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# A Decision-theoretic Multi-dimensional Model for Meeting Users' Information Filtering Needs

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## ABSTRACT

The overall objective of this study is to comprehensively investigate the various factors that lead to effective information filtering. We propose a decision-theoretic approach for the information filtering process. The novelty of the current study lies in the focus on the user aspect and the coverage of the knowledge it produces. A decision-theoretic multi-dimensional model from a user-centered viewpoint is derived, and the model is used to describe user information filtering needs can be met effectively and efficiently.

## Keywords

Information filtering; Decision-theoretic model, User-centered approach

## INTRODUCTION

With the advance of computer technology in recent years, electronic information has increased exponentially on the World Wide Web or in any large information repositories, such as digital libraries. The huge amount of available electronic information and its high speed of growth have created the pressing need for methods and tools that can assist people in efficiently and effectively locating relevant information from a large, diverse, and dynamic data space. In other words, information filtering is more important than ever.

According to Belkin and Croft (1992), filtering information implies removing data from an incoming stream of unstructured or semi-structured data and presenting the data left to users, often based on individual or group profiles that represent user preferences and interests. The relatively dynamic information sources and the preservation of user profiles are the distinguishing features of an information filtering process (Oard & Marchionini, 1996). While most researchers in the field focus on the technical perspective to facilitate this information filtering process, we address the issue from a multi-dimensional perspective, in which diverse perspectives from technological, behavioral, and social disciplines are integrated into a conceptual framework for information filtering. Based on the framework, a decision-theoretic model from a user-centered viewpoint is derived. This model describes how to effectively and efficiently meet users' information filtering needs. The overall objective of this study is to investigate the determinants (decision factors) that lead to the success of information filtering and to provide a rational mechanism that can be applied to information filtering systems in practice.

## BRIEF LITERATURE REVIEW

Research in information filtering can be loosely classified into two main categories.

### System-centered Approach

The research that follows this approach generally focuses on the information and system aspects of information filtering. The focus is on either one or multiple technological issues such as query representation methods (e.g., Belkin, et al., 1995), profile learning mechanisms (e.g., Middleton, Shadbolt, & De Roure, 2004), information filtering models (e.g., Mostafa, Mukhopadhyay, Palakal, & Lam, 1997), and performance evaluation techniques (e.g., Ault & Yang, 2002). As a result, a great deal of progress has been made toward matching relevant information from a query or user profile and judging the quality of a search, using mainly statistical techniques. However, only focusing on refining algorithms to improve filtering performance is not enough if users' information needs are not well understood. Hence, the omission of the user dimension in information filtering is considered to be the major disadvantage of these system-centered approaches.

## User-centered Approach

User-centered research focuses on accurately describing users and their needs for information filtering. The user aspect is vital for effective information filtering since the ultimate objective of information filtering is to satisfy the users' information needs. In addition, it is the users who know best whether the filtering results are relevant to their needs. Therefore, the importance of design issues from the user aspect in information filtering has been increasingly recognized. Many studies have been conducted to explore the impact of individual differences on their information searching or filtering behaviors (e.g., Zhang & Chignell, 2001), the users' perceptions of information filtering performance (e.g., Fidel & Crandall, 1997), the interactions between users and information filtering systems (e.g., Mulhem & Nigay, 1996), and the cognitive process of users who perform information filtering tasks (e.g., Ingwersen, 1996). These research efforts have yielded important results, including various user modeling implementations, which can be used to prototype user characteristics in information filtering, and numerous cognitive models, which depict users' cognitive activities during the information filtering process.

The current study can be classified as user-centered because it takes a cognitive approach in building a decision-theoretic model. The resulting model specifies the determinants for effective information filtering from the user's point of view. Our study differs from the existing research approaches in two important ways. First, our study synthesizes major factors from multiple dimensions into an integral framework for information filtering in contrast to a traditional narrowly focused, single-dimension approach; Also, our study regards an information filtering process as a multi-criteria decisional problem, which includes decision factors (success determines) and an ultimate outcome (meeting users' information needs). Such an approach is novel, and such a study can contribute to the research field both methodologically and theoretically.

