DESIGN RATIONALE: THE ARGUMENT BEHIND THE ARTIFACT

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ABSTRACT
We assert that the product of user interface design should be not only the interface itself but also a rationale for why the interface is the way it is. We describe a representation for design based around a semi-formal notation which allows us explicitly to represent alternative design options and reasons for choosing among them. We illustrate the approach with examples from an analysis of scrolling mechanisms. We discuss the roles we expect such a representation to play in improving the coherence of designs and in communicating reasons for choices to others, whether designers, maintainers, collaborators or end users.

KEYWORDS: Design rationale; User interface design; Problem solving; Design capture; Tailorability; Notations; Knowledge base

WHAT IS DESIGN RATIONALE?

To understand why a system design is the way it is, we also need to understand how it could be different, and why the choices which were made are appropriate. We are developing an explicit representation which allows us to describe a *design space* rather than a specific artifact. The design space consists of a *decision space* (alternative *options* which might be appropriate), and an *evaluation space* (explicit reasons such as *consistency* and *criteria* for choosing from among the possible options). The set of options which are selected for the final design describe the *artifact*, and the alternatives and reasons for the choices provide an *argument* (or rational) which supports and helps understanding of the choices made. We believe that such a description should be a product of the design process just as much as the final artifact. We use the term *Design Rationale* to refer to this representation. Our interest is in the design of user interfaces, but our representation can handle more general design problems to capture the range of constraints (e.g. technological, organisational) which may impact the user interface. A Design Rationale is *not* a record of the design process – it is a co-product of design along with the artifact and itself has to be designed. Consequently, our approach contrasts with those which wish to capture and document the actual process of design (e.g. see Petersen [15]; Potts et al [16]; Conklin et al [5]). (We do not deny the utility of recording the design process. Indeed, we would expect such a record to be a valuable source of data to help produce a design rationale. However, valuable as it may be, such a record is neither necessary nor sufficient, as should be clear from the example in this paper.)

The development of a representation for design rationale involves two distinct research questions:

1) What is an appropriate representation?
2) How can the representation be used?

This paper illustrates the main concepts we use in our representation with small extracts from an analysis of a window scrolling mechanism. The paper concludes by discussing the benefits we would expect to see if the product of design was a Design Rationale of the sort we describe rather than a "naked" artifact.

REPRESENTATION OF DESIGN RATIONALE

The representation we are developing is based on a semi-formal notation. Although we are interested in formalising aspects of the design where it is helpful and feasible to do so, this is not the main objective. In contrast to AI based approaches to design (e.g. see Mostow [12]), our primary goal is to aid the human designer or user, and thus intelligibility and flexibility are more important than formalisation. Hypertext systems are well suited for representing a mixture of formal information, which gets mapped into structural relationships, together with some less formal textual content (e.g. see Marshall [11]; Conklin [4]). We are currently using NoteCards [8] for much of our work, but have also explored the use of Systemic Grammar Networks [2], which provide a more rigid structure.

We need to emphasise that the content of a Design Rationale is an idealisation of the design space (cf. Parnas and Clements [14]). It includes not only the description of a potential artifact, but also includes alternative options, and reasons for choosing specific ones to implement the artifact. The alternatives and reasons for choosing among them together make up the argumentation which sets the context for understanding the artifact produced. The aim is to ensure that the essential issues will be obvious to others (or indeed to the original designer) at a later time. For example, intuitive design solutions for which designers can find it difficult to articulate a justification (Rosson et al [17]) should be fleshed out. Designers are clearly capable of producing such rationales - for example Johnson and Beach [10] give an excellent overview of the design of style sheets for the Viewpoint office system, emphasising a logical rather than chronological account. The argumentation which makes such an account coherent has itself to be carefully crafted - it is unlikely that it will emerge from simply recording the chronological process of design.

A Window-Scrolling Interface Example

We will illustrate the main Design Rationale concepts with examples from an analysis of window scrolling mechanisms. The analysis started from considering scrolling in the Xerox Common Lisp (XCL) environment. In XCL, windows provide views onto larger objects (such as documents) which are too large to be viewed in their entirety. A scroll bar is provided to control what appears in the window. This scroll bar appears outside the edge of the window when the mouse-controlled cursor is slid off the left edge of the window - we will call this the *appearing scroll bar*. Depending on which of three mouse buttons is pressed, the area being viewed can be changed to a position relative to the current window contents, or to an absolute position within the document. A bubble inside the scroll bar gives feedback on the current size and position of the window relative to the whole document.

