Characteristics of users'needs and activities: A design space for interactive information retrieval systems

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Abstract

One of the new design challenges in Information Retrieval (IR) and Human Computer Interaction (HCI) is to face a huge quantity of structured and accessible information which is available to a variety of users having different information needs. This article proposes a dimension space that should help in the design of current and future interactive information retrieval systems. To do so, we adopt a user centered perspective: our problem space is comprised of 3 sets of dimensions. The two first ones are used to characterize the user: her/his information needs and her/his knowledge about the system. The third set of dimensions deals with the notion of input expression: how the user specifies her/his information need. Based on our design space and Norman's Theory of Actions we then model users' activities while accomplishing a retrieval task. The discussion is illustrated with IRIS-M, an Interactive Information Retrieval System that we have developed.

1. Introduction

An Information Retrieval System (IRS) allows various users to search and retrieve information. One of the new design challenges for Information Retrieval (IR) and Human Computer Interaction (HCI) is to face huge quantities of structured and accessible information which is available to a variety of users having different information needs. IRS are inherently interactive systems with a constant growth of the number of end-users. Here we underline the key role that Human Computer Interaction (HCI) plays in an IRS. IRS must not only rely on effective retrieval mechanisms but must also provide efficient interaction with the end-users. Nevertheless little attention has been paid to the user interface in the design and evaluation of an IRS. For instance the evaluation of an IRS is based on recall/precision metrics which are computed according to a set of predefined tests. The user activities are not taken into account in the evaluation process. We address this need in our work: the global goal is to incorporate the user, characteristics and activities within the design process of an IRS. To do so we apply design methods from the domain of HCI. Design methods are based on a conceptual study of the user, her/his information needs and tasks. Results of this conceptual study are used to design the user interface. Finally the designed user interface is developed and evaluated.

This article focuses on the user's need and activities while accomplishing a retrieval information task. We propose a framework that should help in the design of current and future IRS. To do so, we adopt a user centered perspective: our problem space is comprised of 3 sets of dimensions described in section 2.

- The two first set of dimensions are used to characterize the user: her/his information needs and her/his knowledge about the system.
- The third set of dimensions deals with the notion of input expression: how the user specifies her/his information need.

After a presentation of our design space, we then go one step forward in the design by describing the users tasks. To achieve this goal, we apply the seven step model of Norman's Theory of Action [8]. Section 3 presents our interpretation of the Theory of Action applied to the information retrieval task coupled with the dimensions of our design space. Finally, we illustrate the discussion with IRIS-M, an Interactive Information Retrieval System that we have developed.

2. Characteristics of user's situation: a design space

As pointed out by N. Belkin, information retrieval is a tool that supports human problem management. Consequently it does not attempt to answer questions or solve problems but is intended to help users find information that might be useful for those purposes [3]. The goal of an IRS is therefore that the user obtains a response appropriate to her/his situation. We characterize a user's situation by her/his information needs, her/his knowledge about the domain and the system: information needs and knowledge are two sets of dimensions of our design space. The third set of dimensions or space deals with the notion of input expression: it describes the expression specified by the user in a presentation independent way. This last space is closely related to the two first ones as shown in Figure 1.

