

An Approach to the Design of Information Interface

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Abstract

This paper deals with human-information interactions through information devices, and gives a design method for interface between a human user and information. In the first part of this paper, we introduce the concept of information interface (human-information interface) that represents interactions between a human user and information through an information device. In the second part of the paper, we discuss measures for the quality of information interface, and propose a design method for improving the quality of interactions (information interface) under a certain performance criterion with the use of a multiple regression (MR) method.

Key words: User interface, Information interface, Multiple regression (MR) model

1. Introduction

When one wants to access information, or to perform certain information activities, he/she needs to operate an information device. In this situation the final goal for the user is not operating the information device but performing intended information activities. This situation also shows that operating the information device is one of important dimensions for performing the final goal of the device use. From the viewpoint of the goal of the use of the information device, we first introduce the concept of information interface. The information interface is defined as the surface between a user and a combined information source that consists of the information device and information source. The human user-information interactions through this interface consists of sub-interfaces (low level interfaces). We show the structure and interrelationships of three principal sub-interfaces: Operation interface of the information device (device operation level); Media interface that makes matching sensory channels and information media (media level); and Semantic interface (semantic/content level). We also show the concept of universal information that ensures an equal quality of information service for every user in a target user group.

In the second part of this paper, we show an approach to designing information interface based on a multiple regression (MR) model. We introduce two kinds of quality measures for information interface: Total load of human information processing for perceiving information; and Accuracy of perceived information defined as the difference between the perceived and the original ones. We show a model for information interface with system parameters that can control the quality of the interface. The quality measure, in general, has a rather complicated relation with control parameters. We then approximate the relationship by MR model that has

multi-linear expressions. Using MR model, we can calculate optimal control parameters by a usual optimization algorithm. In the companion paper of this paper [Maehara, Kamata, Usui, & Wakimoto, 2003], we show certain design examples.

2. Information Interface

2.1 Structure of Information Systems

Figure 1 shows a simple diagram that explains how we interact with information through an information device. A human user accesses information by operating the information device. The diagram also shows that the purpose, or the goal of operating the information device is performing certain information activities such as getting information from the source, and sending information. From the goal of the use of the information device, we can focus on the interaction between a human user and information. This view gives another diagram shown in Figure 2. The surface between a human user and a combined information source gives another interface. We call this one Information Interface (human user - information interface).

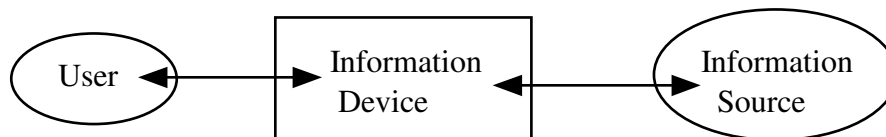


Figure 1. Typical structural elements for information systems. A human user interacts with information by operating an information device.

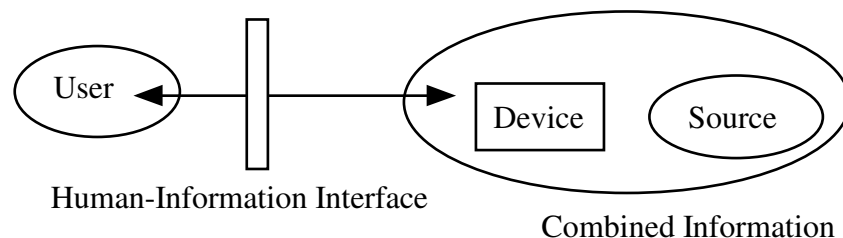


Figure 2. Information interface between a human user and a combined information source. The combined information source consists of the information device and the original information source.

2.2 Structure of Information Interface

The interactions through information interface introduced above consist of several levels, and then the interface has a hierarchical structure. Figure 3 shows principal factors (levels), and their structural relations. There are two main dimensions: Device operation, and information dimensions. The information dimension further has two factors: Media factor that constructs media interface; and Semantic/Content factor for semantic interface. In addition to these ones, use environment is another important factor. Although designing user interface has been intensively discussed [Treu, 1994], we focus mainly on human user-information interaction. In the following, we will show features of construction interfaces and their relations.

