved design'

and

- *'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'*

Bevan (1995) has suggested that *'quality of use'* should be the major design objective for an interactive software product using the criteria *'does the product enable the intended users to achieve the intended tasks, rather than does it merely satisfy its*

specification'. Juran (1979) defines quality as being '*fit for purpose or use*'. It has seemed appropriate therefore to investigate the ways in which TQM techniques may contribute to meeting Hartson and Boehm-Davis's aims.

In order to address these issues Smith and Dunckley (1996) are currently developing a new interface design methodology called the Logical User Centred Interface Design (LUCID) method which integrates the application of Taguchi techniques from the arena of total quality management into the development approach. This paper describes a commercial application of the LUCID method to a Windows based help system, following two earlier pilot studies.

2 INTRODUCING LUCID

The discipline of human-computer interaction is maturing rapidly and a wide number of interface design methods, for example Supportive Evaluation (Robinson and Fitter, 1992) and Method for Usability Engineering (Lim and Long, 1994), have been developed within the last decade. It might at first, therefore, seem unnecessary to propose yet another method.

The rationale behind the LUCID method outlined here is to develop a more systematic and rigorous procedure for developing and optimising the user interface. LUCID is founded on the following underlying principles:

- *adoption of a user-centred development approach*, whereby users and developers can work together on the identification of factors which effect usability and which specify performance,
- *effective use of iterative and parallel prototyping*, so as to facilitate user participation, maximise the effectiveness of the interface evaluation process whilst minimising the time required for development,
- *integration of Taguchi techniques*, thereby providing the rigour necessary for the identification of the optimum interface,
- *systematic and logical integration of techniques*, so that the method can be applied by commercial interface designers.

The Taguchi approach to interface design is an evolutionary technique but, through a crucial parallel phase, places an emphasis on the design, rather than the iterative testing of the interface. Application of Taguchi techniques within the LUCID method will 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?*

The basic stages in the proposed method are outlined in Figure 1 and an outline diagrammatic comparison between the LUCID approach and alternative prototyping approaches is provided in Figure 2. Although a number of phases within LUCID are still in development, and full implementation data is not yet available, Figure 2 suggests that although the parallel prototyping phase is later in the process, the iterative prototyping stage is much shorter and the overall development time could be reduced whilst enhancing quality. The proposers of the methodology look forward to further validating such claims.

3 TAGUCHI DESIGN METHODS

3.1 Taguchi in general

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. The majority of the applications of Taguchi methods are within production control where in order to investigate quality a quality characteristic (e.g. *strength* in a production environment) 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.

	Phase	Activities
1	Functional Analysis and Design	<ul style="list-style-type: none"> requirements capture task analysis etc.
2	Exploratory Investigation	<ul style="list-style-type: none"> through brainstorming sessions users and developers identify key factors, associated level and performance criteria <i>exploratory</i> prototypes tested
3	Taguchi Design	<ul style="list-style-type: none"> selection of appropriate orthogonal array investigate interaction between factors design of experiments
4	Taguchi Testing	<ul style="list-style-type: none"> user <i>assessment</i> testing analysis of results: <i>first-shot</i> and <i>detailed</i> analysis selection of optimum design
5	Refinement	<ul style="list-style-type: none"> confirmatory <i>validation</i> testing further iterative refinement

Figure 1 Stages in the LUCID Method

Figure 2 LUCID vs. Alternative Prototyping

Emphasis is given to the process of optimising production processes and product factors in such a way as to minimise 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 from the environment (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. 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. 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 summarise the standard Taguchi procedure below.

Design and Conduct of Experiments

The basic concept is for the design team to agree on the quality characteristic, or combination of characteristics, for measuring the performance of the product or process under study. The team then identifies the input factors and associated levels which are considered to influence the quality characteristic of the output. When applying Taguchi methods within LUCID an example factor might be *menu nesting level* which could have two levels of *broad and shallow* and *narrow and deep*.