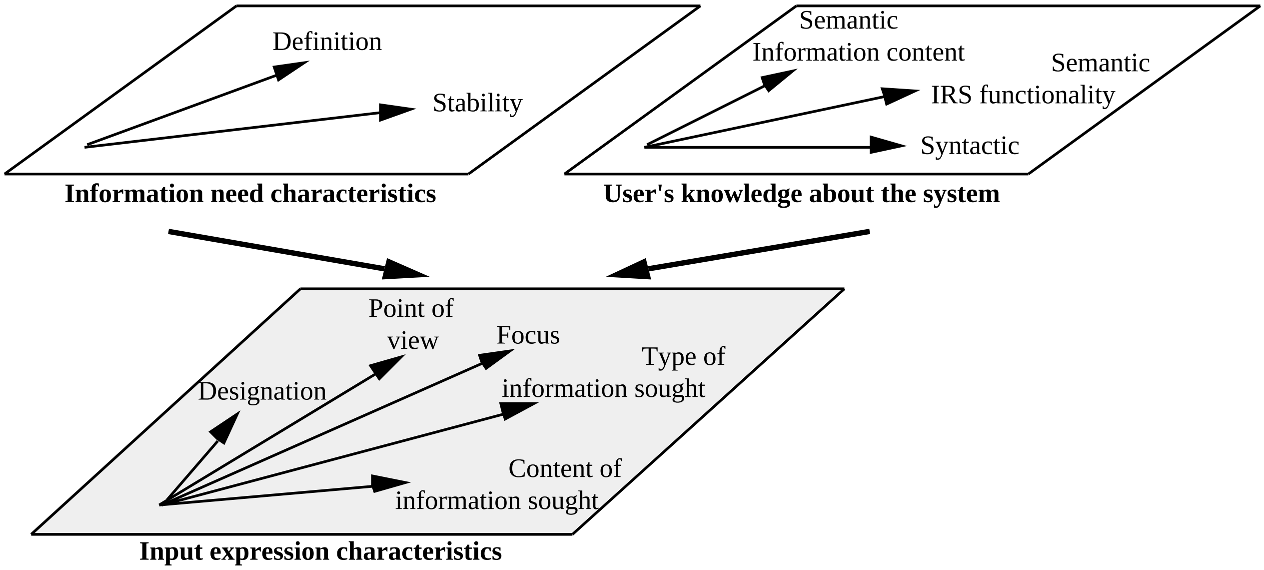

Figure 1: Our design space, information need, knowledge and input expression.

2.1. Information need characteristics

This first set of dimensions expresses the intrinsic properties of an information need. Such properties are closely related to the user's cognitive state. The user's cognitive space includes various cognitive elements such as the work-task, the interest domain, the cognitive state and the problem space that are identified in the Global Model of Polyrepresentation in IR [5]. The "information need characteristics" dimensions include two basic properties, namely definition and stability.

2.1.1. Definition of information need

This axis primarily covers the precision or vagueness of information needs. According to her/his knowledge and cognitive space, her/his information need can be well or ill defined. We adopt here a user's point of view. Nevertheless it is important to notice that a well-defined information need from the user's point of view can correspond to a very vague query from a system point of view and vice-versa.

2.1.2. Stability of information need

This axis covers the stability or variability of information need. P. Ingwersen [5] shows that information need varies because it depends on dynamic cognitive structures. We identify two cases of variability: topic and definition variability. The user can decide to change the topic of research while interacting with the IR system. Moreover the definition (precision) of information need can vary. An ostensive approach for IR navigation is a promising way for dealing with instability [1].

2.2. User's knowledge of the system

We here classically distinguish two types of knowledge: the syntactic and semantic ones.

On the one hand, syntactic knowledge refers to the knowledge about how to use the system. Such knowledge has a direct impact on the user's actions while accomplishing a task.

On the other hand, semantic knowledge covers the knowledge that the user has about the domain of the research ("*Information content*") and about how the system is internally functioning ("*IRS functionality*"). For example the user may identify documents that are not properly indexed from her/his point of view:

Such knowledge will influence the user to choose special query words that may not be natural. The user adapts to the system: such a situation especially arises when too many results are provided to the user or when no satisfying results are retrieved.

Syntactic and semantic knowledge develop while interacting with the IR system. The user learns how to use the system while interacting with it. In addition she/he develops a mental representation about how the system works.

2.3. Input expression characteristics

This set of dimensions are used to characterize the input expressions specified by the user. Nevertheless such characteristics do not describe the form of the input expression such as the interaction modality used to specify the expression. The axes define more general properties that can be matched to several interaction techniques while designing the user interface.

2.3.1. Designation (connote/denote)

The "Designation" axis deals with the way information can be designated. We can compare intrinsic properties of an entity so that we connote this entity. For example, when we are looking for a book on computer science, we specify a property of the object sought: the topic of the book. It corresponds to a connotation of the document. On the other hand we can also denote a book by giving its exact title or its unique ISBN identification number. A denotation should always designate only one element (an article, an image, etc.). The distinction between connotation and designation can be difficult to establish when the connotation property is discriminatory. Moreover a unique identification (denotation) is also a property of an object (connotation).

