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Introduction

This book aims to provide users and designers of industrial control and monitoring systems with an easy-to-use—yet effective—method to configure, design, and validate human-machine interfaces (HMIs). Such systems include distributed control systems (DCSs); supervisory control and data acquisition systems (SCADAs); and stand-alone units.

- **Distributed Control Systems (DCSs)** are typically real-time, fault-tolerant systems for continuous and complex batch process applications. DCSs were developed initially for continuous flow processes that required loop, analog, and limited discrete control. A DCS, while functionally integrated, consists of sub-systems that may be physically separate and remotely located from one another.
- **Supervisory Control and Data Acquisition System (SCADA)** is typically a generic name for a computerized system capable of gathering and processing data and applying operational controls over long distances, such as is used with power transmission and distribution and pipeline systems. SCADA systems are designed for unique communication challenges (delays, data integrity, etc.) resulting from the various media that must be used, such as phone lines, microwave, satellite, and so on. SCADA systems are usually shared, rather than dedicated.

- **Stand-alone Units** are typically simple, embedded systems that perform pre-defined tasks, usually with very specific requirements.

This book discusses the overall HMI design process; how that process relates to system design; detailed design methods, principles, and rules for individual displays and groups of displays; and integrating both software-based and hardwired HMIs.

It also provides guidance on the design of HMIs for other, less common, yet important components, such as expert systems and electronically displayed operating procedures. With the information contained in this book, a user or designer can determine how to configure or design a whole new set of displays for a system, or how to enhance specific elements of an existing or planned HMI.

The material originates, to a large extent, from a graduate course (IND 6408 *Human Factors in Process Control*) and a fourth-year course (IND 4803 *Cognitive Engineering for Complex Systems*) that the author has been fortunate to teach for a number of years at the Department of Mathematics and Industrial Engineering of École Polytechnique de Montréal. A substantial proportion of the material is also drawn from the professional practice of the author in HMI analysis, design, and validation in domains ranging from nuclear power plants to the Web.

Audience

The primary audience intended for this book is designers and developers of HMIs; however, it will also assist project leaders and managers, engineers, and system integrators in ensuring that the systems they design will work synergistically with operators, thus leading to improved safety and productivity.

The book was also written with operators in mind. Having been in field service for a number of years, the author recognizes that operators and their supervisors optimize processes on a day-to-day basis. It is hoped this book will help them better understand how to enhance and optimize existing HMIs, and to express their operational requirements in a way that can be more easily understood by HMI designers.

Why Design an HMI?

Having said all that, it is perhaps a good idea to explain why HMI design matters. Borrowing from a popular song[1], the HMI is "not just a pretty face" that will make the system look good. In fact, if the HMI looks aesthetically pleasing, the look will result more from an elegant design than from a conscious effort. Of course, if we can, we will always strive to make an HMI look good. However, the most important objective is to achieve usability, which is defined as:

> *"… the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use…."*

Right away, we realize that usability has little, if anything, to do with individual preferences. Rather, a system will be termed *usable* (rather than *user-friendly*, which means precious little because it is unmeasurable) when it helps specified users to achieve specified goals.

A question frequently raised is the actual need for designing HMIs. After all, have we not designed HMIs for the last several decades? Don't operators know what they want? Doesn't management know what the operators need? The unfortunate answer to those questions is a resounding "no." Rather than taking this answer at face value, let's look at a few facts.

Figure 1–1 shows that the bandwidth made available by modern HMI hardware and software has grown exponentially over the last few decades (Cochran, 1992). Note that current Internet and Web technologies are not addressed in this figure.

Unfortunately, human capability to absorb and understand the information has not grown at the same rate as HMI bandwidth. Neither has our ability to provide the information in a comprehensible way. For this reason alone, it is justifiable to try to design HMIs that better support the operator.

An example can be taken from the petrochemical industry. In the United States alone, it has been estimated that inadequacies in the means available to deal with abnormal situations (including HMIs

