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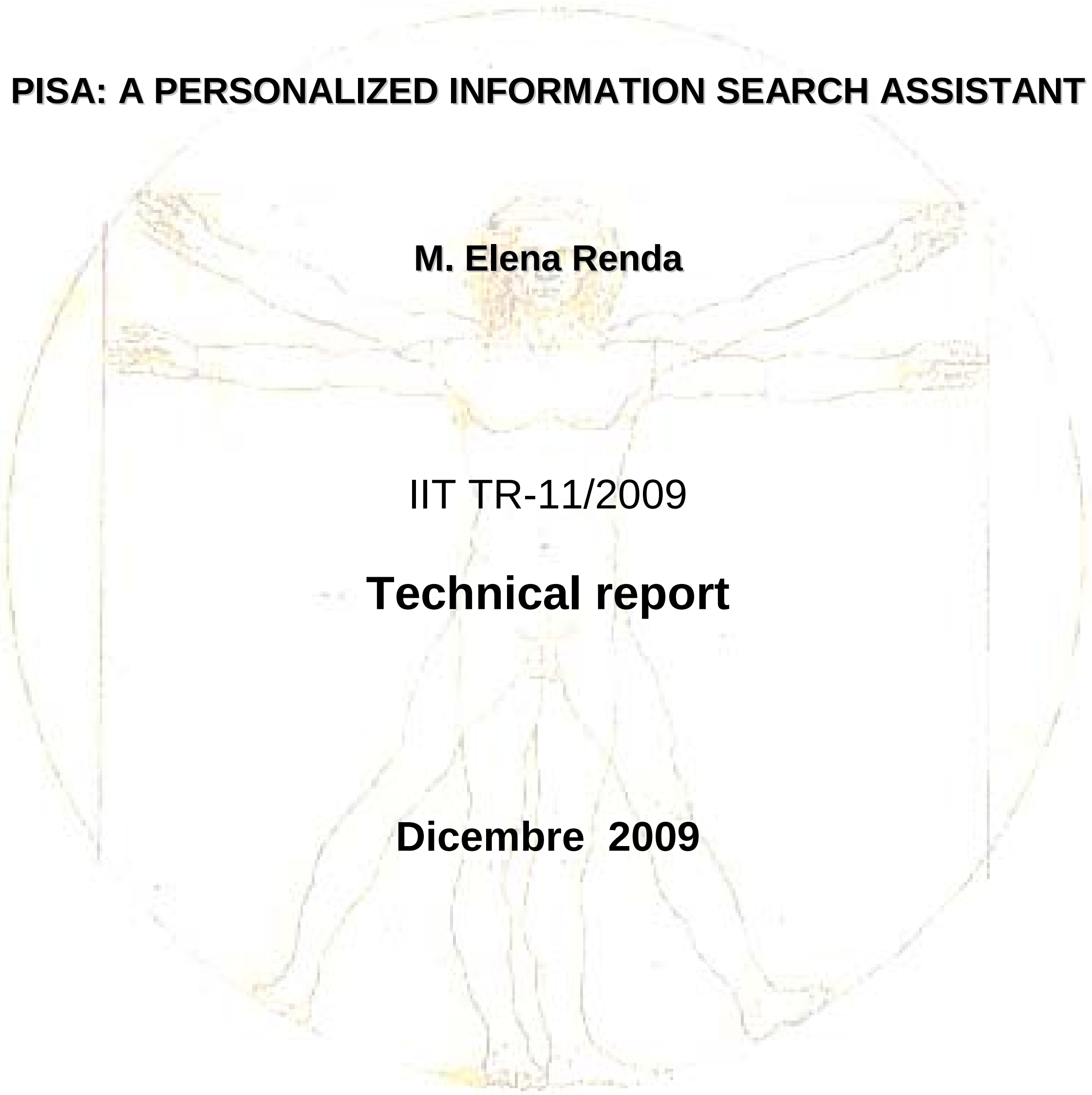

PISA: A PERSONALIZED INFORMATION SEARCH ASSISTANT

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P*I*SA: A PERSONALIZED INFORMATION SEARCH ASSISTANT

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Abstract: A common characteristic of most of the traditional search and retrieval systems is that they are oriented towards a generic user, often failing in connecting people with what they are really looking for. In this paper we present P*I*SA, a *Personalized Information Search Assistant*, which, rather than relying on the unrealistic assumption that the user will precisely specify *what* she is really looking for when searching, leverages implicit information about the user's interests. P*I*SA is a desktop application which provides the user with a highly personalized information space where she can create, manage and organize folders (similarly to email programs), and manage documents retrieved by the system into her folders to best fit her needs. Furthermore, P*I*SA offers different mechanisms to search the Web, and the possibility of personalizing result delivery and visualization. P*I*SA learns user and folder profiles from user's choices, and uses these profiles to improve retrieval effectiveness in searching by selecting the relevant resources to query and filtering the results accordingly. A working prototype has been also developed, tested and evaluated. Preliminary user evaluation and experimental results are very promising, showing that the personalized search environment P*I*SA provides considerably increases effectiveness and user satisfaction in the searching process.

1 INTRODUCTION

Though nowadays more information is easily reachable and in a smaller amount of time than years ago, it is becoming increasingly difficult for individuals to control and effectively seek for relevant information among the information resources available on the Internet. The more users are getting on-line, the more their information needs become complex, the more difficult it becomes to find relevant information in a reasonable amount of time, unless the user exactly knows *what* to get, *from where* to get it, and *how* to get it.