A designation may be either a connotation or a denotation, as well as a combination of the two latter. If the system is able to distinguish these modes of designation, it can accordingly adapt its matching process in a more efficient way. Indeed the denotative part of a query can be processed by a simple non fuzzy matching algorithm. This matching process can be done using a classical database retrieval engine. The connotative part of a query is more complex to process: connotation can refers to various properties of the object sought. For example the following query "I am looking for a book on computer science that is often used by students" is related to the utilization of the book. This way of characterizing a book (connotation) is rarely embedded in an IR system. In addition there is very often a direct relationship between connotation and user's point of view: For example if the user specifies a query like "a picture with flashy colors", the connotation property refers to the user's feeling or preferences. The following axis "Point of view" captures those notions.

2.3.2. Point of view (subjective/objective)

This axis expresses the way information can be described. Two values are distinguished along the "Point of view" axis: subjective and objective.

Subjective characteristics depend on the user's experiences and more precisely the user's feeling like happiness or fear. A query like "movies that frighten me" is typically subjective. Subjective aspects of a query depend on a unique user and are time-dependent: it is thus not a reliable information.

We can contrast subjective points of view with objective ones. For example a query about "a movie with blood" is based on an observable characteristic of images. Nevertheless there is still subjectivity in such a query: "which kind of blood! Everyone knows that in horror movies the red blood is fake!

To sum up, the axis cannot be valued: a continuum from subjective characteristics to objective ones must be considered. Objective characteristics can be easily processed by the system since these just involve measurement. Unfortunately there is often a subjective part in queries. An IRS has to tackle this fact mainly through interaction. Interaction can reduce the subjectivity of a query in favor of more objective aspects. To achieve this goal, behavior databases can be available that allow the system to refine the query. For example the system can incorporate all the words related to "fear" (in a thesaurus). Another way to solve this problem is to let the user navigate and see the document. Thus, by reducing the key role of a query in the global process of retrieval, we can also reduce the subjectivity.

2.3.3. Focus (generic/specific):

This axis characterizes the precision of the expressed need. The need can be fuzzy like "I am looking for pop music" as opposed to "I am looking for Pink Floyd audio compact discs" which is more precise. The expertise of the user does not define the "focus" of query. Indeed an expert may be generic on purpose and a novice may only know few specific words. Again minimizing the key role of the query and increasing interaction and navigation in the information space may eliminate the problem of "focus".

The precision of the need can concern the information content itself as well as the information type or media. The query "a record of Pink Floyd" is more generic than "Pink Floyd audio compact discs" because the record media include magnetic tape, audio CD. Information type and content are described in the two following sections.

2.3.4. Type of information sought

Shannon has defined information as the correlation measure between two random objects [9]. A communication channel can be viewed as the temporal, virtual, or physical link that makes the exchange of information possible between communicating entities. Instead of considering the “linkage dimension” of communication, we stress the importance of the sources and recipients involved in a communication act. Thus, a communication channel covers a set of sensory (or effector) means through which particular types of information can be received (or transmitted) and processed. Several types can be identified along this axis: CD, picture, movie, text etc. Complementing this type, we consider the content of information in the following section.

2.3.5. Content of information sought

We identify two notions in order to describe the content of information sought: the meaning and the code of information. In IR the meaning of a document is represented by its index. But information meaning depends on the receiver's knowledge and the way information is coded ("html page", "secam video") and presented. Information depth can vary according to the expertise of the user: for example on the one hand a digital sound may be understood by everybody if it is played. On the other hand a digital sound may be understood by experts if its frequency spectrum is displayed.

3. User tasks

After a presentation of our design space, we then go one step forward in the design by describing the users tasks. To achieve this goal, we apply the seven step model of Norman's Theory of Action [8]. Figure 2 presents our interpretation of the Theory of Action applied to the information retrieval task coupled with the dimensions of our design space.

