Abstract

As more products become computer-embedded, industrial designers increasingly need to consider the interface in addition to the hardware. Since traditional design processes and techniques largely focus on hardware aspects, new methods and techniques must be investigated and developed.

The aim of this study is to investigate new design education methods for information ergonomics. In particular, it focuses on ways by which designers can be assisted in problem identification, exploration and evaluation of information ergonomics design solutions by using a rapid dynamic prototyping technique. The technique is based on a widely used presentation software application, Microsoft PowerPoint. It can be used to develop fully functional prototypes of computer-embedded products without electronic engineering skills.

The new design education method for information ergonomics involves three phases: i) Understanding user requirements using context scenarios and State Transition Charts; ii) Iterative dynamic prototype implementation of design solutions; iii) Analysis and Evaluation. A case study of the design of a portable information guide for the Museum of Welsh Life in an undergraduate module is presented.

The results indicated that the new education method was well accepted by students and that the prototyping technique helped the student designers to address all aspects of product design for information appliances. A fully functional hardware and software prototype demonstrated the strengths of the method as a vehicle for the iterative design of interactive products. The paper concludes with the findings from our teaching experience, future work and recommendations.

Key words: Information Ergonomics, Industrial Design Education, Interaction Design, Prototyping, HCI, Design methods
Introduction

As the society changes the role and boundary of the industrial design profession must evolve to deal with the significant changes in way that society has developed in embracing the Information age. In its early days, industrial design dealt largely with defining the aesthetics of mass-produced products. The rapid development of both the consumer market and information technologies has made the physical shape a minor part of the entire product system. Industrial designers are increasingly involved in the entire design process from concept to manufacture. In addition to defining the physical form, the activities of industrial designers must now involve careful consideration of how the user interacts with the finished article. The invention of digital products with multi-functionality this has meant the designer having to understand difficult psychological issues relating to people’s attitude to products and the ways they interact with them. Traditional methods of prototyping do not answer the problem well and Industrial Design education has yet to confront the problem of teaching students the psychology of interaction and methods prototyping during the concept stage of a new design. This explains the all too common phenomenon of the video recorder that no one can programme.

Margolin (1998) noted the changes of the role of product design:

… In recent years, the boundaries around these (design) problem areas have begun to collapse due to the influence of new technology, new management strategies, new social forces, and new intellectual currents. As a result, the old divisions of design practice now appear increasingly inadequate and ineffectual. This situation has caused a major upheaval within community of design educators as well as an intense rethinking of the designer’s role by users of design services. (Margolin 1998, p16)

Traditional ergonomics and industrial design have been closely allied since their (almost simultaneous) conception. Ergonomics originated during the Second World War to overcome performance failures due to human error in new high tech defence systems. It is now routinely applied in the design and development of product systems. Industrial applications of ergonomics have increased in response to the need
for improved productive use of human resources, quality of working life and occupational health and safety.

Ergonomics is defined as the systematic application of knowledge human beings in the design and use of all things which affect a person's working conditions: equipment and machinery, the work environment and layout, the job itself, training and the organization of work (IEA, 2001). In traditional ergonomics the focus is on the physical attributes of people such as anthropometrics or strength. Where it is related to computer equipment it might focus on the angle of monitor, keyboard and the users’ postures.

Ergonomics references recommend a number of aspects to be carefully considered by designers (Kellermann et. Al. 1963). The first of these is concerned with anthropometrics. The dimensional data of the human body is crucial for designers to determine the physical size of products and layouts and is available through software applications such as PeopleSize (Open Ergonomics, 2001). Another major aspect concerns data relating to environmental factors and their influence on human performance. These include forces, noise, temperature, lighting, climate and so on and the knowledge are usually based on work physiology.

Another important aspect of ergonomics is the ways that humans receive and process information. Simplified, the model of human information processing consists of receiving information through sensory devices (eyes, nose, ears) using judgement, calculation, comparison, and decision before finally committing to action. The data and knowledge about how people process information has been accumulated through experimentation with types of displays and optimum control layouts such as knobs and pedals that ensure maximum efficiency of operation. This aspect of ergonomics is sometimes referred to as information ergonomics.