Given the exponential growth in the quantity and complexity of information sources available on the Internet, over the last years much effort has been put into the development of approaches to deal effectively with this complexity: Information Retrieval systems have evolved from a simple concern with the storage and distribution of information, to encompass a broader concern with the transfer of "meaningful information". In particular, users could benefit from "personalized" services and systems for finding relevant information for their interests in a broad sense, gaining in time, quality of the documents and information retrieved, and satisfied information needs. Tailoring the information and services to match the unique and specific needs of an individual user (*Personalization*) can be achieved by adapting the presentation and/or the services presented to the user, taking into account the task, background, history, information needs, location, etc., of the user; *i.e.*, the *user's context*.

1.1 Motivation

A common characteristic of most of the traditional search and retrieval services is that they are oriented towards a generic user. If the same query is submitted by different users to a typical search engine, it will probably return the same result, regardless of who submitted the query. Another important aspect of current search systems is that they often answer queries crudely rather than, for instance, learning the long-term requirements specific to a given user or, more in general, to a specific information seeking task.

In searching the Web, besides the *users* with their corresponding *information needs*, we have other main actors playing a fundamental role: the *Web Information Resources*. The resources available on the Web may be extremely heterogeneous, under two main respects: the *topic* of the information they provide, and the *metadata schema* they use to describe the provided information.

The alternative to querying each resource individually has been offered by retrieval systems that provide a unified interface for searching over multiple resources simultaneously, called *Metasearch Systems* (see, *e.g.*, **??**). Metasearch systems have to deal with the two aspects of resource heterogeneity, giving users the impression of querying one coherent, homogeneous resource.

Thus, a system for searching and browsing the Web tailored and customized "ad-hoc" to the user must "know":

1. *where to search*, by *selecting* a subset of *relevant* resources among all those that can be accessed (*Automatic Resource Selection*) (**??**);
2. *how to query* different resources, by matching the query language used by each of the selected resource (*Schema Matching*) (**??**);
3. *how to combine* the retrieved information from diverse resources (*Result or Rank Fusion*) (**???**); and
4. *how to present* the results to the user, according to her preferences (*Result Presentation*) (**??**).

We modeled and developed such a personalized information seeking system (in the following called *assistant*), which helps users in retrieving *actual* relevant information from the Web with minimum cost, in terms of both effort and time. In order to assist the user in the information seeking task, the assistant has to know the user and her profile, a representation of her background, interests and needs (*User Profiling* (**?**)). This profile can be then used by the assistant for finding matchings against content profiles for retrieving relevant information and filter out the irrelevant ones (*Information Filtering* or *Content-based Filtering*) (**?**).

Another orthogonal aspect of personalization we considered when modeling the assistant was the *information organization, i.e.*, supporting the users in the task of organizing the information space they are accessing to according to *their own subjective perspective*.

In this paper we present this *Personalized Information Search Assistant*, called P*I*SA, an environment where the user will not only be able to search/retrieve/be informed about documents *relevant* to her interests, but she will also be provided with highly personalized tools for organizing documents and information into a personal workspace. The major novelty of P*I*SA is that it combines all the characteristics of an on-line metasearch system with working space organization features in a *desktop application*, providing the user with a *single user point of view* personalized search environment. User evaluation and preliminary experimental results are very promising, showing that the personalized search environment P*I*SA provides considerably increases effectiveness and user satisfaction in the searching process.

The paper is organized as follows: the next Section provides an overview of the possible P*I*SA competitors; Section **??** introduces P*I*SA, describing its functionality; Section **??** describes P*I*SA architecture in detail; in Section **??**, the evaluation methodology is described and the experimental results are reported; finally, Section **??** concludes, providing an outline for further developing this work.

2 PERSONALIZED SYSTEMS

The personalization task is becoming fundamental in searching and finding relevant information, as the amount of information and providers increases at vertiginous rates. The environments where personalization is being used are databases, newsgroups, discussion lists, electronic journals, search engines, e-commerce Web sites, and so on. The requirement for personalization is well known, for instance, in the context of Digital Libraries (DLs). Some DLs provide simple personalized search functionality, such as providing the so-called *alerting services* (see, *e.g.*, **?**), *i.e.*, services that notify a user (typically by sending an e-mail) with a list of references to new documents deemed relevant to some of the user topic of interest (manually specified). Other DLs, for instance, give users the possibility to organize their personal information space (see, *e.g.*, **?**), and collaborate within community of users with similar interests (see, *e.g.*, **?**).

Many commercial information filtering systems use the approach of user-defined profiles, used to personalize search results. Other systems, reflecting the desire to place most of the burden of constructing the user profile on the system, rather than on the user, rely on the development of "models" that are collections of *good guesses* about the user (see, *e.g.*, the PIA system (**?**), PENG (**?**)). These systems are online personalized services, which often provide only part of the features P*I*SA has, or require collaborative filtering among the users of similar groups. Differently, the *Personalized Information Search Assistant* we will present in this paper is *personalized* from a single user point of view.

In (**?**), the authors present a system for personalizing search via client side automated analysis of user's interests and activities, re-ranking the final results according to different ways of representing the user, the corpus and the documents. Similarly, P*I*SA is a desktop application, thus it is always available on the machine the user is using, and provides user profiling and document filtering. On the other hand, P*I*SA also provides automatic source selection, rank fusion, different search mechanisms, and the working space organization feature. Furthermore, P*I*SA is a working prototype with a fully featured user interface. To the best of our knowledge, there is no desktop application presented in the literature providing profiling, filtering and metasearch features as the P*I*SA desktop application presented here.