3.1. Theory of Action

Starting from an information need, the different steps underline the mental and physical actions of a user interacting with the representations and using the I/O devices of the IRS. To emphasize the discrepancy between the user and the system, Norman denotes the semantic and articulatory distances as a gulf that must be bridged by the user and the system designer. Two gulfs, the execution and evaluation gulfs, are identified each of them being unidirectionnal:

• The execution gulf is comprised of the input semantic and articulatory distances (Figure 2). It proceeds from goals to physical actions. The starting point is the user's goal "get information". We call this step "user's motivation". Based on the goal, the first step is to build an information need. The latter can be very different according to the user and her/his knowledge ("User's knowledge" dimensions) and can evolve over time. The "Information need" dimensions identify characteristics for describing this step. The second step consists of organizing and transforming the query meaning resulting from the information need into a mental representation of a query: a query shape. Such activities are characterized by the "Input expressions" dimensions. Based on the query shape the user can then specify the actions to be performed requiring translation of the psychological variables in terms of the physical variables, defined and maintained by the system. After defining an appropriate action sequence, the user executes the actions using physical input devices.

• Symmetrically the evaluation gulf includes the output semantic and articulatory distances (Figure 2). Evaluation requires comparison of the current interpreted state of the system with the initial goal and intention. To make the evaluation possible, the current system state must first be perceived and then interpreted. The results to be perceived are very often presented as a simple ranked list of documents. Nevertheless more information can be presented and perceived. For example in TIAPRI [6], users can see a star field on the screen where each star represents a document. In a glance, she/he can perceive and interpret the density of retrieved documents and their distribution according to main keywords. The following section focuses on the evaluation gulf.

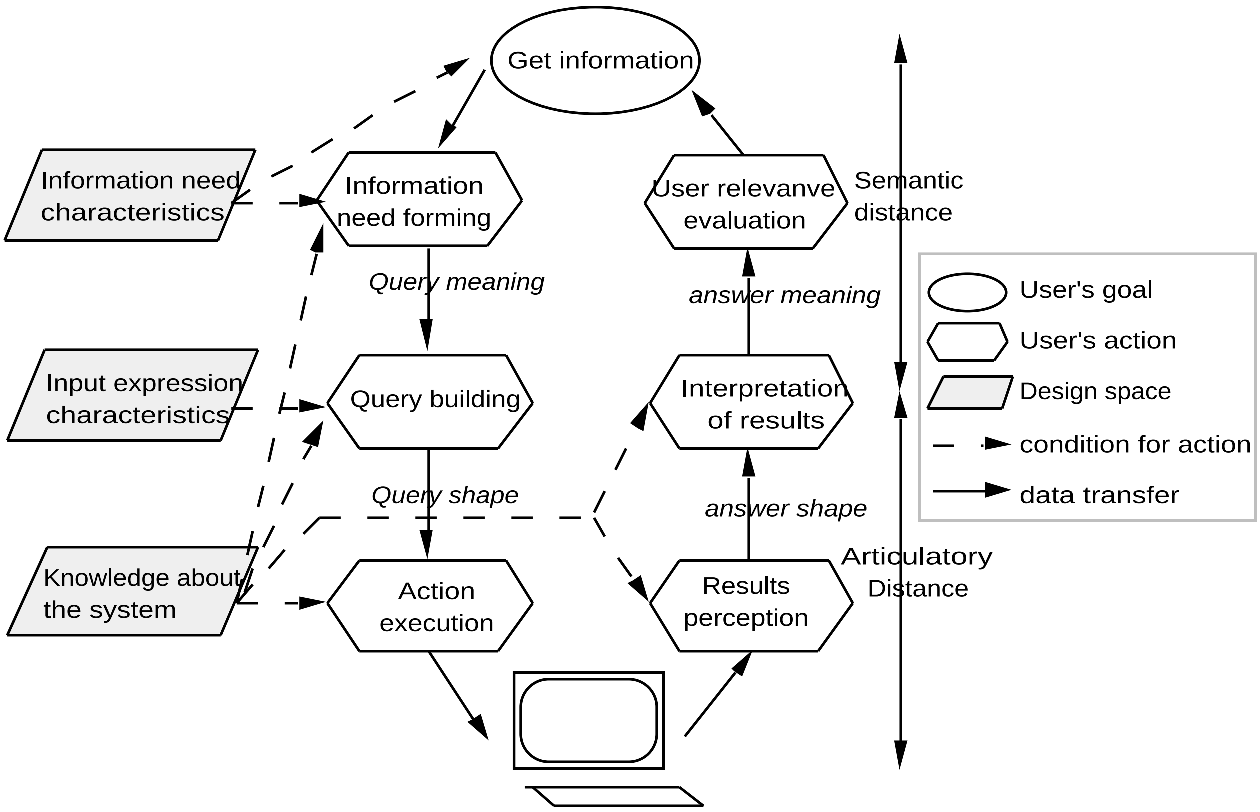

Figure 2: User's activities while accomplishing a retrieval task.