Traditional information ergonomics has focused on the psychological factors that can affect human job performance. These factors include social, cultural, mental and emotional conditions such as boredom, isolation, fatigue and confusion (Lindbeck, 1995). Although the effects of these factors have been examined in relation to different types of controls, display types, dials, letters and panels within the framework of traditional information ergonomics, dynamic interaction between humans and complex interactive products haven’t been sufficiently explored.
The interaction between users and products in computer-embedded products or information appliances are so dynamic and complicated that traditional information ergonomics methods are no longer sufficient and new systematic approaches are required to address the psychological and social issues. The changed circumstances mean we need to reconsider the scope of information ergonomics and devise new methods of exploring the complex issues thrown up by product design in the information age. This study suggests that information ergonomics should be extended to issues related to the psychological and social attributes of human beings and the dynamic interaction between users and product systems in terms of both hardware and software.

The developments noted above and others have meant the creation of a number of new fields of study within ergonomics. The Department of Industrial Design Engineering at Delft University, for example have specialized groups in Physical ergonomics, Sensory ergonomics, Information ergonomics and Cognitive ergonomics. They borrow knowledge from other disciplines, such as physiology, mechanics and biology, but they concentrate a body of knowledge and methods specific to Industrial Design. The information ergonomics studied at Delft is still confined to traditional issues including detection and processing of information, coding, cognitive aspects of product use, presentation of information, lighting, sound and noise, displays in vehicles, user-interface design, control rooms and process control. (TuDelft, 2001)

Branham (2000) suggested the needs of new design methods, techniques and tools for the new paradigm of science which he noted could be illustrated in the physical and social sciences by three shifts in the terms of traditional to new thinking: A shift from structure to process, from building blocks to network, and from part to whole. He stressed new interactive methods, techniques and tools to externalise thoughts and ideas, forcing the designer to be more explicit.

Information ergonomics should not be confused with Human Computer Interface, which is a multi-disciplinary field of study concerned with the design, evaluation, and implementation of interactive computing systems for human use, and with the study of major phenomena surrounding them (ACM, 1996). Although it has a very broad perspective, its main focus is on the design of the interface for computer software applications. Interaction design is concerned with dynamic interactive aspects of both hardware and software elements of a product (Myerson, 2001). Although HCI and Interaction Design has a similar concept with information
ergonomics described above, since we consider the information ergonomics a sub-area of ergonomics that has close links with industrial design practices and a field of view which encompasses more than software interaction, it is more appropriate to use the notion of information ergonomics for industrial designers.

This stated, we should re-iterate the challenge: To find methods by which industrial designers can explore both the new and traditional strands of information ergonomics, encompassing the dynamic and interactive aspects of interactive product hardware and software.

**Issues of Information Ergonomics**

There are a number of issues to be addressed for information ergonomics in industrial design education. We have identified two main issues. The first issue is to develop designer-oriented methods of analysing information ergonomics approaches to design problems. Although there are many ways to study and analyse user contexts in the early phase of design process, many designers still depend on simple observation and interview of users, or even undertake design projects without sufficient initial user study. The techniques suggested by social scientists orphysiologists are not well accepted by the designers due to the different perspectives towards users and environments. Designers tend to consider the artefact to be developed while researchers in physiology and social science tend to concentrate on the behaviour or phenomena.

Any development method should be different from the approaches of other professionals such as computer programmers or electronic engineers. Efficient prototyping methods are essential. Notwithstanding IDEO’s insistence that even ‘sluggish prototyping’ can be an important means for an iterative cycle of product development, quick and easy implementation of information ergonomics models in a form that allows exploration of the issues at a prototype level needs to be achieved to improve complex product interactivity within a timescale and cost acceptable to industry. It is important to consider ways to effectively blend the hardware and software ergonomics since industrial design is still focused on the production of tangible products.
Framework to explore information ergonomics for industrial designers

We in UWIC have developed a framework for addressing both old and new strands of information ergonomics that has already been successfully used to deliver the subject to undergraduate designers. The framework consists of six phases as shown in Figure 1.