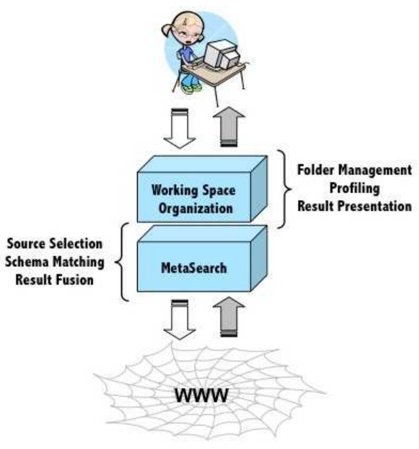


Figure 1: Logical view of P*I*SA functionality.

3 THE ASSISTANT

P*I*SA acts as go-between the user and the information resources, when searching the Web. The main principle underlying the personalized environment we propose is based on the folder paradigm. That is, the user can organize the information space into her own folder hierachy, using as many folders as she wants, named as she wants, similarly to what happens, *e.g.*, with directories in operating systems, and folders in e-mail programs. In our system, a folder is a holder of documents relevant to the user and, tipically, contains semantically related documents. This means that the content of a folder implicitly determines the topic of the folder. For this reason, we associate to each folder its profile, a compact representation of what the folder is about. Thus, *folder profiles*, which depend on the documents the corresponding folder currently contains, determine the documents that will be retrieved for that folder. The user's set of folder profiles represents the collection of topics the user is interested in; consequently, the *user profile* consists of the collection of profiles related to the folders she owns.

3.1 System Functionality

P*I*SA functionality can be logically organized into two main categories (Figure **??**): *working space organization*, and *metasearch*.

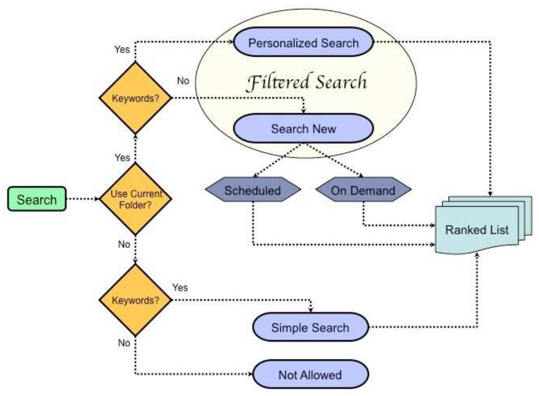


Figure 2: P*I*SA Search Mechanisms.

Working space organization. The working space organization functionality allows the user to login to the system, manage folders and documents, update profiles, and set up her personal data and system preferences; on the other hand, the assistant, based on the user behaviors, tries to "understand" her interests and automatically generates a "profile" representing the user (the user profile), and a set of profiles representing her interests (the folder profiles). These profiles, along with the user preferences, are then used as filters over the results obtained for the specific user request, in order to deliver only the "right" information, and present the personalized result list in the way that is more suitable for the user. Folder profiles and the user profile are updated from time to time (*Scheduled Profile Updating*). When a user has considerably changed the content of a folder, she may also request an immediate update (*On-demand*

Profile Updating) of the profile.

Metasearch. The search mechanisms (Figure **??**) provided by P*I*SA are essentially of two types:

1. *Filtered Search*: the user is interested in finding new documents *not yet* retrieved for the current folder and she is:
   - looking for new documents (*Search New*) - relevant to the folder- published on the resources after the last search was performed (information maintained, for each folder, by storing the SEARCHTIMESTAMP); or
   - looking for new documents related to the folder by providing one or more keywords (*Personalized Search*).
2. *Simple Search*: the user does not associate any folder to the keywords she looks for, *i.e.*, she issues a “simple query” like through Web search engines.

The *Search New* mechanism can be performed *On-Demand* for a specific folder at user request, or for all the folders the user owns at a scheduled time (*Scheduled Search New*), according to the settings the user configured in her system preferences.

Filtered Searches may be accomplished in at least two ways: (i) through query expansions techniques (**?**), *i.e.*, by expanding the query with significant terms of the folder profile and then submit the expanded query; or (ii) issuing the query, and then filtering the result list w.r.t. the folder profile (**??**).

The latter approach is used in *Personalized Search*, where the profile is used as a post-filter, *i.e.*, after the results have been retrieved, while in *Search New* the folder profile is used as a pre-filter, by selecting some of the significant terms of the profile and using them as the query (recall that the user does not provide any keyword). Another important difference between these search mechanisms is the folder-query association: while in the *Filtered Searches* the user explicitly declares to use the folder profile as a filter, and the folder will be the final repository of the results, in the *Simple Search* only the user profile can be used, if possible, for filtering the retrieved documents and the repository of the results will be the user HOME folder (folder created by default together with the TRASH folder). It is worth noting that there is always a current folder: if no folder is selected, the current folder is the HOME folder.

The metasearch functionality allows the user to decide what kind of search she wants to perform over the Web; on the other hand, when a search is started either on-demand or at scheduled time the assistant automatically selects the information resources to query, applies schema matching (if necessary), queries the selected resources, combines the results in a single result list and filters the results, either by means of the folder profile -if the query is associated with a given folder, or by means of the user profile otherwise.

As an example, here we show what happens when the user wants to perform a *Personalized Search*. The user selects a folder and wants to search for documents relevant to that folder containing the KEYWORDS she provides. P*I*SA:

1. automatically selects the resources relevant to the profile of the selected folder or uses -if any- the resources selected by the user;
2. applies the schema matching for each selected resource;
3. searches the selected resources and combines the result lists into a single ranked list;
4. uses the folder profile for filtering out some of the results;
5. delivers the results to the user into the selected folder according to the user preferences;
6. updates the *SearchTimeStamp* for the selected folder.

