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I am submitting herewith a thesis written by Paul D. Rush entitled "Methodology and Guidelines for Human-Computer Interface System Development." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

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METHODOLOGY AND GUIDELINES FOR HUMAN-COMPUTER INTERFACE SYSTEM DEVELOPMENT

A Thesis
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Paul D. Rush
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DEDICATION

This thesis is dedicated to my wife

Mrs. Debora J. Rush

my children

Adam and Ashley

and

to my parents

Mr. Paul E. Rush

and

Mrs. Bobbie J. Rush

who have given me invaluable educational opportunities
and the insight to appreciate such opportunities

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I owe my wife, Debra, a great debt. Without her help and encouragement I would never have reached for this moment.

My mother always insisted that I continue my education. My father enabled me to do so. My children helped with the need.

My thanks mostly to God, who has provided me with this opportunity for accomplishment.

ABSTRACT

Human beings utilize sensory systems to interface with the environment. The environment generates analog signals in the form of light, heat, sound, and force. The sensory systems of the human body function specifically to sense and measure these inputs. We regulate our exposure to the elements, surround ourselves with reproduced sounds, and are regularly found captivated by mass produced video signals.

Information technologies are an extension of this alteration of our environment. Using information technologies, we reduce delays in information distribution, increase the effectiveness of data storage and retrieval, and improve the processing of data. Current information technology interface processes are based on our sensory systems. The same systems which are concerned with the reception of natural environmental signals are being used to interface with this complex machinery. We need to broaden our "tunnel vision" perception of the interaction between the human and information technologies. Given that the micro-computer is a common device used for altering our environment, the interface between the user and the computer will determine the effectiveness of the environmental alteration.

To facilitate the identification, development, and implementation of these new interface processes, a method specifically designed for human-computer interface system development is required. This research presents a methodology that will expand the potential set of interface processes beyond sight, sound, and motion; and will establish guidelines, based on life cycle phases of the system, to increase the effectiveness of the interface process.

Beyond this research, is the streamlining of the development process by establishing tables and matrix charts of potential interaction processes between physiological and digital processes. These charts and tables help form the basis for an extended body of knowledge and for further studies directed towards the optimization of interaction between humans and computers.

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CHAPTER ONE

INTRODUCTION

Advanced technologies tend to awe the general public. These technologies seem to be miracle workers "utilizing smoke and mirrors" to miraculously produce results with the touch of a button or the sound of a voice. The wonder lies in how they operate; how they know what to do in order to create the desired outcome. This perception is especially true for information technologies (IT) which consists of both hardware and software. Since the hardware is visible, it is perceived as being the system. However it is the silent partner, the software, which is providing instructions on how to manipulate input from the environment and transform it for use by entities in that environment. It is the software directing the operation of the tangible hardware which performs the visible and physical operations.

The information technologies are not lone islands of automation, however; they do not operate in a void. They are part of information systems and serve a specific purpose. These systems not only consist of the information technologies, but they also include people, policies, and procedures. They receive inputs across the system boundary from entities, specifically humans, demanding services or information, and they send responses to these demands back across the boundary to the requesting entities. Confidence in these responses requires the demands to be captured and interpreted correctly so that the interpreted input is effectively processed to create a response which is accurate and applicable.

Thus, not only is appropriate processing important for reliable output, but so is the interaction between the human and the computer. This contact is the point of interface. It is the point where the output from the human becomes the input to the information system and vice-versa. It is the initiation of communications. Thus, if the interface is ineffective, all remaining activities (interpretation, manipulation, storage, etc.) are inconsequential. The interface between humans and computers, however, is the boundary between an analog-oriented environment and a digital-oriented system. The output from the human in the environment is analog and the input required by the computer processor must be digital. Likewise, the output from the digital-oriented computer must be translated into an analog form before it can be used by the human.

The human body interacts with its surrounding environment through sensory systems. These systems respond to signals which are generated by the human's environment. This environment generates stimuli such as sights, sounds, smells, and touch/pressure as inputs to the human body. These stimuli are physical events which cause physiological activity in a sense organ. The computer interacts with its environment through physical stimulation of peripheral hardware devices. For both the human and the computer, however, cognitive processes are required between receiving the input and providing the output. For both, the input must be transformed, manipulated, stored, and retrieved to generate a response.

Current human-computer interface technologies also require the computing system to generate signals which can be detected and measured by the human sensory system -- particularly sight and sound. Likewise, current devices used to generate input for the computer, from the human, are primarily hand and touch based. These include the keyboard, the mouse, and the touch screen. New technologies are being designed to provide input through speech recognition and foot touching (Bailey, page 265). Some technologies are being designed to respond to gestures; however, commercialization of such technologies is still 5 to 15 years in the future (Verity). Perhaps other approaches besides these environmental signals may become viable alternatives for providing an interface between the human and the computer.

Advanced technologies could increase the efficiency of the human-computer interface by reducing the need for conversion of the digital signal into analog signals which are detectable and measurable by the basic human senses. One possible approach is to convert digital signals into electrical or chemical outputs which may be directly input to the human physiology. Likewise most human output to its environment has been in the form of physical action and sound. Utilizing new technologies we may include other human generated signals as input to the computer systems and to the environment; thus improving the interface.

The optimization of this human-computer interface requires a formal process for the analysis, design, development, and application of human computer interaction systems. This process of interface system development must include guidelines and procedures necessary to ensure that the system developed will facilitate the requirements of the system.

Background

Two entities have communicated when the message received is the message sent. Between the source and the destination, the message goes through several processes. It is encoded, transmitted over some medium, and then decoded. During these intermediate processes noise may become attached and the message received may be a distortion of the message sent. To eliminate, or minimize such distortions, the intermediate processes or sub-processes must be optimized - both independently and within the framework of the entire interface process. Their optimization requires expertise from several fields. It also requires analysis and design from a systems perspective to ensure the entire communications system is optimized, and not sub-optimized at the individual processes.

To develop a human-computer interface requires knowledge about systems analysis, digital and analog processes, psychology, physiology, and ergonomics. An understanding of how analog signals are converted into digital signals is the foundation of the knowledge base required. To develop an effective human-computer interface, knowledge about the human part of the relationship and the information technologies is required.

To optimize the technologies side of the relationship, expertise in signal generation, switching, amplification, digital logic and machine command languages is necessary. Most of the devices currently used for this interaction are based on processes which were previously developed for use with other technologies. The requirements for these devices were based on the functionality of the human and the computer independently. The devices converted physical motion generated by the human into a binary digital code for the computer. The basic function of these devices was the conversion of mechanical forces into electrical signals which could be converted to a digital format and the conversion of digital signals into analog information.

Basing interface systems on existing equipment design was efficient and allowed for continued development of computer systems. The hardware used as interface systems include keyboards, pointing devices, microphones, switches, video screens, and speakers. All of these devices have been used for other applications and were available when the system designers needed equipment capable of interfacing humans to digital processes. As digital processing became more available, and applications were developed, it was natural for existing human to machine interfaces to be utilized. Switches, keyboards, and video screens were logical choices for the interaction between humans and computers. The individuals involved in the evolution of computing machinery design used the best existing equipment for the interface systems.

The digital technologists who have been involved in systems development have continued to improve the interface systems. Our limitations in this work now center around the digital technologists lack of understanding of human psychology and physiology. Interdisciplinary teams will be required to overcome this problem.

With today's advances in the understanding of human physiology, we are better prepared to research and identify possible points of interface functionality. The human body interacts with the environment utilizing sensory systems. These systems evolved based on signals which are generated by the human's environment. The environment generates sights, sounds, smells, and texture / pressure inputs to the human body. Our current interface technologies require that the computing system generates signals which can be detected and measured by the human sensory systems. With new technologies these environmental signals may not be required for the interface between the human and the computer. We can increase the efficiencies of the interface systems by eliminating the need for conversion of the digital signal into signals detectable and measurable by the basic human senses. We will convert digital signals into mechanical, electrical and chemical outputs which can become direct inputs to the human physiology. Likewise most human output to its environment has been in the form of physical action and sound. Utilizing new technologies we can include other human generated signals; chemical and electrical in nature, as output to the computer systems, and the environment.

To move towards an optimization of information technologies will require the development of all potential human computer interface systems. The development of these interface systems will require an understanding of all potential points of interface between technologies and the human body. A method to identify these interface points and to develop related interface systems is the goal of this research.

The process of developing a methodology for the development of new interface systems requires an understanding of what the current interface technologies are and why they evolved. An understanding of human physiology, psychology and digital processing is also essential. To fully utilize a methodology to develop new interface systems also requires an understanding of information science.

To optimize the use of information technologies requires changes in the interface systems between humans and computers. These new systems will be developed utilizing multi-disciplinary knowledge. Current interface system designs will be replaced with devices which increase the usability of the systems involved. The next generation of human computer interaction systems will reduce constraints placed on computer systems.

Problem Statement

The efficient development of these interface systems will require a formal methodology. A method for the development of interfaces for connectivity between digital processors and analog situations that applies an exhaustion of any latent non-evident solution is required.

Organization of Thesis

The following chapters of this work will provide a basis for the existence of this problem, a history of how the problem evolved, and a guideline for the systematic analysis, design, and application of optimized human computer interaction systems. These interface systems will include all appropriate factors involving the psychology, ergonomics, and sociology of system design. This work will be restricted to analysis on the interaction between the human body and the computer. The approach could be applicable to any analog to digital interaction system involving a human operator.

Chapter 2 discusses the literature concerning concepts of Human Computer Interaction (HCI) , the current situation with HCI, and constraints involved in the development of human-computer interface systems. Chapter 3 describes a methodology for developing a more effective human computer interface system. Chapter 4 contains considerations pertaining to system design and architecture. Chapter 5 presents case studies demonstrating the approach described in this thesis. Finally Chapter 6 summarizes this research and discusses future extensions in developing human-computer interface systems.

CHAPTER TWO

LITERATURE REVIEW

Information technologies are improving business processes and the way people live their lives. The technologies being developed are involved with processing data in a fast and accurate manner. These new technologies improve the storage and retrieval of information, and are capable of gathering data and reacting in a programmed manner to input. This processing of data allows for an improvement in decision making and in the time it takes for decisions to be made.

The problem use to be that adequate quantities of pertinent information were not available to support decision making. Now it is too much information available with no effective means to decipher pertinence. Many branches of science recognize, discuss and study each of these problems. There are schools of information science, computer science, and information systems engineering. Each of these curricula advances the knowledge of how data can be collected, stored, retrieved, and manipulated to provide information on-time and in the form needed to be most effective.

Initially, the problem of too little information being available drove information technology developments. Now, the inability to control and manage the immense quantities of information which inundate us is the impetus for continued improvements. To this second thrust of effort, critical is the inclusion of analysis and design of an optimal interface process.

The technology required to gather, store, retrieve, and manipulate data is available; but the process of appropriately filtering and disseminating the resulting information has not been incorporated effectively. The communication processes between the human operator and the computer is not effective in assuring that the information received is the information needed. Also the medium through which this communication occurs, the interface, has not been given much attention in system development (Jackson, IE514 class-notes).

Several factors have contributed to the slow development of the interface component of information systems. The predominant factor has been system research and development without a system's orientation. Attention has been given to various system aspects, independently, but little has been given to optimizing all aspects together as a whole.

Human Computer Interaction

There are many individuals of science and engineering who are involved in the study of computer and human interaction. These are primary experts in disciplines which are concerned with a specific area of study as it involves the human-computer interface. These disciplines are explicit areas of study including psychology, physiology, physics, health and medicine, and education. The problem is that each have their own perspective of the applications and benefits of information technologies. The psychologist may concentrate on cognitive issues while the medical practitioner will focus on adaptive implications only. An integration of these perspectives is required to optimize the interface systems.

According to (Carroll, 1991, pg. 1), "Human-computer interaction (HCI) is an interdisciplinary area of applied research and design practice. Its key concern is to understand and facilitate the creation of "user interfaces", that is of course as experienced and manipulated by human users. In doing this, it seeks to draw on many established areas of science and craft: psychology, computer science, anthropology, management science, industrial design." At issue is how well these issues are addressed during the analysis and design of the entire system. Carroll indicates that even if they are not independently effective, they can contribute enough knowledge to create one discipline which is. Specifically, he states that "The question of whether or not a body of scientific knowledge exists that can significantly inform the design of human - computer systems is in hot debate. My position is not so much that such knowledge already exists, but that it can now be generated."

In addition there is not a standardized terminology used by all disciplines in their work and communications. What is needed is a shared knowledge base from which all involved could draw upon. (Bottom, 1993, preface), discussed the difficulties that one discipline has reading and understanding the writings of other disciplines. He stated that "the difficulty in communication creates inefficiencies which limit the development of information technologies which maximize human-computer interaction". Elimination of these inefficiencies is critical to the development of an optimal interface.

Design Strategies

In addition to the required interdisciplinary efforts involved in interface design and application, there are problems resulting from a lack of detailed methodology. The need for a detailed procedure to give guidance in the development of interfaces is expressed by (Hoeschele, 1994). "The detailed requirements necessary for conversion system design usually do not exist until the conversion system designer begins asking the questions that can lead to detailed conversion requirements. This lack of requirements at the level needed by the conversion system designer can engender an initial feeling of frustration." In fact, this lack of system requirements at the proper point in the development process, may lead to the development of an interface that does not work or meet the needs of its user.

When new applications are developed by information technologists, they generally are derived from the capabilities of new technologies. The digital scientist often discovers a new capability of digital technologies and then looks for an application.

A weakness of this design approach is best expressed by (Pickover, 1992). "Office technology promised more leisure time, but in the years following the advent of computers, mobile phones, and facsimile machines, work hours spread over another six hours." These technologies, perhaps, have been miss-applied.

To optimize the development of information technologies, the application limitations must be recognized; and a new process must be identified, which begins with a need to develop new technologies. Existing methodologies are based on the premise “Build it, and they will come”. Unfortunately, this premise often leads to wasted research dollars which could be better applied to developing a product for which a real need exists.

A better methodology begins with the observation that an inadequacy exists and ends with the development of digital processes which will enable the improvement. A detailed process of recognizing the limitations, identifying the problem, examining process improvements, and developing and testing solutions is required to allow for the next leap in information technology development.

After the problem is identified, the process of developing the system capable of solving the problem begins. Most systems that utilize information technologies involve the conversion of analog information into a digital format and the conversion of digital signals into analog information. Current technologies involved with human computer interaction are based on utilization of the primary senses: sight, sound, and touch or the sensing of measurable physical forces including heat, pressure, light, and motion. The true capabilities of digital augmentation of our society will not be realized until we open the concept of digital to analog interfaces to include all physiological capabilities of the human. These capabilities include the ability to send to and receive from their environment utilizing the basic senses. Other potential interface points include points of contact with the human neural net, the basic human physiological systems, and most autonomic processes. "The interface (human computer interface) consists of more than the computer terminal; it is the part of the system that represents the user's model of that system." (Meister, 1991, page 341).

The interface process includes the set of systems and there connection. If the goal of the process is to present Beethoven's *Ninth Symphony,* this would best be achieved through an audio form. If the goal is to describe the movement of a humming bird in flight, a video form of presentation might be best. Each goal of information exchange between systems directs the choice of interface process. A formal process of interface analysis and design must include a method of analyzing the systems to be interfaced and the analysis of the potential interface processes which can be utilized. If the goal of the process is to present Beethoven's *Ninth Symphony* to a hearing impaired individual, a solution is not so obvious. More analysis would be required. "The interface should be the first part of the system designed; it is necessary to define the interactions performed by the user / system and then design the interface to permit these." (Meister, 1991, page 342).

The digital systems to be interfaced will include data collection processes, logic controllers, data calculation processes, and data storage processes. Digital processes are binary integrated circuit processes. This digital process we will call computer process. The analog systems will include any analog information generator, collector or processor. These generally include all human processes, and any continuous information process. Analog processes are any real world generation or need of information.

Current Situation

Today the interface process includes devices which accept and translate analog information into binary form. These devices include keyboards, mouse, scanners, microphones, motion sensors, electromagnetic sensors, binary switches and many more industrial control type devices. Digital signals are translated into analog form by video screens, printers, speakers, and industrial actuators which make adjustments to processes. These devices have been established as the main interface process. A concept coined "multimedia" utilizes multiple forms in concerted effort to present digital information to analog systems.

The current body of knowledge involved with digital to analog interface is dedicated to the transformation of digital signals into analog signals and analog signals into digital signals. It is hard to find reference to works involved in the optimization of the interface that includes the study of biological processes that have potential for use as interface points for digital processes. The biological processes are analyzed in great detail, and there are near infinite resources for the study of anatomic processes. There is a lack of reference of anatomic processes interfacing to digital processors. This subject is relatively new and requires much study.

With the new availability of digital processors caused by the market demand for this capability, there is a need for a thorough analysis of the limitations on the utilization of digital processors caused by the limitations of the interface between analog and digital processes. Digital processors are readily available. There is a continuing study of the biologic processes. Interface mechanisms will be developed which will allow for a "seamless" interface between the biologic (analog) and technologic (digital) processes. The development of this technology will be improved with a rigid set of principles and processes which will enable success.

As information technologies become more capable to supply supplemental processes for analog systems, we will see a limitation placed on this capability based on the interface process. The keyboard is already the limiting process in many systems. The process of typing this text takes time away from study and assimilation of thought. This interface is a limiting part of the systems involved in preparing this report. The speed and power of digital processors are increasing exponentially as technology advances. The limiting factor in optimizing information technologies will be the interface between systems. Interfacing digital to analog processes, especially those involving the connection between the micro-processor and the human, will partly control the effectiveness of the entire system.

The current situation has the users interfacing with information technologies with processes which are cumbersome, slow, generic in design, and prone to error. These current interface processes require the user to spend resources facilitating the interface process instead of performing the process involved with the information technology.

Historic Development

Since the beginning of the computer age we have been using visual output and push-button input to interface with computers. The actual design and functionality of the interface hardware has changed but the basic application by the operator has remained the same. Video screens, keyboards, pointing devices, speakers, and microphones comprise most current methods for human to computer interaction. These devices are based on external human sensory systems including sight, sound, and touch. "The enormous interest in human factors of interactive systems arises from the complimentary recognition of how poorly designed many current systems are...". (Shneiderman, 1992, page 19). These "poorly designed" systems result from the lack of properly sequenced design steps.

The user interface software systems have developed more rapidly than the hardware systems. Text based menu systems have been replaced with graphic user interfaces which in conjunction with point and select devices have improved the user interface. The changes in software have been driven by the available hardware interface systems.

