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Varieties of Dialogue in Man-Machine Systems

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Abstract

The performance of man-machine systems may be improved by focussing in design upon the nature and quality of dialogue between operator and system. This paper discusses the characteristics of such interaction and suggests an analysis and taxonomy of dialogue components. Examples suggest that an understanding of the varieties of dialogue can yield more flexible and supportive operator interfaces.

1 Introduction

The seemingly awesome task of supervision and control in dynamic process environments is made more or less difficult by those who design the man-machine interaction (MMI). Ultimately, the operator's attempts to assimilate information, and thereby comprehend system states and potentials, are governed by the manner and relevance of data presentation (cf. [Woo89]). Even so, one should avoid the naïve assumption that the system interface serves only as a window upon the application, through which the activity of the process and the effects of operator actions can be observed. The window metaphor is misleading if intended to describe the function of the whole MMI. In particular, it engenders a view of the interface as neutrally transparent, i.e., as having no significant effect upon operator's perception and understanding of the process. Such a perspective in design may result in poorly supportive interfaces which are 'application biased' [Wei89b], with insufficient attention to the information processing needs of the operator.

In the present paper, I advocate a viewpoint on the nature and role of the man-machine interface, whereby the complex of functions performed by such interfaces is made explicit. This serves to illustrate both the subtleties and the difficulties of MMI design. Furthermore, the resultant perspective allows us to characterise a range of features within man-machine interaction - 'varieties of dialogue' - which, in turn, afford insight on the design of interfaces for man-machine systems.

2 The Nature of Dialogue

The term 'dialogue' is used here to describe the active ingredients of interaction between man and machines. Included, are all aspects of operator input at the machine interface and all manifestations of system generated output and responses. Excluded, are physical components which make up the interface and the machine.

When considering the nature of such dialogue we can helpfully ask what features are required in order to establish desirable interaction facilities in man-machine systems. Three essential ingredients come to mind:

- control flow;
- display manipulation;
- meta-dialogue.

Control flow

Primarily, the system interface provides a means whereby users (operators) can affect the course or operation of any machine or process. To this end, the interface affords opportunities for the input of control actions. Allied to such facilities, information must be provided which allows the operator to gauge the system state and the effects of his actions. These dialogue facilities are essentially tied up with *control flow*. Control flow dialogue includes all operator actions on the application and all status data, including results of operator actions.

Display manipulation

A second desirable feature in man-machine dialogue is the possibility for operators to affect the manner in which system information is presented. This may affect either the mode of presentation or the position of presentation. In the first case, the user may be allowed to select a form of display which meets his preference. This might be dial outputs as opposed to digital readouts, twelve rather than twenty-four hour clock, etc. In the second case, operators may have discretion on the positioning of output information, e.g., whether default options appear on the bottom or top of the VDU screen. Such features are not present in all man-machine systems.

Meta-dialogue

Generally, the topic of meta-dialogue is control of the application. Such dialogue is 'meta' because it does not directly affect control flow. Rather, it covers support information or advice either directly on the subject of control or on relevant aspects of the application. Included within this category is any help facility, such as on-line manuals, event logs, data analysis facilities, etc. Although a desirable feature of interaction, meta-dialogue is not evident in all man-machine systems.

2.1 The Structure of Interaction

The combination of features in man-machine dialogue described above is desirable for optimal joint performance of man and machine. Control flow dialogue may represent the *raison d'être* of the system interface, but the other aspects of interaction, especially meta-dialogue, are essential for effective operator performance on all but the simplest man-machine systems. We may reasonably ask how to attain systems which embody such facilities for interaction.

Recent developments in the design of interface systems have stressed the role of functional separation within the interface itself. User Interface Management Systems (UIMS) embody this philosophy within a software architecture for the design of interactive system interfaces (see [Pfa85] and [Low88]). Elsewhere [Wei89a], I have advocated the related benefits of recognising three conceptual layers in interaction, viz:

- presentation,
- application,
- mediation¹.