4 ARCHITECTURE

P*I*SA has been entirely developed using the Java Programming language, to guarantee the portability of the application across different platforms. Furthermore, in developing the prototype we took care of its modularity: each component can be easily modified/enriched or substituted with minimal effort. In particular, the prototype is based on the following development environment and libraries:

- Java Platform, Standard Edition, and the Java Development Kit (JDK), version 6.0[1];
- MySQL version 5.0.51 and the MySQL Connector/JDBC version 3.1.8[2];
- Apache Lucene library version 2.2[3].

The architecture (Figure **??**) consists of the *Graphical User Interface* (GUI); the *User Database*, for storing user, folders, documents, preferences and profiles data; the *Profiler*; the *Source Selector*; the *Schema Matcher*; the *Fusion Module*; and the *Filter*. In the following we describe each P*I*SA component and corresponding functionality in detail.

[1]`http://java.sun.com/`
[2]`http://www.mysql.com/`
[3]`http://lucene.apache.org/`

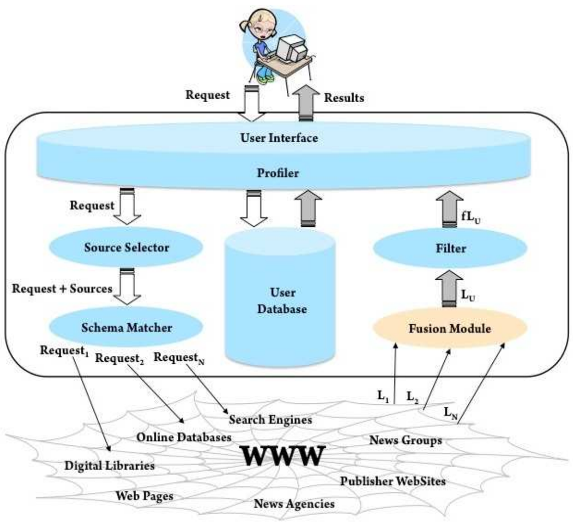


Figure 3: P*I*SA Architecture.

4.1 Graphical User Interface

From the user's perspective, P*I*SA GUI consists of a main menu and a set of windows and actions allowing the user to personalize the system step by step, via the folder and document management, the filters and the set of preferences she can modify. The application has a main pull down menu, with each entry of the menu corresponding to a user action. Every action can be also invoked through keyboard shortcuts.

Each component in P*I*SA has a tooltip text, which comes out by moving the mouse over it, for providing instant help to the user.

Login Window. The first window the user is presented with P*I*SA is the login window. After logging in, the user will be presented with the main user interface window and she can use the system, until she decides to quit. When the user accesses the assistant for the first time (after registering), the assistant automatically creates the HOME and TRASH folders.

Main Window. The main window is composed of three parts: the folder listing panel (on the left), the document listing panels (on the right), and the search panel (at the bottom) (Figure **??**).

The folder listing panel is a tree representing the user hierarchical folder structure. By selecting one folder, the user can: (*i*) have a view of the documents the folder contains; (*ii*) rename the selected folder[4]; (*iii*) create a new folder as a child of the selected one[5]; (*iv*) delete the selected folder[4]; (*v*) empty the selected folder; (*vi*) empty the TRASH folder; (*vii*) move a folder from an existing parent folder to a new parent folder[4] (by simply moving the folder in the folder tree - drag&drop).

[4]Forbidden for HOME and TRASH folders.

[5]Forbidden for TRASH folder.

The document listing panel is a table representing the documents contained in the folder. The table has several columns, each one describing an attribute of the document: the NAME, *i.e.*, the title of the document retrieved, the URL, the RESOURCE from which the document has been retrieved, the SCORE of the document within the result list, the DATE of delivery, and the QUERY the user performed for retrieving that document. Since the documents are not created via user operations, but delivered by the system after a search session, the user cannot modify any of the document attributes. By selecting one of the rows of the document table, the content of that document will be displayed in the bottom side of the document panel. Furthermore, the user can delete the document(s), and cut and paste one or more documents from one folder to another.

In the bottom side of the main window there is the search panel, a tabbed pane with two tabs: WHAT and WHERE.

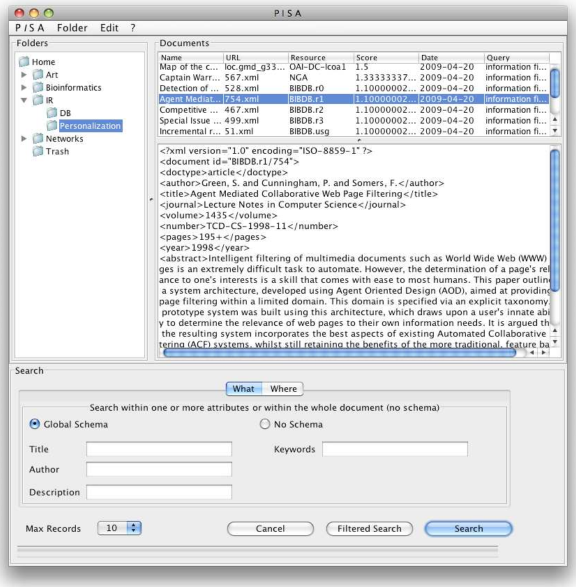
In the WHAT tab the user can choose to search documents with the provided GLOBAL SCHEMA, *i.e.*, search one or more keywords within one or more of the given attributes; alternatively, the user can initiate a search without any schema, *i.e.*, search one or more keywords irrespective of the attribute where they are located in the target schema of the queried resource(s). The GLOBAL SCHEMA P*I*SA provides is composed of three attributes: TITLE, AUTHOR, and DESCRIPTION.

In the WHERE tab the user can chose one or more resources to query if she has some preferences; alternatively, automatic resource selection is performed if the user has not selected any resource.