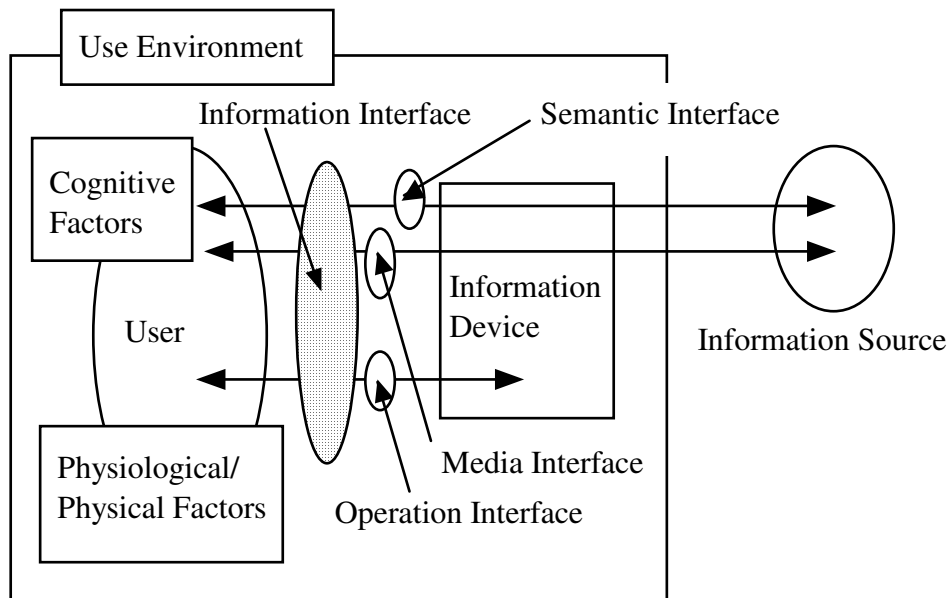


Figure 3. Structure of an information interface. The information interface consists of operation, media and semantic sub-interfaces.

(1) Operation Interface

The function of the operation interface is operating an information device by a user. This interface contains physiological, physical and cognitive factors.

(2) Media Interface

Information is conveyed by a certain physical signal called an information medium. The media interface is defined as a surface between human sensory and a vehicle of information, medium. The function of the media interface is making matching sensory channels of a user and information media.

(3) Semantic Interface

The semantic interaction between a user and an information source is the principle factor of the use of the information device. This interface is important in realising the access to information. The content of information should be transmitted to a user so that he/she can comprehend it well.

(4) Environmental Factors

The environmental factors are illumination, sound conditions and so on. These are independent of a user and an information device, and are relatively controllable by external or additional resources.

(5) Information Interface

The information interface is defined as the whole of those interfaces (sub-interfaces). The function of the information interface then is realised by the effective combination of sub-interfaces, or interfaces of lower levels. Then the access to the information source depends entirely upon how well the information interface works.

2.3 Information Accessibility

We further consider the features of the information interface shown in Figure 3 from both a user group and the purpose of the use of an information device. Everyone in the target user group uses the information device to access information in a manner that he/she intends. Interactions between every user and information (a combined information) should be ensured with reasonable quality. The ensuring interface performance quality leads to the concept of universal access to the combined information source, or in another word, universalisation of the combined information for every user in the target user group.

