

# Naturalness in the Design of Computer Hardware - The Forgotten Interface?

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**Abstract.** Naturalness in human-computer interaction (HCI) facilitates both user motivation and creativity when interacting with software. However, it is argued that the implementation of a variety of hardware devices that embrace the user's natural behavior will help achieve an intuitive environment that supports natural interaction. To identify the potential benefits of adopting a naturalness principle in the design of the hardware interface, the paper describes the development of a user-centered computational environment to support designers during conceptual design and how the provision of appropriate input and output devices could support and extend the designer's capabilities.

## 1. Introduction

Computers are increasingly used in creative tasks, whether it is writing a story, playing a game, or designing a new product. Thus, software should be designed in such a way as to support this creative process. One way in which this can be achieved is through the design of the interface. Referring to the software interface, Selker [1] identified a number of general design requirements that would facilitate user motivation and creativity. First, an idea has to be expressed and captured to be considered; thus the system should facilitate and encourage ideas to be expressed at the moment of relevance. Secondly, it should be productive and non-intrusive so as to allow people to focus on their creative tasks rather than be distracted by the necessity to interact with the interface. In general, Selker notes that by removing physical difficulties, the interface can reduce the effort of expressing ideas and inherently motivate and support creativity in the user. Both of Selker's requirements are, however, also relevant to the design of the hardware interface, which is often overlooked during software design. For instance, in order to facilitate the expression of ideas and enable the exchange of information between the user and the software it is

necessary to provide a range of interaction devices that sufficiently match the skills and needs of the user [2]. Thus, HCI could be improved by presenting an intuitive environment (implemented in software *and* hardware) which supports natural interaction thereby improving the support of creativity.

## **2 Naturalness as a Design Principle for the Hardware Interface**

The role of HCI is to maximize human cognitive and physical abilities. In order to fulfill this role, it is first necessary to support the users' current abilities and only then to attempt to implement computational tools to enable them to undertake new, creative activities. Both of these steps require that software is designed in such a way as to assimilate users' behavior, thereby attempting to make HCI resemble as, close as possible, real-world interactions. For instance, in real-world interactions a myriad of modalities (e.g. speech, eye gaze, gesture, facial expressions, etc.) are used to express thoughts, ideas, and feelings, which differs significantly from the common form of HCI which typically occurs through the use of a keyboard and mouse [3]. Further, while interacting with the natural world, we obtain a rich source of information about the objects that surround us through the various sensorial modalities which is far removed from the static, two-dimensional visual information typically associated with HCI [4]. Thus, one way in which a more natural and intuitive interaction can be achieved is through the provision of input devices that are congruent with the way humans operate generally (i.e. two-handed operation, speech recognition) and with task-specific behaviors (i.e. sketching) and output devices that utilize the various modalities to provide a rich source of information as in real-world interactions.

While the naturalness principle is recommended for implementation in the design of all hardware interfaces, the current paper describes its application in the design of an envisaged user-centered computational environment to support conceptual design in a variety of design domains (i.e. software design, drug design/discovery, product design, aerospace design, civil engineering etc.). Beyond the obvious usability issues, the necessity to consider the naturalness of the hardware interface in such a system resides in the importance of creativity during conceptual design.

### **3 Development of a User-Centered Computational Environment to Support Conceptual Design**

#### **3.1 Conceptual Design**

Conceptual design is considered crucial to the overall effectiveness of the final product [5]. It involves the generation and evaluation of design ideas/concepts, which provides a greater insight into the design problem and structures the design problem space. Consequently, the designer spends considerable time searching through design space [6]. However, Parmee [7] identified a number of factors that limit the searchable design space. First, the initial representation of the problem is often bounded by available (internal and external) knowledge and understanding. Secondly, information processing constraints (e.g. cognitive load) limit the ability to deal with the complexity and (potentially) high-dimensionality of the design space.

One way to facilitate conceptual design in terms of dealing with this complexity and high dimensionality is through the use of computational support. In particular, a computational tool can stimulate creativity by extending the search space beyond that which can be searched by the designer. Further, it can reduce the load on the designer by undertaking mundane tasks. This enables the designer to stay motivated and focused on relevant elements of the task which enables the realization of the task objectives.

#### **3.2 Computer-Aided Design (CAD)**

Due to the bottom-up approach (i.e. dimension-focused and procedural) adopted by current CAD software, they are not appropriate for the top-down approach (i.e. form- and shape-oriented) necessary during conceptual design [9]. Furthermore, the unnatural and non-intuitive interface (both software and hardware) is believed to inhibit HCI and does not provide users with a satisfactory experience for design [10] which could affect motivation and creativity.