Historically we have seen new technologies developed with the analysis of potential applications of the technologies coming later. This results from the development of disciplines which have concentrated on specific technologies, while not focusing on engineering the application. This factor has fostered an efficient process of technology advancement but constrains the development of specific applicability. In order to optimize the development of human-computer interaction systems, a re-sequencing of the development process is required. The first step, in interface system development , needs to be the identification of the specific system requirements. The purpose of the system must be defined. Only after this is done can we develop technologies which fully supports the requirements. This re-sequencing is necessary in order to further optimize the system design process.

Interdisciplinary Involvement

The people who are involved with interactive system design include sociologists, anthropologists, philosophers, and artists as well as the digital and software scientists and engineers. The rapid growth of interest in interactive systems design is evident in the growth of special interest groups (SIGs). "The Association for Computing Machinery (ACM) Special Interest Group in Computer Human Interaction (SIGCHI) had more than 5000 members in 1991 and was the fastest growing of the 35 SIGs". (Shneiderman, 1992, page 6).

As the interface was recognized as a limiting factor in system functionality, the emphasis on advancing the science of human computer interaction increased. As application development becomes more available to the average user, the interface capabilities will increase. The design of interfaces will involve many varied disciplines. Any user will extend their expertise into the design of their system. This broadening of involvement will require more flexibility in the interface systems. This flexibility will require less standard functionality and more custom design of interface configurations. To accomplish this we will need to design modular interface equipment which will allow for diverse combinations of equipment. The development of this equipment will result in the creation of new disciplines which will be combinations of digital electronics, software engineering, human factors, human physiologists and individuals with specific subject knowledge which pertains to the user who will employ the interface.

The analog world appears random to a digital system. "The system and the human function in a probabilistic universe. This means simply that it is impossible for either of them to predict with absolute certainty the sequence and nature of the stimulus events that will effect them in the future." (Meister, 1991, page 78). This effects the development of human computer interaction systems. The system design must also include psychological analysis as pertaining to how the human user perceives the system.

Until now, information technologies have been limited by the notion that the technology's interface with the human should occur at the external sensory systems. This was reasonable, considering that digital scientists have little knowledge of biological processes beyond the obvious. Sight, sound, and touch were the obvious choices for this interface between computers and humans. In the areas of medicine and rehabilitation, the adaptation of interfaces involving the basic senses have been successful. There are many systems, other than the basic senses, of the human body which generate and receive signals. There are chemical, mechanical, and electrical signals generated and received by anatomical processes. These signals are potential points of interface to computer systems. To optimize human computer interface system development will require the inclusion of experts in human physiology. An interdisciplinary knowledge of digital and anatomical processes would accelerate the development of optimized information technologies.

"The most significant difference between hardware and software design is the development of dialogue mechanisms." (Meister, 1991, page 268). Current software interface is the result of applying a conversation control system utilized by the human operator. This control system is the process where the operator controls the action of the computer. As these systems have evolved, not all system attributes were optimized. "Actual design is, however, variable, disorderly, complex, inconsistent, and difficult to understand. Ergonomic knowledge is usually employed only in an implicit, unsystematic, incomplete way." (Meister, 1991, page 268).

We are limited in our utilization of information technology by the systems we have developed which interface the human operator to the technology. Utilizing basic human sensory systems to interface with computers was a logical starting point for interface system development. To optimize human computer interaction we must look deeper into the human systems for interface point opportunities.

CHAPTER THREE

METHODOLOGY

The purpose of this research is to identify and describe a methodology for designing and developing effective human-computer interface systems. The literature review established the need for a more structured approach in the development of interface systems and this chapter presents an approach which addresses that need. This methodology may be applied to interface systems involving microcomputers and human physiological functions. The human sensory systems and all other physiological processes form the set of potential points of interface with information technologies and are addressed in a structured approach to human-computer interface design and development.

Human-computer interface systems are unlike other human-machine interfaces because of the extreme variability involved. The processes of the computer allow for analog inputs to directly effect digital processes and vise versa. Human - computer interaction is a conversation between the two systems. The human provides input to the computer in the form of commands or queries and receives output in the form of responses and messages. Both the inputs and the outputs may be provided across a broad spectrum of media for various purposes. Thus the effectiveness of this conversation has a huge impact on the effectiveness of the system process.

To fully optimize human-computer interaction, this extreme variability must be addressed. The interface system must be customizable for its various applications. In order to truly optimize human-computer interface systems, we must develop tools which allow for specific physiological (human) functions to interact with digital technologies.

Current interface systems include hardware and software which have been designed for generic sets of users. The optimization of the interaction between the user and the digital technology will require components which are specific in function, and control software which allows for variability in the application. The hardware must detect, measure, or transmit specific signal types that the human physiology can facilitate in communicating with the digital technology. The software must be capable of managing the input and enabling accurate communication between the human operator and the computer.

The detection of changes in physical motion, sound, light, electrical charge, and chemical composition are activities by which the micro-computer could interface with the human operator. The output from the human to the micro computer can be either a controlled response or an autonomic reflex response. The response can be either direct manipulation or a trained biofeedback reaction. This response is a result of external or internal stimulation. To develop an interface system between the human physiological systems and a micro computer requires the development of a system which translates the output from one system into input for the other system, and vise versa.

The Development Life Cycle

A structured process that has evolved for the development of computer information systems is based upon the concept of a sequence of necessary and important activities through which all information systems must pass during their existence. Groups of related activities are combined into phases. Each of these phases represent stages of the life cycle of a system. "This approach is called the life cycle methodology or commonly, the Systems Development Life Cycle, or SDLC." (Gore, 1988, page 8).

Gore describes four phases of the System Development Life Cycle. These phases of Gore's SDLC, as shown in Figure 3.1, cover the study, design, development, and utilization of the system. The Study phase involves problem identification and analysis, and a recommendation of a feasible solution after alternate solutions are evaluated. A detailed design of the system, recommended in the Study phase, occurs during the Design

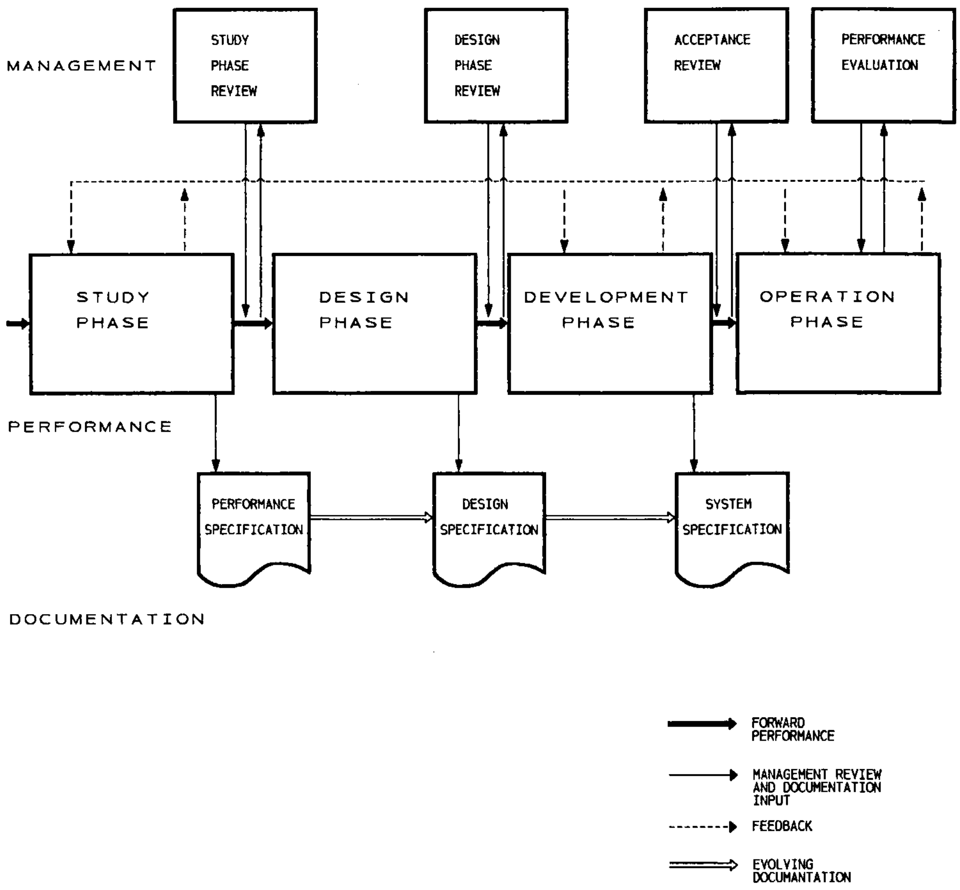

Figure 3.1 The Four Phases of an Information Systems Development Life Cycle

phase. This design includes developing specifications and determining resources which will be required to complete each task performed to develop the information system. The Development is the phase in which the system is constructed according to the specifications, and the final phase, Operations phase involves operation and maintenance of the implemented system.

For the purpose of human-computer interface system development, we will divide the life cycle into three phases. These sequential phases are the Study and Design phase, Development phase, and Operation phase Figure 3.2. The study and design phase are grouped together to allow for a feed back loop between the study and design of the system. Figure 3.3 describes the steps of activities within these three system development life cycle phases.

Because of the customization required to develop an optimized human-computer interface system, there needs to be integrated study and design activities. As the processes of the system are analyzed, they need to be incorporated into the design. The system might then be simulated or modeled to test proposed designs with respect to desired system performance measures. Prototypes of the human-computer interface system could also be useful in this phase. The prototype might evolve into the functional system; providing phased implementation of the system with continuous analysis and improvement of the design. Many human-computer interface system developments will involve the actual user. The user will be available for trials and for discussions about specific design considerations of the system.

The System Development Life Cycle (SDLC) of any human-computer interface system begins with the Study and Design Phase. The study process involves an analysis of the problem and a preliminary judgment of feasibility for developing a solution; and it results in a general design requirement for the system. The design of the system, is where the system is specified. This design of the system is based on the requirements developed

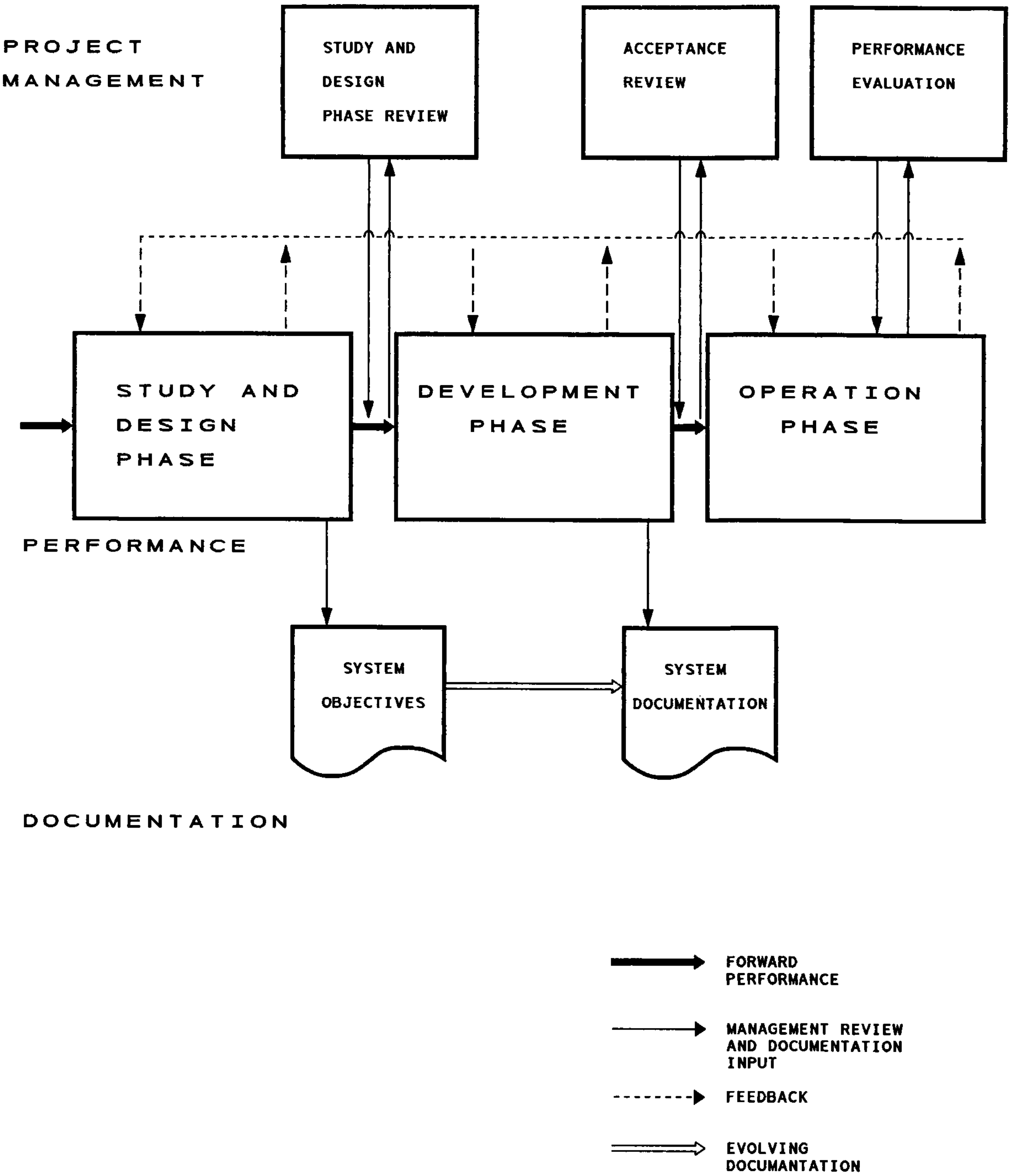

Figure 3.2 The Three Phases of The System Development Life Cycle for a Human-Computer Interface System

1. Study and Design Phase:

    Step 1. Establishing the specification of the desired outcome.

    Step 2. Examination of potential interface processes for the two client systems being interfaced.

    Step 3. Development of system design criteria

    Step 4. Documentation of system specifications.

2. Development Phase:

    Step 1. Planning the implementation.

    Step 2. Construction of physical interface system

    Step 3. System testing and user training.

    Step 4. System implementation.

3. Operation Phase:

    Step 1. System Initiation.

    Step 2. User feedback and system upgrades.

    Step 3. Termination of the system when obsolete.

Figure 3.3 Human-Computer Interface System Development Life Cycle in the system study. The system design is where the inputs, processes, and outputs of the system are also specified.

The next phase, the Development phase, is where the design specifications are utilized to construct the actual physical system. This phase also includes the implementation planning, system testing, and user training. The last phase of a System Development Life Cycle is the Operations phase. This is were the system is utilized to perform its specific purpose. This phase also includes the termination of use of the system whenever it is obsolete.

As with any system development life cycle, digital to analog interface systems follow this pattern in regard to life phases. The specific activities involved in each phase are unique to the design and implementation of human-computer interface systems.

The Study and Design Phase

The study aspect of creating an interface system includes identification and analysis of those tasks that are to be performed by the system. The parameters of the tasks, such as accuracy and speed are also investigated. Once the output (task occurrence) is specified, the potential interface process can be studied.

The design results in the specification of the system as determined during the study of the system. This design is the blue-print which will guide the Development phase. As the design of the system proceeds, further study is often needed based on feedback from the design process. The study and design of the system must be an open loop control process.

The analysis of an interface process involves the examination of two other systems. In the case of a human-computer interface, the two systems are the human operator and the computer technology and all of their subsystems which will be involved in the interface process. The communication between these two systems is the interface.

The effectiveness of this communication has a direct effect on determining the effectiveness of the technology application.

Step One (Specification of the Outcome)

The first step in the study and design of a human computer interface system is the establishment of the desired end result of the interface process. An interface process is the ability for one system to communicate with another system. The interface system translates digital data into analog information and analog signals into digital data. The basic process of interface could be described in the following form.

Output from System 1 + Interface Process => Input to System 2

This equation indicates the two parts of the input; the signal which is generated from the output system and the interface process. The relationship between the system generating the output and the interface process is where important decisions are made concerning the design of the interface. This design will be based on the results required of the system. Each of the process systems can be digital processes or analog processes. We will only consider interface systems between digital and analog processes in this study. Many interface system tasks involve output from a human as input to a computer. The human generates a signal which must be conveyed to the computer for storage and processing. The outcome to be specified is the process of using the capabilities of one system to affect another system.

To facilitate the study and design of a human computer interface system, we should utilize a process flow diagram. Because of the nature of human-computer interaction, a functional flow diagram could facilitate the understanding of the processes involved in the system. Since interface systems process an output into input, decision / action diagrams would work well to model the system processes. These diagrams can be utilized as part of the logical model of the system.

There are differences between functional flow diagrams and decisions / action diagrams. "The most significant difference between the two techniques is the addition of the decision blocks (diamonds) ." (Meister, 1991, page 334). An example of a decision / action diagram modeling a human computer interface process is shown in Figure 3.4. This figure shows that the output from one system can be processed into input for another system, and that communication between the two can be made more effective through adequate feedback.

To properly describe the outcome from a system, an understanding of the potential system inputs is necessary. An example of such a system has the output being the storage of information pertaining to a specific event. To adequately describe this outcome it is necessary to understand the form of the input information. The form of the input information may be analog: such as sound, text, or visual. The output will be a digital representation of the input. If the input is digital in nature, the output generated will be analog in nature, understandable by the human operator.

An understanding of the input signal and the desired outcome supplies the basis for the interface process design. All of the specifics about signal form, such as frequency, duration, criticality and accountability must be detailed for the desired outcome and the known inputs.

This specification of the outcome from the system process is the first step in the study and design of the interface system. The outcome of the system process may be any result of the input and processing of the input.