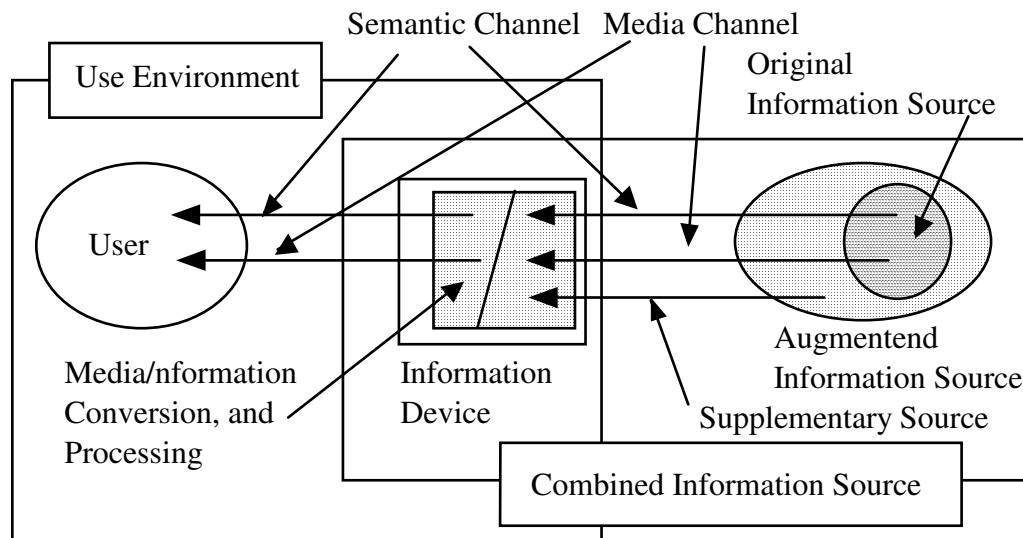


Figure 4. Universalisation of information by using supplementary information added to an original information source, and an information device.

In this section we assume that the target user group includes people who may have some limitations in physical, physiological and cognitive factors. Universal access (universal service), in this case, means that every individual is able to access information in a reasonable quality regardless of limited capabilities and limitations. Note that the concept of universal access/universal service is also required from a fundamental social principle, normalisation principle. In the process of universalising the combined information, we can use controllable parameters for each of an original information source and an information device. Figure 4 shows some of primary functional factors in semantic and media interface levels. The key to the universalisation of the combined information source is the cooperative processing between an augmented information source and an information device.

(1) Augmentation of the original information source

The original information source itself can be used for making easy every user to understand the content by processing at an information device in each of media and semantic interfaces. We explain one example for Text-to-Speech processing when a user is not able to use vision either permanently, or tentatively. In Text-to-Speech processing, we can add some phonological information to the original text so that an information device can generate speech accurately and easily. This is also the same for the case of Text-to-Braille translation. Thus the augmentation of original source, or adding supplementary information, makes the information device easy, and accurate to perform required information processing.

(2) Media and information conversion

The accuracy in media/information conversion can be improved by the cooperation between the information device and the augmented information source. There are two main channels in information interface: Media channel; and Semantic channel. In the case of Text-to-Speech system, for example, media conversion is mainly processed at the information device. The semantic channel, in this case, is realised both by sentence conversion (paraphrasing) that enables a user easy to understand, and by accurate speech conversion of sentences. Sentence conversion (paraphrasing) is rather complicated language processing for the information device, and is preferable to be processed at the information source end from both viewpoints of economic and total processing efficiency.

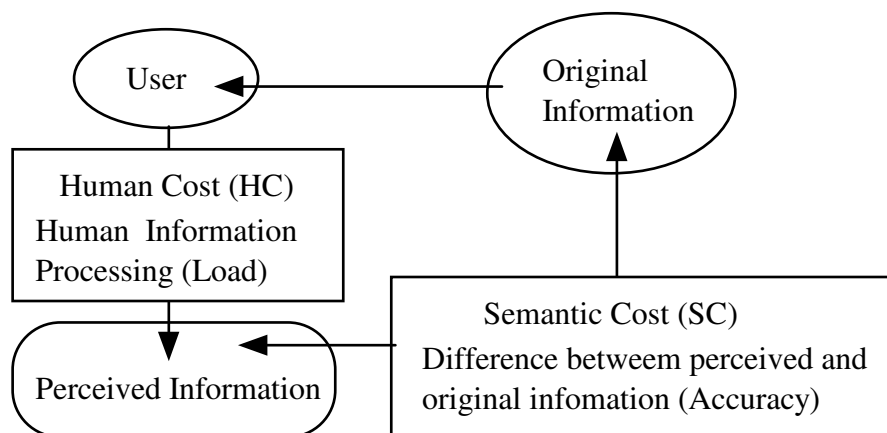


Figure 5. Measures for information accessibility/universalisation.

