HUMAN FACTORS IN INFORMATION TECHNOLOGY 1

Intelligent Interfaces

Theory, Research and Design

Edited by
P.A. HANCOCK & M.H. CHIGNELL

NORTH-HOLLAND

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NORTH-HOLLAND
AMSTERDAM · NEW YORK · OXFORD · TOKYO

ISBN: 0 444 87313 9

Publishers:
ELSEVIER SCIENCE PUBLISHERS B.V.
P.O. Box 1991
1000 BZ Amsterdam
The Netherlands

Sole distributors for the U.S.A. and Canada:
ELSEVIER SCIENCE PUBLISHING COMPANY, INC.
655 Avenue of the Americas
New York, N.Y. 10010
U.S.A.

PRINTED IN THE NETHERLANDS

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PREFACE

The interface is the focal nexus of human-computer interaction. However, only a small number of books have as yet been written on how to design high quality human-computer interfaces. Most existing texts generally rely on guidelines and experimental results that come either from research in cognitive psychology or from practical experience with interface development. However, computing technology continues to advance and many of the existing interface design guidelines stem from experience with earlier generations of computing technology. From the perspective provided by a number of different researchers, this book is intended to provide an introduction to a new form of interface design that is based upon present and future technology, rather than yesterday's.

The interface is typically conceived of as a physical structure composed mainly of screen and keyboard. However, present day interests extend beyond these traditional aspects to the broad and more problematic cognitive characteristics of interface activity. The present work concerns the nature, composition, and implementation of the cognitive interaction between the human and the computer, through the development of intelligent interfaces. The definition of what intelligent interfaces are, and how they may be built, is still in the earliest stages of creation. However, intelligent interfaces may be characterized presently as the types of interface which include tools that minimize the cognitive distance between the user's model of the task and the appearance of the task that is implied by the input and output characteristics of the computer software.

Current research on intelligent interfaces represents the latest step in the evolution of interface technology which mirrors, but generally lags behind, hardware and software technology. At the leading edge of user interfaces, the focus has shifted from purely physical concerns to cognitive conceptions which include the first efforts to incorporate mediating intelligence into the communication between operator and system. This progression has resulted in contemporary interfaces which represent a compilation of still emerging and on occasion conflicting evolutionary pathways. One goal of intelligent interfaces is to reconcile

these differences, when they arise, by providing interpretive translation and a common communications medium in the event of conflicting demands.

The chapters in this book address the topic of intelligent interfaces from a variety of theoretical, empirical, and design perspectives. The contributions to this text represent a foundation for subsequent intelligent interface development which will eventually lead to efficient interfaces that are both physically and cognitively compatible. The chapters are designed to be read in the order in which they are presented, but each chapter also provides a self-contained overview of the specific topic that it addresses.

Each chapter is written by authors who are currently carrying out research in interface design and related issues. The first two chapters (by Chignell, Hancock, and Loewenthal, and by Card) introduce the topic and provide a preliminary definition of intelligent interfaces. The chapter by Kantowitz then discusses the relationship between human and machine intelligence and illustrates the process of adding intelligence to software. These first three chapters set the theoretical context for the book. The next four chapters summarize important research findings that relate to intelligent interface design. The chapter by Eberts and Eberts places the intelligent interface concept within the broader context of human-computer interaction, while the chapter by Polson, Wickens, Klapp, and Colle reviews recent findings in cognitive psychology that have application to intelligent interface development. The chapter by Jacob reports basic research on the concept of direct manipulation that is a desirable feature for interfaces in general and intelligent interfaces in particular. Elkerton and Williges focus on issues of dialog design and show how dialogs within intelligent interfaces can be viewed as an evolution from earlier dialog design approaches.

The final three chapters discuss intelligent interface applications. Trollip and Lippert suggest knowledge engineering as a useful instructional process, and their work illustrates the type of application domain that would benefit from the introduction of intelligent interfaces. Myers, Scerbo, Limanowski and Fisk discuss recent approaches to on-line documentation, another area where intelligent

interfaces are needed. The final chapter by Higgins, Chignell, and Hancock calls for knowledge-based supervisory control in aerospace systems, which represents an evolving technology in which intelligent interfaces may add significantly to the safety and efficiency of flight operations.

This book should be of use to researchers, designers, and software engineers who are interested in the development and evaluation of new technologies for human-machine interface design. It is important for human factors engineers who are responsible for improving human-computer interaction and software developers to whom intelligent interface development presents a challenge and a necessity within an increasingly competitive environment. For the student, the present text provides a first and hopefully enticing glimpse of one emerging facet of human-computer interaction. It is our hope in this text to open new and exciting avenues through which to conceive of operator-machine communication.

