Design of User Interfaces for Computing Systems†

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†Accepted for publication, Cutter Consortium, Arlington, Massachusetts.

‡ This project was initially sponsored by the WAN SIG, MIT Auto-ID Labs. Thesis supervisor David L. Brock.

INTRODUCTION

Two powerful information-processing systems exist in the world, the human mind and the digital computer. The main connection between the two systems is the display of information, commonly called a User Interface (UI).

The primary goal of designing a UI is to create opaque objects that map an information space, affording a guide for human interactions that increases cognition. A properly designed UI will increase the productivity of information transfer leading to better insights. Understanding the factors that determine a good UI design is important knowledge for all who work with or design computing systems within organizations.

This article examines the factors that influence an effective user interface (UI). In particular, the article discusses the need for a role-based UI that takes into consideration the job functions and cognitive abilities of the user.

DEFINITION OF THE UI

Simply stated, the UI marks the point of interaction between the user and a computing system. The aim of the UI is to be a representation that best satisfies the needs of the user while conveying an accurate portrayal of underlying information contained in a computing system. To satisfy these needs, the UI needs to take into consideration many facets of the user. Some important considerations include experience of the user in the area of use, and role of the user in the context of the organization.

Ultimately, the user judges the aesthetics of the display and directly interacts with the UI. Therefore, the user is of crucial importance in UI design. This is also reinforced in the fact that the two major aspects of an effective UI are usability and functionality, which are both user-focused elements. Usability emphasizes the interactions between the user and the UI. Functionality focuses on how the user can manipulate the available information. Both these elements must achieve balance in designing an effective UI.

The role of the user can be better understood by examining the relationship between a “kind” of user and a “system.” What this means, is that the users’ needs, interests, expectations, behaviors, and responsibilities (which defines the “kind” of the user) drive the “system” over which the UI needs to be built. An explicit design should focus on how the UI satisfies customer wants and needs rather than the mechanics of building the UI. Some of the main criteria to consider include, experience, role, data aggregation level, and cultural variations. The role or job of the user is one of the key criteria that should be factored into UI design. This aspect varies across different industries and is generally project or area-specific.

COGNITIVE FACTORS THAT INFLUENCE UI DESIGN

It is important to choose the right kind of representation for each task. Vessey characterized the relationship between task characteristics, user and representation format using the “cognitive fit” hypothesis. Cognitive fit is defined as “a cost-benefit characteristic that suggests that, for most effective and efficient problem solving to occur, the problem representation and any tools or aids employed should all support the strategies (methods or processes) required to perform the task.”[1]

Although most of the stimuli in interfaces are received through visual means, additional data is collected by the other senses. A more comprehensive term that is used instead of visualization is perceptualization. The process of visualization depends on many factors, of which cognition is an important element. Cognitive processes interpret the visual data coming in and hence it is important to account and exploit these effects.

Chunking

Miller,[2] in a classic paper, put forth the idea that the size of the short-term memory is approximately seven items or registers or chunks of information. This phenomenon is called the "chunking limit." The error was found to be one or two entities. Other authors have since offered other sizes with most being slightly smaller estimates.

Although the short-term memory has a certain number of 'entities' that it can hold, with learning, the size of the individual entities grows. With familiarity of a system, the amount that the short-term memory holds will get larger.

On the other hand, the chunking limit decreases as the complexity of the information increases. By chunking information, the communicator improves the consumer's comprehension and ability to access and retrieve the information.

In any data flow diagram, it is important to not go more than nine levels deep – even less if the functions are complex. Similarly, while understanding the level of detail in a problem, there is a limit to how deep or how many levels deep a person can dig through to understand a situation. Data beyond approximately seven layers becomes useless and meaningless for solving most problems.