When the factors and levels are agreed an orthogonal array is selected, the factors are assigned to columns, and experiments to rows, thereby determining the conditions for individual experiments. Experiments are then conducted to determine values of the quality characteristic associated with the factor levels determined from the orthogonal array. Figure 3 illustrates the first two orthogonal arrays, the L_4 array which would deal with up to 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, or in our case interfaces (rows), B is the number of levels and C is the number of factors (columns). The two arrays shown relate to bivariate factors (just two levels), however it should be emphasised that other arrays allow for multivariate (many levels) factors.

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 levels.

Expt.	Factor		$L_4(2^3)$		
	A	B	C		
1	1	1	1		
2	1	2	1		
3	2	1	2		
4	2	2	1		

Expt.	Fac.		$L_8(2^7)$						
	A	B	C	D	E	F	G		
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 3 Orthogonal Arrays

Orthogonal arrays are balanced because there are always an equal number of occurrences of each level in every column. In some situations factors in the design may influence each other and may not be independent. The Taguchi method will allow the design study to investigate both the input factors and the suspected interactions between the factors. 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.

Analysis of Results

The main effects are evaluated and their influence determined quantitatively thereby determining the optimum conditions. 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 versus the noise in the environment. After completing the analysis a further test of the optimum conditions must be made to confirm the performance.

3.2 LUCID and Taguchi

In terms of incorporating Taguchi techniques within interface design it is necessary for us to discuss the role of both the factors and quality characteristics. 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 become restricted. At this stage it will be possible to determine a range of factors, with their respective levels. The quality characteristic for the Taguchi approach to interface design will be either selected or calculated from a range of usability metrics. Normally it is expected that one single overarching, system specific, characteristic will be determined.

4 IMPLEMENTING LUCID

4.1 MANAGER help system

The particular application of the LUCID method which we report here relates to the optimisation of the on-line help system supporting a piece of software called *Manager*. *Manager* is available from Plasmon Data Ltd and allows a computer to have transparent access to one or more optical disk jukeboxes. The application area was concerned with the installation and configuration of jukeboxes for distributed systems with computing technicians as typical end users.

4.2 Overview of the Study

In this particular implementation we are focusing on the optimisation of an existing system. It was not necessary therefore to undertake Phase 1 of LUCID, Functional Analysis and Design. Furthermore it was possible to take the previously implemented version of the Manager Help File System as the exploratory prototype when initiating the analysis within Phase 2, Exploratory Investigation. Knowledge of usability issues such as common user errors and difficulties framed the construction of task scenarios used later in development. Following discussions within the design team it was possible to identify six separate factors, each with two levels, together with the likelihood of one interaction between two of the factors. Two points should be made concerning the selection of factors and levels. Firstly it should again be emphasised that the

method could have coped with multivariate factors. Secondly whilst some of the factors may appear to have an obvious required level, based on well known guidelines, the total systems approach ensures that trade-offs between guidelines can be systematically managed. The factors and levels themselves are shown in Figure 4. In preparation for Phase 4, Taguchi Testing, the design team was able to identify three distinct usability metrics:

- total time to complete a task
- number of button presses required to complete a task
- user satisfaction level.

Phase 3, Taguchi Design, involves the detailed experimental design. With seven factors in total it was necessary to employ the L_8 orthogonal array (Figure 3) which indicated that eight interfaces would need to be produced and tested. The specification of the eight interfaces is shown in Figure 5. Whilst, at first, it may seem rather resource intensive to have to build eight distinct interfaces, in reality the modifications necessary required only minimal effort using current software development tools.

During Phase 4, Taguchi Testing, the usability tests were undertaken. One particular aim of this implementation of the LUCID approach was to investigate the effect of restricted access to users for testing purposes. It was decided to involve just five computer services technicians as typical end users in the usability tests. In order to take account of the learning effect the users were tested on each interface in a random order which did not bias any one interface. Eight separate task scenarios were developed requiring the users to find out technical information from the help files. Whilst the scenarios included different queries they required very similar actions. Prior to formal testing each user was able to use a ninth interface and scenario for system familiarisation.

