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Designing Usable Marine Interfaces: Some Issues and Constraints

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Although there have been improvements to the interface design of marine systems, there are still calls for increased usability as designers are blamed for systems that users find difficult to operate. This paper examines some of the issues and constraints that the designer faces when attempting to design a usable interface. The approach to designing that the developer may take is considered as well as more practical issues such as the limitations of using design principles. The importance of domain and context knowledge is stressed as well as other issues such as safety and culture. The paper concludes that design is a complex compromise but user involvement throughout the lifecycle can improve the ease of using marine systems.

KEY WORDS

1. Design. 2. Interfaces. 3. User-centred Design. 4. Marine Systems.

1. INTRODUCTION. Time and again, particularly in marine electronics, poor design is blamed for human error and system failure, with the latest estimate of associated costs for software failure generally being around $60bn in the USA and €60bn in the EC (Anon, 2004). Sometimes, functionality of a marine system has been separated from that of the human-computer interface with the latter being specifically highlighted in terms of poor design. However, to many users, the interface *is* the system since any hidden functionality is often not known to the user. In the case of most marine electronics, there is an additional historical factor in that the system is often developed from an embedded systems background with a minimally sized interface which may even be limited to text.

The Global Maritime Distress and Safety System (GMDSS) caused some furore before its implementation with false alarms being accredited to poorly designed interfaces and lack of user training. With some of the early systems this certainly seems to have been the case (Mills, 1995a) but later designs took advantage of discussions with users and other bodies, producing systems, particularly for Digital Selective Calling (DSC), which have well designed interfaces. Still, it seems, false alerts abound and systems' failure is attributed to the design of the interface (Tzannatos, 2004), even though systems are produced that have usable interfaces and which are recognized as such by the users (Mills, 1998b).

All design is inevitably a compromise between a number of factors and designing an interface will reflect other issues such as functionality, usability and the general

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design of the system. There are a number of design paradigms that can be used for the whole system (Cross, 2000) from traditional methodologies such as that of Yourdon for real-time systems (Yourdon Inc, 1993) to other methods such as a user-centred design approach. In the latter, the users are considered at all stages of the design, ideally with their input being based on analytical methods such as task analysis (Mills, 1998a) implemented through prototyping.

This paper does not propose to discuss the methods of designing for efficient functionality in technical terms such as code execution but endeavours to identify some of the problems that can arise in interface design. An engineering approach is taken by considering the different ways in which a designer can fill a blank 'canvas' (or screen) as s/he attempts to produce a usable interface for the functionality of the given system. Examples will be used to illustrate where necessary.

2. GENERAL REQUIREMENTS FOR THE INTERFACE.

The interface is the user's only means of interacting with the system and most users will be using the system to achieve a goal or goals, which may well have nothing to do with the system itself. For example, a person using a telephone to summon help is just one use of the telephone in functionality terms; here, the telephone is the instrument by which help is summoned but it can also be used for other forms of talking and possibly text messaging. Any product needs to assist the user in meeting their goals, which are usually achieved by a combination of tools and humans. For example, a word-processor helps to achieve the goal of writing this paper but the content needs cognitive input with which the word-processor is unable to help, but it can and does help with spelling, typographical errors and other presentation features as well as editing the text. On another occasion, the word-processor can be used for creating a poster, a different goal but one achieved by using the same tool. Computerised technology, then, is usually used as a tool to help the user achieve a goal or goals. We can loosely define the actions on objects needed to achieve goals as *tasks* (Mills, 2000b).

The designer of the interface needs to know how the product will fit into the task sequence and, for this, s/he needs to know the users' overall goals. In addition, user domain knowledge (Mills, 2000b) is needed as otherwise it is difficult to identify which tasks in the cycle/sequence will be undertaken by the human and which by the computer. Traditionally, this domain knowledge has been obtained through interviews (Yourdon Inc, 1993) and perhaps observation of the user at work but such methods are poor substitutes for real experience. It is well known that users describing a routine sequence often omit evidence which may be vital to a good design, simply because it is so familiar that it becomes overlooked. Another problem is the level of task description that the user conveys to the designer; the user may well not know which parts of the task sequence are important in product terms. For this reason, some marine electronics companies already try to employ people who have spent time at sea and so understand the working environment in which the product is to function. Thus, 'knowing the user' is of paramount importance for good design (Faulkner, 2000).