Human cost (HC) represents total processing load of a user for perceiving information. Semantic cost (SC) represents the accuracy of perceived information of a user.

2.4 Measures for Information Accessibility

When we discuss designing an information system for an individual user to perform certain information activities with allowable performance quality, we need a measure for the quality of interactions through the interface. In this section, we introduce two kinds of measures for information interface.

The first measure is the total human information processing load of a user for performing information processing: perceiving information. We call this measure Human Cost (HC). The other one is the difference between perceived information and the original one. This means the accuracy of perceived information, and we call this measure Semantic Cost (SC). In the companion paper of this paper [Maehara, Kamata, Usui, & Wakimoto, 2003], we show practical design examples by using these quality measures.

3. Approach to Interface Design

3.1 Model

We show a practical model for designing information interfaces shown in the previous chapter. The system has several construction elements as shown in Figure 6.

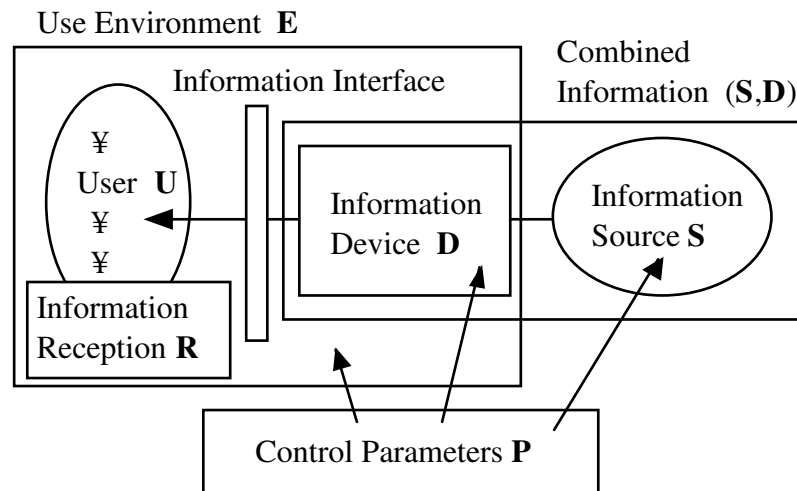


Figure 6. Model for an information system.

(1) Information Source **S**

We assume there are N sources, S_1, S_2, \dots, S_N , that an individual user will access in the system. Then an information source **S** is defined as a set of sources $S = \{S_1, S_2, \dots, S_N\}$.

(2) Device Characteristics **D**

Device characteristics covers various parameters that affect interactions between a user and information. One typical factor is the display size of an information device that we will discuss in the companion paper [Maehara, Kamata, Usui, & Wakimoto, 2003].

(3) Combined Information (**S, D**)

A combined information is defined as system (**S, D**), and represents the characteristics of information to a user.

(4) Information Reception Characteristics (**R**)

Information reception characteristics **R** represents how information source (**S, D**) is processed and perceived by a user. This is characterised by factors: User characteristics **U**; and Use environment characteristics **E**.

(i) User Characteristics (**U**)

User characteristics includes physiological, physical, psychological, and cognitive factors for users in a target group.

(ii) Use Environment Characteristics (**E**)

Mobile information devices such as MPs (Mobile Phones) and PDAs (Personal Digital Assistants) are used in various situations such as in a room, outdoors, in a poorly illuminated, or noisy room, and so on. The characteristics represents these environmental factors.