For each of the 40 tests the performance metrics identified above (total time and number of button presses) were determined. After each test the users completed a simple satisfaction questionnaire. One feature of LUCID is the identification of a single overarching systems specific quality characteristic. In this case it was possible to develop a composite metric based upon equal weighting and scaling of the three individual metrics (Figure 6).

Factor		Level 1	Level 2
A	method of help access	graphical	textual
B	menu nesting level	wide and shallow	narrow and deep
C	interaction A with B		
D	window size	large	normal
E	line spacing	single	1.5
F	font style	Arial	Bookman
G	colour of hotword	same as help text (i.e. black)	green

Figure 4 Factors and levels identified

	Levels of each factor (A - G)						
Interface	A	B	C	D	E	F	G
1	graphical	wide / shallow		large	single	Arial	same
2	graphical	wide / shallow		normal	1.5	Bookman	green
3	graphical	narrow / deep		large	single	Bookman	green
4	graphical	narrow / deep		normal	1.5	Arial	same
5	textual	wide / shallow		large	1.5	Arial	green
6	textual	wide / shallow		normal	single	Bookman	same
7	textual	narrow / deep		large	1.5	Bookman	same
8	textual	narrow / deep		normal	single	Arial	green

Figure 5 Factors and levels by interface

4.3 Analysis of Results

One feature of the Taguchi / LUCID approach is the fact that a non-statistician can easily identify a *first-shot* optimum interface. By calculating the average metrics for all factors at each level the optimum interface can be suggested. In Figure 7 we present the average data for each level of every factor relating to the individual and composite metrics.

The results show a high degree of commonality. The data shown in bold is the lower of the two values (all metrics conform to a *lower the better* criterion) and indicates the required level for each of the factors. Overall the first-shot analysis predicted that the optimum interface is described by A₂B₁C₂D₁E₁F₁G₁ with Factors A (textual method of help access) and B (wide / shallow nesting level) being the most significant as indicated by the percentage difference between the levels.

Int	Time (sec.)	Button Presses	Satis. Rating	Comp. Metric
1	153.2	19.0	12.4	0.867
2	216.6	28.4	14.0	1.165
3	181.6	25.2	15.4	1.083
4	194.9	27.25	15.7	1.146
5	123.2	14.0	10.6	0.693
6	153.6	21.4	13.6	0.931
7	174.0	20.0	15.8	1.002
8	190.8	26.0	15.4	1.113

Figure 6 Summary of metrics by interface

Time			Button Presses		
Fac	L1	L2	Fac	L1	L2
A	187	160	A	25.0	20.4
B	162	185	B	20.7	24.6
C	184	163	C	23.4	22.0
D	158	189	D	19.6	25.8
E	170	177	E	22.9	22.4
F	166	181	F	21.6	23.8
G	169	178	G	21.9	23.4
Satisfaction Rating			Composite Metric		
Fac	L1	L2	Fac	L1	L2
A	14.3	13.9	A	1.07	0.935
B	12.7	15.6	B	0.914	1.09
C	14.4	13.8	C	1.04	0.963
D	13.6	14.7	D	0.911	1.09
E	14.2	14.0	E	0.999	1.00
F	13.5	14.7	F	0.955	1.05
G	14.4	13.9	G	0.986	1.01

Figure 7 Average data by factor and level

Within the detailed analysis stage the results were subjected to a detailed statistical analysis using Taguchi's adaptation of ANOVA for saturated designs in which the least significant factors are pooled and assigned to the error sum of squares in order to enable the calculation of the *F ratios*. Multiple trials were analysed using Taguchi's concept of the signal to noise ratio. This is a useful concept for estimating the strength of the noise involved in the experimental design in contrast to the effects of the main factors. The *S/N* ratio is the reciprocal of the variances of the measurement error. It is a maximum for the combination of factor levels that has the minimum error variance i.e. the optimum design. For the Composite Metric the *S/N* ratios of the factors are given in Figure 8.