## A MULTI-DIMENSIONAL FRAMEWORK

As the first step of this research-in-progress, a preliminary theoretical framework is developed as a decision-making mechanism for information filtering. Factors that are related to the satisfaction of information needs, both in implicit and explicit ways, are identified from three general aspects -- the mental, process, and characteristics layer.

### The Mental Layer

The mental layer represents the user's cognitive structure and emotional state pertinent to the information filtering process. The mindset of users indirectly determines users' information seeking behaviors and their perceptions of information need. These cognitive and psychological factors are classified into two dimensions, which are the cognitive and affective dimensions. The *cognitive dimension* contains factors that depict the users' cognitive states of information filtering, including work space (work domain, tasks, and information filtering behaviors), knowledge space (what is known about the domain and tasks), and problem space (uncertainties that lead to the desire for information filtering). The *affective dimension* reflects users' thoughts and feelings that influence their judgment of information filtering effectiveness. Emotions, such as user trust toward the information filtering system, as well as attitudes, such as acceptance of filtered contents, belong to this dimension.

### The Process Layer

The process layer captures the human-computer interactions during the information filtering process. "Process", in contrast to "system," means an activity conducted by humans, perhaps with the assistance of a machine (Oard & Marchionini, 1996). Therefore, this layer focuses on the information filtering components that involve the users and influence their perception of filtering performance. From the users' point of view, the information filtering process can be decomposed into three states: pre-information filtering, information filtering, and post-information filtering.

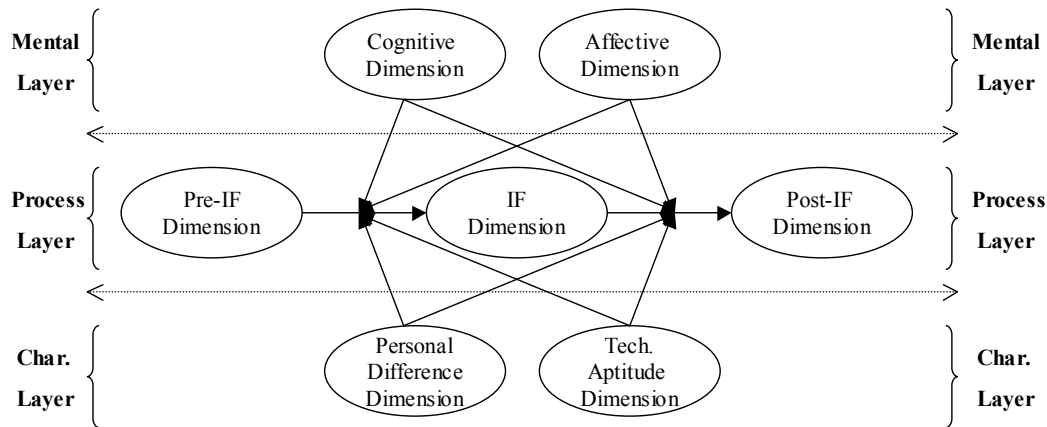
During the *pre-information filtering* stage, the user profile, which contains information about the user's filtering preferences and needs, is acquired. In addition, the user may have the options to select the information sources, view the information that the system gets from the sources, or even get help for articulating the problem. During the *information filtering* stage, the system matches the user profile with selected information and generates filtering results. On the other hand, the user is concerned with factors such as the quality, availability, representation, and refinement of the filtering results, which have significant impact on the perceived filtering performance. And the third stage, the *post-information filtering* stage, is concerned with activities after the filtering of information. During this stage, the user profile is updated to accommodate latest changes in user interests. Other activities such as evaluating filtering results and saving filtering history also play some role in meeting users' information needs. These three stages form a linear process that a user must complete during an information filtering process.