As stated previously, the optimization of human computer interaction will require application of hardware and software which will be customized to the specific situation. After the desired outcome is specified; potential interface processes can be analyzed with the goal being to minimize effort and error of the interface process. Any applicable function of the human physiology and digital technology process should be examined as

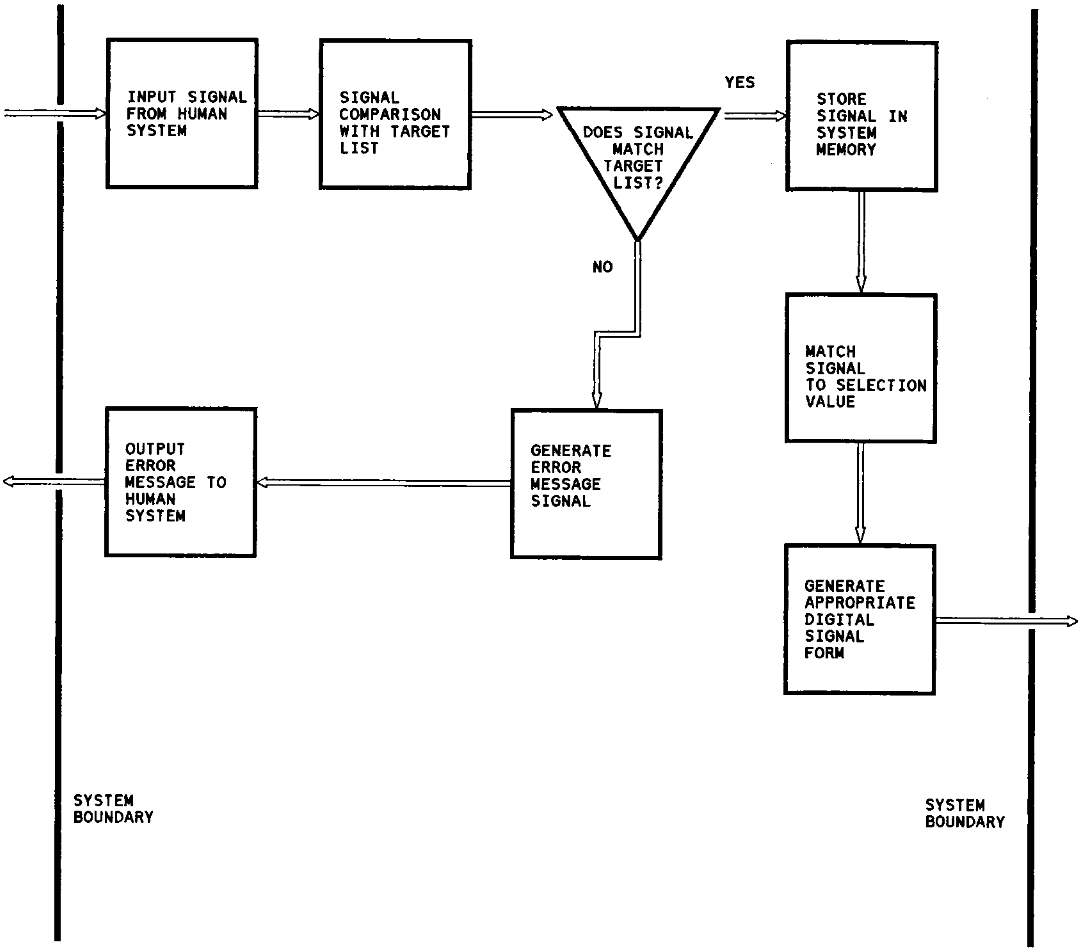

Figure 3.4 Decision Action Diagram of a Human-Computer Interface Process

potential use for human - computer interface systems. As we learn more about human physiology and develop new technologies, this list of potential processes will grow. Any human - computer interface system analyst will need to stay current with these subjects

Step Two (Potential Interface Process Analysis)

Next, an exhaustive search of potential processes that could be used for human - computer interface is performed. This search is based on the specifications from the previous step. Attributes relating to the desired system must now be specified in order to provide guidelines for the specific system. Factors such as speed, accuracy, criticality, cost, and safety must be determined. These factors may vary, depending on the level of interaction. These guidelines will be used to determine the level of system optimization which would be appropriate.

A basic examination of one type of human-computer interaction including the processes involved in the human and digital systems follows: The human brain performs a thought process which is a response to a decision prompt. This could be in response to a question poised by the system. The brain then facilitates the movement of the hand to activate keys on a keyboard. The keys are designed to generate digital signals to be processed as a response. The generated signal is converted into a digital form. The digital signal is then processed as a response or may be stored in machine memory for further processing.

An alternate process could have the brain activate the speech function as a response. The keyboard could be replaced by a microphone which in turn generates an analog electric signal which is converted into a digital signal by an analog to digital converter. Another alternate process might be to direct the signal from the operators brain to a device which in turn generates a digital signal. This process would reduce activities not prime to the system objective, like the user pushing a key. In any case, it becomes obvious that there are many activities involved in even a basic human-computer interface system.

The process of human-computer interaction requires at a minimum, a thought response to a stimuli, manipulation of analog signal generation, analog to digital conversion, and storage or processing of the digital signal. Each of these activities impact the effectiveness of the human-computer interface.

The second activity, manipulation of analog signal generation, is where the user generates a specific signal which is later converted into a digital structure. This is the activity where the interface really occurs. There maybe alternative approaches to this activity. The switching device could be of any form which is capable of generating an electric signal. The signal could be optical, sound, mechanical, chemical, or electrical. As an example, when the brain generates the response thought process, the thought process could be considered as the signal. The signal that is generated could be amplified and converted into digital data with out the physical motion steps. This would require an adaptation of hardware that could receive and convert brain waves or nervous system signals into digital signals. This type of interface would be complex. The end result however would be an efficient system, reducing user effort. The cost of the system must be compared to the level of interface optimization required.

Human computer interaction can occur at three System Interface Levels (SILs), Indirect Physical Interaction, Direct Physical Interaction, and Biophysical Interactive Connectivity. These levels are described in Figure 3.5, along with examples of interface media. Each of the system interface levels represents a group of interface points defined by the type of physiological involvement.

The first level, Indirect Physical Interaction (IPI), utilizes physiological functions which allow for physical separation of the human operator and the computer.

1. Indirect Physical Interaction (IPI)

   Definition: Involves physically separating the user from the computer

   Examples: Voice recognition (microphone-audio pattern recognition).

   Optical pointing devices.

   EEG Pattern recognition

   Galvanic skin response

2. Direct Physical Interaction (DPI)

   Definition: Involves mechanical switch manipulation

   Examples: keyboards,

   pointing devices

   position digitizers.

3. Biophysical Interactive-Connectivity (BIC)

   Definition: Requires intrusion into the human physiology

   Examples: Electro-physical connectivity

   Chemical reaction connectivity

   Physical pressure and motion

Figure 3.5 System Interface Levels

Interface systems at this level do not require the physical manipulation of a switch or a control. Examples of an IPI system include speech recognition, optical character recognition, and light based pointing devices. Problems that can result from this level of interaction include signal error which is a result of the input type and conversion error which results from the systems complexity. This level of interaction most resembles a dialog between two humans.

The next, Direct Physical Interaction, (DPI) currently represents the most common forms of human - computer interaction. This level of interaction is where the human operator physically manipulates the pointing devices, keys, and switches utilizing basic control manipulation movements. Direct Physical Interaction fully utilizes the human operators abilities to process and react to a stimulus with physical manipulation. Direct Physical Interaction systems consist of simple hardware, including switches and controls, which generate electrical signals. These signals are converted into digital signals by a special processor attached to the microcomputer.

The third, Biophysical Interactive Connectivity (BIC) involves intrusion into or connection to the physiology of the human body. These interface points include any connection not possible external to the human physiology. This level of interface generally requires more processing by the computer and interface system and less processing by the human operator. An example of this type of system would be a connection involving electrical signal generation by the human nervous system and an electrical detection system attached to a microcomputer by means of an analog to digital converter.

There are many problems associated with BIC. These problems include the dangers inherent with direct connectivity between some physiological processes and technologies. Other problems include the lack of acceptance by the general public of such types of systems.

The Biophysical Interactive Connectivity between human physiology and digital technologies offers the most promise for optimizing the human computer interface. BIC will allow for full integration of human and digital systems. Only with direct interactive connectivity with the human physiological systems and technology will there be opportunities to interface the computer with an autonomic human response. This level, however; requires the greatest amount of customization of the system. Generally the interface systems at the IPI level would require more complicated hardware and software than Direct Physical Interaction (DPI). An IPI system allows for more processing by the hardware and software, and less processing by the human operator than DPI. The constraints determined during the system study and design will dictate the appropriate System Interface Level.

To facilitate the development of an interface system between digital processes and the human physiology, we need to categorize the potential sets of interface points. The human physiology consists of systems which represent combinations of organs of similar or related functions which work together as a unit. Figure 3.6 lists the systems of the human body (Crouch). It describes the components and functions of the eleven systems, Each of these physiological systems have multiple processes which may or may not be potential points of interface. The integumentary, nervous systems, muscular, skeletal, and basic sensory systems have potential for all three interface levels while the other systems of the human body may have potential for Biophysical Interactive Connectivity only.

In addition, an inventory of potential signal forms which could be used in conjunction with the physiological processes is needed. These signal forms represent the effectors which can be manipulated, creating input and output from a digital processor. Figure 3.7 lists processes which are utilized for input to micro-computers. These signal

1. Integumentary System

Consists of: Skin, hair, nails and glands.

Functions: Protection, reception of stimulus, secretion, and temperature regulation.

2. Skeletal System

Consists of: Bones, cartilage, and connective tissue.

Functions: Support, movement, protection, and blood formation.

3. Muscular System

Consists of: Skeletal Muscles.

Functions: Works in conjunction with skeletal system providing movement.

4. Circulatory System

Consists of: Heart, blood vessels, and lymphatic.

Functions: Transport foods to cells, carries away waste products, and regulates body temperature.

5. Endocrine System

Consists of: Glands including pituitary, thyroid, parathyroid, and adrenal.

Functions: Body function communication and control.

6. Sensory Systems

Consists of: Sight, sound, touch, taste, and smell.

Functions: Physiological interface with the environment.

Figure 3.6 Basic Systems of the Human Body

7. Digestive System

Consists of: Mouth, pharynx, esophagus, stomach, intestines, liver and pancreas.

Functions: Reduces the food to particles of small size so that it can be absorbed into the blood or lymph.

8. Respiratory System

Consists of: Lungs, larynx, trachea, and bronchi.

Functions: Supplies oxygen to the blood stream and expels carbon dioxide.

9. Excretory System

Consists of: The kidneys, ureters, and bladder.

Functions: Excretion and body fluid balance regulation.

10. Reproduction System

Consists of: The gonads, ductus deferens, seminal vesicles, prostrate gland, urethra, and bulbourethral glands.

Functions: Perpetuation of species.

11. Nervous System

Consists of: Brain, spinal chord, nerves, ganglia, and sensory organs.

Functions: Orientation, control and coordination, and reception of stimulus from the environment.

Figure 3.6 cont. Basic Systems of the Human Body

1.	Electrical:	This process can be binary (on or off) or may be a potential measurement.
2.	Chemical:	This process detects the presence or absence of specific chemicals.
3.	Physical movement:	This process detects the presence of motion or measures specific attributes of movement, such as speed, force, and direction.
4.	Audio:	This process detects the presence of sound or measures specific attributes of sound such as frequency, volume, and pitch.
5.	Video:	This process detects the presence of light or measures specific attributes of video such as spectrum, intensity, and frequency.

Figure 3.7 Analog Signal Forms

forms represent a summary of those described in the literature. Each of these processes can be used to detect and measure signals generated by the environment.

An investigation which culminates in the matching of digital to physiological processes that optimizes the interface between the human and computer systems requires an understanding of the desired purpose of the interface. The purpose of any interface is to have transactions occur between the two systems. A matrix, Table 3.1, which relates the physiological signal forms with potential computer system input processes will indicate potential transaction points. This table indicates that the reproduction system has no potential for human computer interaction, and that many of the human physiological systems may have limited potential for interface to a micro computer. This matrix was developed relying on observations and the author's intuition and experience. The integumentary system has receptors which can sense voltage, chemicals and physical movement. The chemical signal form is not identified as a potential transaction process because it could result in a degradation of the integumentary system for signal reception. When evaluating the analog signal forms as transaction processes for the nervous system we know that chemical and electrical processes have potential. The other analog signal forms appear to have no potential for use with the nervous system to facilitate the interface between the human operator and information technologies. Again, each of the combinations represented in Table 3.1 represent the authors judgment and need to be fully investigated for validation.

After the physical process of the human-computer interface system has been designed, the logic of the interface can be fully specified. The logic of the interface process includes all inputs, outputs and the rules directing the processing of inputs into outputs. After the analog to digital conversion occurs, the digital signal creates a resultant output, used for input, by the computer. This output is predetermined, based on

Table 3.1

Physiological and Computer Input Process Matrix

	Analog Signal Forms				
Human System	Electrical	Chemical	Physical Movement	Audio	Video
Integumentary	POTENTIAL	N/A	POTENTIAL	N/A	N/A
Skeletal	N/A	N/A	POTENTIAL	N/A	N/A
Muscular	POTENTIAL	POTENTIAL	POTENTIAL	N/A	N/A
Circulatory	N/A	POTENTIAL	N/A	N/A	N/A
Endocrine	POTENTIAL	POTENTIAL	N/A	N/A	N/A
Digestive	N/A	POTENTIAL	N/A	N/A	N/A
Respiratory	N/A	POTENTIAL	POTENTIAL	N/A	N/A
Excretory	N/A	POTENTIAL	N/A	N/A	N/A
Reproduction	N/A	N/A	N/A	N/A	N/A
Nervous	POTENTIAL	POTENTIAL	N/A	N/A	N/A
Visual	POTENTIAL	N/A	POTENTIAL	N/A	POTENTIAL
Auditory	POTENTIAL	N/A	POTENTIAL	POTENTIAL	N/A
Tactile	POTENTIAL	N/A	POTENTIAL	N/A	N/A
Olfactory	N/A	POTENTIAL	N/A	N/A	N/A
Taste	N/A	POTENTIAL	N/A	N/A	N/A
Proprioception	POTENTIAL	N/A	POTENTIAL	N/A	N/A

a list of expected input signals and decision logic. A decision / action diagram works well in documenting the logic involved in a human-computer interface system. The logic algorithm should supply the interface with a variable control mechanism. The software will allow for adjustments in the response to input signal. An improvement would be to incorporate predictive logic in the algorithm. This would reduce the amount of input required to facilitate the system.

Step Three (Development of System Design Criteria)

After the desired outcome and the physical interface processes have been specified, the design criteria of the system can be developed. This process is where, given the goals of the system and the interface methodology, the criteria needed to perform the interface process is developed.

One part of the design criteria is in the form of an initial systems attribute list. The attribute list is a statement of design factors which the system will adhere to. This list includes the point of interface with the human system, the type of interface process, and a list of desired conditions and results from the system. Another part of the design criteria will be a description of control logic used by the system.

The design criteria will also contain a system performance definition which "is the transformation from a logical performance requirement to a physical one. The process includes the statement of general constraints, specification of specific objectives, and description of the outputs to be provided." (Gore et al, 1988, page 191). This system performance definition will become the "abstract" of the system specification documentation. There are four steps in developing a system performance definition. These steps are, creating a logical model of the system, documenting a statement of constraints, listing and ranking the objectives of the system, and designing the system process flow detail.

The system model could be a functional flow chart or decision-action chart, as described earlier. This flow chart should be information orientated and describes each element of the system and how the elements relate with each other. This model of the system must include all inputs, logic processes, and outputs that might occur with the system. A physical model may be required to facilitate the connectivity to the human physiology.

The statement of system constraints is a list of all possible limitations placed on the system. These limitations can be internal or external to the system environment. Constraints can be control factors for the system design or limitations caused by outside forces.

Listing and ranking the objectives of the system is listing the goals of the system in order of importance or priorities. Since the human-computer interface systems deal with humans, the first objective will always be to take care of the well being of the human operator. Other objectives should be ranked based on the importance of speed, accuracy, cost and the actual outcomes expected from the system.

Describing the systems process flow detail is where each part of the system is specified. The human system and the technologies to be involved with the system are described. The software is defined in terms of function. All inputs and outputs are listed.

Step Four (Documentation of System Specifications)

The system specification documentation will be the blue print from which the system is developed. This documentation will include detailed documentation of the other three steps of system study and design. The desired outcome specification, the interface points, all design criteria and constraints, and system specifications are detailed to the point that system development can begin.

This documentation will contain the information necessary to transform the logical system into the physical system. All system descriptions, lists, tables, and diagrams will be standardized, documented, and organized. The system specifications will be used by the system hardware and software producers. The format for this documentation should be organized and orderly. A recommended outline for this documentation is presented in Figure 3.8. Each of the requirements is described and an explanation of their relevance in the development process is provided.

The Development Phase:

The Development phase is the system development life cycle phase where the system is constructed based on specifications developed during the Study and Design phase. Activities that are performed, during this phase, relate to implementation planning, equipment acquisition, algorithm design and programming, user training, and system implementation. This is where the actual system is created. The project expands to include the purchase, or fabrication and assembly of the hardware, and generation of software. The hardware and the software are brought together as a functional unit.

Step One (Planning the Implementation)

The Development phase of the SDLC of a human-computer interface system begins with an implementation plan. This is necessary in order to properly manage the tasks related to the production of the system. An implementation plan is a detailed list of activities involved in the implementation of the system. This plan should include a critical path network diagram and a project time-line. These charts and diagrams will help assure that all necessary steps involved with the system implementation are identified and addressed.

The implementation plan will include testing procedures for the components of the system and the entire integrated system. There also must be a training plan to assure that the

1. System objectives:

   This will be a listing of the objectives and purpose of the system. All reasons for the system development will be presented here.

2. System Constraints:

   All limitations that will be placed on the system must be specified. This information will give guidance to the system producers as to the extent of the system.

3. System Attributes:

   This is documentation which describes the systems characteristics pertaining to functionality.

4. Model of System:

   The system will be presented in a form which simulates the functionality and logic involved with the system. Usually in the form of a functional flow diagram.

5. User Profile:

   This is an optional part of the system specification which relates if there is a special consideration for the population of users that needs to be considered.

Figure 3.8 System Specification Documentation Format intended system user benefits from proper training. If the system is to replace an existing system, a conversion plan should be developed.

The system specifications are examined along with the ranked system objectives to determine the sequence of implementation steps. These implementation steps must take into account the interface objectives as well as the overall system design. The system specification documentation, prepared during the Study and Design phase, is a resource for developing the implementation plan. Information pertaining to the systems objectives, constraints, and attributes. along with a model of the system, is used as a guideline for developing the implementation plan. Even though the Development phase is where most of the resources involved with the project are consumed, it should not be difficult if the study and design of the system were performed properly.

Step Two (Construction of the Interface System)

This is where the actual human-computer interface system is produced. The hardware and software involved in the systems operation are created. The hardware consists of devices which will facilitate the interface process. During this process, the system attributes and constraints determined during system study and design, are utilized. This hardware is designed and constructed to meet the design criteria of the system. "Choosing hardware always involves making a compromise between the ideal and the practical." (Shniederman, 1992, page 269). The software should be designed independent of the hardware when ever practical. The control logic algorithm should be able to facilitate the inputting signal independently of the type of input device.