It should always be remembered that marine electronic systems may have to function in a safety critical situation (Redmill and Rajan, 1997), in which the users do not act rationally and the system's information is likely to be misunderstood. The

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way different people behave under stress, especially in life threatening situations such as the sinking of a vessel, is known to be random in the sense that finding patterns of behaviour are difficult. In these situations, training of personnel and the use of the equipment can help enormously (Redmill and Rajan, 1997) as people may operate in an 'automatic' way. The system should respond to users' needs by supplying all possible information automatically and by clearly requesting user input when this is essential. In other words, the systems need to be designed to a high quality level if they are going to support the users in life-threatening situations.

Many marine electronic systems are essentially information systems which output information so that the mariner can make decisions. In this case, the system supports the user, not by actively helping to achieve a goal, as in the task above of writing this paper, but passively, as the system's information is used for decision-making. This difference is important because a typist can verify the output by reading and using other tools such as a manual dictionary if necessary, but the mariner can only verify information given electronically by using the same information given by another system. Thus, duplication of systems becomes necessary for data/information verification and also as a back-up if the system fails.

In addition, most marine systems have been designed from an embedded systems' approach which means that a neutral fallback position of data representation is given; in other words, the system reverts to some pre-programmed settings if system failure occurs. This could be potentially fatal as the default reading for a GPS may suggest a vessel is in safe waters when, in fact, it is not. In a situation such as a vessel's grounding, the user's working environment becomes safety critical and it is important that the system design, including the interface, recognises this. Thus, information needs to be both reliable and easy to assimilate, both characteristics placing a heavy burden on the designer since the user is likely to act irrationally and need strong system support (Redmill and Rajan, 1997).

3. INTERFACE DESIGN.

Armed with the functionality requirements of the user and also as much knowledge of the goals and tasks as possible, the designer has to turn a blank canvas into a usable screen interface. While the physical attributes of the screen usually remain constant, the designer has to accommodate the functionality into a series of screens. It is becoming common to have a general template which remains constant while the contents of each screen reflect the tasks and goals being carried out. This contributes to the principle of consistency in the design. Users traditionally interact with the system through dialogue screens which prompt the user for input and respond after this is provided. A blinking cursor is the traditional signal to the user that the system is waiting for some input.

There has been discussion as to whether interface design is an art or a science but traditionally it has developed along the lines of graphic design. Designers usually begin to fill the blank canvas by considering the type of system and what are current designs in the market. For the screen design itself, a mathematical proportion is often used such as the Golden Section to divide the page into columns. Many web pages use a similar proportional approach of a basic three to five vertical sections. In more sophisticated interfaces, a deeper mathematical paradigm may be used; for example, in 3-dimensional interfaces designs based on solids in Euclidean geometry have been utilized to simulate a 3-dimensional effect. Whatever underlying structure of the

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design is used, the content will often be based on a metaphorical approach. The most common in use is probably the desktop with its associated language and pictures (often icons) of files and folders. All graphical user interfaces use some form of metaphor to represent data. For example, an electronic chart mimics the paper one with land often being shown in white (and not brown or green) with sea coloured blue. Here the paper chart has been used as a metaphor for the design of the electronic one. Often, though, metaphors are used more extensively as in the case of the desktop being extended into a design paradigm for the system.

One of the problems with many electronic marine systems is that the screens have not yet progressed into becoming graphical user interfaces, as they are still essentially text-based screens. It can be argued that graphics are not necessary for ships' personnel to gain information about the position of the vessel or wind direction. However, if these data are to be fed into an electronic chart, for example, then a diagrammatic representation, such as is shown for wind speed and direction on the weather forecasts on television, may be beneficial providing exact data are not required. Here we have one of the underlying problems of all interface design. There will be some occasions when, for example, the mariner only needs to know wind direction and classification of speed, while at other times, it will be necessary to know the exact speed. In other words, the same data may be used for multiple tasks and the designer has to represent the data so that they can be used in whatever way the user wants. In this simple example of wind direction and speed, it is simplest to give the data in character (words and numbers) form so that the mariner can have exact data whenever this is needed. If only an indication is needed, then the user can immediately know this from the more detailed data. This is adequate for the professional user who will have been trained in using wind data but for a novice user, unused to equating wind speed with say the visual aspects of the Beaufort Scale, the application to the scale of the wind data (for example, if the wind is dangerously high) may be lost. The point here is that graphically represented data has a different function from exact (or nearly accurate) data as they are used to give a general representation and can show trends over time, whereas character-based data are usually read in an instance of time with changes being independent of particular readings. Thus, if the mariner wants to know if the wind speed is increasing when the output is only character-based (text and numbers), it is necessary for him to scroll through the previous (recorded) data or to remember the previous data.