**The Characteristics Layer**

The characteristics layer consists of the individual differences that influence users’ information seeking performance and their filtering needs. Users are individuals, each with distinctive characteristics. These characteristics lead to different information filtering behavior and are helpful for understanding the users and their needs and grouping users. Some prominent user characteristics are classified into two dimensions: the personal difference and technical aptitude dimensions. The *personal difference* dimension includes some physical attributes of a user, such as age, gender, and personality. The *technical aptitude* dimension relates to the user’s technical skills and ability to perform computer-based information filtering tasks. Factors such as experience with computers, expertise on the task domain, and academic background all contribute to this dimension.

**THE DECISION-THEORETIC MODEL FOR INFORMATION FILTERING**

The combination of the three layers, namely the mental, process, and characteristics layers, provide a comprehensive infrastructure for understanding the information filtering process and meeting users’ information needs. Figure 1 shows the dimensions as discussed in the previous sections. The model reflects the interdependent nature of its components and presents and interactive process of information filtering.



**Figure 1. The Decision-theoretic Model for Information Filtering**

Table 1 defines the layers, related dimensions and factors, and their literature sources. The framework, though still preliminary and in need of refinement and evaluation, suggests a starting point for further investigation of the decision factors that affect the users’ perceptions and relate to effective information filtering. Figure 1 shows how human-computer interactions can be enhanced and how a successful information filtering process can be built around the factors.

Layers	Definitions	Dimensions	Factors	Literatures Sources
<b>Mental Layer</b>	Presents users’ cognitive structures and emotional states with respect to information filtering	<i>Cognitive Dimension</i>	Work space, Knowledge space, Problem space	Ingwersen (1992, 1996), Morris (1994)
		<i>Affective Dimension</i>	Trust, Acceptance	Ho & Lui (2003), Kuhlthau (1991), Montaner, Lopez, & Rosa (2002), Wang & Emurian (in press)

<b>Process Layer</b>	Captures the human-computer interactions during the information filtering process.	<i>Pre-IF Dimension</i>	User profile acquisition, information source selection, Information representation, Problem articulation	Kuflik & Shoval, (2000), Marchionini (1992), Oard & Marchionini (1996), Shapira, Hanani, Raveh, & Shoval (1997), Somlo & Howe (2001)
		<i>IF Dimension</i>	Filtering results quality, Filtering results availability, Filtering results representation, Filtering results refinement	
		<i>Post-IF Dimension</i>	User profile maintenance, Filtering results evaluation, Filtering history preservation	
<b>Char. Layer</b>	Consists of the individual differences that influence users' information seeking performance and their filtering needs	<i>Personal Difference Dimension</i>	Age, Gender, Personality	Borgman (1989), Leckie, Pettigrew, & Sylvain (1996), Marchionini, et al. (1993), Wildemuth, de Blied, Friedman, & File (1995).
		<i>Technical Aptitude Dimension</i>	Experience with computers, Expertise on the task domain, Academic background	

**Table 1. Definitions, Factors, and Literature Sources for Framework Dimensions**

## CONCLUSION AND FUTURE DIRECTIONS

User-centered research on information filtering has thus far been disjointed and narrowly focused. The current study aims to bridge the gap by investigating the various factors that lead to effective information filtering in a comprehensive manner and proposing a decision-theoretic approach for the information filtering process. The novelty of this approach lies in the focus on the user aspect and the coverage of the knowledge it produces.

Future research will concentrate on the iterative development of the decision-theoretic multi-dimensional model and its applications for meeting users' information filtering needs. Data will continue to be collected from literature sources of multiple disciplines to substantiate and refine the model. The model will be then subject to evaluation and validation in a field setting. Ultimately, a domain-specific information filtering system will be developed as an implementation example, which will operationalize the factors presented in the model and can in turn be applied to actual information filtering situations. The study is expected to provide new insights into the design and implementation of the information filtering process that meets users' information needs.

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