At present, there is limited computational support for conceptual design [11,12]. In developing appropriate software, it is important to

learn from the mistakes of traditional CAD software in terms of the design of the interface, in order to enhance HCI.

### **3.3 The Future of Conceptual Design**

One suggestion to support the designer during conceptual design is through the development of a user-centered computational environment [for more details see 5,8]. In essence, it is proposed that by utilizing machine intelligence (i.e. evolutionary and adaptive computing, machine learning, fuzzy inference, etc.) a much greater design space can be explored [7]. The outcomes of this process can then be presented to the user for evaluation, which will result in gradual improvement in problem understanding, re-formulated representations, a developing knowledge-base, and the eventual identification of a solution(s). Thus, an iterative and fully interactive process emerges through which the designers' capabilities are supported and extended through the implementation of computational support.

However, in order to ensure an effective and efficient HCI, it is necessary to embrace the user's needs and abilities in the design of the software. A particularly important issue governing the effectiveness of the software is the successful exchange of information between the user and the system: the user must be able to represent their knowledge to the system, which will be facilitated through appropriate natural input devices, and the system output must be presented to the user in an understandable and natural format through appropriate output devices.

In the following sections, a number of input and output devices are briefly considered in terms of their potential to support natural behavior and task-based (design) behavior, and to extend the stimulate creativity. It is acknowledged, however, that some of the devices, particularly recognition technology, require further work to improve their efficiency and effectiveness because people bring expectations to HCI based on natural interaction that are not currently met by these devices [13].

### **3.4 Input Devices**

#### *3.4.1 Two-Handed Operation*

Many everyday tasks are classified as bimanual activities, as they require the use of both hands [14]. Thus, implementing two-handed operation in the design of the interface offers more natural and intuitive HCI as it mimics natural behavior in real-world interactions [15]. Indeed, the implementation of two handed operation during the computer-aided conceptual design (CACD) process is important as it provides the user with greater efficiency and flexibility [16].

#### *3.4.2 Free-Hand Sketch*

Sketching using pencil and paper plays a major role in design, particularly conceptual design [17] where it can stimulate creativity [18]. Thus, given the importance of sketching to the design process, and the potential to extend capabilities of sketching through the use of computational tools (i.e. multi-angle visualizations) a sketching facility could be considered a necessary inclusion in CACD systems

#### *3.4.3 Recognition Techniques*

In developing a natural interface, it is deemed important to incorporate recognition techniques capable of handling natural inputs [19] such as speech, handwriting/annotation, gesture, and emotion/affect [13,20,21]. In the design process this capability would enable the designer to express themselves in a natural manner, and opens up the possibility of conveying ideas as they occur.

### **3.5 Output Devices**

#### *3.5.1 Visual Display*

Vision is the most dominant of the five senses in humans. Consequently, visual displays (often two-dimensional) tend to dominate HCI as a way of presenting information to the user. However, as we perceive the world as three-dimensions, the most natural format in which to present visual output is through a three-dimensional channel. Ye, Campbell, Page, and Badni [11] note that a design system that implements a three-dimensional visual display would support design reviews as it is not only easier to interpret than two-dimensional images but also enhances understanding of complex visual information, which would ultimately enable a better understanding of the design problem and reduce the number of design errors.

### 3.5.2 *Haptic Technology*

Haptic technology interfaces the user through the sense of touch by applying forces, vibrations and/or motions [22]. This capability can be of great benefit to designers as it enables them to naturally and continuously act on their environment [23]. What is more, combined with a three-dimensional visualization it presents a more natural and intuitive interface that enables the user to see, touch, and feel output directly [11].

### 3.5.3 *Auditory Output*

Sound is a familiar and natural medium for conveying information [24]. Sounds can stand alone as independent sources of information or be utilized to improve further the realism of the visual output [25]. An obvious use of auditory output within the envisaged CACD system is to provide feedback to users about their actions during the design process.

## 4 **Conclusions**

Natural hardware interfaces are an important element toward shifting HCI much closer to the needs of the user [3] during a specific activity. By assimilating users' natural and task-based behavior in the provision of interaction devices it should be possible to facilitate natural and intuitive HCI. Moreover, providing users with the appropriate tools to undertake a given task can help maintain motivation and enhance creativity [1]. As shown, this is particularly important in the development of a user-centred computational environment (on which we are working) and through which more effective design solutions will be made possible by supporting and extending the capabilities of designers.

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