A Roadmap to Personalized Information Systems by Cognitive Expansion of Queries

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Abstract

Choosing adequate user preferences for retrieval is an essential part in modern information systems. Though deriving and modeling preferences has gained wide attention, choosing and combining preferences in a sophisticated way for retrieval purposes is still an open problem. This paper aims at showing ways to expand queries in tight cooperation with the user. Due to the cognitive knowledge involved, these complex queries can be expected to return more relevant results than traditional database queries. The paper surveys crucial influences and proposes a suitable architecture for implementation.

1. Introduction

Research in advanced personalization has in recent years shifted its focus more and more towards the user. Modeling user preferences has become an essential part of retrieval in databases and information systems [CAC00, HKP01] and formal preference engineering has gained much attention [Cho02, Kie02]. However, to engineer preferences the question, how user preferences can be obtained or derived has to be answered. Generally speaking today's systems offer two possibilities:

- Users have to **explicitly state** their preferences in order to customize a service or to pose a query.
- The system **derives preferences automatically** from earlier interactions of the same user or assigns the user to a typical usage profile.

An example for the first group of systems are personalized news-services or portals like [Cnn02, Blo02] where users can state their interest profiles and all articles/channels are rearranged according to the specific user's interest. However, those systems tend to be rather static, because the interest profile does not change over time according to the user's interests, but always has to be adapted manually. And what is more, psychology shows that users are not always entirely aware of what they really want. Experiments in [AE72] show that major parts of the human information gathering strategies are unconscious. But whereas expressing needs more or less unconsciously e.g. in body language, gestures or specific natural language terms is of extreme help in human interaction, it won't be very helpful in human-computer interaction.

The second way is deriving preferences automatically from previous user interaction. Data mining techniques can be used to detect correlations in usage data e.g. obtained from log-files. A good example for this paradigm are e-shopping systems like [Ama02, Eba02], etc. In these systems users can customize their profiles by a relevance feedback over lists of items that have been proposed by the system as being somehow similar to already purchased items. However, since the systems do not reflect for what reason an item had been purchased, the assignment of profiles is sometimes dangerous. Consider for instance items purchased as a gift that are nevertheless used to adapt the user's personal interest profile. The situation even gets worse if preferences are collected and exchanged over different retrieval systems. A good example are color preferences in e-commerce applications. Basically those preferences may be important when purchasing a car, etc., however, in e.g. on-line bookstores color preferences can hardly make sense.

Thus we have deal with two problems: first how to get sensible preferences and secondly how to choose the applicable preferences for user queries. In the course of this paper we will take a closer look on the steps necessary for personalized retrieval, investigate the influences and present a prototypical architecture.

2. Cognitive Expansion

User preferences comprise the notion of relevance and specific user interests (and thus the expectations) of users. In today's systems especially the characterization of such preferences are suffering from a lack of intuition. Often they are restricted to the mere declaration of keywords.

The research area of **socionics** [CC96, Mal98] poses a new paradigm for human-computer interaction. Working interdisciplinary between sociology, psychology and computer science, socionic knowledge tries to model an artificial relationship between human and computer. In recent years this knowledge was mainly adopted in the area of distributed artificial intelligence, especially in multi-agent systems. In these systems a variety of autonomous agents have to interact and try to achieve their individual goals. In contrast to classical artificial intelligence the solution of complex problems should be reached by using various smaller intelligently behaving units.

For advanced personalization of databases and information systems cognitive knowledge has to be used in a slightly different way. As the basic principle [AE72] states that although user interaction with retrieval systems will generally be purposeful, the user will in general not be conscious of all the necessary measures to be taken. Thus in order to raise its performance in terms of relevance, a retrieval system has not only to focus on explicit user specification, but should also take information into account, that is specified by the user's notions, situation or behavior. These information can mainly be gathered from four sources:

- **long-term preferences**: The notion of relevance from previous retrievals is used
- **intention**: The specific user's purpose of the retrieval is included in searches
- **situation**: The present state and environment of a user is used
- **domain**: Knowledge on the specific domain is used

For effective retrieval knowledge from all these sources has to be blended with the specific user-provided details and keywords. Expanding queries with derived search terms is a technique very popular in information retrieval. Tests in large document collections have shown that the quality of retrieval results could essentially be improved using query expansion [SC97]. In most cases additional terms are derived using thesauri and suitable ontologies or additional terms are derived in an interactive manner using relevance feedback. Automatic expansion techniques range from a simple expansion by thesauri supplied keywords [CR99] to complex statistical approaches where the discriminative power of search terms is evaluated (reweighting methods) [BS95].