We would like to thank our wives (Frances and Sandra) for supporting us in the editing this book, and we would also like to thank Kees Michielsen at North Holland for his assistance and encouragement in completing the project. There are a number of other people who have figured prominently in the production of this book. These include Nancy Knabe who assisted in the preparation of the camera-ready copy, and Bob Froelig, who acted as an invaluable and helpful technical consultant on matters concerning the computer generation of the text output. We would like to acknowledge the support of the IEEE Systems, Man, and Cybernetics Society who sponsored the original session on intelligent interfaces at their annual meeting in 1986 that led to a number of the chapters in this book. Lastly, we could not have produced this work without the support provided by NASA, the National Aeronautical and Space Administration. The grant monitor, Sandra Hart, facilitated the production of the text through administration of Grant NCC 2-379, which enabled the completion of the processing of the work. Their continuing support is much appreciated.

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1. AN INTRODUCTION TO INTELLIGENT INTERFACES

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1.1. INTRODUCTION

Computing has evolved rapidly along several dimensions which include processing speed, software complexity, and mass storage capability. Although mainframes and minicomputers are generally more powerful than microcomputers at any given point in time, contemporary microcomputer workstations not only exceed recent mainframe capabilities (Peled, 1987), they also include high resolution screens, efficient pointing devices, and a wide range of powerful software applications to promote operational efficiency. At the center of these developments is the interface. Intelligent interfaces represent the latest development in human-computer interaction and interface design.

This concept of an intelligent interface is one of a number of proposals that offer innovative solutions to the problems encountered in human-computer interaction. Related developments range from the construction of advanced interfaces (Engelbart, 1963; 1986), through related concepts of adaptive interfaces (e.g., Edmonds, 1981) and dynamic media (Kay & Goldberg, 1977), to more recent implementations of specific systems (e.g., Hollan, Hutchins, & Weizman,

1984; Mark, 1981, 1986).

In our view, an intelligent interface is:

> An intelligent entity mediating between two or more interacting agents who possess an incomplete understanding of each others' knowledge and/or form of communication.

Clearly, the views represented by other authors in the following chapters of this text do not necessarily support our definition. It is instructive to compare their perspective against our own, as it is through such a process of refinement and argument that a consensus definition of the concept may be derived.

The principal role of an intelligent interface as defined in this book is one of an intermediary which bridges the gap between humans and computers (Card, this volume; see also Chignell & Hancock, 1987). The function of this intermediary is to encode and translate information which must be communicated between computer and operator and vice-versa. In this introductory chapter we define the concept of intelligent interfaces and integrate such an approach with related strategies for human-computer interaction, including developments in direct manipulation, natural language interfaces, hypertext, and expert systems. We also provide a broad overview of the issues associated with intelligent interface design. The what, when, and how of intelligent interfaces describe a developmental process. The what concerns the nature purpose of the intelligent interface. The when is the critical consideration in knowing the relevant circumstances in which an intelligent interface is required. Our knowledge in regard to this step is currently fairly rudimentary because there has not be a great deal of experience in building and using intelligent interfaces. The how refers to the identification of appropriate component elements and the manner in which they are assembled into a functional whole. We consider the different models of intelligent interfaces that are available, when these types of interface are appropriate and how they may be constructed. During this discussion we will show how later chapters in the book address the issues that are raised.

1.2. ADVANCES IN INTERFACE TECHNOLOGY

Intelligent interfaces represent the latest stage of development in the evolution of the computer interface. This process has occurred with extreme rapidity. It is little more than a decade since large numbers of computer cards were stacked in heavy and unwieldy boxes for repetitive processing on card readers. Even that method was an improvement on earlier uses of such media as paper tape input. Today, interfaces are screen-oriented and utilize abstract models of data on the screen rather than the more cumbersome physical models of the past.

As the physical interface continues to become more transparent, with the utilization of pointing devices, windowing technologies, and similar tools, the role of the cognitive interface (Chignell & Hancock, 1986a; Norman, 1986) becomes progressively more important. At present the computer tools that support this cognitive interface are still fairly rudimentary. Despite the increases in the size of working memory available to the user, only a small portion of this capability in personal computers is given over to manipulating the interface. In comparison to developments in hardware technology, methods of interface design are fairly primitive, largely because there are few models to guide the interface designer. In order to make interfaces intelligent, we will need to develop sophisticated models of how interfaces function, along with tools that can implement these models in software systems. We begin by considering what the purpose of the interface really is and what functionality is implied by this purpose.

1.2.1. Functions of the Interface

In general, an interface may be thought of as a device or representation that allows two agents to perform a task cooperatively. The environment represents the background against which this interaction occurs. The environment may be conceived of as a hierarchy of embedded envelopes which constitute tolerable limits for action (Hancock & Rosenberg, 1987). While concerns for interface optimization rarely focus on the nature of the ambient surround, there are circumstances in which the physical characteristics of the environment may have an overriding influence on the manner in which