Decision Space

The *decision space* describes *what* the components of the finished artifact might be. Its primary elements are *Options*. The Options are organised around *Design Questions*. For convenience of presentation we consider the aspects of a design under four headings (in practice these aspects are more inter-related than this division implies):

- The set of tasks supported (i.e. the range of activities it allows the user to perform)
- The set of operations it provides (i.e. the actions the user can ask it to carry out and the information it makes available)
- The interaction design (i.e. the general way the user will interact with it)
- The detail design (i.e. the specific details of its appearance and behaviour)

The tasks supported by the scroll bar involve moving around in a document (or any other scrollable object) and keeping track of the present view. This aspect of the analysis therefore lays out a space of navigation tasks. The operations are primitives to which the user has access. Figure 1 shows the operations and main tasks supported by the scroll bar. The four tasks shown here each map directly onto single operations, typically a necessary requirement for scrolling since it is often a background component of more complex tasks. For example, consider the task of moving text in a text-editor. This would include at least three operations: selecting the move function; selecting the source text; selecting the target destination; and in some circumstances a scrolling operation to select the source or target.

TASKS	OPERATIONS
Change view to new position relative to current position	Jump relative to current position
Change view to absolute position in document	Move view to absolute position
Find out what part of document is currently in view	Indicate position of current view
Find out size of document	Indicate size of current view relative to whole document

Figure 1: XCL Scroll bar: The main navigation tasks supported, and the corresponding operations to carry them out.

The interaction design and detail design are where we start to focus on how the design will be realised - how the operations are going to be made manifest to the user. The small example from the detail decision space shown in figure 2 assumes that we have committed to a scroll bar as the solution we are going to explore, and examines some of the decision space around a commitment to use a scroll bar which appears only when needed. The figure illustrates the main concepts we use to represent the decision space - *Design Questions* and *Options* (or potential "answers" to the questions). For example, a relevant question would be "Where and when should the scroll bar be displayed to the user?". Possible options might be "Permanently attached to an edge of the window" or "Appears only when necessary". The latter option would in turn raise the *Consequent Question*, "How should the scroll bar be invoked?", which would in its turn allow a number of possible options.

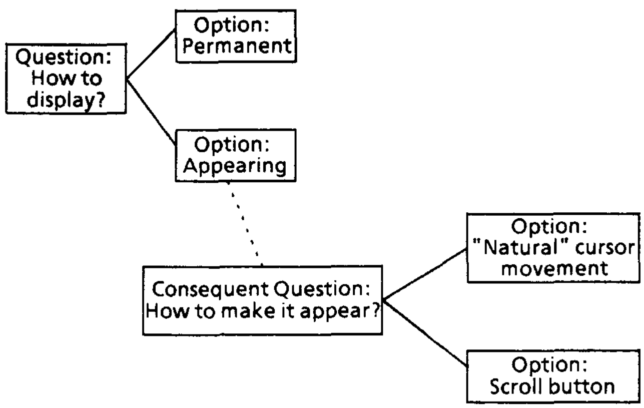

Figure 2: A fragment of the detail decision space around the decision to use "a scroll bar which appears only when needed".

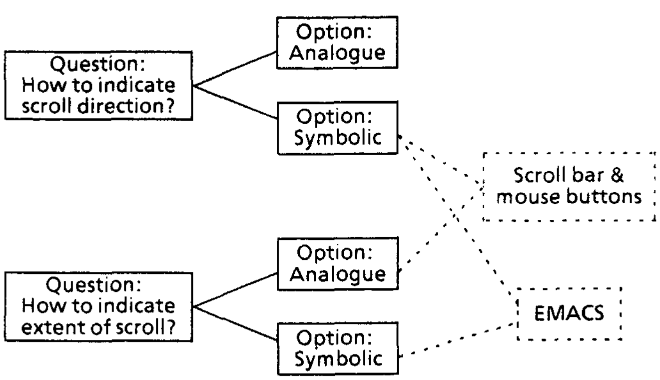

Figure 3: A part of the interaction design space for the navigation task.

Interaction design can be regarded as where the 'style' of the interface is determined, and the characteristics of the design at this level are broadly equivalent to the 'points of style' described by Newman [13]. Figure 3 shows a small portion of the interaction design. The kind of scroll bar being considered here uses an analogue representation for extent of movement (distance down the bar) and a discrete choice for the direction (left or right mouse button in the case of XCL). The options appropriate to this level of analysis (such as analogue and discrete) are fairly abstract, and are sufficiently general to allow a broad design space to be represented without needing an excessive number of options. When more detail is required, one of the specific options (such as scroll bar) can be focussed on in more detail.