The hardware will facilitate the detection and conveyance of signals. For the human generated output, the devices produced will be required to take the natural analog signals, as generated by the human physiological process, and generate an electrical signal which will be converted into a digital electronic signal by the analog to digital converter.

For the computer generated output signal, the devices will take the digital or analog signal and produce an electrical, chemical, audio, visual, or physical motion signal. This signal will be such as to have pertinence to a human operators physiological or basic sensory system.

The system interface level will dictate the complexity of the hardware to be utilized. Many Indirect Physical Interface and Direct Physical Interface designs can take advantage of existing hardware. Most Biophysical Interface Connectivity designs will require the creation or adaptation of specialized equipment. As this special equipment is constructed and cataloged, there will become a base for use in future applications.

The software will facilitate the logic of the system. While the hardware detects, generates and transmits signals, the software controls the effect that the signal has on the system. The software constitutes the language by which the hardware communicates with the computer system. These drivers will be specific to the operating system of the computer, but should be kept general in regards to the interface hardware. This flexibility can be facilitated with the understanding that the interface hardware detects and transmits signals which could be standardized.

There are many software systems capable of controlling the interface system. A combination of a logic control system and a procedural language will satisfy the need. Any ladder logic software which will interact with a micro-computer control system can be utilized for the software system of the interface.

Step Three (System Testing and User Training)

The development process should proceed with a thorough testing of the system. This testing usually involves the gathering of feedback, review of the feedback, and system adjustments and changes until the desired results are obtained. The system testing is where the system should be proven. This is the opportunity for an optimization of the interface process. At this point it is decided if the system can be implemented and put into use.

All documentation pertaining to the use and function of the interface system must be well written and must be understandable by the designed user. This documentation will serve as reference and user guidelines. If the designed user is available, hands on training is preferred.

<u>**Step Four (System Implementation)**</u>

The system implementation is where the system is made available for use by the intended user. All steps necessary for the successful implementation of the system are complete. The system is safe and ready for use. The system is implemented by a team. The team may include the user and the system developer. For more complex applications, other professionals may be required. The implementation may have set backs which require further study and design activities.

The Operation Phase:

The Operation phase follows the Development phase. This is where the value of the system is realized. After the user is trained with the system, either through formal instruction, system tutorial, or literature, the human-computer interface can be utilized for its intended purpose. There will be a learning curve with the initial application of the new interface system. The duration and magnitude of the learning curve depends on the complexity of the interface, its proper design, and the attributes of the human user.

<u>**Step One (System Initialization)**</u>

The human-computer interface system may be an initial application or a changeover from another system. Either way, the system will be initialized and placed into use.

Successful startup of the system will depend on many things. The Study and Design phase, and the Development phase activities are important but not totally responsible for a successful system . A good system may never "get off the ground" if the user does not accept the system. This system acceptance by the user, is critical for successful utilization of the system. Not only does the system need to do its job, the user needs to understand the scope and limits of the system. False expectations of any system can lead to a user rejecting a system.

After the initial application, and when the learning curve has flattened out, routine operation of the human-computer interface system is possible. Routine should not imply "without problems", but is where the system is routinely utilized to perform it's desired function.

Step Two (User Feedback and System Upgrades)

After the interface system has been utilized for routine operations for some time, a performance evaluation should begin with a post installation review. This review will compare the actual interface system performance with specific performance objectives. Any problems or concerns observed during the post installation review should be documented. Each problem must be examined for root cause. The problem may be an actual system failure, or may be the operators lack of training or willingness to fully utilize the new interface system.

This post installation should be followed by periodic reviews. These reviews provide for feedback to the interface system designer and to ensure the interface systems integrity. This system utilization feedback is paramount in the continued development of the interface system designer. The information generated from the periodic system reviews should be compiled for use with later versions of the interface or for use in the development of a new interface system.

Step Three (Termination of the System When Obsolete)

When the system is made obsolete by a newer technology or any other reason, the system should be properly terminated. This must be the responsibility of the user and the user should be informed of the importance of this step. Any system which comes into direct contact with the human physiology could poise dangers if not operated properly. The safety of the system cannot be assured if the system is utilized for other than its intended purpose. If other than the designed user utilizes the system, it may not perform correctly, and results cannot be guaranteed.

For an optimized human-computer interface system, the termination of the system would be an upgrade to a newer version of the system. A properly designed and developed system will include considerations for future upgrades. It will allow for modular improvements and for adaptability to changes in the user's needs.

In summary, the effective development of a human-computer interface system requires detailed activities to be performed in a sequenced order. These activities are involved with the analysis, design, development, and operation of the system. These activities are grouped together into system development life cycle phases as an organized process for the effective development of human-computer interface systems. The phases are, the Study and Design phase, the Development phase, and the Operations phase. Each of these phases consists of steps, which when properly executed will greatly improve the effectiveness of the system development.

The phases of the SDLC are based on sequences groups of activities. Each of the system development phases involves specific sets of tasks or steps. The first phase, Study and Design, includes the analysis of the system goals and the establishment of specifications for the proposed system. The second, Development, is where the hardware and software of the system are procured and created. The last phase, Operations, include the initiation, operation, and termination of the system.

All activities involved in the development of a human-computer interface system, must be properly managed and documented. The utilization of classic project management tools including a time line Gant chart and process flow diagrams along with descriptive text are essential for the proper management and documentation of human-computer interface system development.

Appendix A presents the detailed steps of the methodology which was provided in figure 3.2. The human-computer system development is outlined in a flow chart showing the action, decisions, and outputs required throughout the entire process. This flow chart will lead the system developer through the steps of the three phases of the system development life cycle for a human-computer interface system.

CHAPTER FOUR

GUIDELINES

There are unique requirements involved in the development of information technology system. Systems involving human-computer interaction have different design requirements than other types of information technology systems. The utilization of a process, specifically developed for the design and implementation of an integrated business information system, to develop a human-computer interface system, would be wasteful and potentially ineffective. Each type of system has factors which require different methodologies in the effective study, design, development and operation of the system. The basic steps are the same for developing any system. "In general, the computer system design process is much the same as that of traditional hardware systems, although there are differences in degree. One [the developer] begins with an analysis to define what the system will do, the feasibility of designing such a system, and the development of design objectives." (Meister, 1991, page 268.) The differences required of the design process becomes more apparent when the actual functionality of the system is analyzed. This functionality is where the focus of the system development is defined.

A human-computer interface system has a unique attribute which must be considered by the system designer at all times. This attribute of interface systems, by definition, is that they serve as a functional border between two other systems. The interface system is the linking process between the other systems. The client systems involved with human-computer interface processes are the human operator and information technologies. All outputs and inputs involved with a human-computer interface system are the communications between the user and the information technology.

Inputs to, and outputs from, the human-computer interface system occur with the user. The user utilizes physiological processes to facilitate the interface system. The actual processes utilized by the user must be defined in detail in order to effectively develop the interface process. The user has many physiological systems capable of being utilized for human-computer interface, including: auditory systems, visual systems, tactile systems, chemical systems, and neurological systems. A human-computer interface system could utilize any or all of these systems as generators of output, or receivers of input, for interface system processes.

Likewise, the information technology system being interfaced with the human must be understood. Specifications pertaining to physical operating attributes must be tabulated and control logic must be formulated. To fully optimize the human-computer interface process, the information technology system may require a re-design to optimize the functionality of the interface system.

The effective development of a human-computer interface system depends in part on a proper focus during all phases of the SDLC. This focus results from an understanding of the attributes of human-computer interface systems. These attributes are factors which are common with all systems and those which distinguishes a human-computer interface system from other systems. As the human-computer interface system development life cycle progresses, the system developer should take into account the following principles and guidelines. These guidelines pertain to the understanding of the system objective, the systems boundaries, user profile, system architecture, operation of the system, and termination of the system when it is necessary.

System Objective

A good design process for human-computer interface systems would begin with an examination of the users needs. This examination must include an exact statement of the interface system's objectives. This is where the initiation of the need for a system begins. Either something can't be done or something needs to be done better. This is the classic cause for the development of any system. This system objective will drive the entire development process of the interface system. Without this statement of need, there should not be design activity taking place. It is suggested that the human decision making requirements should be the initial emphases for system design. (Metersky et al, 1989).

A consideration to keep in mind with human-computer interface system design is the level of system detail involved. Human-computer interface systems are a subset of a larger concept, human-computer interaction (HCI). The human can interact with a micro-computer much easier than with a large computer system or a network of computers with multiple applications. This fact is the result of the impact the interface has on the total system. The effect of the interface on the system must be understood for the optimization of the interface process. The effects of the human-computer interface process on a single application computer, are simpler to understand than the effects of the interface on a large network of computers with multiple applications. Human-computer interface system design involves detailed examination of the process of human connectivity to the computer, but it also must take into account all of the effects of the interface on the total functionality of the systems involved.

To develop a human-computer interface, which optimizes the communication between the operator and a computer system, requires an understanding of the objectives of the interface systems processes. The objective of the system is the outcome of the interface process. The objective of a human-computer interface system is the communication between the operator and the system. Effortless and error free communication between the operator and an information technology is the ultimate goal.

This communication takes the form of a dialogue which facilitates the function of the systems. This dialogue can take many physical and logical forms.

The system objective must be supported with a complete listing of system requirements and constraints which support the system specifications. The systems requirements help detail the specific purpose of the system and the operational characteristics. The constraints are the limits within which the system must operate. It is important to distinguish between the objectives of the interface system and the objectives of the client information technologies applications.

There are other considerations for the development of human-computer interface systems. An optimized human-computer interface system generally requires customization to facilitate the client systems. Thus, the specific client systems must be involved in the Development phase, as well as the Study and Design phase of the system development life cycle. This results in an over-lap of the development phase with the other phases of the SDLC. This over-lap of phases allows for a feedback from the user to the system developer regarding information and concerns about the interface system objectives.

The system objective must be considered during all phases of the SDLC for a Human-computer interface system. As the system is implemented, the results should be gauged against the objectives for the system. Since the objective of a human-computer interface system is effective communication between the user and an information technology, this interaction is the result by which to measure a successful implementation of the system.

For a human-computer interface system, the system objectives must be expressed in specific terms. The system objective must be expressed in more detail than simply "to develop an effective communication process between a user and an information technology". The system objective must be supported by detailed lists of requirements, constraints, and characteristics followed by detailed system performance specifications.

The measurement of the system's performance is dependent on the system's ability to fulfill its intended purpose. The attributes which determine a systems performance are the systems effectiveness and the systems efficiency. The effectiveness of the system relates to its ability to fulfill its designed objectives. It is measured by the systems usability, safety, and durability. The efficiency of the system involves a comparison of the effort required to obtain the desired output. It is measured by the systems price / performance ratio and user effort / system output ratio. A list of these two attributes and a matrix which tabulates performance measurements for an effective interface process is shown with Table 4.1. These performance measurements represent factors which should be considered during the development of an optimal human-computer interface system.

The system's performance attributes are based on the ability of the system to do the tasks that it was designed for, and the efficiency of the completion of the tasks. Metrics involved in the measurement of the effectiveness of a system include it's usability, safety, and durability. These measurements are chosen because of their fundamental objective nature. Other metrics, such as quality or level of user satisfaction are more susceptible to subjective interpretation and more difficult use in a comparative form. The efficiency of the system should be measured in simple terms as well. The cost of building the system must be compared to the value that the system produces. Another measure of efficiency is the effort by the user as compared to the output from the interface system.

Table 4.1

System Performance Attribute Measurement Matrix

Attribute	Metric	Description of Metric	Target Metric Value
Effectiveness			
	Usability	The systems ability to be utilized by the intended user.	Increase or degrease in effort by the system's user.
	Safety	The assurance that no danger to client system is caused by process.	Potential of harm to client systems.
	Durability	The ability of the system to be available to perform it's intended functions.	System availability.
Efficiency			
	Price / Performance	The ratio of price to the systems function.	Level of System cost compared to added value.
	User Effort / System Output	The ratio of effort by the user to the output from the system.	Acceptability by the user.

System Boundaries

To effectively develop any system, the boundaries of the system must be established. This is especially true for human-computer interface systems. These boundaries Figure 4.1, are where the processes of the client systems are independent of the human-computer interface system. Once these boundaries are established, the interface systems constraints and criteria can be better defined.

When designing interface systems, a boundary must be established which is the segregation of the function of the interface from the information technology applications. Beyond this boundary, the client information technology systems are innocuous to the process of the human-computer interface system. Without this boundary, the design process would become mired down with unnecessary and ineffective system analysis. At this boundary the processes of the client systems are independent of the human-computer interface. Beyond this boundary is where the client system's processes involve the result, but not the method of the interface process..

Likewise a boundary must be established with the human user systems. Beyond this boundary is where non-involved human physiological systems are not directly effected by the interface process. This boundary serves as a control function to assure that the interface process does not interfere with the normal activities of the human. The establishment of this boundary is extremely important. Establishing this boundary beyond the scope of the interface process or beyond safety considerations would be an irresponsible act by the system designer.

The system boundaries established during the Study and Design phase should not be changed during the implementation of the interface system. If it is determined that an

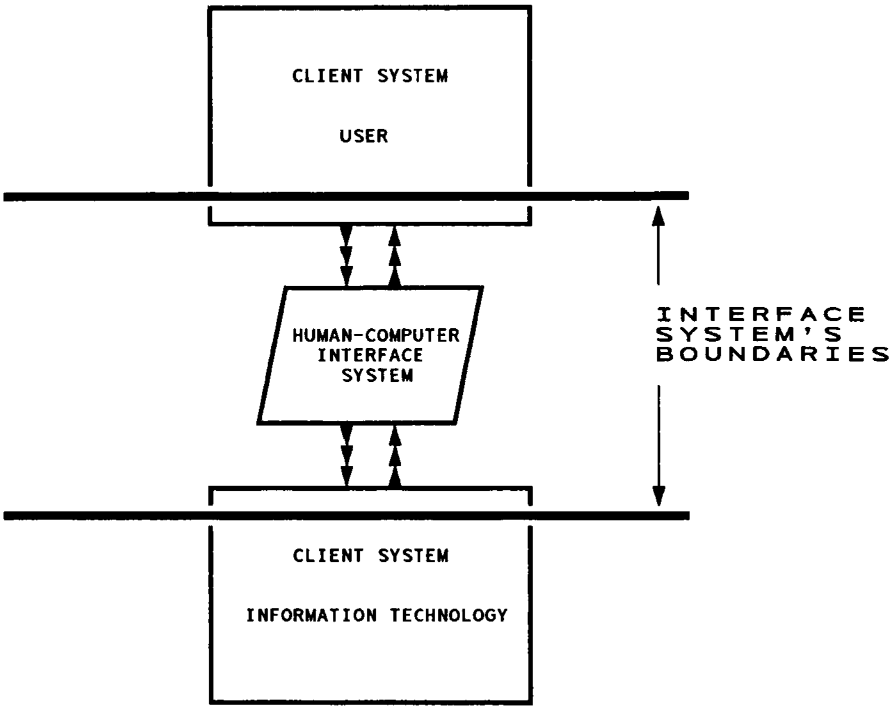

Figure 4-1 Human-computer Interface System Boundaries

adjustment of the boundary is necessary, further study and design is required. There may be considerations pertaining to the client systems which are not evident to the implementation team. Any adjustment to the boundaries will effect attributes of the client systems and the human-computer interface system. The system boundaries contribute to the definition of the systems constraints and requirements. Any adjustment to the boundaries will require returning to the study and design phase of the SDLC.

The boundaries, for a human-computer interface system are not easily defined. They usually involve the client system processes to some extent. This results in a virtual overlap of the involved systems. This concept my contradict classical system theory but becomes apparent when striving for a "seamless" interface process. If the goal of a truly effortless and error free interface process is to be realized, we must also accept the concept of the total system, consisting of the client and the interface processes.

User Profile

The analysis and design of any human-computer interface system must include considerations of the user that the system is being developed for. To optimize the human-computer interface, we must look past the concept of generalizing the user profile. To optimize an interface system requires an examination of the specific user. This user may have special requirements not addressable with a generalized user specification. This detail of user specificity would be impractical with regard to the total functions of a large multiple-application information system. The interface system will "generalize" the profile of the user, making the user generic in regards to the information technology applications. The applications design will have their own user profiles which they are designed for. The interface designer must focus on the interface functions; namely, the communications between the operator and the information technology, when considering the user specifications.

The human-computer interface should be adjustable. "One design objective should be to build human-computer interfaces with critical elements that change as the user becomes more experienced." (Bailey, 1989, Page 259). The full range of values for attributes related to the interface should be addressable by the interface system. As the user of the system gains experience in utilizing the interface, adjustments must be possible which allow for a minimization of effort and error potential of the system. "A well designed system will reduce the opportunities for errors, increase the user's ability to detect errors, and provide the users with an immediate opportunity to correct any errors that do occur." (Bailey, 1989, page 262).

This is an especially important consideration with Biological Interactive Connectivity (BIC) human-computer interface systems. These interface systems must have controlled variability of signal generation and detection for the safety of the user and the accuracy of the system. The limits of these attributes must be designed with safety factors which will prevent any possibility of danger to the human operator.

The interface process designed should be at a speed which matches the user and the computer. A process which slows down the communication between the user and the technology is a poorly designed system. The pace of the interface process should correspond to the pace of the user and the information technology; leaving a feeling of continuation, and not a feeling of discrete segregated activities. The system should not cause the user to wait.

Another important consideration to maintain during the design of a human-computer interface system is the implication to the human capability. No interface system should be considered that could result in a reduction in the capabilities of the human operator. This negative effect may seem remote, but indeed is a common occurrence. In the area of disability augmentation through information technology, there are occurrences where the handicapped operator does not achieve a physical capability because of the availability of the technology to perform the task instead.

A detailed user profile is paramount during the Development phase of the system development life cycle for a human-computer interface. This user profile should be well documented. If possible, there should be access to the actual user during all phases of the development of the system. For a human-computer interface system, the user profile must contain very specific attributes of the user. All constraints and functional capabilities which could relate to the interface process must be documented.

System Architecture

The system architecture is the style the system takes. This style is initiated during system study and design and continues through to implementation and utilization. There are many system styles which could accomplish the same task. The system architecture must take into account the processes of the interface. Simple control functions involving the manipulation of a switch in response to a stimulus might have a different style than a system which receives autonomic responses to variable external stimuli. To be successful in optimizing the interface process, we must establish standards which will govern the system architectures of human-computer interface systems.