The presentation layer is the level of input and output (i/o), where the operator *presents* his actions to the system and the system *presents* its responses to the operator. Conceptually behind this layer of presentation, the actions of the operator are directed toward some functionality which he is trying to manipulate. In a control system, the operator's actions are directed toward an effect on the process. In a database system, the user action would be directed towards retrieval of some information. Whatever the domain, the invocation of some functionality which lies 'behind' the presentation layer is the immediate objective of the user interaction.

Note that the concepts of presentation and application are sufficient for two of the three dialogue categories listed above, i.e., control flow and display manipulation. Control flow dialogue requires presentation facilities for handling i/o and an application which will be controlled and whose data will be reflected in presentation. Similarly, display manipulation dialogue requires presentation handling facilities and some source of dynamic data, i.e., an application.

On the other hand, meta-dialogue requires something more than either presentation or application. To these we must add the realm of mediation. This intermediate layer of interaction affords a more complex mapping between presentation and functions in the application than is evident in simple control flow dialogue. In addition, mediation serves as a source of meta-control information. (Possibly, both information about application control and information about the operator)².

2.2 Illustrating the conceptual layers

We may better comprehend the roles of our three layers in interaction through an example. Consider the requirements for programming a video cassette recorder (VCR). After selecting program mode on the VCR, the user must enter the requisite items of information, i.e., day, channel number, recording start time and recording stop time. The procedure whereby this information is elicited from the user is controlled at the level of mediation, without reference to the application functionality, and employs the presentation layer as the medium for i/o. The separate roles of the mediation and presentation layers in this interaction are illustrated in Figure 1.

3 Varieties of Dialogue

The three conceptual layers of presentation, application and mediation, provide a ground for the dialogue requirements detailed above. In addition, they allow us to realise several lessons about the nature of man-machine interaction. Firstly, the conception of the interface as a 'window' on the application emerges as inappropriate for anything beyond simple presentation/application mappings. Secondly, in giving us a better understanding of the constituents of such interaction, these layers provide a theoretical basis for the design of man-machine interfaces. Since such complex interaction can be understood as invoking

¹This classification is closely related to that used by exponents of UIMS.

²See [Wei89a] for more on dialogue mediation.

Simple user-presentation dialogue describes any interaction which incurs change *solely* at the presentation layer. For simple systems, there may be few examples of such dialogue. This is to be expected since less complex man-machine systems provide limited scope for variety in display and so will require fewer possibilities for presentation.

User-presentation dialogue, either simple or complex, may be classified according to the type of change affected at the presentation layer. In this respect, we have the following three alternatives:

Input echo - Such change in the presentation layer simply reflects operator input. This acts as an acknowledgement of the operator's actions, although it may not indicate that such actions have had the desired effect on the process (application).

Output display - This alteration in presentation either reflects a change in the state of the application or conveys information passed from the mediation layer of interaction, e.g., support or help messages.

Mode change - Such changes in the presentation layer affect the manner in which data or information is displayed. A change from analogue to digital representation of data is one such example. Likewise, altering the output of a VDU from colour to monochrome affects only the mode of display and has no impact upon the rest of the interactive system.

Ordinarily, simple user-presentation dialogue affects only the modality of display. For example, a database system may provide a set of data which can be displayed in a variety of ways, as a Cartesian plot, bar chart or data table. These alternatives may be invoked by the user and need affect no other part of the interactive system beyond the presentation layer.

In our VCR domain, we can find examples of such dialogues. Most VCRs include a tape position indicator which displays a three or four digit counter. This indicator increments whenever the tape is in forward motion and decrements when the tape moves in reverse. Clearly, this presentation facility reflects a condition of the application (the video cassette) in respect of its motion (speed and direction). In such normal operation, the position indicator is part of *output-display* dialogue but the actual numerical value displayed need not relate directly to the tape position. At will, the operator can reset the counter to a zero value. In so doing, no change is effected upon any part of the system save for the presentation layer. Thus, resetting the counter value is *simple user-presentation* dialogue which effects a *mode-change* at the presentation layer. Similarly, choosing a twelve hour clock display, in preference to the twenty-four hour version, is a display mode change and, thus, an aspect of user-presentation dialogue.

3.2 User-mediation

User-mediation has the operator interacting with the intermediate layer beyond presentation but has no direct effect upon the application (cf. the VCR programming example given above, in which the process of 'program elicitation' is driven from the mediation layer and subsumes user-presentation dialogue). We can identify two aspects to user-mediation:

- user-application mapping;
- meta-dialogue resource.