In the search panel the user can also choose the maximum number of documents to be returned in the result list. Figure **??** shows, as an example, the main application window with the WHAT tab selected.

Finally, the user clicks on the SEARCH button for performing a *Simple Search*, or on the FILTERED SEARCH button for performing a *Filtered Search*. If the user does not type any keyword and clicks on the FILTERED SEARCH button she issues a *Search New* search w.r.t. the currently selected folder, while if she clicks on the SEARCH button, she will be warned of the action inadmissibility (recall Figure **??**).

Personal Settings Window. In this window, the user can fill a form with her first name and last name, the country, the gender, the birth-date, and the email. Note that none of these data is mandatory, but they can be used for personalization too if available (think, for instance, at the Country when looking for infor-



Name	URL	Resource	Score	Date	Query
Map of the c...	loc.gmd_g33...	OAI-DC-lcoa1	1.5	2009-04-20	information fi...
Captain Warr...	567.xml	NGA	1.33333337...	2009-04-20	information fi...
Detection of ...	528.xml	BIBDB.r0	1.10000002...	2009-04-20	information fi...
Agent Mediat...	754.xml	BIBDB.r1	1.10000002...	2009-04-20	information fi...
Competitive ...	467.xml	BIBDB.r2	1.10000002...	2009-04-20	information fi...
Special Issue ...	499.xml	BIBDB.r3	1.10000002...	2009-04-20	information fi...
Incremental r...	51.xml	BIBDB.usg	1.10000002...	2009-04-20	information fi...

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<journal>Lecture Notes in Computer Science</journal>
<volume>1435</volume>
<number>TCD-CS-1998-11</number>
<pages>195+</pages>
<year>1998</year>
<abstract>Intelligent filtering of multimedia documents such as World Wide Web (WWW)
ges is an extremely difficult task to automate. However, the determination of a page's rel
ance to one's interests is a skill that comes with ease to most humans. This paper outlin
 a system architecture, developed using Agent Oriented Design (AOD), aimed at providing
page filtering within a limited domain. This domain is specified via an explicit taxonomy.
 prototype system was built using this architecture, which draws upon a user's innate abi
y to determine the relevance of web pages to their own information needs. It is argued th
 the resulting system incorporates the best aspects of existing Automated Collaborative
tering (ACF) systems, whilst still retaining the benefits of the more traditional, feature ba
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Figure 4: P*I*SA Graphical User Interface: main application window. The folder listing panel (on the left), the document listing panels (on the right), and the search panel (at the bottom), with the WHAT tab selected.

mation strictly bounded with the geographic location of the user).

Preferences Window. In this window the user can explicitly define some action the system performs. In particular, the user can set:

- when the system periodically updates the user profile;
- when the system periodically updates the folder profile;
- when the system periodically search for new documents for each folder owned by the user;
- how the system notifies new documents (the options are: a pop-up window, a sound, or nothing; the default setting is: *no event*);
- how the system ranks the new documents found (the options are: by score, by date, by resource, or no preference; the default setting is *by score*).

Both the Preferences and the Personal Settings windows can be accessed by the user both via the pull down menu on the main window or via the corresponding keyboard shortcut.

Warning Windows. These windows are used by the system to warn the user on an invalid -or unsuccessful- operation.

Confirm Windows. These windows are used by the system to ask the user to confirm some actions, like, *e.g.*, quitting the application.

Acknowledgment Windows. These windows are used by the system to acknowledge the user of the outcome of an action she started.

4.2 User Database

For each user, P*I*SA locally creates and maintains a database with several tables, and provides methods for creating, reading and updating them. The USER DATABASE has been realized with the MySQL open source database. The connection and interactions with the database has been realized with the MySQL Connector/J, a native Java driver that converts JDBC (Java Database Connectivity) calls into the network protocol used by the MySQL database.

When the user first register herself to P*I*SA, the system automatically creates (i) the *Preferences Table*, for storing the system preferences (set by the user or provided by default by the system); (ii) the *Settings Table*, for storing the personal information provided by the user; (iii) the *Folders Table*, for storing all the information related to the folders owned by the user; (iv) the *Documents Table*, for storing all the information related to the documents already retrieved for the user; (v) the *Profiles Table*, for storing the folder profile of each folder owned by the user and the user profile.

4.3 Profiler

The Profiler's task is to create user and folder profiles, and update them either on-demand or at scheduled time. In the following we will describe how to build and maintain these profiles by adopting the approach proposed in **?**.

Let's denote by t_k, d_j, and F_i a text term, a document, and a folder, respectively. Following the well-known vector space model, each document d_j in a folder F_i is represented as a vector of *weights*:

$$d_j = \langle w_{j1}, \ldots, w_{jm} \rangle \ , \qquad (1)$$

where $0 \leq w_{jk} \leq 1$ corresponds to the "importance value" of term t_k in document d_j, and m is the total number of terms occurring in at least one document saved in the folder (**?**). The folder profile f_i for folder F_i is computed as the *centroid* (average) of the documents belonging to F_i, *i.e.*:

$$f_i = \frac{1}{|F_i|} \cdot \sum_{d_j \in F_i} d_j \ . \qquad (2)$$

This means that the profile of F_i may be seen as a data item itself (**?**) and, thus, is represented as a vector of weighted terms as well: $f_i =< w_{i1}, \ldots, w_{im} >$, where

$$w_{ik} = \frac{1}{|F_i|} \cdot \sum_{d_j \in F_i} w_{jk} \, . \quad (3)$$

The profile p_u of the user u is built as the centroid of the user's folder profiles, *i.e.*, if $\mathcal{F}_u$ is the set of folders belonging to the user u, then:

$$p_u = \frac{1}{|\mathcal{F}_u|} \cdot \sum_{F_i \in \mathcal{F}_u} f_i \, . \quad (4)$$

As for folder profiles, the profile p_u of user u is represented as a vector of weighted terms as well: $p_u =< w_{u1}, \ldots, w_{um} >$.