There are many basic architectures for human-computer interface systems. One option would be to design the functions around the process of the human neural network. This would have the system function much the same as the neurons in the human nervous system. A logic system of this type may be well suited for interface systems involving neurological systems. Another system architecture could have a process where information is embedded in the system allowing for some level of artificial intelligence. Such an "expert system" would reduce the amount of human involvement in the interface process. This type of system would be well suited for a decision and response process. A system which utilizes the selection of responses and has imbedded constraints. The architecture of the human-computer interface system should correspond with the architecture of the client systems.

The implementation of an optimized Human-computer interface system can take many forms. Interface systems which are simple and non-intrusive to the human operator maybe "off the shelf" and successfully installed by the systems user. Interface systems which are more complex and specific as to the user profile and application, may require intervention from a help source or professional system integrator during the implementation of the system. Very application specific and physiologically complex interface systems will require a team approach. This team could consist of digital technologists, system designers, psychologists, and medical professionals.

Operation

The life cycle continues through operation of the system, up to termination and shut-down. The operation phase of the system development life cycle, must include feedback to the system development team. This feedback concerns the functionality of the system, its documentation, and its safety. Information is gathered and analyzed, with the intent to improve the human-computer interface system and to assist any future development work.

The placing of the system into operation is a very important task in the operation phase of the interface system development life cycle. In addition to the integrity of the hardware and software of the system, there must be considerations for user acceptance. The system will not be effective if the user does not accept the system and take ownership of it. If the system performs its function effectively, and is fully understood by the user, it should be accepted by the user.

The documentation of the system, produced during the Development phase, will be utilized in the Operations phase. This documentation includes user information and technical information. User information should include training and reference materials geared towards understanding of the system by the user. The technical information includes the system structure and process descriptions. For a human-computer interface system, the documentation should include a detailed description of the intended user and a list of constraints and limitations of the system.

Termination

The termination of the human-computer interface system is a result of the obsolescence of the system, the elimination of the need for the system, or the failure of the system through breakdown. In any case the system is eliminated from service. Since many optimized human-computer interface systems are systems designed for a specific purpose, the system should generally not be used for another purpose or user profile. The system should not be utilized for an interface process between other than the designed client systems. The system may be recycled, however; by a system developer who utilizes the system's components in the development of a new system. This begins a new system development life cycle.

Summary

These guidelines are intended to be used in conjunction with the steps described with the human-computer interface systems development life cycle, outlined in chapter 3. Other factors will become apparent as we increase the complexity of our interactions with information technologies. As these new factors and considerations are identified we must be prepared to document them. We must keep in front of us the goals of our work and the understanding that the optimization of human-computer interaction requires input from many areas of study. No one will be capable of achieving expertise in all of the areas involved with the optimization of a human-computer interface system. It requires a team approach, involving many different areas. A good human-computer interface system developer must possess the ability to locate and involve individuals with these necessary abilities.

CHAPTER FIVE

CASE STUDIES

This chapter presents two case studies of human-computer interface systems. This analysis is of processes which could be improved, utilizing the methodology presented in chapter three, and applied with the guidelines presented in chapter four. The interface systems discussed include a current hardware system which shows inefficiencies resulting from the current lack of formal methodologies and guidelines for human-computer interface development. The other case study is an example where a need is identified and a new interface process is developed based on the application of this research.

The human-computer interface systems discussed in this chapter include, the Prentke Romich Touch Talker, and a data collection system for tracking material movement in a manufacturing setting. The Touch Talker is a specialized laptop type computer which has programmable keys. The operator of this device utilizes the programmable keys singularly and in sequence to select words and phrases for speech synthesis. A system called Minspeak generates synthesized verbalization based on the selection process. The Touch Talker has communication ports which can be used to interface additional devices, allowing the Minspeak system to be utilized with other input and output processes. The Touch Talker has the capability for interfacing a personal computer. Here it can supplement the keyboard and mouse as an input device.

The other interface system examined involves the collection of information documenting the movement of raw materials into a manufacturing process. Information concerned with inventory management and lot control is gathered and entered into an integrated manufacturing management system.

Case 1: The Touch Talker

The Touch Talker from the Prentke Romich Company is a specialized computer designed as a prostheses for speech impaired individuals. The interface processes between the user and the machine include a keyboard with 140 keys, and a 40 character by 2 line LCD (liquid crystal diode) display. The keyboard can be used in two modes, spell mode and communications mode. The keyboard has 128 keys which can be custom programmed. In addition the device utilizes a speaker which verbalizes the synthesized speech, facilitated by means of the Minspeak system. This analysis will focus on the Touch Talker's human-computer interface processes and the utilization of the Touch Talker as an interface system between the speech impaired operator and a personal computer. A picture of a Touch Talker is in Appendix B.

The basic PRC Touch Talker utilizes a direct physical interface (DPI) for input from the operator by way of the keyboard. The operator must press the keys to either spell words or express phrases. Any length of sequence of the 128 programmable keys can be utilized by the Touch Talker's operator. These programmable keys are managed with over-lays, which have symbols, words, and letters corresponding to each key.

Output from the device can occur three ways. There is a speaker which produces synthesized speech utilizing Minspeak. "Minspeak is not a language but essentially an index system for retrieving text by means of mapping sequences of keystrokes to stored phrases." (Edwards-Strong, 1995, page 53). There is also a display which spells out the text before it is generated into speech through Minspeak. This display allows for editing the speech before it is made audible. In addition there are two communication ports for interfacing the Touch Talker with other information technologies.

One interface that is identified as a problem with the Touch Talker is the keyboard. The client systems of this interface process (keyboard) are the Touch Talker processor and the human operator. For the user to facilitate the Touch Talker, keys and/or sequences of keys must be pressed. This is very time consuming and requires additional cognition and physical processing by the user which is not inherent to the natural process of speech. This interface process is inefficient, slow, and limits the vocabulary of the user by how many sequences of keystrokes that can be memorized. The process of word and phrase selection for the Minspeak software system, is served well by this keyboard. The facilitation of the keyboard by the operator, however could be improved.

The Touch Talker keyboard system is not standardized. Each Touch Talker is programmed individually by a specific user. This fact increases the flexibility of the system by allowing for an adjustable vocabulary; however with non-standardized programming the Touch Talker is not usable by multiple users. In addition, the utilization of key-strokes for verbal communication is unnatural and inefficient. Also the keyboard is not totally portable in that it must rest on a lap or other flat surface in order to be operated. (Edwards-Strong, 1995)

An improved input interface process, for the Touch Talker, would take into consideration the limitations placed on the machine by the keyboard. An optimal interface process would utilize a more natural activity by the user. During the Study and Design phase of the SDLC for the Touch Talker, more emphasis should have been placed on the individual functions of the interface processes. The objective of the input interface system of the Touch Talker is to allow a human operator to select words and phrases for use by the Minspeak system. This selection process facilitates the synthesis of speech, enabling a speech impaired individual audible communication. An improved process would utilize a more natural and easier operation than the searching, finding, and pressing of a key.

The first step of the Study and Design phase is to describe the objectives of the system, refer to chapter 3, (Table 3.3). This is the specification of the desired outcome.

The objective of the interface system between the Touch Talker speech synthesis process and the human operator is the selection process of words and phrases by the human operator. These words and phrases will be generated into synthesized speech by the Minspeak system. This selection process should be natural, fast, error accommodating, and not require a new set of skills to be mastered by the user. The purpose of the word and phrase selection process of the Touch Talker, is to facilitate the synthesis of speech, enabling a speech impaired individual to communicate audibly.

The second step of the Study and Design phase is to examine potential interface processes. The utilization of a keyboard for this process allows for most human operators to select a finite number of words and phrases. This use of a keyboard does not fully address the objective of a speech prosthetic device. Using the system objective established in the first step, the system designer must look at the user's physiological systems for potential points of interface.

Many speech impaired individuals learn to communicate with sign language. Because of the standardization of sign language and its universal acceptance, it should be considered as a selection facilitator for the input interface process for the Touch Talker. A device can be constructed which recognizes the position, articulation, and orientation of the users hand. The signals generated by these sequences of movement can be recognized by software specifically written for this purpose. This improvement of the interface would reduce limitations and utilize skills that many speech impaired individuals already acquire.

There are devices being produced commercially which would facilitate this human computer interface process (Edwards-Pausch, 1995, page 175). The Polhemus Tracker, manufactured by MacDonnell-Douglas Electronics Corporation, is a device which generates signals based on relative movement. The signals can be mapped into signatures for the word and phrase selection process. This type of direct physical interaction (DPI) between the forming of gestures and the Minspeak software could also be utilized as a sign language teaching tool.

Another improved interface process could utilize brain wave patterns generated by the user as the selection facilitator for input to the Minspeak system. These signals could be detected by an electroencephalogram signal recognition system which would translate the signal into a response for the Minspeak system. These signals could be utilized as a selection process for the interface system using a combination of bio-feedback and system programming. Such a system would require extensive training sessions for both the human operator and the selection program. This interface system design would eliminate the need for the user to assimilate the speech function into a facilitation activity, such as the pressing of keys or the forming of gestures. This level of human-computer interface would be classified as biophysical interactive connectivity (BIC), because of the requirement for a bio-feedback training process.

During the Study and Design phase, it is necessary to focus on the goal of the system. The goal of the input to the Touch Talker is to allow for the selection of words and phrases by the user. This selection process could include hundreds of words and phrases. To facilitate such a task would require an interface system capable of generating as many selections as the words and phrases in the users vocabulary. Instead of utilizing a single input process, (140 key keyboard), the system could utilize multiple input systems. A combination of signal generation systems could be coordinated in order to supply the quantity of signals necessary to facilitate the users vocabulary. Using a gesture recognition system in conjunction with an electroencephalogram recognition system would supply a larger capacity for the selection process.

The third step in the Study and Design phase, is the development of design criteria. The input interface process for the Touch Talker must address criteria pertaining to the systems usability, safety, and durability. The system must be trainable by the user.

This training function deals with the ability of the user to program the recognition processes of the interface system. The system should be portable. Utilizing the system should feel natural and not cumbersome. The use of the device should begin at an early age of the user. This will allow for a natural progression of system usability. The system must be safe to operate. The system must be durable enough to provide continuous operation under design conditions.

The interface system must also address criteria pertaining to cost verses value and user effort as compared to system output. The cost of the system should be compared to providing speech capabilities to the speech impaired individual. The effort to facilitate the synthesis of speech must be compared to the usability of the synthesized speech.

Eliminating the keyboard and replacing it with a combination of gesture and electroencephalogram signal recognition processes could allow for a more portable, natural, and efficient interface between the human operator and the Minspeak system. Such development activities would require a more custom application of information technology than the utilization of a programmable keyboard. The processes would be developed for specific users, taking into account all attributes of the user which would effect the development of the system.

The forth step in the Study and Design phase is to document the system specifications. These specifications will be guidelines for the Development phase of the system's development life cycle. The system's constraints are included in the system's specifications. The system should be standardized where applicable; the price for the system should at most match its value; and the system must be designed around the capabilities of the systems designed user profile.

The attributes described in chapter 4 (Table 4.1), should be fulfilled. The system should be usable, be safe to utilize and be durable. The usability of the system can be measured by the level of activities required by the user and the systems added value. The safety of the system is measured by the possibility that the user may be harmed by the system. The durability is measured by the failure of the system to be available to perform it's intended purpose.

The system performance measurement, for the proposed Touch Talker interface system, are charted in Table 5.1. The system performance measurement attributes of the existing interface process, the keyboard, is similarly tabulated in Table 5.2.

The usability of the keyboard system is hampered by the requirement for memorizing the functions of the keys. This results in a limitation on the vocabulary of the user. The proposed system will have less constraints based on memorization. The combination of the two recognition systems will increase the capability of the user, by reducing the effort involved in the selection process. The electroencephalogram brain wave pattern recognition system will increase the capability of the user to select words and phrases by reducing the effort of the process. The keyboard system requires using sight to select the appropriate key, and physical movement to press the selected key. Each of these activities include cognitive processes controlling the physical tasks. The proposed system will reduce the amount of physical and cognitive activities required to perform the human-computer interface process.

The usability measurement of the effectiveness of the system is measured by the amount of effort required from the user to utilize the interface process. User effort to accomplish the systems objective, to effectively simulate speech, is compared for each of the interface processes. The effective simulation of speech, requires that the simulated speech be continuous and smooth. There should be very little delay between the simulation of a response or statement and the generation of the synthesized speech. The speech prosthesis system must accommodate the entire vocabulary of the user. With these requirements in mind, the existing process of finding and choosing a sequence of

Table 5.1

System Performance Attribute Measurement Matrix

for a Combination Gesture Recognition Interface System

for the Touch Talker

Attribute	Metric	Description of Metric	Metric Value
Effectiveness			
	Usability	The systems ability to be utilized by the intended user.	Medium level of usability.
	Safety	The assurance that no danger to client system is caused by process.	Low potential for harm to the user.
	Durability	The ability of the system to be available to perform it's intended functions.	High system availability.
Efficiency			
	Price / Performance	The ratio of price to the systems function.	Medium to high.
	User Effort / System Output	The ratio of effort by the user to the output from the system.	High acceptability by the user.

Table 5.2

System Performance Attribute Measurement Matrix

for Keyboard Interface System

for the Touch Talker

Attribute	Metric	Description of Metric	Metric Value
Effectiveness			
	Usability	The systems ability to be utilized by the intended user.	Low level of usability.
	Safety	The assurance that no danger to client system is caused by process.	Low potential for harm to the user.
	Durability	The ability of the system to be available to perform it's intended functions.	High system availability.
Efficiency			
	Price / Performance	The ratio of price to the systems function.	Medium to high.
	User Effort / System Output	The ratio of effort by the user to the output from the system.	Medium acceptability by the user.

keys, is not rated as very usable. The value for the usability metrix for the keyboard system is low. The complexity of the proposed system requires much effort in training the user and the system. This additional effort also impacts the usability of the proposed system. This usability issue is compensated by the proposed system's ability to fulfill it's objectives. The value for the usability metrix for the proposed system is medium.

Safety factors of the proposed system will be more complicated than the keyboard system. Because of the BIC level of system interface, there is an increase in safety considerations. The bio-feedback training that is required may induce stress to the operator. Additional stress, resulting from a more complicated interface system, is reduced by providing an effective and easy to use system training process. The ability to communicate naturally and more effectively should reduce frustration after the user and system are adequately trained.The value for the safety metrix for both systems is low potential for harm to the user.

The durability of the proposed system will be a consideration due to the added complexity of the system. Because of the design of the proposed system, this durability concern can be minimized. The electroencephalogram and gesture recognition systems will have few moving parts. The existing keyboard interface is a proven system and is considered to be very durable. The keyboard system's value for the durability metrix is high availability. The proposed system's value will be medium to high availability.

The safety and durability of both systems are considered similar. Any system that deals with a human should take into consideration all aspects of human-factors. The proposed systems durability can be enhanced with a properly applied preventive maintenance plan.

In comparing the efficiency of the redesigned system, it is necessary to look at the denominator of the efficiency equations. For the price verses performance metric, the ability of the system to perform it's objectives must be compared to the cost of developing the system. The cost of developing the combination recognition system will greatly exceed the cost of the keyboard system. When this cost is compared to the added functionality of the system, this cost increase is justifiable. The price to performance comparison for both systems is medium to high. This indicates that the ratio of price over performance is comparible for both systems. Even though the price of the proposed system is much greater than the keyboard system, the proposed system's performance will also be much greater. The price over performance for both systems is considered similar.

This same logic should be used when comparing the interface systems in regards to user effort compared to system output. After the proposed system and user are properly trained, the user effort will go down and the system's output will increase. This is not true for the keyboard system. The keyboard system becomes more complicated to use as the user's vocabulary increases. As the user attempts to fully realize the ability to communicate audibly, the system becomes to complicated to use. This metric indicates the greatest amount of improvement realized by replacing the keyboard with the new system.

The user profile for the Touch Talker system includes generic and specific factors. The generic factors include the inability of the user to perform normal speech. The user of the proposed system will be required to know sign language. Specific factors concerning the individual user will include other physical and cognitive abilities pertaining to the functionality of the system.

Step one of the Development phase, planning the implementation, will require preparation of plans pertaining to the training and start-up of the system. These plans will include project management charts.

The implementation plan must include test plans, training plans and a plan covering the physical creation of the system. This implementation plan will continuously be updated throughout the system's Development phase. Because of the extended implemented step, a result of the extensive training of the system and the user, the implementation plan for this type of interface system will be over a large span of time.

Step two of the Development phase, involves the construction of the physical interface system. This involves the purchase and fabrication of the hardware components and the writing of the controlling software. The hardware will consist of the relative movement tracking devices and the electroencephalogram recognition system. Each of these systems will generate signals when facilitated by the user. The process of this facilitation is addressed with specialized attachment devices. The relative movement tracking devices will be manipulated by the user's hand and arm movements. Special gloves and arm bands will allow for the attachment of the tracking devices to the user. The electroencephalogram recognition system is an adaptation of devices utilized by the medical profession. The sensors for this process are attached to the user's temples and forehead. This application of the sensing devices is supported by the application of a modified cap.

The systems software consists of an algorithm which translates the signals generated by the two recognition systems into the word and phrase selection. This software will be programmable by the user, to allow for flexibility in the recognition of the signal signatures from the sensing systems.

Step three of the Development phase, system testing and user training, will require the development team to work directly with the Touch Talker and the user. The system will be tested by actual facilitation by the user. This process will take longer than is the case for testing most interface systems. Since the Touch Talker is used as a speech prosthesis, it is suggested that the system be introduced to the user at an early age. The same age that sign language is introduced to the user is suggested. The training process will correspond to the special education programs which are introduced to the user at a very early age.

Step four, of the Development phase, systems implementation, should correspond to the development of the user's cognitive and extremity control abilities. As the user develops these skills, the interface system should be involved. The gesture recognition system will become an aid to facilitate the learning of sign language.

The Operation phase of this interface system will correspond to the system implementation step of the Development phase. This is due to the long term nature of this system's implementation.

Step one of the Operation phase, system initiation, will be when the system is introduced to the user for use. This will overlap with the implementation step of the Development phase, and will continue through to a steady state.

Step two of the Operations phase, user feedback, will also be involved with the implementation step. This will involve the continuous adjustments made to the system as the user progresses. These adjustments will include changes in the size of the gloves, bands, and cap, as well as the growth of the users vocabulary.