The larger the difference the greater the significance for the factor. There would appear to be a close relation between these results and those indicated in the first-shot analysis. In this application the sources of noise were considered to be due to the users' abilities, learning styles and any differences in the task scenarios.

Factor	Level 1	Level 2	Diff.
A	-7.716	-6.644	1.072
B	-6.278	-8.082	1.804
C	-7.681	-6.679	1.002
D	-6.362	-7.999	1.637
E	-7.255	-7.106	0.149
F	-6.680	-7.681	1.001
G	-7.051	-7.310	0.259

Figure 8 S/N Ratios, Composite Metric

Figure 9 summarises the detailed statistical results giving the *F critical* values at 90% as a guide. However Taguchi recommends, based on his own experience, that factors which give rise to *F* values greater than 2 should all be taken into account. In the different cases, shown below, the three or four least significant factors in terms of percentage contribution were pooled together to form the error sum of squares so that the *F* variance ratio could be calculated. The table shows that, although there is some variation in the results using the different metrics, in general the three significant factors in this application are *method of help access*, *menu nesting level*, and *window size*. This indicates that further refinement of the interface should concentrate on these factors. In addition *font style* was a significant factor in terms of user satisfaction, although it does not appear to have an impact on user performance whilst *method of help access* was not rated as highly by the users. The possible interaction between *method of help access* and *menu nesting level* was investigated in this experimental design. It was found to be statistically significant for the *total time* metric but not in the other cases. This indicates that future refinement of the interface should bear this in mind.

Overall the detailed analysis provided confirmation of the first-shot analysis indicating that the LUCID approach can be applied at two levels:

- by all interface designers at the first-shot level without recourse to the statistical techniques
- with statistical back-up to confirm and provide additional information using the Taguchi variation of ANOVA.

Time			Button Presses		
Fcrit(1,3)=5.53			Fcrit(1,4)=4.54		
Fac	F	%	Fac	F	%
A	4.12	13.9	A	9.48	25.3
B	7.29	24.7	B	6.83	18.2
C	6.57	22.5	C	-	2.24
D	8.56	29.0	D	17.18	45.8
E	-	0.01	E	-	0.27
F	-	7.53	F	-	5.59
G	-	2.63	G	-	2.57
Satisfaction Rating			Composite Metric		
Fcrit(1,3)=5.53			Fcrit(1,4)=4.54		
Fac	L1	L2	Fac	L1	L2
A	-	2.26	A	4.77	18.4
B	37.5	70.6	B	8.34	32.1
C	-	2.75	C	-	5.75
D	5.54	10.4	D	8.84	34.1
E	-	0.26	E	-	0.01
F	6.07	11.4	F	-	8.85
G	-	2.26	G	-	0.80

Figure 9 Average data by factor and level

5 CONCLUSIONS

LUCID is in the relatively early stages of development. Current work is focusing on Phases 3 and 4 as these are clearly crucial to the total approach. Taken together the pilot study (Smith and Dunckley, 1996) and this more extensive study suggest that the LUCID / Taguchi approach to interface design is both feasible and worthwhile. It enables the interface designer to test a limited number of interface designs at an early stage in the development process and determine with a high degree of certainty the major factors within the optimum interface specification. Iterative prototyping, based upon the optimum interface, can later be used to refine other more minor factors which may not have been included. Future emphasis will need to be placed on Phase 2, Exploratory Investigation, where building upon current techniques for user-centred design, support will be provided for the identification of key factors and performance criteria.

Whether or not LUCID should be considered to be one of 'breakthroughs' that Hartson and Boehm-Davis

(1989) seek, it certainly provides significant support for two of the issues which they highlight, as outlined in the introduction. The Taguchi parallel design and testing strategy ensures, subject to early prototype constraints and the identified quality characteristic, the identification of the optimum interface design. In addition the Taguchi variant of ANOVA provides a technique whereby the features most significantly effecting usability (credit and blame) can be determined.

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