In our case the queries have to be expanded with cognitive heuristics and information (**cognitive expansion of statements**). For this expansion, however, no typical database selections can be used, because due to the exact match retrieval model, heuristic information could simply overwrite user-provided information and/or the results set could rapidly get empty by too many hard constraints. So the intended expansion has to be implemented using soft constraints, that may be relaxed step by step until there are definitely objects matching the expanded query (cf. **cooperative answering** [Chu93, Min98]).

Considering the state of the art for the query expansion in our case neither classical cooperative answering methods, nor conventional preference models can be used. For instance it may strongly depend on the domain, intention or situation to determine, which user preferences are applicable for a given query. Consider e.g. our color preferences in on-line bookstores. Similarly, user-specific profiles may demand a procedure aberrant from standardized queries and retrieval processes. For instance only recently location-based services like e.g. personalized newspapers have successfully been developed, that gather information about the relevance or the user's level of interest of each article from the user's location or place of residence [Gra00]. Of course, these heuristics will definitely fail, if somebody is specially interested in worldwide news or the development of certain topics given by the long-term preferences.

In this case **meta-preferences** are necessary, that will derive the sensible relaxations not only in type, but also in their most reasonable order of execution. A meta-preference here is a preference, which will be relaxed only under special conditions of a more general type. Therefore meta-preferences strongly influence the retrieval strategy and thus also the retrieval result. The conditions to apply a meta-preference may be of a more heuristic nature or depend on the specific collection of data.

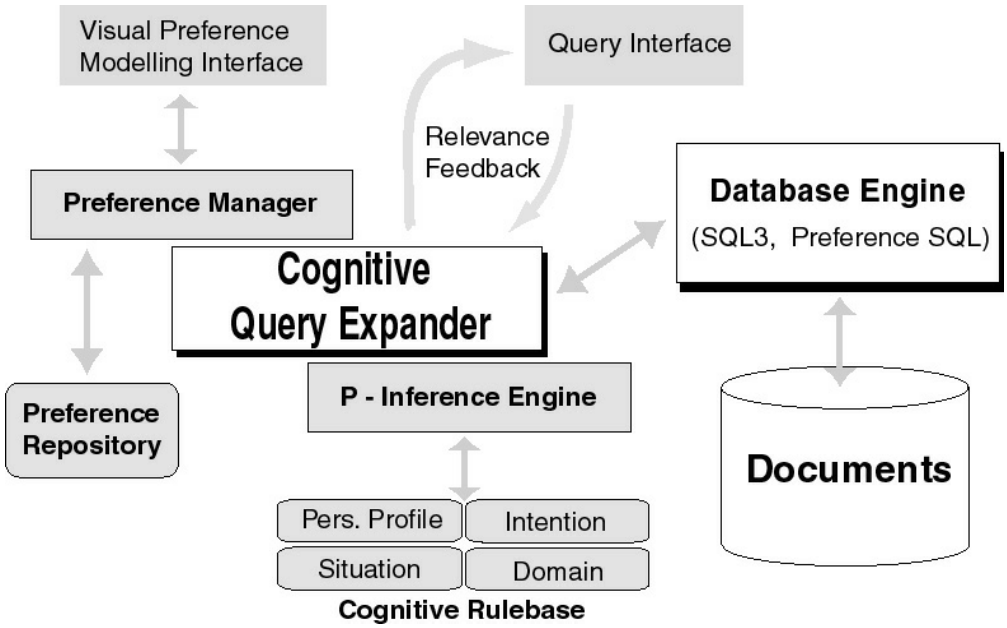

Fig. 1: Intended architecture for cognitive query expansion

3. Implementation Issues

The concepts of preference evaluation and query expansion of course strongly influence the design of cognitive retrieval systems. To implement all concepts of a cognitive query expander, however, extensive research is still needed in basically three areas:

- A general survey of personal notions of relevance and typical user behavior within the retrieval process using results of the cognitive research community to build up a rulebase
- The sophisticated expansion of queries by user preferences, intentions, situation, environment and domain
- The efficient processing of queries together with the integration and evaluation of result sets.

In the last section we gave some consideration especially on the first and second area; for the last area see [GBK00, BGM02].