3.2. Perceiving the corpus

While experimenting with our TIAPRI interface, we have pinpointed the importance of perception and interpretation. As shown in Figure 2, the user's knowledge about the system influence the perception and the interpretation of the system output. This interpretation in turn has a direct impact on the evaluation of the system state. The evaluation step is in fact the most important one because it defines the user's satisfaction. That is why we concentrate our effort in improving the user's perception so that she/he can establish a correct mental representation of the system functioning. We underline here the key role of the user's knowledge about the system while interacting with the IR system.

The system can present the documents, its choice among them and its knowledge. The knowledge includes document indexes, thesauri, document links and matching functions. Several user interfaces [2, 4, 10] are efforts to present such knowledge. Our work focuses on the presentation of the system concepts that help the user to improve the definition of his need and the perception of the results. The results belong to the collection of documents (corpus) managed by the system. On the one hand the system has access to the whole set of documents. So the system selects the relevant documents based on the examination of the entire set. On the other hand the user's evaluation is only based on a sub-set of documents that are selected by the system. The relevance evaluation step is then severely distorted by this fact. In order to establish a more accurate relevance evaluation, we think that the user has to be able to perceive the whole corpus from which the selected documents are extracted. The remaining problem is to design an output interaction technique that enables the user to perceive the selected documents as well as the whole corpus. Our IRIS-M system presented in the following section is one such attempt.

4. The IRIS-M system

As shown in the appendix (Screen dumps 1 and 2) IRIS-M is an IR system that displays a representation of the corpus by clustering documents and presenting each document cluster as a 3D cone. Each cone belongs to a plane. The stack of planes represent levels of abstraction:

- The lowest plane is the lowest level of abstraction where documents are clustered.
- The clusters in plane n are clusters of the ones in plane (n-1).

The whole hierarchical structure presents the corpus. This structure is computed using a simple cluster algorithm. Using a zoom the user can focus on a cluster: the documents and the number of documents that are related to a given topic. When the user selects a cluster, all the embedded clusters in the bottom planes are lightened. Using a toolglass (magic lens), the user can see documents through the cones. Only few elements of documents are visible (title, main keywords, abstract). The navigation between planes and cones enables the user to perceive the corpus without initial queries. It is possible to keep track of the interaction because the path is lightened. The user can therefore always perceive the context of the search: the neighborhood and the path. Moreover the user can designate a document using a connotative value. Denotation corresponds to a query identifying one document. The different planes embody a hierarchical structure: the user can focus on a large spectrum of documents ranging from the generic to the specific. Finally toolglasses enable the user to perceive the documents according to their information types and contents.

The software design of IRIS-M is based on the PAC-Amodeus software architectural model [7] and IRIS-M is running on NextStep environment using RenderMan for 3D visualization.

5. Conclusion

In this article we have proposed dimension spaces that should help in the design of current and future interactive information retrieval systems. They draw upon psychology, HCI and IRS with their associated notions of information need, user's knowledge and input expression. By doing so, they identify salient characteristics for design studies of interactive IR. Based on our design space and Norman's Theory of Actions we then model users' activities while accomplishing a retrieval task and stress the key role of the perception and evaluation steps. Finally we have shown the relevance of perception of the whole corpus in a retrieval session.

In future work we plan to refine our design space and then establish a taxonomy of UI properties based on the identified characteristics. Such a taxonomy may be directly useful for the design as well as the evaluation.