Anchoring

In the case of long-term memory, the most important consideration that needs to be taken into account is the case of interference between similar functions, programs or representations. Long-term memory internalizes data and representations making it easier to process information and situations in the future. This phenomenon is known as anchoring. Anchoring is the preference of humans to work with familiar representations. It describes the common human tendency to rely too heavily, or "anchor" on one trait or piece of information while making decisions. Once an anchor is set, there is a bias towards that value. A consequence of this is that most people make decisions based on initial value rather than an exploration of the entire range of alternatives. This anchoring and adjustment heuristic was theorized by Amos Tversky and Daniel Kahneman.[3]

Symbols and icons can help describe concepts, functions, and/or tasks easily. The use of familiar symbols can greatly enhance a UI and make it easier to understand. This follows along the line of anchoring which is a fundamental consideration in ease of use. The symbols that are used need to be harmonized within the sphere of use i.e. they need to be consistent across the application. The actual style that the different symbols are represented with should be consistent in order to harness the potential use for symbols. The basic semantics of the symbols should be as standard as possible. There are many standards established for symbols depending on the industry of the product in the supply chain. For example, the Institute of Electrical and Electronics Engineers (IEEE) has standards for the electronics industry.

Shape

Shape is a critical dimension of visual representation. The old say "a picture is worth a thousand words" has its value in UI design. In many cases, graphical representations are more powerful than textual ones. Therefore, it is important to use graphics, graphs, and charts to represent voluminous data. For simple representations or small amounts of data, tables, and other textual representations work well. Tables are less effective as the amount of data increases.

Color

Color is generally superior to shape to search for a given item within a display. Visually, humans require more time and processing to identify shapes. The caveat with colors is that there is a limit to the number of distinct colors that can be processed. There is a limit of less than ten colors that can be used in one interface with effective results.

Individual Parts versus the Whole

Gestalt psychology emerged in the early 1900s. The best description of this psychology is "the sum of the whole is greater than its parts". This model studies the interrelationships among objects in an image. It recognizes the fact that the image perceived by a human brain depends not only on the set individual objects that constitute the image, but on the relationships between them. This idea is now almost universally acknowledged in the field of human vision research. Gestalt is the German word for "form" and means "unified whole" or "configuration".

IMPLICATIONS FOR THE UI DESIGN PROCESS

After examining all the different aspects of role-specifc characteristics, human cognition and capabilities, there are some key takeaways for UI design. As specified earlier, job functions can vary across industries and hence must be examined on a case-by-case basis. From chunking requirements, we see that there should be less than ten elements on the screen and less than nine levels of depth or drilldown. From anchoring considerations, it is important to have familiar representations that make it easier for users to learn and use the system quickly.

Due to the short-term memory limitations that we have discussed, we see that there are limitations to the number of entities that can be processed at one time. Therefore, our recommended is that the UI should have a maximum of ten elements per display screen. In addition, it should be kept in mind that the number of levels of detail that a human can process is around the short-term memory limit.

We see that there are many aspects to the design of a user interface. In most systems today, the UI is given little importance. This has led to many UI failures including complexity that hinders the user in their functions. A good UI must take into account both the users perspective and the data perspective, blending them seamlessly to provide the best functionality and representation that accurately represents the data and satisfies the needs of the user.

FUTURE WORK

There remains a great deal of work to do in this area for the future. The design and implementation of the ideas we discuss in this paper are key step to take in the short-term. In addition, other areas of cognition are gaining credence. UI design needs to take an interdisciplinary approach to satisfy users' needs. Existing and future UIs need to be evaluated using standardized metrics like ISO or project-specific metrics based on some of the ideas presented in this article. Pilot testing with representative samples needs to be undertaken. This article is intended to be a springboard for further exploration. The crossover of various disciplines within UI design, the importance of all aspects of the user, and re-evaluation of new data made available, provide perfect opportunities to work towards building effective UI in practice.

1. Vessey I, Galetta D.F., *Cognitive Fit: An Empirical Study of Information Acquisition*, Information Systems Research, 2:1, pp. 63-84, 1991.

2. Miller A.R., *The ABC's of AUTOCAD*, San Francisco: Sybex, 1988.

3. Kahneman D, Slovic P, Tversky A., Editors, *Judgement under Uncertainty: Heuristics and Biases*, Cambridge, UK: Cambridge University Pres, 1982.