Besides the folder and user profiles, the Profiler is also responsible for the personal data the user provided (if any) and the system preferences set.

4.4 Source Selector

Automatic Resource Selection is based on the assumption of having a significant set of documents available from each information resource (see, *e.g.*, **?**). Usually, these documents are obtained by issuing random queries to the resource (*information resource sampling*, see, *e.g.*, **?**). This allows to compute an *approximation of the content* of each information resource, *i.e.*, a representation of what an information resource is about (*information resource topics* or *language model* of the information resource).

As a result, a *sample* set of documents for each information resource is gathered. This set is the *resource description* or *approximation* of the information resource. This data is then used in the next step to compute the *resource score* for each information resource, *i.e.*, a measure of the relevance of a given resource to a given query. In the following we describe how P*I*SA computes the *resource goodness* for automatic resource selection by using an adapted version of the CORI (**??**) resource selection method.

Consider query $q = \{v_1, ..., v_q\}$. For each resource $\mathcal{R}_i \in \mathscr{R}$, we associate the *resource score*, or simply the *goodness*, $G(q, \mathcal{R}_i)$, which indicates the relevance of resource $\mathcal{R}_i$ to the query q. Informally, a resource is more relevant if its approximation, computed by query-based sampling, contains many terms related to the original query. However, if a query term occurs in many resources, this term is not a good one to discriminate between relevant and not relevant resources. The weighting scheme is:

$$G(q, \mathcal{R}_i) \quad = \quad \frac{\sum_{v_k \in q} p(v_k|\mathcal{R}_i)}{|q|} \, , \quad (5)$$

where $|q|$ is the number of terms in q. The *belief* $p(v_k|\mathcal{R}_i)$ in $\mathcal{R}_i$, for value $v_k \in q$, is computed using the CORI algorithm (**??**):

$$p(v_k|\mathcal{R}_i) \quad = \quad T_{i,k} \cdot I_k \cdot w_k \quad (6)$$

$$T_{i,k} \quad = \quad \frac{df_{i,k}}{df_{i,k} + 50 + 150 \cdot \frac{cw_i}{\overline{cw}}} \quad (7)$$

$$I_k \quad = \quad \frac{\log\left(\frac{|\mathscr{R}|+0.5}{cf_k}\right)}{\log\left(|\mathscr{R}| + 1.0\right)} \quad (8)$$

where:

w_k	is the weight of the term in the query;
$df_{i,k}$	is the number of documents in the approximation of $\mathcal{R}_i$ with value v_k;
cw_i	is the number of values in the approximation of $\mathcal{R}_i$;
$\overline{cw}$	is the mean value of all the cw_i;
cf_k	is the number of approximated resources containing value v_k;
$\lvert\mathscr{R}\rvert$	is the number of the resources.

In the above formulae, $T_{i,k}$ indicates how many documents contain the term v_k in the resource $\mathcal{R}_i$. As cf_k denotes the number of resources in which the term v_k occurs, called *resource frequency*, I_k is defined in terms of cf_k inverse resource frequency: the higher cf_k the smaller I_k, reflecting the intuition that the more a term occurs among the resources the less it is a discriminating term. The belief $p(v_k|\mathcal{R}_i)$ combines these two measures.

Finally, given the query q, all information resources $\mathcal{R}_i \in \mathscr{R}$ are ranked according to their resource relevance value $G(q, \mathcal{R}_i)$, and the top-n are selected as the most relevant ones.

4.5 Schema Matching

Given a user query $q = \{A_1 = v_1, \ldots, A_q = v_q\}$, written with a specific schema T, called *target* or *global schema*, and a resource R with its own schema S, called *source schema*, the *Schema Matching* problem (**??**) can be defined as the problem of transforming each attribute $A_T \in T$ of the query in the correct attribute $A_S \in S$, in order to submit the query to R.

P*I*SA relies on a simple and effective method to automatically learn schema mappings proposed in **?**. It is based on a reformulation of the CORI resource selection framework presented in the previous Section. Renda and Straccia (**?**, page 1079) state than, "similarly to the resource selection problem, where we have to automatically identify the most relevant libraries w.r.t. a given query, in the schema matching problem we have to identify, for each target attribute, the most relevant source attribute w.r.t. a given structured query". Given a resource S and its metadata schema with attributes $S_1,...,S_n$, the resource selection task can be reformulated in the schema matching problem as follows: given an attribute-value pair $A_i = v_i$, with A_i being an attribute of the target schema T, select among all the attributes S_j those which are most relevant to the attribute A_i given its value v_i, and map A_i to the most relevant attribute.

Let $\mathcal{R}_k \in \mathscr{R}$ be a selected resource. The problem is to find out how to match the attribute-value pairs $A_i = v_i \in q$ (over the target schema) into one or more attribute-value pairs $A_{k_j} = v_i$, where A_{k_j} is an attribute of the (source) schema of the selected resource $\mathcal{R}_k$. Now consider the resource $\mathcal{R}_k$ and the documents $r_1,\ldots,r_l$ of the approximation of $\mathcal{R}_k$ $Approx(\mathcal{R}_k)$ (computed by query-based sampling). Each document $r_s \in Approx(\mathcal{R}_k)$ is a set of attribute-value pairs $r_s = \{A_{k_1} = v_{k_1},\ldots,A_{k_q} = v_{k_q}\}$.