Figure 1: Summary of the framework to explore information ergonomics for industrial designers

The first phase is to conduct context analysis. This gains understanding of the user environment for a particular design problem. A number of techniques can be employed in this phase. One useful technique is the narrative scenario and related storyboard (Kolli et. al., 2000). Narrative scenarios are ‘reality’ stories in prose form, sometimes illustrated with pictures or drawings. They can depict the context for which the product is developed (current context scenarios) or they can illustrate the role of the new product or system in that context (future context scenarios). The scenarios make it easier to mentally create a vivid picture of the actual context of use. They are particularly useful in group brainstorming sessions as the members of the group can
submit concept sketches of the product that can be compared and discussed. The final contextual scenario usually takes the form of a storyboard. Storyboards are linear sequences of pictures illustrating various functions of the future product or showing its context of use, along with explanatory text about what’s happening in the pictures. The scenarios and storyboards allow designers to formalise their concepts of the users’ activities in relation to the context of the product under development.

Once the context analysis is satisfactorily completed, designers create a primitive interaction model using state transition charts. Important states are identified and the relationship between states is examined. The flow of certain tasks is described by this combination. The method works particularly well for menu-driven software interactions (as so many computer-embedded products are). The accessibility of each states can now be judged and altered according to its relative importance. The concept design work dealing with the product’s appearance, number of buttons can take place along side the state transition chart development as they will usually directly affect one another (number of buttons, size and location of key input devices and so on) so that traditional and information ergonomic issues can be dealt with side by side.

Next phase of the framework is to refine the state transition charts. A useful method for developing early state transition charts is the combination of a whiteboard and ‘Postit’ notes. The states are described on a ‘Postit’ and the relationship and sequence described on the whiteboard. Each configuration can be captured by digital camera to record the development history.

When the initial state transition charts reach a point where the designer is relatively happy with the concept more realistic depictions of the user interface can be developed and displayed on an advanced state transition chart. ‘Soft’ models can also be developed along with the early simulation prototype in order to further develop the form. The advanced state transition charts allow designer to combine the form and interaction streams to make their ideas more concrete ready for a dynamic fully interactive prototype. Figure 2 shows an example of the refined state transition chart for a pager interface simulation.
The importance of the tangible prototype has been stressed by many design practitioners. According to Myerson (2001), IDEO highlights that the physical model is a key source of idea development and they always produce tangible model at each stage of the design process. It is at this stage that the tools and methods required for designers to effectively and rapidly build and examine the hardware and interaction aspects of the products without outside expertise are needed and thus where most effort was expended in determining a dynamic prototyping methodology. Only by allowing designers to carry out this work alone can we be sure of creating designs that look at the entire spectrum of the product-user experience, both quantitative and qualitative. For this reason, the last phase of the framework is to create a dynamic prototype that can be fully tested in a user environment for such aspects as aesthetics, comfort, ease of grip, sensory feedback and Computer Human Interface.

Dynamic Hardware-Software-Hybrid Prototyping

As stated above, an effective dynamic prototyping methods is what is required for the final stage of the design framework. The Requirements for a designer-oriented prototyping method are described in Nam and Gill (2000) and are as follows:

- The prototyping method should be scalable to complex level for products with sophisticated operations
- Designers should be able to produce detailed graphical representation of products.
- It should be easy for non-programming literate designers to build dynamic and interactive elements of the interface.
- It must allow a flexible and evolutionary approach to interface design.
- For educational effectiveness, the method must be cheap and achievable with a widely available standard software application.
- The method needs to provide a good metaphor for the development of new information ergonomics concepts. In particular, the state transition and context analysis of the early phase of the framework needs to be well appreciated by the method.

The lack of dedicated software for prototyping computer-embedded products has led to the use of multimedia authoring tools like Toolbook (Hustedde, 1996), Director (Gross, 1999) and Hypercard (Goodman, 1998). The most popular of these among professional interaction designers is Director by Macromedia. However, the use of multimedia authoring tools for the prototyping has a number of limitations, such as being depend on mouse and screen interface, limited flexibility in programming, difference of interaction metaphor, difficulties of connecting the prototype to hardware models and the cost and availability.