Step three of the Operation phase, termination of the system when obsolete, will occur if the system is replaced or the need for the system is eliminated. This termination of the system frequently will result from a replacement which is the result of future improvements in interface processes. This improved interface process will be advanced by feedback from the user to the interface system's developer.

To further improve the input interface process for the Touch Talker, an examination of the other human-computer interface system's effect on the input interface system is required. The Touch Talker's video output display is a 40 character by 2 line liquid crystal display (LCD). The display allows for the edification of the words and phrases before speech synthesis. For this purpose it performs well. Eighty characters of words and phrases represent a reasonable amount of vocalization to edit. The angle of the display is not adjustable, however; resulting in less than desired user comfort when utilized. The display angle is dependent on the angle of the keyboard. Since the device is used as a speech prosthesis, it would be an improvement to provide a small screen at the users eye level. The objective of the video display is to provide for edit feedback to the user. This allows the user to confirm the speech before it is made audible. Placing the screen on an extension arm or providing a visor screen would reduce this problem.

Examining the objective of this video output interface, the edification of the words and phrases before speech synthesis, suggests another process may be capable of performing this task more effectively. Another interface process which could provide this edit function, would be the generation of an audio form of the words and phrases as they are selected. This audio output, of what the user intends, would provide a more effective edit function than a textural format. This audio signal could be supplied back to the user with a simple ear-plug. This would allow the user to hear the selections as they are generated, and would allow for an immediate edit capability prior to the generation of synthesized speech.

As the new interface processes are developed, they must be well documented. The system specification prepared, during the Study and Design phase, needs to be extended into system documentation. This documentation will serve as reference and training material for the Development and Operation phases of the system's development life cycle. The documentation will be utilized by the system development team and by the user.

The PRC Touch Talker accommodates the integration of other information technologies with the communication ports. The Touch Talker's developers should be complimented on their insight for accommodating this flexibility. There are adaptations of the Touch Talker being developed by the Prentke Romich Company. One adaptation is called the Liberator. This device allows for utilization of the Minspeak system by way of an icon based graphical user interface (GUI) system. This system scans icons, representing words and phrases, allowing an individual to select them by way of a single switch. While this process enables more individuals to utilize the Minspeak system, it is very slow, and not conducive to interactive communication..

Case 2: Material Tracking Data Collection

The communication between the human operator and an information technology must be effective. The optimization of this communication will require very specific application of interface processes. The detail of the communication will determine the specifics of the process. The following example is a case where information pertaining to the movement of materials from a raw material storage area into a manufacturing process needs to be recorded. The situation involves the movement of bundles of bar stock to the first stage of the manufacturing process. A human operator utilizes a specialized material handling system to place the material onto an automatic material feeding system. The accurate documentation of the type of alloy, the specific heat lot number, and the quantity of the material moved is required. The application of the methodology and guidelines presented in this research to this situation is described.

The first step in the Study and Design phase, is to specifically define the objective of the interface. As already stated, the objective of this interface is the collection of accurate information concerned with the movement of the raw material. A detailed examination of the situation is required to establish the constraints and attributes of this activity. During the Study and Design phase of this system's development life cycle, a detailed specification of the desired outcome is developed. This specification will provide the information necessary to analyze potential interface processes.

The objective of this human-computer interaction is to efficiently enter accurate information into a database. The information to be entered into the database must be defined. The material description, the specific heat lot number, and the quantity of the material moved is required. While this information is obvious to the system developer, there may be other information which is needed, such as the operator's identification, and the date and time of the material movement. All of the information, which will be involved with the interface process, must be identified.

The second step of the Study and Design phase, is to examine the potential interface processes. To facilitate this examination, such questions as where the information comes from must be answered. In addition to this detail about the information, the constraints and user profile detail must be documented.

The efficient collection of the information, with minimal errors, would be assisted by reducing the amount of effort by the user. The information defining the alloy, description, and specific heat lot number, is already resident on the database. Utilizing this fact would allow for a reduction in the amount of information to be entered into the system. The specific heat lot number could be entered and the system could relate this value to the materials description. This would reduce the amount of information to collect and communicate to the information technology.

The collection of the lot number of the material being moved could be facilitated using a bar code label and a scanner. As the material is placed in the automatic feeder system, the label could pass over a scanner system. As the alloy material is placed into production, it's bar code label would be scanned. This system would be managed by the operator, controlling the input into the system, while not directly generating it.

The material handling system consists of a crane and a cradle system. The crane utilizes a scale system automatically calculating the weight of the alloy bundle. The crane can be fitted with a grid location system which would allow the operator to indicate to the data collection system the location where the material was moved to. The information concerned with the quantity and location of the material can be communicated to the system with out the need for collection of the information by the technician. Thus the human-computer interface system can become a control and validation function instead of a manual data input system.

Other information, such as the operators identification and the system values, date and time, can be automatically applied by the system. The operator will be identified as the user profile signed on to the system. The date and time are system values which are automatically plugged into the database.

After the communication between the operator and the information technology has been detailed, the potential interface processes can be analyzed. This involves an examination of how the information is generated, and how the information is utilized by the information technology. The user profile is also defined at this time.

It has been established how the information is generated. The material's description and specific heat lot number are generated from the scanning of a bar code label. The lot number is all that is collected. The description is already available to the system, in a data base corresponding to the specific heat lot number. The quantity of the material, in weight units, is generated by the material handling system. The operator identification date, and time are system values.

The user is a materials technician who is typically over allocated in the support of the operation. Efficient completion of the collection and input of the material control information is critical. There is no question as to the importance of the information being collected. The technician is called on to supply the material to the manufacturing process based on a visual queuing system. When material is removed from the manufacturing process staging area, it must be replaced. The technician is comfortable operating the material handling equipment and has fundamental data entry skills.

Based on the description of the process and the user profile, we can examine potential effective interface processes. The technician procures the alloy from the raw material staging area and transfers it to the manufacturing process area. A bar-code label on the bundle of material is scanned as it is positioned into the staging area. The quantity of the load is collected from a load scale, which is part of the material handling system. The information, specific heat lot number and quantity is presented to the technician by way of a video screen. After the technician verifies that the information is correctly collected, a single switch can be manipulated, transferring the information to the database. This transaction automatically collects the system information, user identification, date, and time. The human-computer interface system consists of a simple display screen and a single switch or button.

For the manufacturing environment, the display should be large enough, and close enough to the technician, to reduce the chance of error. The switch could be incorporated into the release mechanism of the material handling system. This would fully integrate the movement of the material with the information collection system. To address the error detection and correction requirement, an override numeric key-pad could be provided. To prevent this override function from being abused, all override input would require supervisory approval. This will prevent the system from being constantly used in a manual fashion and would formalize feedback for error correction.

The third step in the Study and Design phase, is the development of design criteria. The human-computer interface system must address criteria concerned with the system's effectiveness and efficiency. Factors such as the systems usability, safety, and durability are used to evaluate the systems effectiveness. The cost of developing the system, and the amount of effort involved in utilizing the interface system, as compared to the output from the system, is used to evaluate the system's efficiency.

The system must be usable. The effort involved in the collection of data when material is moved from the raw material storage area into production should be minimized. This reduction of effort is facilitated with the minimization of information to be collected and the utilization of specialized equipment to collect the information.

Safety must be considered with any system involving a human being. By minimizing the effort of collecting and entering information, the technician is able to concentrate on the physical activities involved. By properly sequencing the human-computer interface activities with the physical tasks, danger to the technician can be minimized.

The durability of the human-computer interface system is also improved by the simplification of the system. By reducing the complexity of the interface, the effort needed to maintain and repair the system is reduced. Less effort involved in maintaining the human-computer interface system, results in an increase in the systems availability.

The efficiency of a human-computer interface system is measured by the ratio of cost and user effort compared to the system's output. By reducing the interface processes to a single switch and simple video screen, the costs are minimal. The effort is also minimized by reducing the amount of information to be collected. These factors result in a very efficient interface process as measured by the attributes from table 4.1. The system performance attribute matrix for the material movement data collection human-computer interface system is presented with table 5.3.

Step one of the Development phase, planning the implementation, will include test plans, training plans, and a plan pertaining to the purchase, assembly, and startup of the system. The implementation plan for the human-computer interface system will correspond with the implementation plan for the material handling system.

Step two of the Development phase, is the construction of the system. This involves the actual purchase and assembly of the hardware components, and the creation

Table 5.3

System Performance Attribute Measurement Matrix

for Material Movement Data Collection

Human-Computer Interface System

Attribute	Metric	Description of Metric	Metric Value
Effectiveness			
	Usability	The systems ability to be utilized by the intended user.	High usability.
	Safety	The assurance that no danger to client system is caused by process.	Low potential for danger to operator.
	Durability	The ability of the system to be available to perform it's intended functions.	High system availability.
Efficiency			
	Price / Performance	The ratio of price to the systems function.	Very low cost to performance ratio.
	User Effort / System Output	The ratio of effort by the user to the output from the system	Very high acceptability by the user.

of system software. The interface system's hardware is a single switch device, and a video output device. The software will be field input algorithms and a validation process. Other hardware involved include the material handling scale system and a bar code scanner.

Step three of the Development phase, system testing and user training, will correspond to the testing and training for the integrated material movement system. This step is where the data collection process adjustments will be identified along with any simple modifications to the systems hardware.

Step four of the Development phase, system implementation, will also correspond to the implementation of the integrated material handling system. The human-computer interface process is a component of the material handling system and will be implemented as a component of the larger system.

The Operation phase of the human-computer interface system will correspond to the Operation phase of the integrated material handling system. Feedback pertaining to the effectiveness and efficiency of the system, will be communicated to the system developer for future enhancements and to further the optimization process.

The first step of the Operations phase, system initiation, is where the system is first used in actual production. If the steps of the system's Study and Design phase and system's Development phase where properly performed, the implementation should not include any major problems or concerns. The system will be initiated in conjunction with the start-up of the integrated material handling system,

The second step of the Operations phase, feedback from the user to the system developer, continues throughout the effective life of the system. This is where information pertaining to the system's ability to fulfill it's objective is gathered and communicated to the system developer.

Step three of the Operation phase, termination of the system, occurs when it is replaced or the need for it is eliminated. Because this human-computer system is an integrated component of a larger system, the termination of the interface system may be the result of the termination of the larger system.

This discussion of a data collection system was intended to assist in the description of the development of an optimal human-computer interface system. The interface processes described in this example are not exotic or high tech. They are, however, intended to fulfill the requirements of the communication between the operator and the information technology. The human-computer interface systems described in this example are a simple character video device and a simple switch. This is all that is necessary to interface this material technician with the data collection system. All of the information is generated by the source. There is no need for the technician to collect the information from the material and the crane scale. It is only necessary for the technician to validate that the material has been transferred from the raw material storage area into production. This minimizes the complexity of the interface process, reducing it to only what is necessary.

The video screen, which presents the information to the technician is for validation. This is actually unnecessary except to allow the technician to accept the information and to acknowledge that the transaction was performed correctly. With out this function, the technician could not be held responsible for the accuracy of the transaction. As we automate these processes, it is important to remember the relationship of responsibility with authority.

Summary

The examples of interface processes, presented here, do not address the total potential for optimizing human-computer interface systems. They do describe the steps taken during all phases of the system development life cycle for the human-computer interface systems. Criteria evaluating the effectiveness and efficiency of the systems is tabulated and used to measure improvements.

CHAPTER SIX
SUMMARY AND RECOMMENDATIONS

Summary

This thesis presented a methodology for the development of optimized human-computer interface systems. This methodology consists of tasks grouped into phases of the development life cycle of the system. As discussed in chapter 3, it consists of three distinct phases of the development life cycle for a human-computer interface system (Table 3.1) (1) Study and Design phase, (2) Development phase, and (3) Operation phase. These phases consist of steps or activities which are required for effective system development. In combination with defining these activities, this research identified principles which serve to establish guidelines concerned with optimal human-computer interface system development. These guidelines, as discussed in Chapter 4, focus on system development concepts which have special considerations for human-computer interface systems development.

Application of this methodology was tested with two case studies. The first, the PRC Touch Talker, evaluated the existing input system (keyboard system) and a proposed improved system (combined gesture and brain wave recognition system). In rating the two systems, the proposed system is found to be an improvement. This is based on the efficiency attribute of user effort compared to system performance. The existing keyboard system fails to provide the user with a viable method of selecting the quantity of words and phrases required to perform the system's objective, (speech synthesis). The proposed system will reduce the amount of memorization required to perform the selection process, and supply the user with a process capable of fulfilling the systems objectives.

The second case study demonstrates how the use of the methodology results in an efficient human-computer interface process. The system's objective is the focus for all phases of the system's development life cycle. The information collection and input process, described in the case study, is transformed into a simple validation of information which is automatically collected or generated by the system. This case study demonstrates how a properly sequenced development process results in an efficient and effective human-computer interface system.

Human performance improvement, in regard to information technologies, should be the main focus for individuals involved with the development of human-computer interaction. This performance improvement would increase the effectiveness and efficiency of the information system. The improved interaction between the user and the computer is a broad based concept involving many areas of science, art, and business. The development of optimal human-computer interface systems is a detailed sub-set of the larger concept called Human Computer Interaction, (HCI).

The interface system which optimizes the communication between the user and the information technology was the focus for this research. Measuring the performance of a system involves the analysis of discrete attributes of the system. Such factors as times for task completion and error rates are usually investigated. In regards to human-computer interface system design, however, this performance measurement scheme is too simplistic. An operator of an information technology may be required to supply different levels of attention to the interface process. An interface process which requires total concentration and dedication of the user's facilities to effectively operate would be less efficient than an interface which requires little attention from the user, given similar error and effort rates. New performance measurements need to be devised for this purpose. A combination of statistical analysis tools and common sense is required to assist the system designer in decision making about the system development.

An optimal human-computer interface system will have certain attributes. These attributes include error detection and correction, natural pacing, and require minimal levels of activities by the operator. Most human-computer interface systems utilized today require activities by the operator which have nothing to directly do with the objective of the interface system. An optimal human-computer interface process will appear as a natural extension of the users physiological systems. This optimal interface system will also appear as part of the information technology that the user is interfacing with.

"It is often said that disabled people are handicapped by their environments and not by their lack of abilities, but this is true of everyone." (Edwards-Newell, 1995). Modern information technologies create handicaps which can be reduced by either adaptation by the user, or by the use of a good prosthesis. The optimal human-computer interface system is a technical prosthesis much like an artificial leg. The artificial limb is designed for a specific user. It is fitted to the user and must have specific design characteristics in order to fulfill it's objectives. The human-computer interface, to be optimal, must also be designed for a specific user, taking into consideration attributes from the systems which contribute to the interface process.

Recommendations

In the future we will go beyond using the basic human sensory systems as interface points for human-computer interaction. The evolution of information technologies will bring humans and machines into more intimate contact than at the present. As this occurs, we must be prepared to control this intimacy while optimizing the potential improvements that it could bring. We will be going "on-line" with our information systems, utilizing them increasingly to alter our environment. This future will require an optimization of the processes involved in interfacing the human to the information technologies.

To achieve this level of information technology utilization will require the use of a dedicated system development process; one specifically designed for the development of an optimized human-computer interface system. This thesis presents such a development methodology. The application of this development process will require a combination of subject matter expertise. Teams of individuals concerned with system development, human-factors, and the client systems being interfaced will be required.

The full benefits of information technologies will not be realized until we overcome these limitations created by inefficient human-computer interaction. This inefficient human-computer interaction results from many factors. One of these factors has been the lack of an effective human-computer interface system development methodology. With the process design for the optimization of the human-computer interface systems, (as described in this thesis), we will now be able to focus on other factors which limit the benefits expected from information technologies.

The current situation usually consists of a lone individual identifying a need and applying technology as a solution. This approach results in a vacuum situation where the successes and failures are not shared with others. In addition it is impossible for an individual to fully optimize human-computer interface systems because of the inter-disciplinary requirements. There must be more publication of this work, sharing the information with other individuals who are involved in the development of human-computer interface systems. As we develop the next generation of human-computer interface systems, it will be necessary to document all progress and failures for use by others involved in the field.

To fulfill this future will also require the creation of new schools of study. These new curricula will involve combinations of areas of expertise. These areas include information technology, information science, human factors engineering, physiology, and psychology. Other areas of knowledge will be involved with specific applications of these new fields. The development of optimized human-computer interface systems will also require involvement by individuals who are experts in the subject technology systems being interfaced. "Although the situation is changing, very little HCI research fully takes into account the individual differences among potential users of software and the vast range of abilities of human beings in general." (Edwards-Newell, 1995). The optimization of a human-computer interface must consider specific attributes of the user. Optimized human-computer interface systems will require a more custom application of information technology then is currently achieved.

Another factor is the cost of development. The need for customization drives this cost consideration. The customization will necessitate cost controlling measures. These cost controls will include the use of methodologies, such as presented in this thesis, which are specifically developed for human-computer interface system development. In addition, we must reduce the duplication of efforts involved in interface development by improving on the documentation and communication of research and development in this area. To further the containment of costs associated with the development of human-computer interface systems, will also require the establishment of a set of basic components or sub-systems specifically developed for this purpose.

The future must also provide a means for users to develop their own interface processes. An example would be the extension of our current capability to format the icon layouts for graphical user interface (GUI) systems. This capability for the development of interface systems by the user will be advanced by the establishment of modular interface system components. These components will consist of sensing devices, signal converters, signal generators and controlling software systems. These components will be utilized by end users, and system developers to reduce all levels of disabilities which are induced by information technologies. This thesis addressed the need for more user involvement, but it did not offer a procedure to do so. As the components are developed, we will need to develop guidelines for the implementation of these components and a process of measuring the improvements realized with this user involvement in the interface development process.

In the near future we will directly connect our memory processes to digital storage devices. We will utilize the micro processor to augment our own cognitive abilities. Information technology augmentation of daily living activities performed by individuals with disabilities will "close the gap" between the disabled and the general public. We will develop processes to connect humans to machines that perform functions which will not require additional cognition and physical activity from the human operator. The human operator will be allowed to respond autonomically to output from the information technologies.

Information technologies are going to become increasingly involved in the daily lives of human-beings. The use of these technologies is the next main factor involved in the advancement of our societies. These information technologies will be involved in business, politics, medicine, war and piece. We must be prepared to take full advantage of these technologies as they evolve. Only one of the factors controlling our ability to take full advantage of information technologies is effective interaction with the technologies. This interaction is facilitated with optimized human-computer interface systems. When we achieve effective interaction with the information technologies we will recognize other opportunities for improvement.