From $Approx(\mathcal{R}_k)$, we make a projection on each attribute, *i.e.*, for each attribute A_{k_j} of the source schema we build a new set of documents:

$$C_{k,j} = \bigcup_{r_s \in Approx(\mathcal{R}_k)} \{r \mid r := \{A_{k_j} = v_{k_j}\}, A_{k_j} = v_{k_j} \in r_s\} \ . \tag{9}$$

The idea proposed in **?** is that each projection $C_{k,1},\ldots,C_{k,k_q}$ can be seen as a new library, and CORI can be applied to select which of these new resources is the most relevant for each attribute-value pairs $A_i = v_i$ of the query q (see **?** for more details).

4.6 Rank Fusion

In P*I*SA, we adopted the rank-based method called *CombMNZ*, considered as the best ranking fusion method (**??**). *CombMNZ* combination function heavily weights common documents among the rankings, basing on the fact that different search engines return similar sets of relevant documents but retrieve different sets of non-relevant documents.

Given a set of n rankings $R = \{\tau_1,\ldots,\tau_n\}$, denote with $\hat{\tau}$ the *fused ranking* (or *fused rank list*), which is the result of a rank fusion method applied to the rank lists in R. To determine $\hat{\tau}$, it is necessary to determine the *fused score* $s^{\hat{\tau}}(i)$ for each item $i \in U$, being $U = \bigcup_{\tau \in R, i \in \tau}\{i\}$, and order $\hat{\tau}$ according to decreasing values of $s^{\hat{\tau}}$. In *linear combination ranking fusion methods*, the fused score $s^{\hat{\tau}}(i)$ of an item $i \in U$ is defined as follow:

$$s^{\hat{\tau}}(i) = h(i,R)^y \cdot \sum_{\tau \in R} \alpha_\tau \cdot w^\tau(i) \ , \tag{10}$$

where (i) all the rank lists $\tau \in R$ have been normalised according to the same normalization method; (ii) $y \in \{0,1\}$ indicates whether hits are counted or not; and (iii) $\sum_{\tau \in R} \alpha_\tau = 1$ and $\alpha_\tau \geq 0$ indicates the priority of the ranking τ. In **?**, the authors report experimental results on comparing several *rank-based* and *score-based* fusion methods. According to the results reported in that paper, in P*I*SA: (i) each rank list $\tau \in R$ has been normalized and the *normalised weight* $w^\tau(i)$ of an item $i \in \tau$ has been computed according to the *rank normalization method*:

$$w^\tau(i) = 1 - \frac{\tau(i) - 1}{|\tau|} \ ; \tag{11}$$

(ii) $y = 0$, *i.e.*, hits have not been counted; (iii) $\alpha_\tau = 1/|R|$, *i.e.*, all rank lists have the same priority.

4.7 Filter

When the ranked results are available, the Filter role is to filter out some of the results. In particular, if the search issued was the *Personalized Search*, the Filter has to compare each document w.r.t. the folder profile. Recall that each document d_j is represented as a vector of *weights* $d_j = \langle w_{j1},\ldots,w_{jm}\rangle$, where $0 \leq w_{jk} \leq 1$ corresponds to the "importance value" of term t_k in document d_j (Table **??**), and that each profile is represented as a vector of weighted terms as well, *i.e.*, $f_i = [w_{i1},\ldots,w_{im}]$ (Table **??**).

In order to compute the content similarity sim_{ij} between the folder profile f_i and the document d_j, we compute the well-know cosine metric, *i.e.*, the scalar product between two row vectors, and select only those documents with $sim_{ij} > 0$.

Furthermore, the Filter will deliver up to the maximum number of documents requested by the user and visualize them according to the user settings, as set in the System Preferences Window.

	t_1	$\ldots$	t_k	$\ldots$	t_m
d_1	w_{11}	$\ldots$	w_{1k}	$\ldots$	w_{1m}
d_2	w_{21}	$\ldots$	w_{2k}	$\ldots$	w_{2m}
$\ldots$	$\ldots$	$\ldots$	$\ldots$	$\ldots$	$\ldots$
d_n	r_{n1}	$\ldots$	w_{nk}	$\ldots$	w_{nm}

Table 1: The Document Matrix.

	t_1	$\ldots$	t_k	$\ldots$	t_m
f_1	w_{11}	$\ldots$	w_{1k}	$\ldots$	w_{1m}
f_2	w_{21}	$\ldots$	w_{2k}	$\ldots$	w_{2m}
$\ldots$	$\ldots$	$\ldots$	$\ldots$	$\ldots$	$\ldots$
f_v	w_{v1}	$\ldots$	w_{vk}	$\ldots$	w_{vm}

Table 2: The folder profile matrix.

5 USER EVALUATION

In order to provide a preliminary evaluation of P*I*SA usability, we asked 10 users, after a short presentation of the functionality, to use the system and test the GUI. The users first highlighted that such a personalized system is safer to use locally, in terms of privacy (*i.e.*, they did not like the idea of being profiled on the server side or by on-line services). All the users reported that P*I*SA resemblance with a common email program helped them to quickly understand how several GUI components work. The GUI has been classified as intuitive and robust.

To evaluate P*I*SA effectiveness in providing personalized services, we asked the users to create a certain number of folders, populate them with "pertinent" documents, update the correspondent profiles, and issue a number of queries ranging from 1 to 10 for each profile. They created 30 different profiles, and issued a total number of 150 queries. The returned results have been scrutinized and classified by the users as either relevant of irrelevant for the corresponding profile, and the precision performance metric (which, we recall, is defined as the ratio of the number of relevant documents to the total number of retrieved documents) has been evaluated. The maximum number of returned query results has been set to 10. In order to evaluate the benefits of P*I*SA personalized search mechanisms, we asked the user to run the same set of queries without profile, when they first accessed the system, with empty HOME folder and issuing a simple query (*i.e.*, with no profile, no automatic source selection, no filtering).