Evaluation Space

The *evaluation space* describes *why* the choice of particular options makes sense for the design as a whole. The two main concepts in the evaluation space are *consistency links* which highlight relationships within the design space or between the design space and the outside world, and *criteria* – the principles which shape the final artifact. A specific design is characterised by the set of options which are actually selected. Important as it is to formulate design questions and lay out alternative options, that by itself is not sufficient to ensure good design. It is essential that the chosen options are compatible with one another, so that they fit together to form a coherent whole. The questions asked must be appropriate, and options must be selected for principled reasons.

Consistency Links highlight dependencies and interrelationships between options selected in one part of the design space and constraints placed on potential options elsewhere. Broadly speaking, such links emphasise either internal consistency between different parts of the design space, or external consistency with the world outside the system. As an example of the former, let us assume that a scrolling mechanism uses the left mouse button to move down a document, and the right button to move up. If up and down movement is to be carried out with the mouse in another part of the design, clearly the same mapping should be used. Thus some design questions are recognised as being instances of the same *class*, and this kind of internal consistency link takes the form of a pointer from an individual option to the generic representation of the class it belongs to. External consistency can be represented by a conceptual model. For example, the XCL navigation mechanism embodies a model of a document as a long vertical strip with the window sliding up and down to view different parts, whereas other systems use book or page based models. This kind of external consistency link takes the form of a pointer from an option to a representation of the model, indicating that the particular option chosen is compatible with and supported by the model.

CRITERIA

OPTIONS	Low Effort	Screen Compactness	Continuous Feedback
Appearing	−	+	−
Permanent	+	−	+

Figure 4: The relationship between two alternative options and some of the criteria which may be used to choose between them.

The most important rationale concept is the *Criterion.* A criterion is a principle or standard against which different options are judged. As with the other parts of the design, appropriate criteria have to be invented by the designer. Criteria are important in justifying and evaluating options in local parts of the design space, and their appropriateness can be judged by how well they do this job. Figure 4 shows one way of representing local relationships - a matrix of options against criteria (cf. Marshall [11]), in this case for helping to choose between a permanent or appearing scroll bar. For simplicity of exposition, the relationship between options and criteria are shown only as positive or negative. The first impression that this figure gives may be that the permanent scroll bar is a better bet than the appearing one since it "wins" by two criteria to one. This is not necessarily the most appropriate conclusion, and we can use it as a starting point to illustrate some uses of the representation to explore the design space, and perhaps to change our initial evaluation. Our conclusion may be affected by any of a number of possible 'moves':

- We may decide to give different weight to different criteria - for example emphasising screen compactness at the expense of low effort and continuous feedback.
- We may add new criteria - for example, a criterion of "low computer processing requirements" would have a negative relationship to the permanent scroll bar option if feedback on the current position being viewed had to be continuously updated .
- We may argue about the relevance of the "score" on a criterion by considering new options in a related part of the design space. For example, if a "natural" cursor movement is used to make the scroll bar appear (see figure 2), then the low effort criterion will no longer be a problem, and so that version of the appearing scroll bar will begin to look more attractive. (A "natural" cursor movement would be used if the scroll bar is made to appear by moving the cursor to where it would have to be moved anyway were the scroll bar already visible),
- We can infer the priorities of the original designer when we analyse an existing design (such as this scroll bar). By laying out what alternative options *could* be plausible, and what criteria *could* be relevant we can see what considerations are likely to have driven the original design. In the case of XCL, screen compactness would appear to have been important. (This is the approach taken in the "rational actor" model [1]).

Criteria also have a more global impact on the design space. The relative weightings on different criteria are a factor in determining the overall style of the interface - in this respect they have a role similar to 'requirements' in the analysis of Newman [13]. For example, if "giving a lot of feedback" is more important than "response speed" a very different set of decisions is likely to be made than if the reverse is the case.

One danger of which we have to be aware when specifying the design space and rationale is that of excessive detail. It is all too easy to create a representation of unmanageable size, so an important aspect of the notation we use is that of expandable detail. The principle is that it should be possible to present only the information necessary for the purposes under consideration, and if more detail is required then any aspect of the representation can be expanded for further exploration and scrutiny. One example of this principle is that the argument for any decision does not have to be spelled out all the way back to a set of *general criteria.* A *bridging criterion* may provide an acceptable and convenient 'short circuit' for a complex set of interdependencies. An example from the scroll bar domain is "ease of hitting a target with the mouse". This was used to justify an appropriate choice for the minimum width of the scroll bar. This criterion bridges between decisions taken elsewhere in the design space (i.e. to use a mouse) and the general criteria of speed and accuracy, and encapsulates them into a single entity in the rationale. Of course, if such a bridging criterion is questioned, it should be possible to examine it in more detail - in this case resorting to classic studies of the mouse to justify considering it as a device which obeys Fitts' law (Card et al [3]), and to Fitts' law itself to justify a specific decision.