There are many guidelines in existence to help the interface designer. These design principles range from International Standards such as ISO 9241 in its many parts, to texts such as that by Gardiner and Christie (1987) which concentrate on the psychological principles of the user. Numerous interface design texts such as that by Faulkner (2000) or Shneiderman (1998) give guidance to the designer for a variety of different types and styles of interface. Why then, we may ask, does the production of a usable design seem difficult? First of all, the guidelines may seem sensible and easy to apply in their own right but as the screen design takes shape, it is possible for the guidelines to conflict, sometimes amongst themselves and also with constraints such as cost and hardware limitations. Some guidelines may be totally irrelevant, such as those relating to colour when a monochrome screen is to be used. Again, with text-only screens, there is often not room to leave space around the text for easier reading and often the font size and style is limited by the size of the presentation display. Even so, proven design principles can help to improve a design and can add usability to an

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otherwise difficult to use screen. Thus, without a sound knowledge of basic screen design guidelines, the designer is unlikely to produce a usable screen which will support the user at all times and particularly in times of stress and critical safety.

A number of marine systems use buttons or a touch-screen to input data and to select from menus. While these are fine as input devices in normal conditions, buttons can become clogged with salt (just as mouse-balls can) and they need to be large enough for the user to use while working on other tasks. Touch-screens are not very suitable for use at sea, as they usually require the user to remove gloves and, even when this is done, they can become sticky with salt very easily. Buttons are often used in combination, especially for more complex functionality, and this can lead to cognitive overload as the user is forced to remember the button combinations for the required tasks. In a safety critical situation, this could lead to wrong information being entered or outputted, if the button combination is recalled incorrectly or confused with another combination. In these cases, a clear menu structure is to be preferred, since it is visual and leads the user through the stages of the task sequence (Murphy, 2004); in this case, the system has reduced the system's characteristics for an expert user to those of a less experienced user, which mirrors human behaviour under extreme stress (Redmill and Rajan, 1997).

4. EVALUATION OF INTERFACE DESIGN. All designs should be evaluated by experts who have played no part in the design, since the designers themselves are too knowledgeable about the system. Traditionally, evaluation has taken place after building at least part of the system, even a rough prototype. More modern thinking, however, urges the designers to allow evaluation as early as possible in the product's lifecycle, even at the 'paper' stage before any coding has taken place (Bowden *et al.*, 1995). A human factors' expert can be most helpful at this stage of the development when basic usability problems can be detected and removed from the system. For example, a text output of say four lines may be found to be inadequate for some information and it may be better to design the interface large enough to accommodate five lines of text. This can result in the hardware being redesigned to accommodate the larger screen, which is too costly to do once the hardware has been built. Evaluation should continue throughout the lifecycle of the product and should ideally involve both human factors' experts and 'real' users at all stages of the design.

There are many different methods of evaluating software, from heuristic evaluation to laboratory testing. These methods differ from those of traditional software testing by often involving users and giving measured and controlled feedback. For example, when the product is usable within a working scenario, it is helpful to use some measurable instrument for ascertaining users' perceived levels of satisfaction and control, such as SUMI (1996), as well as for the system's overall usability (Macleod *et al.*, 1997). Such evaluation can save the developer from having to withdraw the software at the α-stage or β-stage of testing, when, in any case, changes to the design can be very costly.

5. OTHER DESIGN FACTORS. Marine systems are used globally and manufacturers understandably sell their products in many countries. However, cultural differences can cause problems with software usage, as ship owners may choose to equip a vessel with nationally produced products even when these are

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known not to be the best (Mills, 1998b). English is supposed to be the universal language of the sea, but there are many ships' captains whose English is scanty and who, therefore, may not be able to operate the software, especially if training has been neglected.