In the former case, the user-mediation dialogue serves to derive data from the operator which may be used in subsequent mediation activity upon the application (e.g., in program execution). In the latter case, user-mediation serves solely to elicit an information service from the mediation layer of the interface system. Of course, these two aspects may be interrelated, as when the VCR is programmed (user-application mapping) and the user then requests information on the program settings he has given (meta-dialogue).

VARIETY OF DIALOGUE	ACTIVE LAYERS		
	Presentation	Mediation	Application
user-presentation	√	-	-
user-mediation	√	√	-
application-mediation	-	√	√
user-application	√	√	√

Figure 2: Varieties of Dialogue and their Active Layers.

3.3 Application-mediation

An example of application-mediation dialogue is also evident in VCR programming. In the 'program execution' phase, the mediation layer handles the switching of VCR functions according to the values given by the user during the elicitation phase. Thus, at the selected times the VCR is switched to record and, thereafter, switched off. Here, we have a case of application-mediation wherein the mediator layer and the application engage in interaction. Note however, that the state of the application will also be relayed to the user via presentation, i.e., when the application is switched to record, this will be reflected in the presentation layer by the illumination of a 'record' light.

For systems in which each discrete application state is indicated by the presentation layer implementation of this facility may bypass the layer of mediation. A similar approach is appropriate for dynamic control interfaces in which dynamic update of process variables is an essential feature of presentation. In such cases, the mediation layer need not be involved where the tie between application and presentation is either intimate or otherwise irrelevant to the workings of mediation.

3.4 User-application

In user-application dialogue the link between user input and application is immediate. This is true of operator actions having direct effect upon the application. 'Stop', 'play', 'rewind' and 'fast-forward' are examples of such actions in the VCR domain. As before, the presentation layer responds to reflect the status of the system functions, but user action directly invokes the underlying functionality of the application.

The varieties of dialogue in man-machine systems and the participation of different layers in interaction is illustrated in Figure 2. Note that for each variety of dialogue communication is usually two-way. Thus, for user-application dialogue there will be both input from the user and output from presentation. In user-mediation there is communication from the mediation layer to the user and response from the user to mediation (in both instances, via presentation).

4 Designing for Variety

Recognising the scope and possible complexity of dialogue in man-machine systems is a useful starting-point from which to consider the problem of design. Systems which strive to achieve optimal interaction must accommodate the varieties of dialogue detailed in this paper. Furthermore, the conceptual layers of interaction here described, suggest an approach to design which explicitly recognises the range of needs in man-machine dialogue and afford a structure for satisfying these needs.

The design of man-machine interfaces, in line with the varieties of dialogue described in this paper, is underway within the ESPRIT project #857 ('Graphics and Knowledge Based Dialogue for Dynamic Systems')³. In this project, the distinct realms of dialogue are embodied in the software architecture of the GRADIENT operator support interface. This results in greater flexibility and sophistication in the MMI, with corresponding benefits in operator support and performance. The structure of the GRADIENT interface system is shown in Figure 3.

³The resultant system, known as 'GRADIENT', is detailed in [Woj88]. GRADIENT's approach to dialogue design is described by [AM87] and [AW87].