ROLE OF DESIGN RATIONALE

If we have a Design Rationale as a product of design, what benefits might we expect? Two groups of people might be expected to benefit. Designers should benefit in two ways. It should serve as an aid to problem solving, assisting with thinking about a design, and it should act as an aid to communication, allowing other designers (or system maintainers) to understand a design better. End users should also benefit, as it should be able to provide to vehicle to improve communication with the intentions of the original designers.

Design Rationale as an Aid to Designers

An explicit representation should allow the designer to envisage the design space in a more structured way. It allows a number of designs to be compared relatively easily. For example, it is reassuring to note that although our analysis starts with a single scroll bar design, as the design space is mapped out, other scroll bars (such as ViewPoint [19] and Macintosh) emerge from the analysis and are locatable within the same space. Even more interestingly, by laying out alternative solutions within a single design space, we can see combinations of alternatives which have not been considered. For example, referring back to figure 3, we can consider the possibilities offered by a scrolling mechanism which offers analogue control of both distance and direction. A possible realisation might be to think of it as a gestural device, with an indicated line being "thrown" in the direction required (i.e. up or down). Such possibilities seem easier to imagine within a well formed supporting structure, so we would argue that as an explicit structure is created, the possibility of generating good designs is improved.

Generating good questions is even more important than generating options, as the questions play a key role in generating as well as structuring options. In some cases, a question may be generated from an arbitrary option which "springs to mind". A recent preliminary observation from attempts to use rationale in some of our own design work suggests that options can suggest themselves in this way. (This accords with the results obtained by Rosson et al [17] in interviews with professional designers.) Once a question is generated to which the option is a possible answer, it then seems much easier to generate alternative options and explore the space more thoroughly.

Breakdowns in design often occur because of cognitive limitations (e.g. Guindon, Krasner and Curtis [7]). We would expect an explicit structure to support reasoning and so help to avoid such breakdowns. VanLehn [18] has documented the use of NoteCards for formulating and managing arguments and has demonstrated two incidents where such a tool helped to uncover major flaws in an argument which had initially been carried out without such support.

It is clear that effective use of design rationale will depend on the provision of appropriate tools to support its creation, examination, and manipulation. In practice, a rationale should seldom have to be created completely from scratch, since much design borrows ideas and techniques from other existing designs. If tools exist to help borrow the rationale of such ideas too, it should be feasible to re-use components of design much more than is possible at present.

As well as helping the individual designer, laying out the arguments explicitly should serve to record salient aspects of the design for reference at a later date, and also to improve communication both between members of a design team and between designer and client. Hammond et al [9], for example, showed that designers often have their own, sometimes idiosyncratic, analyses of users' needs and capabilities. Having an explicit design rationale should help to identify areas where inappropriate assumptions have been made, or key assumptions have not been spelled out, and to counteract designers' tendency to overlook possible alternatives when making important decisions. The rationale should also be of help to those maintaining a system or building a later one, by showing why the system was designed the way it was and helping them to foresee the consequences of any proposed alterations.

Design Rationale as an Aid to End Users

The end user too can benefit from being told more about the rationale of a system, whether to find out how it works or to make changes to it. When end users are allowed to tailor a system towards their own requirements, they are effectively being faced with a design problem, but with no training or experience in design. Access to a rationale for the system being tailored, especially the user interface, could be crucial in enabling such users to maintain the system's coherence. For example, let's assume a user is faced with a tailorable interface which allows characteristics of the window scrolling mechanism to be varied. This particular interface is also supplied with a rationale for the design space. The user may be given a choice of options, such as the width of the scroll bar, whether it is permanent, or appearing, and so on. Each option has a set of criteria summarising its good and bad points. When the user selects an option, inconsistencies with other parts of the environment are pointed out – for example if different applications allow different details in their scrolling mechanisms, inconsistencies which will make the different applications difficult to use together may be pointed out. To make such a scenario a success, the original designer will have to design not just a specific design, but a *design space* within which the user tailors. The designer has to make decisions about what to include in the space so as to make the space responsive to tasks, and to make decisions within the space simple for the user. This "tailoring space" should of course have its own argumentation behind it (not for the user - only other designers). The tailoring space is provided to the user and is effectively a constrained "design space" within which the user tailors the system, and uses the Design Rationale. In this case we see the argument not simply behind the artifact, but merging with it, as there is real utility for the user in being presented with a crafted argument which will help with creating a system to meet specific personal needs.

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