Perhaps the sea is one of the last working environments where the workers do not always have much of a choice in the equipment with which they have to work. Of course, there are ship owners who consult their workers but some still operate in a dictatorial way requiring their personnel to use equipment that has been poorly designed (Mills, 1998b). Management decisions are often influenced by costs and, in some countries, national pride, so it is possible that systems may be specified which are poorly suited for the users' tasks. Certain electronic marine equipment needs Government type approval but this is left to individual governments and so can vary enormously from country to country. Such issues may seem beyond the designer's remit but good designers will try to accommodate such compulsory users (Sutcliffe, 1995) by creating a usable design which, in turn, can help enormously to encourage a happy workforce.

As with any design, the context of use of the product is important (Mills, 2000b). The sea-faring environment is harsh for both humans and equipment. We have already noted the effect of salt on the equipment and often space can be restricted too. A small fishing vessel's wheelhouse, for example, must accommodate a variety of different electronic aids ranging from radars, echo-sounders and possibly (horizontal) sonars to GMDSS and other communication equipment. This equipment must work in a salty environment and must be robust enough to be operated by damp and salty fingers. As most fishermen design their own wheelhouses in terms of the placing of the various pieces of equipment, it is essential that the components function individually without interference and can be seen from all angles and positions. Much has been written on the design of bridges (Mills, 2000a) and further discussion is beyond the scope of this article; however, the interface designer needs to accept that the suite of screens under design are likely to be placed alongside others giving similar but possibly different information.

The designer must remember that the user of marine electronic aids will be required to perform tasks well beyond those associated with a control room ethos (Ivergaard, 1989). Often the users will be physically tired and mentally stressed, not only from lack of sleep, but also from being away from families and shore-life. Watch-keeping itself can cause stress through irregular sleep patterns, coupled with irregular eating and cold and wet working conditions (M. 1190, 1986). This is exacerbated by periods of inactivity (such as when a fishing vessel is steaming to the fishing grounds). All these factors emphasise the need for a thoughtful and tested design by the developer.

The design of marine electronic aids, then, has a number of important associated factors which should be considered throughout the design lifecycle.

6. DISCUSSION.

From the above, it is obvious that designing any interface is not a simple matter of placing objects on a screen, even in accordance with design principles. There are a number of factors which not only influence the design but also may dictate constraints.

Any software designer is limited by the hardware and this is most noticeable in marine electronic applications. We have already noted that many applications allow

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for text only output and how this itself is limited to a small number of lines of output. Some manufacturers, aiming particularly at the leisure market, have increased the size of the interface (screen) and introduced some graphical symbols to replace a text-only interface. For example, some fish-finders now have a fish symbol to indicate a 'hard' object under the vessel. However, the use of such symbols can be misleading since there is no indication that the under-water object is actually a fish – it could be a rock with potentially hazardous consequences. Here, the metaphor is incorrectly used, increasing the cognitive load of the user and leading to confusion for the inexperienced user.

The small size of the interface again limits the text message that can be exhibited to the user. In some cases, this may not be a problem but one of the causes for concern (conveyed to this author privately) over the designs of some GMDSS equipment was that the message space was insufficient for the users, particularly when stressed, to appreciate the full implications of the message. Again, the small number of lines often has a small font size associated with each line and this can be a problem for seamen who need to use spectacles for reading. A monochrome screen also does not help as recommended colour combinations for aiding reading in daylight are white text on a dark blue background (RNIB, 2004). In this situation, text should also be sans serif for clarity.

We have noted that the text interface is an inheritance from embedded real-time systems and little progress has been made generally in introducing a more object oriented interface involving graphics. There are notable exceptions as at least one company has had success with an object (graphical) representation of its trawl system even though the cost of such systems is inevitably higher than traditional systems (Mills, 1995b). However, a trawl system lends itself to easy graphical representation while a lot of other data, including vessel speed, attitude and wind speed, may not. Even so, as the electronic chart becomes more affordable such data could be presented in graphical form on the chart with a separate graph available for indicating rising or falling profiles. The question we must ask, though, is whether such graphical representations add any value to the mariner's working experience?