Acknowledgements

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6. References

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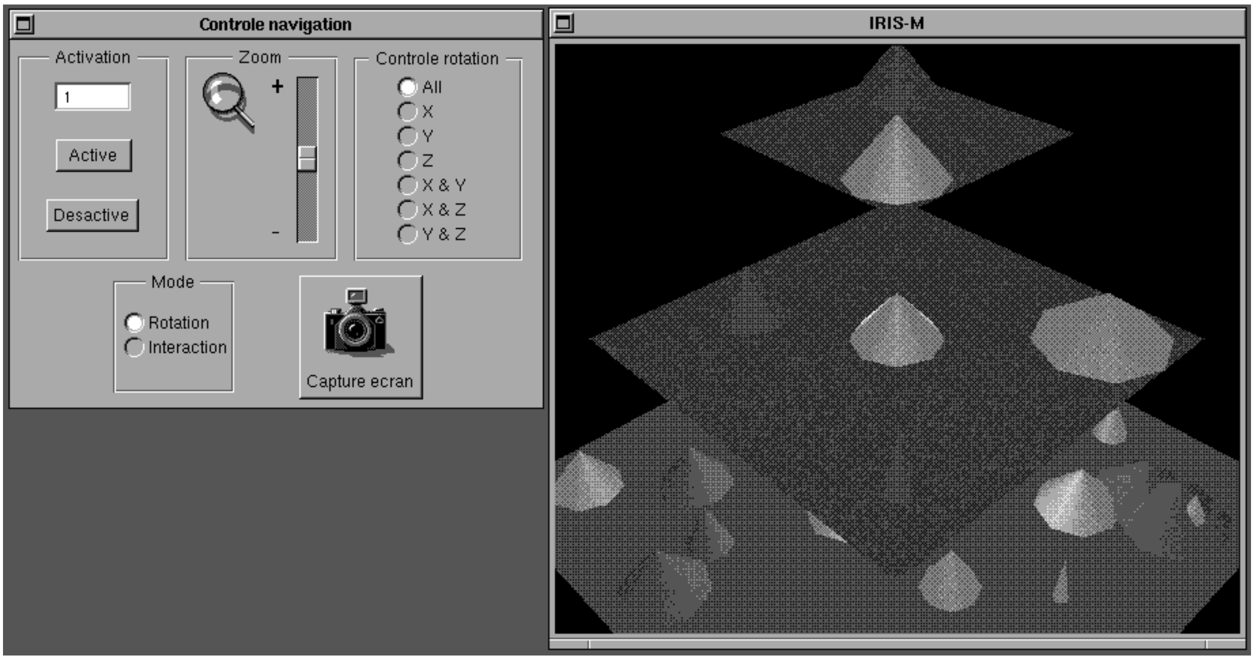
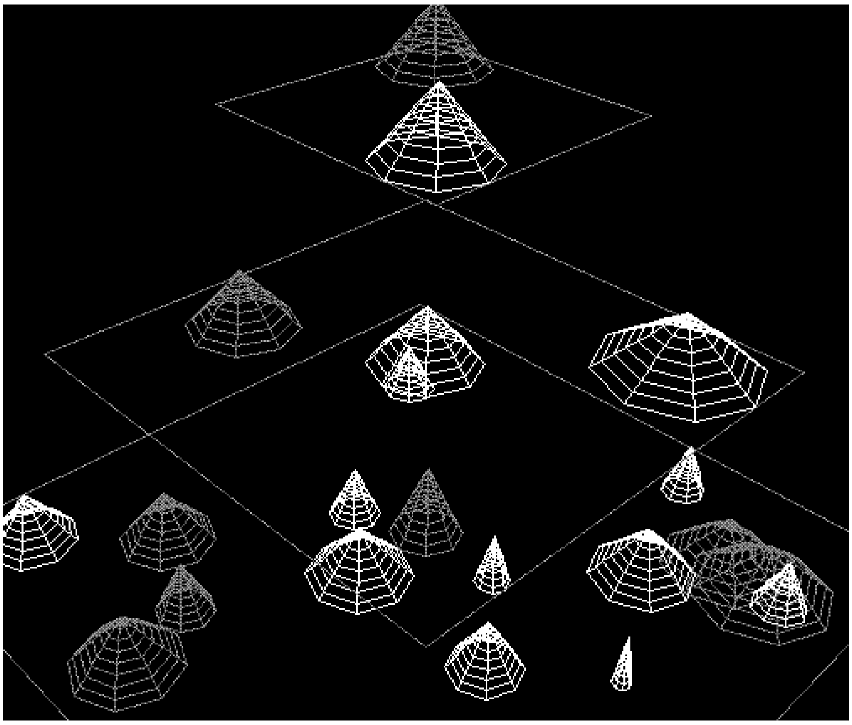
Appendix: IRIS-M



Screen dump 1



Screen dump 2