A development process specifically designed for application with human-computer interface systems is the first step. Next must come the continued advancement of this field with further research. This research must be managed and controlled by further establishment of organized groups of individuals focused on the development of optimized human-computer interface processes. There will be an increasing need for people who are capable of supporting this research and development. Thus, the analysis of the skills and knowledge needed to optimize each phase of the development process is a natural extension of the research presented.

As information technologies evolve, so will their applications. Thus, the development of optimal human-computer interface systems must continue to evolve and the methodology presented in this thesis will continually require enhancements to meet the ever changing requirements.

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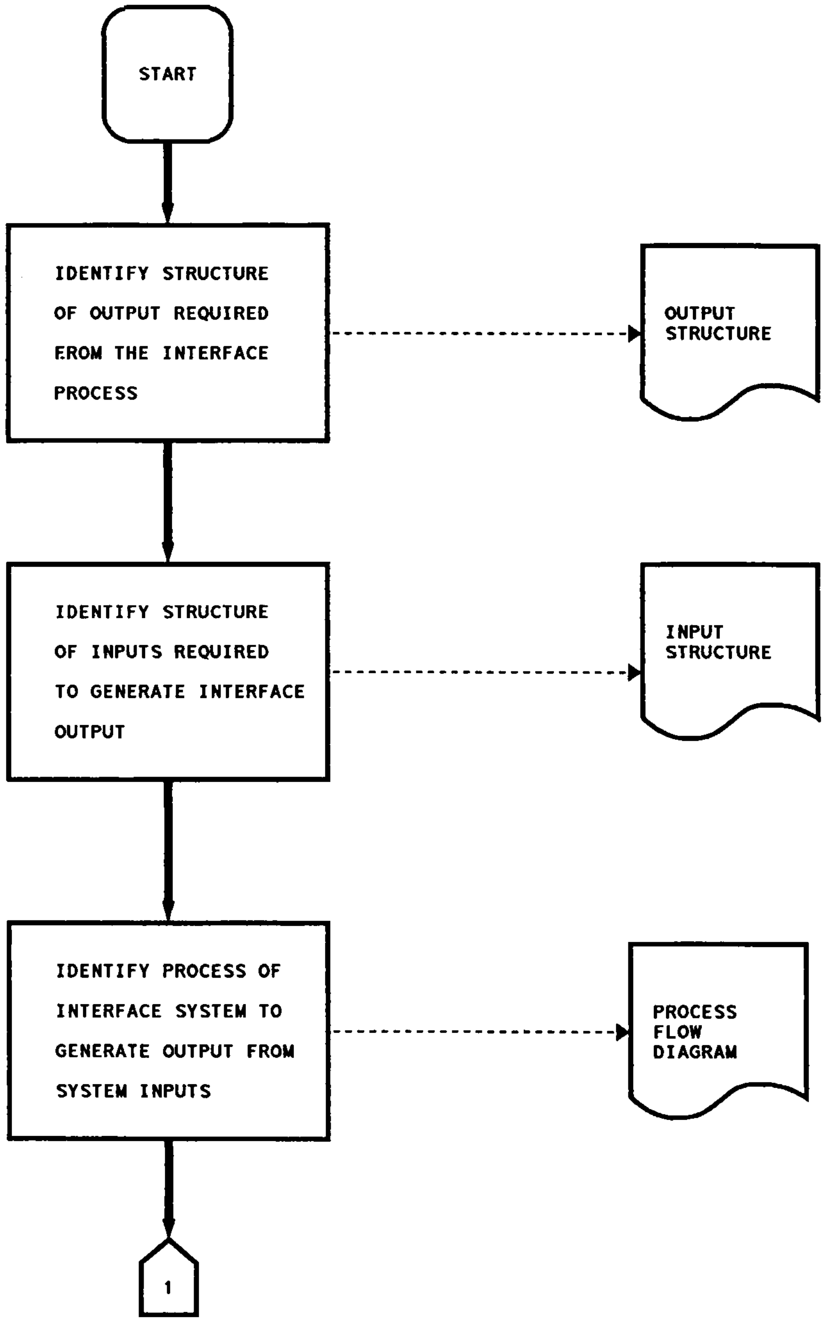
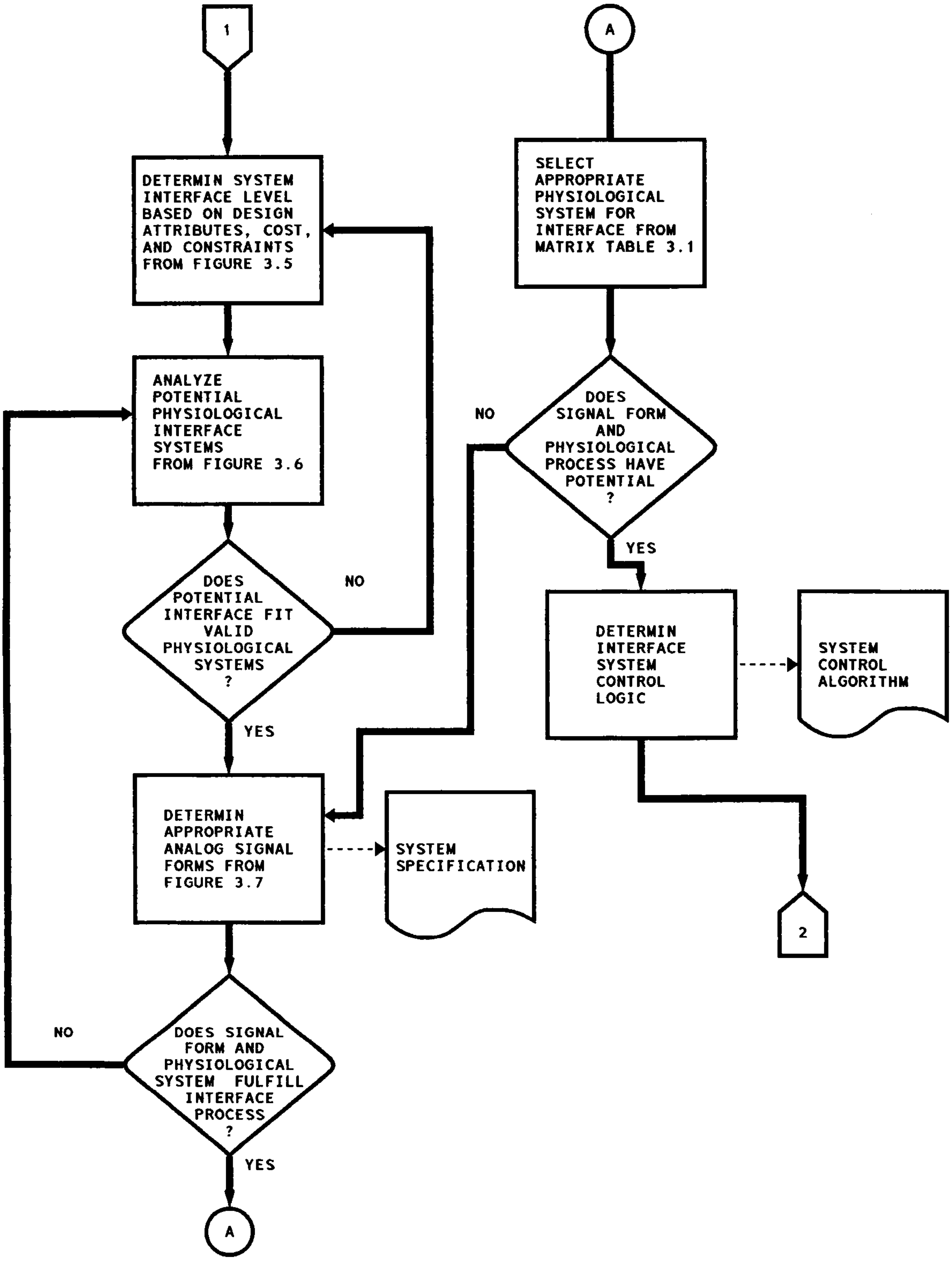
APPENDICES