We have already seen that text is exact in representation, although it may not be in reality, and this can be a major problem causing lack of trust in the data. Graphical data give an overall impression but charts and symbols rarely convey the accuracy needed for navigation. A third way to represent the data, which is used by the BBC, for example, on television news, is to combine the easily represented graphical data, such as wind direction, with text data such as wind speed. Such a representation on an electronic chart should serve both the needs for quick identification of direction and knowledge of wind speed. However, this presupposes that the text window has been integrated into a chart display large enough to show all the necessary information. This is particularly important in stressful situations where the user needs clear and exact information/data immediately available (Redmill and Rajan, 1997). Training can help but the user should not have to rely on training for safe and efficient operation of a product.

However, not all data can be combined in this way and there are many vessels with individual systems giving the data needed for safe navigation. These situations rely on the mariner's experience to read and decide actions from the individual outputs. In a safe situation, this is probably quite adequate but raises issues should the mariner's actions become safety critical. In this latter situation, the user may read the wrong

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data or those from the more inaccurate systems or may not be able to remember the data profiles. With text, there is always an element of visualisation which requires cognitive effort; the counter-problem is that the designer's graphical representation may not match that of the user and so cause further confusion. The design guidelines suggest that text should be used where accuracy is required while graphics should represent overall trends.

Marine electronic equipment is invariably used as tools to help the mariner navigate and carry out other tasks within an often hostile and unpleasant environment. The working patterns of the mariner can lead to tiredness and stress without the added complication of the possibility of the vessel becoming involved in a safety critical situation. These aspects all impinge on the way in which the user will interact with the systems and so the designer needs knowledge of these aspects of the user's working life so that the design can accommodate the user's various situations. Herein lies another problem as, without direct experience of domain knowledge, life at sea in this case, the designer will be handicapped (Mills, 2000b).

Even with domain knowledge, design guidelines become woefully inadequate as the designer tries to grapple with so many constraints from environmental issues to those of the user's aging sight. Indeed, the guidelines also may contradict each other at times. In addition, if a user-centred design approach is used, the users will have suggestions which may not always be viable. The handling of such conflicts is beyond the scope of this article but the designer needs to be aware of as many constraints as possible so that these can be catered for within the design.

The design of any artifact is difficult and requires flair beyond the rules of design given through guidelines and principles. Inevitably, a designer will find out how similar functionality has been designed previously into the interface and will seek inspiration from these studies. If the employing company has already marketed successfully a previous version of the product, it may even put constraints on the changes that the designer can make. After all, all product design is market driven.

Taking a user-centred design approach does not automatically guarantee that the interface is usable but it should help to alleviate some of the problems that the user may find. However, involving users can bring uncertainty, especially if new systems are being developed, since users do not always know what they want and will change their minds during the production of the system. Even so, all but the simplest systems should benefit from the involvement of users throughout the lifecycle of development. It can be surmised that developers who solely use a Yourdon based development lifecycle are missing this important aspect of design since Yourdon, being developed primarily for embedded systems, does not have a user involvement stage, except for expert interviews of the environment (Yourdon, 1993).

The perfect design approved by all users is still far away and will probably remain a figment of the user's imagination for some years at least, if not forever. It is easy for users to criticise a design and blame the designer when things go wrong but it is necessary to remember that any design needs to be suitable for different types of users and in different situations. The designer never designs for one person (costs do not allow this); the nearest is for a similar group of people such as navigation officers. In marine applications, some producers seem more proficient at producing intuitively usable software than others but the added quality may be reflected in the price. There is little doubt that users' involvement throughout the design lifecycle can help enormously (Jordan *et al*., 1996), even after allowing for all the constraints discussed above.

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7. CONCLUSION. This article has shown that designing a marine system can be complex and inevitably leads to some compromise between the various guidelines and other requirements and constraints that the system's environment and user groups will bring. However, in the final design, the compromises and constraints should not be apparent to the users who should find the product easy to use while allowing their goals to be reached effectively, efficiently and satisfactorily (ISO 9241-11, 1994). This is the ideal and it is pleasing that many marine electronic products do accomplish this; however, there are still too many marine electronic systems available which could benefit from input from human factors' experts as well as professional users with experience of working at sea.

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