Based on these requirements, we devised a new prototyping method using Microsoft Powerpoint in conjunction with its own embedded Visual Basic programming language. The prototyping methods are described in more detail in Nam and Gill (2000). The approach is different from a standard Visual Basic programming environment because users can make use of a variety of presentation features so that the necessity for complex programming is dramatically reduced. Users first develop an interaction model using standard modelling techniques such as state diagrams. The model is transferred into a slide show using hyperlinks to join the various slides. Each slide represents a certain state of the product interface and the hyperlink represents an event change. This basic slide show using state transitions can then be evolved into a dynamic prototype using the programming features. For example, when a user presses a button to show an altered status in the product, the associated Visual Basic script can control the visibility of a graphic element in the presentation.

Having developed this approach our next goal was to look at methods of building a physical hardware prototypes driven by software simulation Using operational hardware prototypes, a designer can examine tangible aspects of interface elements,
such as the size and arrangement of the controls. We found that this could be easily achieved by connecting the interactive software simulation to a hardware mock-up through a special keyboard. The keyboard intercepts external interface events and converts them into key strokes (Figure 3). The hardware mock-up can be built easily as it uses simple electronic components, such as standard key switches.

![Figure 3: Modified interface keyboard](image)

It was expected that the new prototype method addressed all the requirements listed above and well fitted for the framework.

**Case study: Information Ergonomics module at UWIC (University of Wales Institute Cardiff, UK)**

In order to examine feasibility of the framework for the design education and the usefulness of the prototyping method, we applied the framework to the Information Ergonomics module at the University of Wales Institute Cardiff. Information Ergonomics is a second year module for the students of Product Design BA, BSc, and Electronics Design BSc course at the school of Product and Engineering Design, University of Wales Institute Cardiff, UK.

The aim of the Information Ergonomics module is to teach students how to deal with a range of human-product interface issues for computer-embedded products and
systems. It was designed to address the changed scope of information ergonomics described above. Students are expected to deliver critically developed information-based products considering various static and dynamic interactivity issues. To reflect the framework investigated, the module was divided into three main phases. In the first phase, students are introduced the overall concept of interaction design, in the second phase they learn a variety of techniques required to carry out a project and in the third phase they are given a practical project in which they are required to produce a demonstrable prototype. It was stressed to students that in order to achieve the aims of the module, effective and easy prototyping tools are essential. The module runs for a single semester, which leaves little time to consider the details of the tool itself. It was expected that students at the end of the module produce a fully function and scalable hardware/software hybrid prototype for a design brief.

For completion of the module, students carried out a live design project. The brief was to design a portable digital information guide for the museum of Welsh life. The Museum of Welsh Life located in Cardiff, UK is one of Europe's most outstanding open-air museums and the most visited heritage attraction in Wales. It has over forty original buildings moved from various parts of Wales and re-erected to show how the people of Wales lived throughout the past centuries. The experience of visitors can be greatly improved with information aids due to the large scale and distributed facilities of the Museum. Students were required to design a portable electronics information guide and build a functional prototype that demonstrated its functions.

The following objectives were suggested in the module assignment.

- Help maximise the quality of visitors' experience during their visit.
- Help visitors efficiently navigate the Museum.
- Explain sites, historic objects or the indoor gallery using texts, graphics or multimedia (including audio and video).
- Be convenient to carry
- Be easy and comfortable to use
- Be aesthetically pleasing

The module run for 14 weeks and students spent five weeks for the initial investigations, including site visits and context analysis. The five weeks were spent refining the state transition charts and the development of dynamic working
prototypes. In the early phases, students worked in teams to carry out context analysis. Narrative scenarios and storyboards were developed in each phase. (Figure 3) For effective assessment, the subsequent phases were accomplished by individual students. Soft models were also developed along with the early state transition charts and they subsequently produced a hardware mock-up. Figures 4 and 5 show examples of models produced by the students and the arrangement for operating the fully working prototype. All the models were operational by connecting them to software simulations through the interface unit.