Figure 1 gives an impression of the architecture necessary to implement a cognitive query builder. The essential component is the **Cognitive Query Expander**, that refines the query and passes it to the databases engine. The refinement mainly consists of two steps:

- The **Preference Manager** administers all the explicit query preferences for each user and stores them in a suitable repository for further use
- The **P-Inference Engine** decides what preferences to choose for expansion depending on personal profiles, intention, situation and domain using a rulebase of cognitive heuristics

To interact with users two interfaces can be useful: in addition to a traditional query interface a visual modeling tool for complex preferences is needed that helps to understand the connections between preferences stated and may also be used to manually alter incorrect preferences that have been derived. The deriving of preferences requires interdisciplinary cognitive research to build up an adequate rule base for the expected usage patterns, domains, situations, etc.. Using modern SQL-3 technology and suitable extensions like e.g. PreferenceSQL [KK02], all expanded statements can be processed by modern database retrieval engines and -if necessary- post-processed using interactive relevance feedback steps.

Since we have to choose preferences, the concept of a meta-preference for the P-inference engine can be seen as an utility that is assigned to every collected preference. Cognitive sciences have investigated utilities closely over the last decades especially in the context of decision making [Koz81]. Utility has different facets, there are:

- objective utilities which often refer to costs, the situation or a domain like an item can be purchased cheaper from a different vendor

- subjective utilities which often refer to personal preferences or intentions like taking a taxi to the hotel is more desirable than riding the bus

Generally speaking the subjective utility of applying a preference will for each user always depend on those objective and subjective parts leading to a utility estimation that can be compared to the utilities of other preferences. Getting an overall psychological utility consists of different steps:

- the internal representation and thus notion of relevance is needed for each user (user model)
- the subjective utility has to be determined by considering the intention, situation, domain, etc.
- the subjective probability that a preference is applicable has to be estimated
- the subjective expected utility (SEU) can be used to compare preferences and decide how to expand the query

The internal structure of a cognitive query expander performing these steps is shown in figure 2.

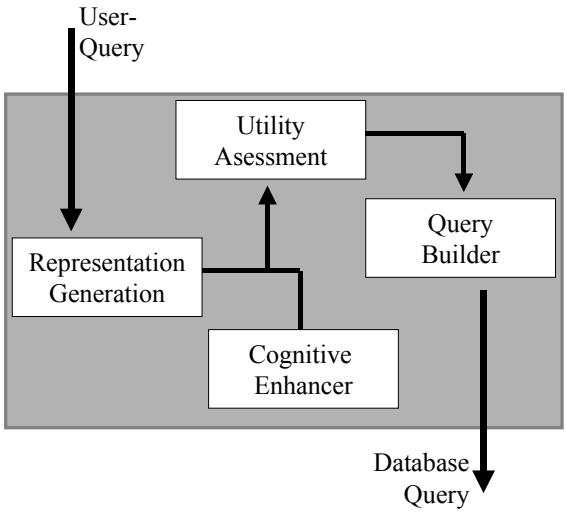

Fig. 2: Cognitive query expansion

Based on a user model the query is enhanced with cognitive knowledge and the subjective expected utility is assigned. Considering the utilities for different combinations of preferences within a query a trade-off between query complexity or processing costs and an expected improvement of the query result has to be optimized. Comparing subjective expected utilities eventually leads to a decision about the retrieval strategy and an adequate query can be generated. This query is processed by the database retrieval system and the results are returned to the user.

4. Summary and Outlook

In this paper a concept for advanced personalization in retrieval systems is investigated. Since preferences of all types have become the centerpiece of personalized information systems, future architectures have to provide adequate interfaces for modeling and input of preferences. However, psychological experiments show that users will experience difficulties with complex preference queries. Thus systems also should use cognitive techniques to support users in stating their profiles far beyond simple keyword collections.

Cognitive expansion of queries aims at the implementation of a knowledge-based query builder that allows complex query building in tight cooperation with the user. Due to the cognitive knowledge involved, these complex queries are expected to return more relevant results than traditional database queries. Besides advanced techniques in personalization (preference modeling, etc.) research issues will have to focus on results from sociology and psychology to include implicit knowledge about human behavior and social expectations in the retrieval process.

Cognitive database retrieval will not only use the explicit user-provided search terms, but also a long-term profile of general preferences and dislikes (if applicable), the specific intention for the search (purpose directed), the personal situation and environment (location, time, emotions, etc.). Together with domain knowledge this collection of user-related information seems promising to define the specific notion of relevance and enables an extensive modeling of retrieval preferences far beyond the deliberate query terms provided. Thus the user is supported in query tasks and even the evolution of user knowledge in each domain can be taken into account by adaptable user profiles containing more and more specific information.

Future work will focus on the way of modeling, choosing and combining preferences. Since first applications in usage patterns for web services have yielded promising results [WBK01], further case studies are planned to extend the area of application and get a better understanding of cognitive processes during retrieval tasks. Also the assignment of subjec-

tive expected utilities needs to be adapted to several application domains for comparability reasons.

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