1. Shania Twain's *Not Just a Pretty Face.*

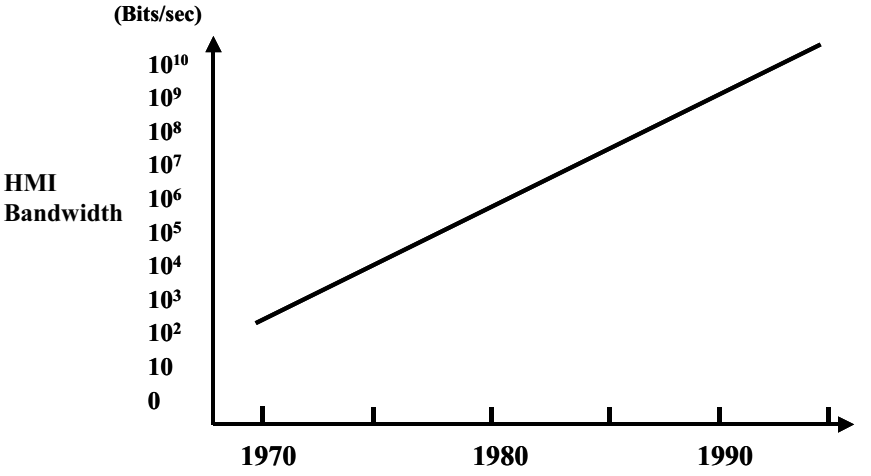

Figure 1–1 *Growth of Bandwidth Offered by HMIs*

used to identify, diagnose, and deal with those situations) cost the industry between ten and twenty billion dollars each year. Clearly, there is a need to do better and, as we will see, it is possible, and even easy, to achieve that objective.

We do not pretend that HMI design is a panacea; rather, we see it as a key component of sensible system design. Even more, given that a system's architecture is driven by the design of its interfaces (Meier & Rechtin, 2002), and since the HMI is one of the major interfaces of an interactive system, it becomes clear that the HMI's design will exert enormous influence on the architecture and design of the larger system.

This viewpoint may come as a shock to design engineers who typically look first at functionality, flow diagrams, electrical diagrams, etc. and only later worry about how the system will be used. The trick here is to realize that the system is there to support its users in achieving a set of operating goals that the organization desires to attain. One of those goals, at least for commercial organizations, is to achieve a near-optimal productivity. This goal rests, in part, on sub-goals the operators achieve through their own goals and sub-goals. Those operators' sub-goals, and the strategies they use to reach them, drive (to a large extent) HMI design and define sub-functionalities the

system will have to provide. The same argument can be made for goals related to safety.

Organization of the Book

Since this book is intended for a wide and diverse audience, the material has been organized to meet various objectives. It should be noted that no assumptions have been made about the technology that will be used. While specific examples are given in the context of a given technology (e.g., software, hardwired panels), the content of the book applies to HMIs in general, ranging from individual control panels all the way to the display suite of a complete monitoring and control system, whether implemented in hardware, software, or a combination of both.

The first chapter deals with the toughest scenario: designing an HMI from scratch. Depending on the reader's role, this chapter may be read in detail (e.g., by design staff) or at a higher level, concentrating more on the process used than on the details (e.g., by operation or management staff). It explains each of the steps of the design process and offers a fictitious, yet realistic, example of what is involved.

The next chapter deals with the evaluation of the HMI that has been designed. Two important methods are introduced and discussed in detail. This chapter should be of interest to both technical and non-technical staff.

The results of the design exercise will then feed into the system requirement specification. The third chapter explains how to specify an HMI design in such a way that it can easily be integrated into the project's technical documentation.

Once an HMI and its associated systems have been designed, validated, and implemented, it will evolve to fit the needs of the organization. The fourth chapter deals with the continuous improvement of the HMI and provides methods to ensure that initial benefits, which are expected to be substantial, do not eventually erode.

Chapter five describes specific aspects of HMI design for DCS and programmable logic control (PLC) applications, while chapter six discusses the integration of heterogeneous components, such as wireless devices and third-party HMI components.

Chapter seven discusses how consoles that will host the HMI will be integrated into the control center, thus leading to a synergistic interaction between those components.

Strictly speaking, an HMI comprises all of the elements that a user will touch, see or otherwise use to carry out his or her tasks. This implies that components that have not traditionally been considered as being part of the HMI need to be considered in the design to ensure that the resulting product will optimally support the user, who is striving to achieve the organization's operational and safety goals. Chapter eight thus discusses designing and integrating decision-support systems and operating procedures into HMIs.

Rather than cluttering the book's text with endless individual design rules, those rules have been assembled into Appendices. They can be readily referenced, as required, into examples provided in the main chapters. They are also easy to find at design time.

Paper-based Publications

Cochran, Edward L., *Control Room User Interface Technology for the year 2000: Evolution or Revolution?* in Proceedings of the Human Factors Society 36th Annual Meeting 1992. pp. 460-464.

Meier, M., Rechtin, E., *The Art of Systems Architecting*, ISBN: 0-8493-0440-7 (Hardbound), CRC Press, 2002.