Figure 3: Example Storyboard

Figure 4: Example prototype models

Figure 5: Arrangement for operating fully working prototype
Discussion and Future Work

The framework was successfully incorporated into the Information Ergonomics module for two years. Students gained a sound ergonomics understanding and actively used the technique and knowledge for their final year major projects.

1. The most significant result is that the students could effectively make fully functional prototypes something that has been impossible to date with the facilities available. The ability to prototype rapidly has vastly increased detailed exploration of user contexts and interaction. No less important is that fact that none of the hardware it uses is expensive, that all the components are available ‘off the shelf’, or that the software used is free to educational institutions worldwide and is amongst the most widely available in the world.

2. The framework was also a useful means of collaboration between designers and engineers. Engineering students participated in the module and approaches and skills were exchanged between engineering and design disciplines. Working together in the module, both types of students could appreciate and share the different strengths they brought to addressing the same design problem.

3. This method of prototyping offers an excellent means of collaboration between professionals from different domains. Since so many product features can be easily demonstrated using an interactive prototype, communication between designers, ergonomics specialists and engineers becomes easier, increasing the efficiency of multi-disciplinary collaborative projects. This means that the application of this type of methodology is not restricted to education. Applications abound in both research and practice. Design research activities, for example, are better facilitated since fuller interface analysis is possible using fully functional prototypes.

There are however, some aspects that need improvement. We found that systematic methods in early phases of the method need developed. The context analysis may be combined with other analysis methods, for example using task analysis or statistical tools (Brenham 2000).
Consideration needs to be given to increasing students’ programming skills to maximise the effectiveness of this method. Although the method reduced learning time students spent a lot of module time on implementation. Ways of incorporating basic programming skill and logical thinking into industrial design education need to be carefully considered.

In terms of the tools used, the interface keyboard can be improved by transforming into a smaller interface unit. A small PCB board with PIC chips may replace the keyboard used in this study. This could be incorporated within the prototype model. Another direction of the interface method is to use wireless communication between the software simulation and hardware prototype. An infrared keyboard unit connected to a hardware model and a main PC could be considered.

One of the most obvious benefits of the method is in the user evaluation phase of new product development. Using this method a system of analytic product evaluations could be incorporated within the prototype. Statistical software, for example, could be connected or incorporated to examine the usefulness of certain controls. By measuring the frequency and the time used for each of the interactive elements it would be possible to quantify the efficiency of interaction in a quantitative manner.

In terms of design education, the module was delivered through a networked learning environment, which was an important means of transferring the skills to build the prototype. Sample software codes together with other resources for information ergonomics were prepared for students to download and modify.

The techniques can also be incorporated into an integrated Computer Aided Design education program. In order to reduce the time and effort students spend making a hardware mock-up, the entire prototype could be developed using Computer Aided conceptual design tools and subsequently Computer Aided mechanical design, analysis and manufacturing tools. The interface could be studied using the framework presented in this paper and implemented using Computer Aided electronic design tools.

If the usability evaluation of the new design is smoothly incorporated within this program, an integrated design approach can be achieved in a new computer-based design education environment.
Conclusion

The role and the boundary of the traditional industrial designer has evolved. With the advent of new information appliances and computer-embedded products, designers increasingly need to consider dynamic interaction between products and users. These changes necessitate new methods and techniques in design practice and education.

In this paper, we discussed the relationship of ergonomics to industrial design and redefined the changed scope of information ergonomics and we presented a framework to explore the information ergonomics issues from the design perspective. The framework involved three steps: i) Understanding user requirements using context scenarios and State Transition Charts; ii) Iterative dynamic prototype implementation of design solutions; iii) Analysis and Evaluation.

The key characteristic of the new framework is the employment of an efficient and dynamic prototyping technique for an evolutionary investigation of dynamic product-user interaction. Our case study of the design of a portable digital information guide in the teaching of information ergonomics demonstrated that designers could effectively investigate dynamic interaction elements for a new product and produce a software and hardware hybrid prototype with minimum effort in a short time scale. It is expected that this framework and prototyping method can be flexibly adopted for larger scale design education, research and practice projects.

References