(5) Information Interface (II)

Information interface is defined as the whole of sub-interfaces in the previous chapter. Using those factors above this can be considered as the human-information interactions specified by information reception characteristics **R** and combined information source specified by information source **S** and information device **D**.

(6) Control Parameters

We can control certain functional parameters of the system so that an individual user in the target user group can access information source as equally as possible. The set of control parameters are represented by $\mathbf{P}=(p_1, p_2, \dots, p_M)$. Note that these control parameters $p_m, m=1, 2, \dots, M$, will be device parameters, environmental factors, or certain factors that affect information source. That is, we can set any factors as control parameters when the factors have properties: Factors can effectively control the characteristics of the information system for improving the quality of interactions through the interface.

3.2 Formulation

(1) Evaluation Indicator

We define evaluation indicator $\mathbf{W}=\{W_1, W_2, \dots, W_K\}$ as a measure of interface quality. These indicators will reflect human cost HC and/or semantic cost SC.

(2) Quality Measure of Interface

Quality measure is defined as $N \times K$ matrix $\mathbf{Q}=[w_{nk}]$, $n=1, 2, \dots, N$, and $k=1, 2, \dots, K$. Where, w_{nk} represents the evaluation for source S_n based on indicator W_k . We must express the elements of \mathbf{Q} , $w_{nk}, n=1, 2, \dots, N$, and $k=1, 2, \dots, K$, by control parameters $p_m, m=1, 2, \dots, M$, so that we can adjust control parameters optimal under a quality criterion.

The structure of quality measure \mathbf{Q} depends highly on the indicator, and generally speaking its structure will be very complicated. We approximate the measure \mathbf{Q} , or $w_{nk}, n=1, 2, \dots, N$, and $k=1, 2, \dots, K$, by a set of multi-linear functions of control parameters $p_m, m=1, 2, \dots, M$, with the use of a multiple regression (MR) technique. We collect a data set of quality measures w_{nk} for control parameters and users (subjects) with the use of a measurement technique such as physical, and cognitive performance measurements. By processing these measured data, the evaluation, then, is expressed by a multiple regression (MR) model [Everitt, & Wykes, 1999]:

$$w_{nk}^P = a_{nk}^0 + a_{nk}^1 p_1 + \dots + a_{nk}^M p_M \quad \text{for } n=1, 2, \dots, N, \text{ and } k=1, 2, \dots, K.$$

The set of multi-linear expressions gives certain description for the relation between quality measure w_{nk}^P (dependent variables) and control parameters p_m (explanatory variables). Note that the multiple regression (MR) model is only an approximation of a real relationship between quality measure $\mathbf{Q}=[w_{nk}]$, and control parameters p_m .

(3) Parameter Adjusting

We first specify target value of quality measure $\mathbf{Q}^{\text{target}}$, or element value w_{nk}^{target} for $n=1, 2, \dots, N$, and $k=1, 2, \dots, K$. We then try to adjust control parameters $p_m, m=1, 2, \dots, M$, optimal that gives values as close as possible to the target value. We set the object function F for specifying optimal control parameters:

Object function F is defined as the sum of square errors between target indicator values w_{nk}^{target} and w_{nk}^P : Total sum of $(w_{nk}^{\text{target}} - w_{nk}^P)^2$ for all n, k .

With the use of a usual optimisation algorithm such as quasi-Newton method, we can calculate optimal control parameters p_m^{optimal} for $m=1, 2, \dots, M$, that minimises the object function F .

4. Concluding Remarks

This paper has introduced the concept of information interface that represented human user-information interactions, and proposed an approach to designing information interface based on a multiple regression (MR) model.

The purpose of the use of an information device is performing certain information activities. From this point of view, we have introduced a model for user-information interactions called information interface. The information interface had a hierarchical structure, and was defined as the whole of sub-interfaces: device operation level interface; information media level interface; and semantic/content level interface. The information interface was modeled and approximated by MR model that had a set of multi-linear expressions with control parameters. We also have shown that the optimal parameters could be calculated by usual quasi-Newton method.

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