Data sets. On-line web information resources periodically modify their interfaces, so that the wrappers to their result pages have to be maintained constantly up-to-date. In order to avoid spending time in such a tedious activity and concentrate on the personalization evalution, we decided to download the content of some resources and implement a "static" interface to these local resources. For this purpose, we implemented an indexing engine for locally storing a certain number of information resources.

The INDEXER has been implemented taking advantage of the Lucene libraries, which provide Java-based indexing and search technology, as well as spellchecking, hit highlighting and advanced analysis/tokenization capabilities. In the indexing process, we have analyzed the individual documents and their content, split into terms, applied stemming, and eliminated stopwords. In the retrieval phase, Lucene libraries allow us to get back statistical information on the resources, such as the frequencies of the individual terms at the field level and at the document level, and the resource size.

We have locally downloaded and indexed 8 resources for a total of about $45,000$ searchable documents:

1. BIBDB, containing more than 5000 BibTeX entries about information retrieval and related areas;
2. DUBibDB, containing almost 3463 documents with bibliographic data from the Uni Duisburg University BibDB;
3. HCI, containing 26381 documents with bibliographic data from the Human-Computer Interaction (HCI) Bibliography;
4. DC, containing 6276 OAI documents in `Dublin Core` format;
5. ETDMS, containing 200 OAI electronic theses;
6. RFC1807, containing 467 OAI documents in `RFC1807` format;
7. WGA, containing 265 documents from the european Web Gallery of Art [6];
8. NGA, containing 864 documents from the american National Gallery of Art [7], Washington, DC.

Part of these resource collections have been provided by INEX - Initiative for the Evaluation of XML Retrieval[8]. In particular, DUBibDB and HCI collections are part of the INEX Heterogenous Collection Track 2006.

For the profiling and filtering tasks, we computed term weights of the documents by applying the well known $tf*idf$ term weighting model (first introduced in **?**). The *term frequency* tf_{ij} of term t_i in document d_j is defined as:

$$tf_{ij} = \frac{n_{ij}}{\sum_k n_{kj}} , \qquad (12)$$

where n_{ij} is the number of occurrences of the considered term in document d_j, and the denominator is the sum of number of occurrences of all terms in document d_j. The *inverse document frequency* idf_i is a measure of the general importance of the term t_i in the corpus of documents D and is defined as:

$$idf_i = log\frac{|D|}{df_i} , \qquad (13)$$

where $|D|$ is the total number of documents in the corpus, and the denominator is the *document frequency* of term t_i, *i.e.*, the number of documents where the term t_i occurs: $df_i = |\{d \in D : t_i \in d\}|$.

[6]`http://www.wga.hu`
[7]`http://www.nga.gov`
[8]`http://inex.is.informatik.uni-duisburg.de`

A high weight in $tf * idf$ is reached by terms with a high term frequency in the given document and a low document frequency in the whole collection of documents. Thus this model is a good discriminant of common terms.

Results. The average and variance of precision for the set of queries submitted are reported in Table **??**. As seen from the Table, P*I*SA is very effective in improving precision, which is almost doubled w.r.t. the case of no personalization. In particular, P*I*SA resulted very effective in: (i) filtering out irrelevant results; and (ii) delivering relevant results in presence of very general queries. The effectiveness of P*I*SA in discarding irrelevant results can be deduced by Table **??**, which reports the average (and variance) of the number of returned documents in case of personalized and non-personalized queries (we recall that the maximum number of returned documents was set to 10 in both cases). As seen from the Table, the average number of returned documents dropped from 9.79 without personalization to 8.23 with personalization, with higher variance in the latter case. As for (ii), we mention a specific query a user highlighted (several similar queries displayed the same behavior): the query “model” (an intendedly very general query) had precision improved from 0 to 0.7 when executed in the “database” folder, w.r.t. the case of no personalization.

	Precision		**No. of Documents**	
	Profile	No Profile	Profile	No Profile
Average	0.72	0.38	8.23	9.79
Variance	0.08	0.06	7.57	0.49

Table 3: P*I*SA Experimental Results.

6 CONCLUSIONS

In this paper we presented P*I*SA - a *Personalized Information Search Assistant*, a desktop application which provides the user with a highly personalized information space where she can create, manage and organize folders, and manage documents retrieved by the system into her folders to best fit her needs. Furthermore, P*I*SA offers different mechanisms to search the Web, and the possibility of personalizing the result delivery and visualization. P*I*SA learns user and folder profiles from user’s choices, and these profiles are then used to improve retrieval effectiveness in searching, by selecting the relevant resources to query and filtering the results accordingly. Preliminary user evaluation and experimental results are very promising, showing that the personalized search environment P*I*SA provides considerably increases effectiveness and user satisfaction in the searching process.

P*I*SA prototype has been developed pursuing the goal of realizing modularity, so that each component can be easily modified or substituted with minimal effort. We are currently working to extend P*I*SA by including more sophisticated result presentation techniques. Suppose the documents retrieved are considered not relevant by the user, it could be useful not to entirely download the documents. The *assistant* could highlight important passages within the documents, presenting the user only with the “best” document passage (*Passage Retrieval*) (**?**), or summarize the documents, presenting the user only with the *document summary* (*Summarization*) (**?**). After analyzing the passages or the summaries, the user can decide whether it is worth downloading the documents and save it in her information space. Furthermore, we plan to investigate different ways of modeling the user, the documents and the corpus (as proposed, for instance, in **?** and references therein), in order to further improve search effectiveness.