STUDY AND DESIGN PHASE STEP 1
SPECIFICATION OF THE OUTCOME

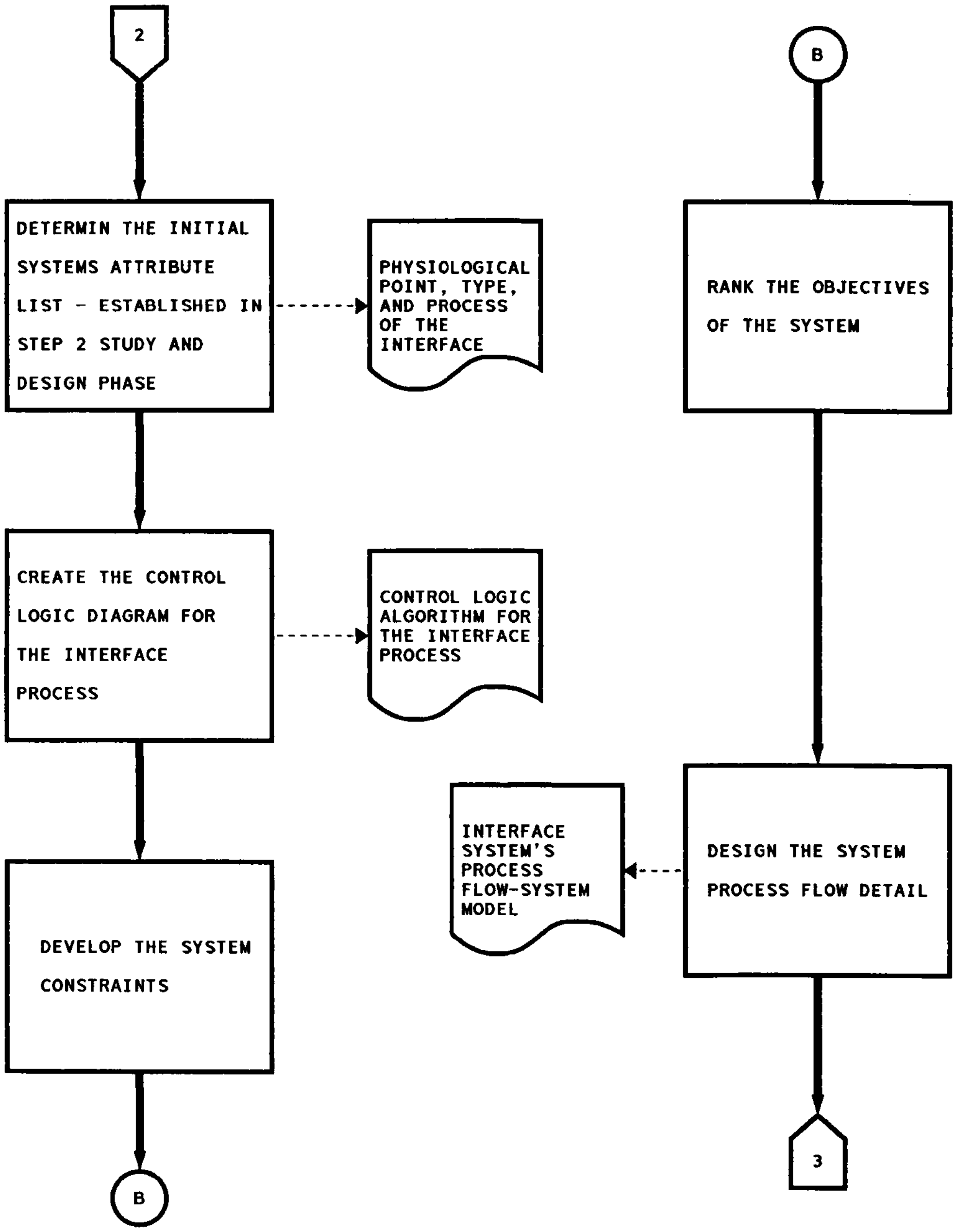
Appendix A: Methodology Flow Diagram



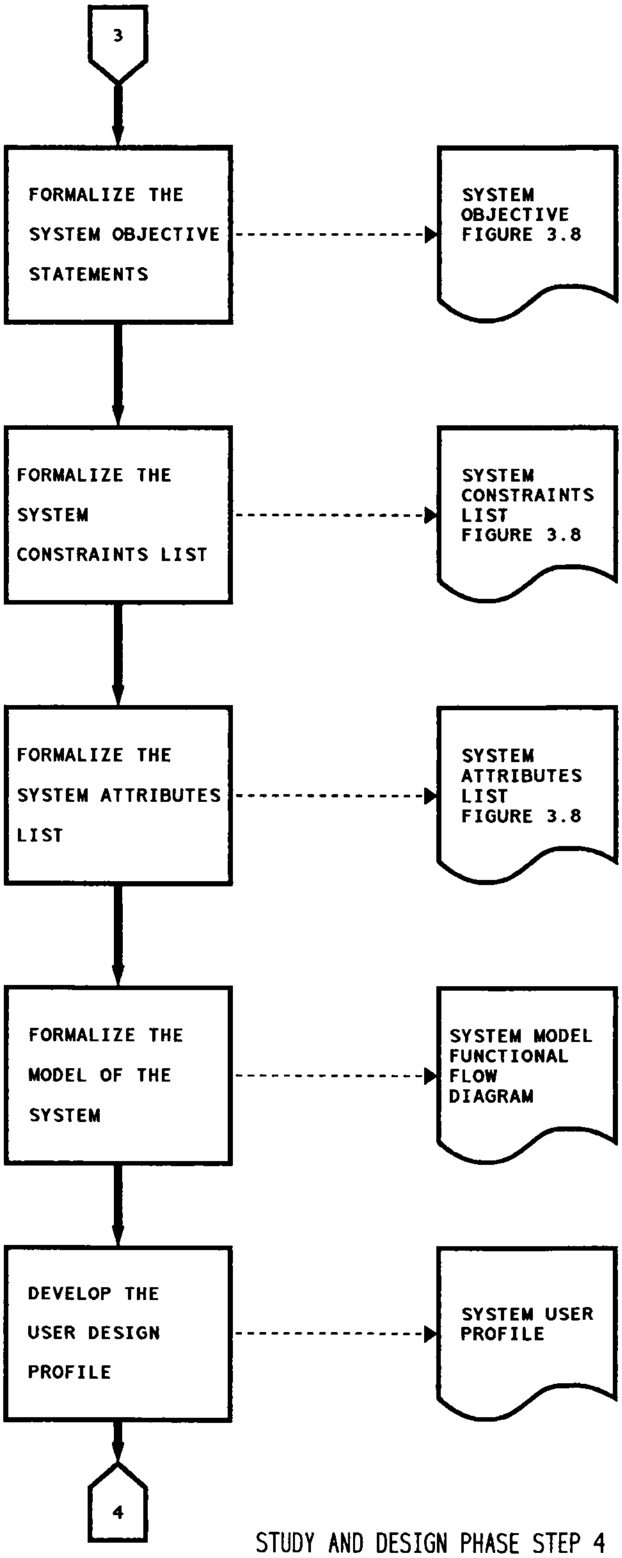
STUDY AND DESIGN PHASE STEP 2

POTENTIAL INTERFACE PROCESS ANALYSIS

Appendix A: Methodology Flow Diagram

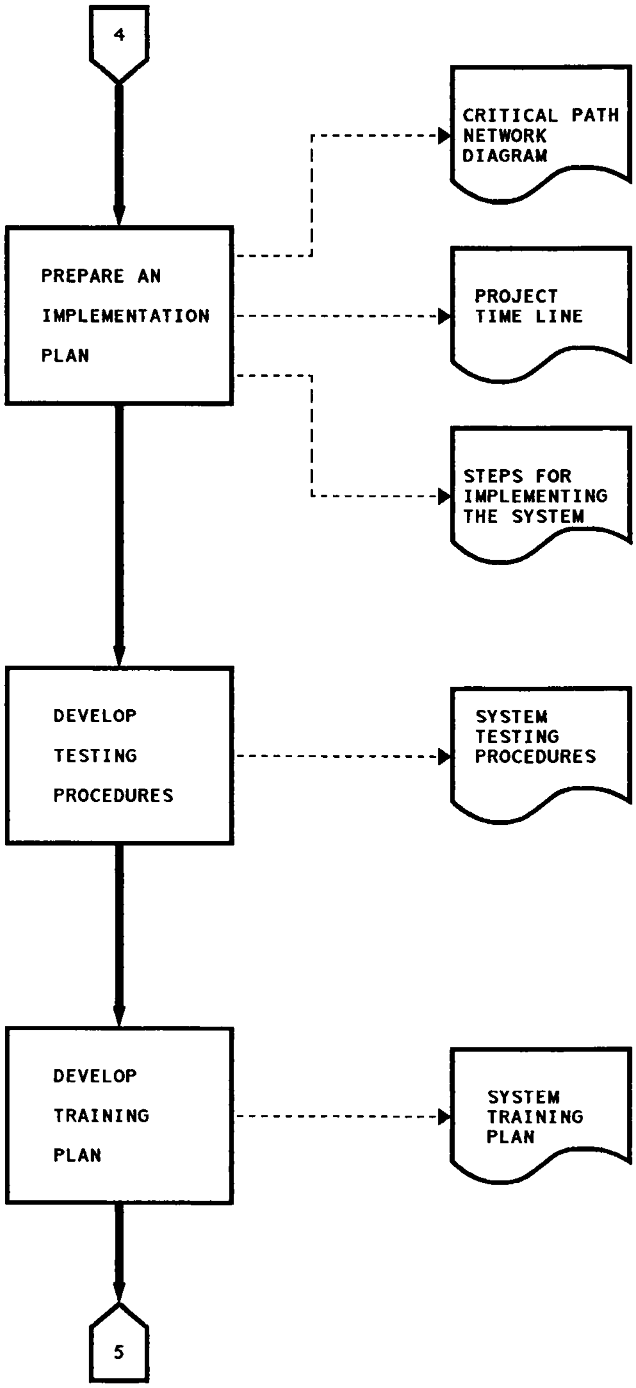


STUDY AND DESIGN PHASE STEP 3
DEVELOPMENT OF SYSTEM DESIGN CRITERIA



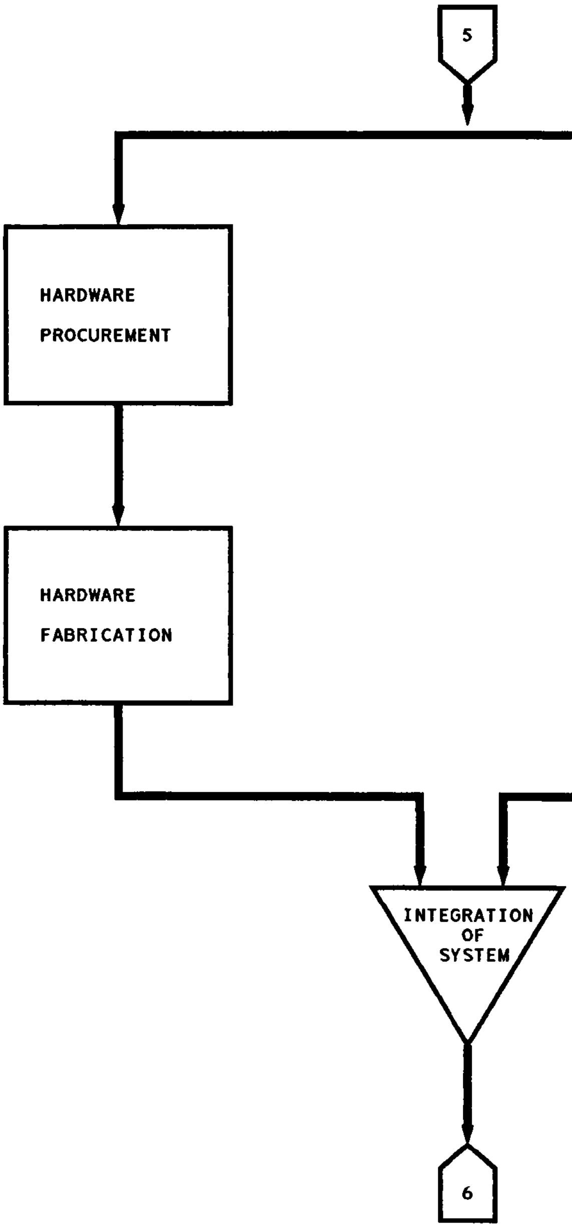
STUDY AND DESIGN PHASE STEP 4
DOCUMENTATION OF SYSTEM ATTRIBUTES

Appendix A: Methodology Flow Diagram

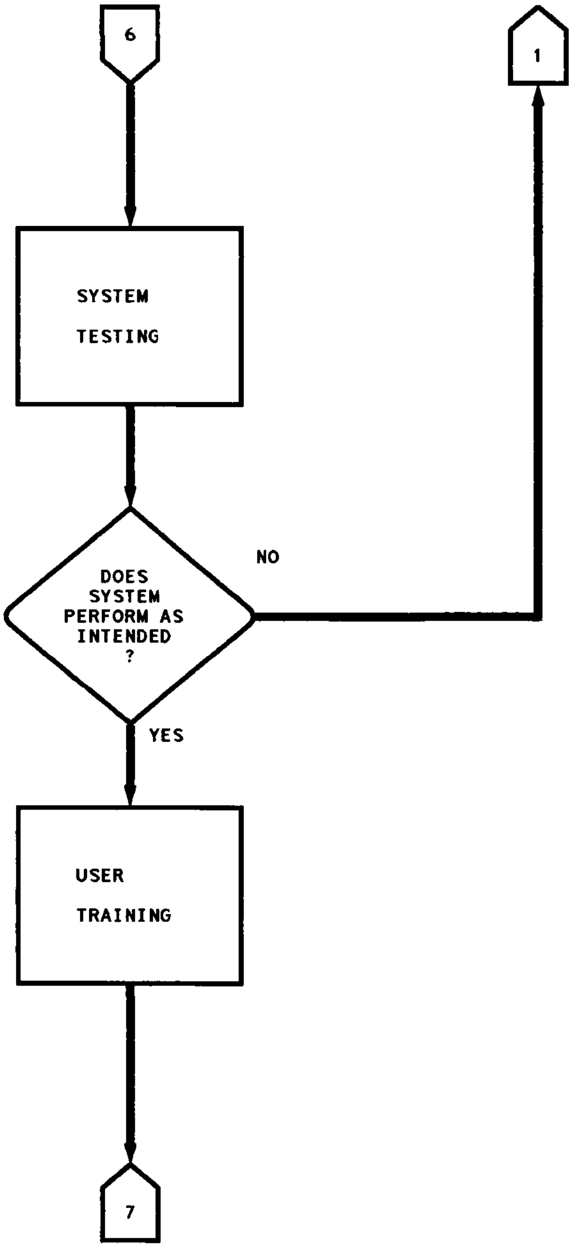


DEVELOPMENT PHASE STEP 1
PLANNING THE IMMPLEMENTATION

Appendix A: Methodology Flow Diagram

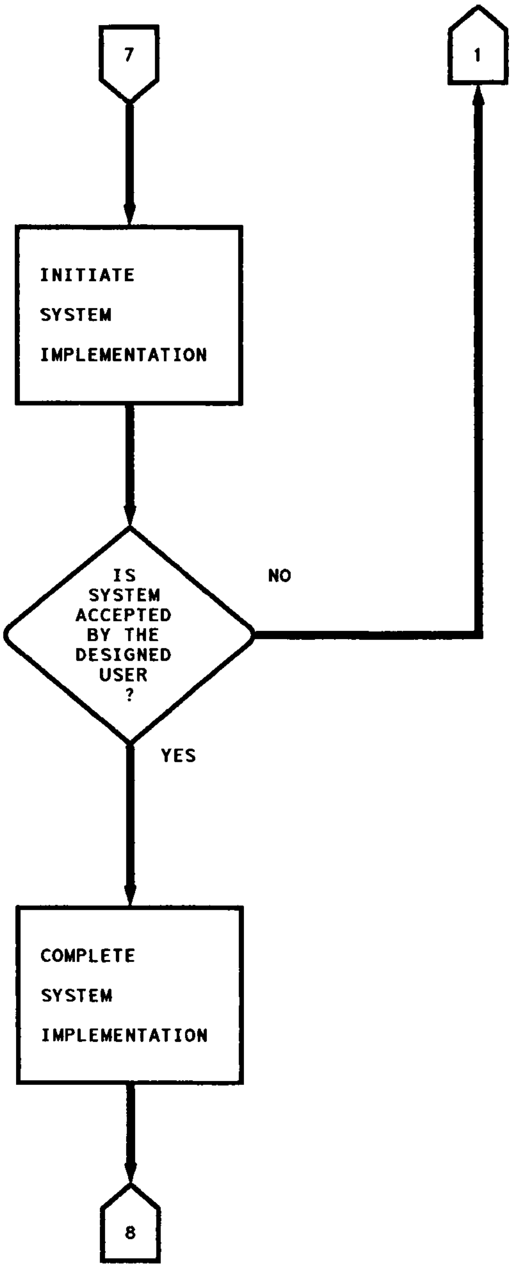


DEVELOPMENT PHASE STEP 2
CONSTRUCTION OF THE INTERFACE SYSTEM

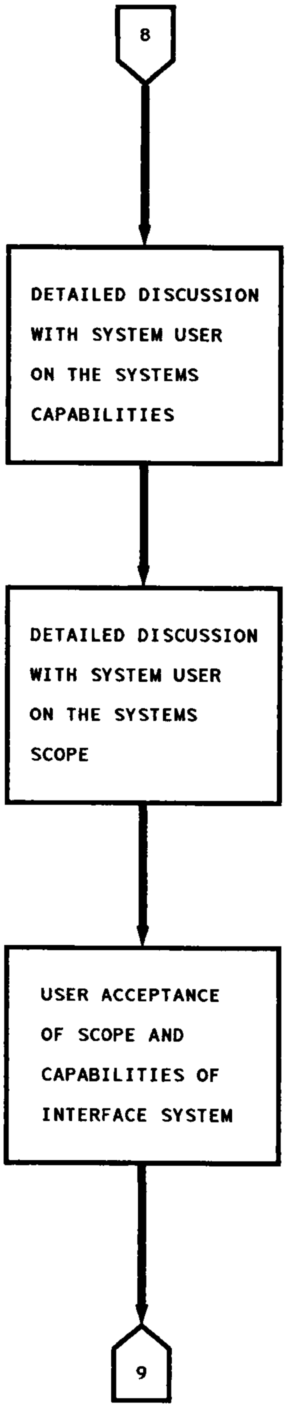


DEVELOPMENT PHASE STEP 3
SYSTEM TESTING AND USER TRAINING

Appendix A: Methodology Flow Diagram

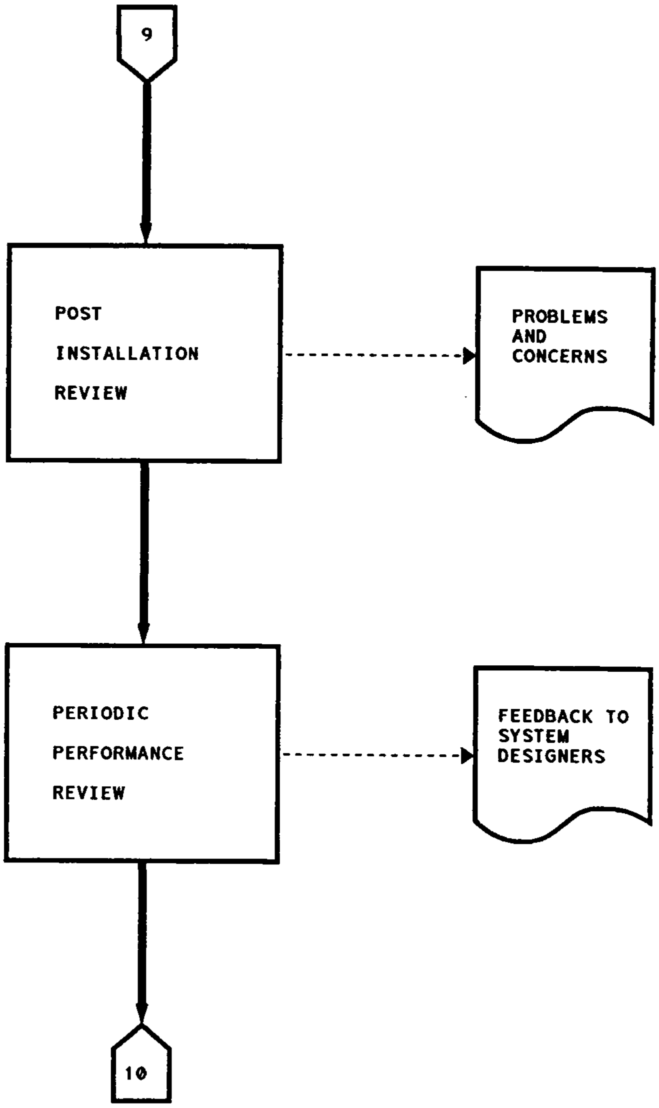


DEVELOPMENT PHASE STEP 4
SYSTEM IMPLEMENTATION

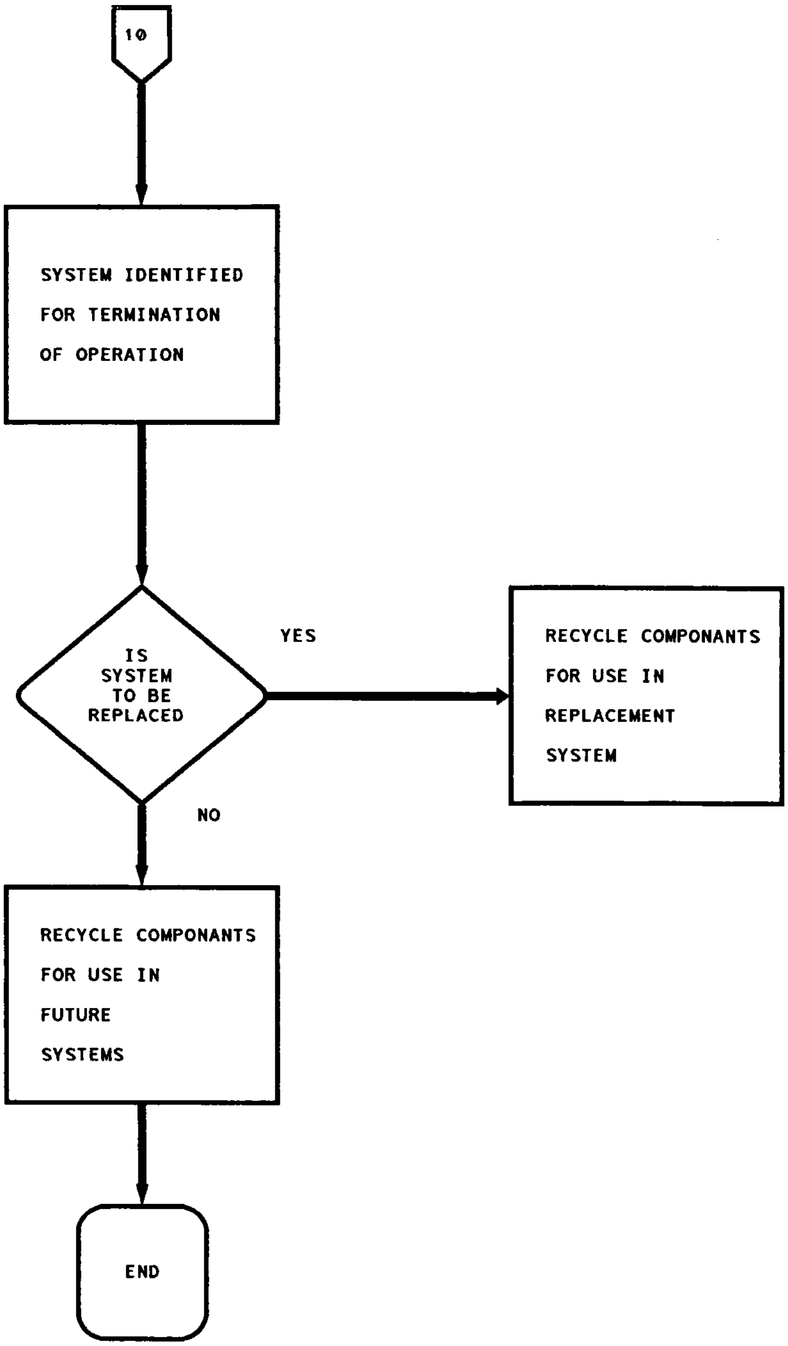


OPERATION PHASE STEP 1
SYSTEM INITIALIZATION

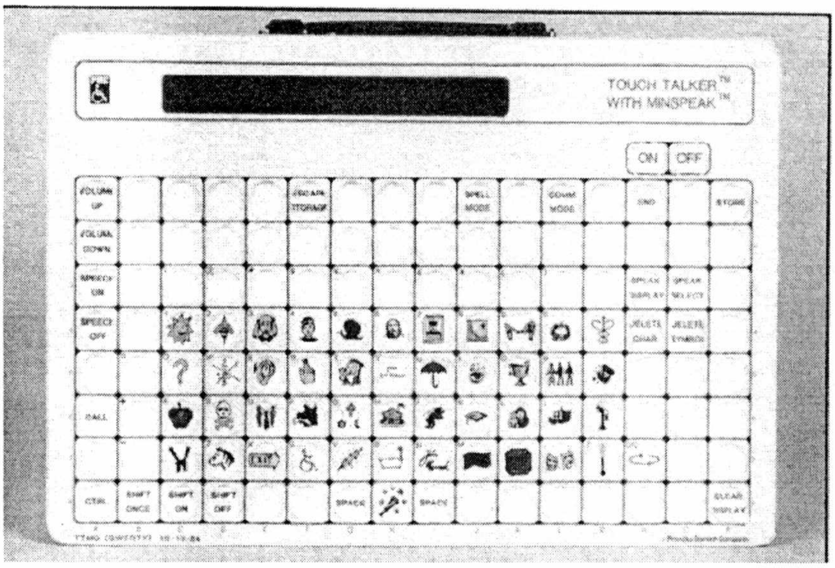
Appendix A: Methodology Flow Diagram



OPERATIONS PHASE STEP 2
USER FEEDBACK AND SYSTEM UPGRADES



OPERATION PHASE STEP 3
TERMINATION OF THE SYSTEM WHEN OBSOLETE



Appendix B: PRC Touch Talker

APPENDIX C.

GLOSSARY

Analog process: A process which either generates, collects, calculates, or manipulates continuous information.

Anatomic process: A process involved with the physical human structure. All human physiological processes.

Biophysical Interactive Connectivity (BIC): Human-computer interface processes which require intrusion into the human physiology.

Client systems: Systems which are served by another system.

Conversion interface process: The process of converting a digital signal to analog information, or the process of converting analog information into digital data.

Digital process: A process which utilizes binary coded data. This is the process of a electronic circuit.

Direct Physical Interface (DPI): Human-computer interface processes which involve direct physical contact with the human physiology.

Hardware system: The physical system. The devices and hardware components making up the system.

Human-Computer Interaction (HCI): The multi-discipline analysis of the interaction between the human being and computer systems.

Human-computer interface: The process of communication between the human being and computer systems.

Indirect Physical Interaction (IPI): Human-computer interface processes which are physically separated from the user's physiological processes.

Information Technologies (IT): The application of sciences involved with the acquisition, recording, organization, retrieval, display, and dissemination of information.

Interface system: The system used to process the interface. This system will include hardware and software that forms the connection between processes.

Multimedia: To include multiple methods of interfacing digital systems to analog systems. An example would be video and audio processes which work in concert to connect a micro computer to a human operator.

Neural networks: A network constructed from a great many simple computing elements, whose properties are loosely modeled on the behavior of real neurons.

Physiological system: Any system comprising the human body. There are eleven physiological systems in the human body (Crouch 1972).

Software system: An algorithm procedure incorporating all logical steps of the control of the system. Mechanically stored and placed in memory as used.

System boundary: Point of interface separating two systems. This is where the process of one system is independent of the process of the other system.

System Development Life Cycle (SDLC): Distinct phases of the life cycle of a system. Development activities are grouped together in logical phases.

System Interface Level (SIL): Levels of interface processes grouped by the level of contact or intrusion into the client system.

System specification documentation: A tabulation of attributes, constraints, and criteria by which the designed system must adhere.

User profile: A description of all system pertinent attributes, of the user that the system is designed for.

VITA

Paul D. Rush was born in Knoxville, Tennessee on August 21, 1955. He attended the public school systems of Knoxville. and Knox County, where he graduated from Gibbs High School in June, 1973. He worked in the health care industry until 1976 when he entered The University of Tennessee. He received the Bachelor of Science in Industrial Engineering in August 1981. After working in industry for eleven years he entered the Master's program in Industrial Engineering at The University of Tennessee, Knoxville in August of 1991. After working full time and going to evening school he will receive the master's degree in December, 1996.