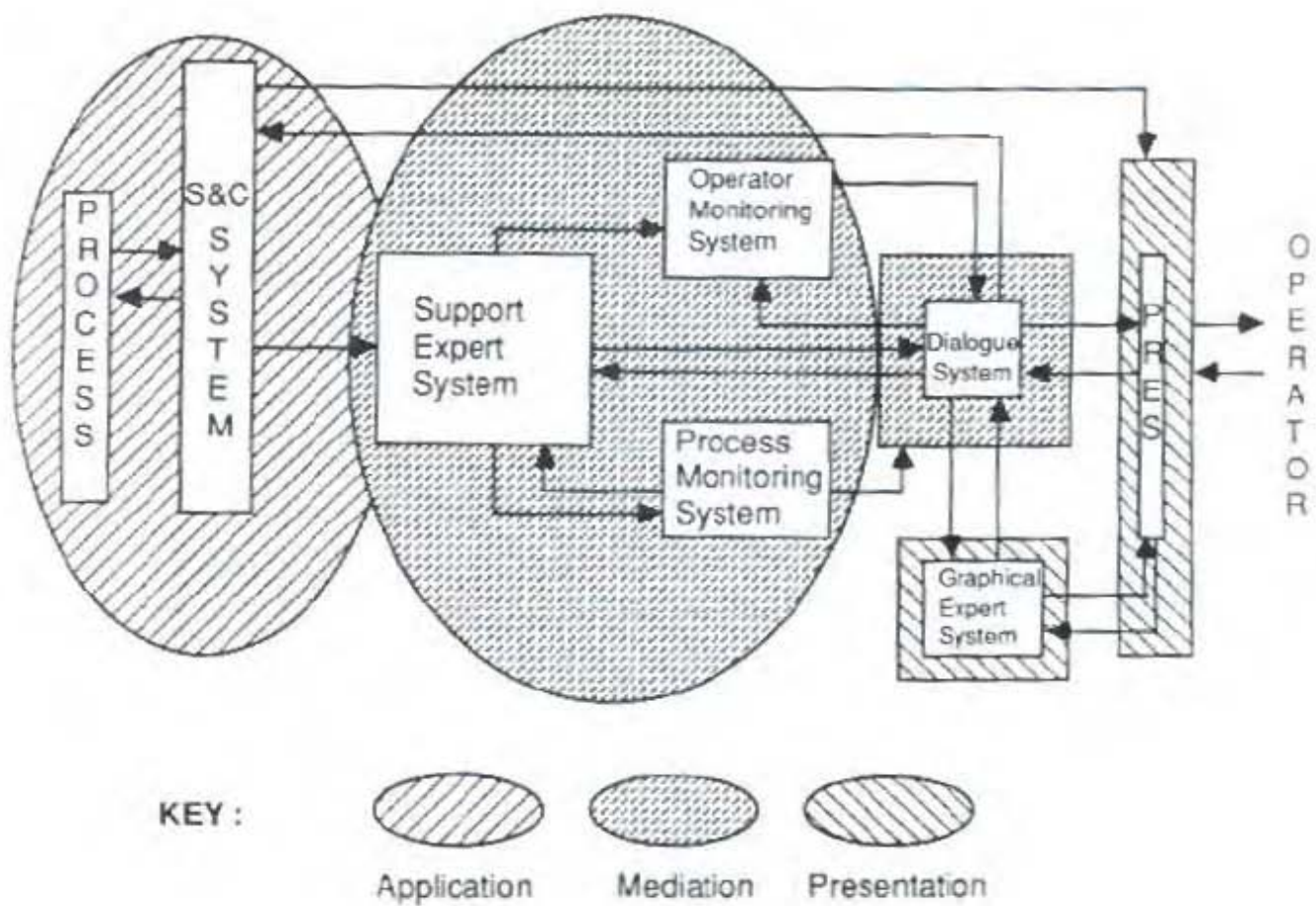


Figure 3: Structure of the GRADIENT Interface System

4.1 Design methodology

Although a system such as GRADIENT embodies the functional separation of interaction layers in a software architecture, and thereby promises improvements in operator support, this embodiment must come through an appropriate design methodology.

The analysis of dialogue here presented suggests several pointers. Firstly, since the mediation layer ties together the application and presentation aspects in dialogue, this must be the crux of interaction design. Techniques available for mediation design include the use of dialogue specification formalisms (for examples, see [Jac85], [Shu82], and [Gre85]), path algebra analysis [AR85] and rapid prototyping. Furthermore, functional decomposition of application tasks provides an efficient means of specifying the minimal range of dialogues required for system control (cf. [HW88]).

The requirement is for a principled approach to overall design of the man-machine system which embraces the needs of the application whilst accommodating the information processing needs of the operator. Such design appropriately begins from a consideration of the application functionality through to the requirements this imposes on presentation. The operator's information needs extend beyond application control (control flow) to meta-dialogue (mediation) and display manipulation (user-presentation dialogue). Each of these needs must be properly located in the methodology for man-machine interface design.

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