U-Doc, a research vehicle for hyper document retrieval on the Internet

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Summary

In this article we present the UDOC architecture, which describes a thematic mirror based on the filtering of composite documents on the Internet or on others large networks. The main innovations of the paper concern the integration of filtering methods for images, sounds and videos, the research by concepts independent of the media, the concept of thematic mirror, and the placement in tertiary memory. The disposition of new technical means for multimedia document indexation will allow a more massive utilization of these documents, which is currently limited on large networks. Our approach will be validated by a true magnitude experimentation. Prototyping is currently under way.

Key words

thematic mirror, multimedia indexing, filtering, Internet, video, research by concept, cooperative filtering

1. Introduction

The rapid development of a massively distributed information (at planetary scale) on the Internet is a major evolution of the current data-processing. Although the bandwidth of the network increases, the increase of documents volumes and of the number of users implies very variable quality of service and response times. The pertinence of accessed documents is also limited by current selection methods.

On the one hand, the cache and mirror utilization has for purpose to limit response times by modifying the network topology[1-4]. Documents stored in the cache become far closer to the user than in their initial site. In the case of individual caches, this allows to reduce access times others that the duration of first access. In the case of persistent and collective caches, the period of the first access to a document for a user can be reduced, but usual cache sizes do not allow information persistency for long periods. However a document accessed by a user has vocation to be consulted by a person having neighbor interest centers, but not necessarily at the same time. Finally access to documents of very heterogeneous size (for example of the new and videos) has a unfavorable effect on cache management.

Mirroring techniques are also available. In this case the mirror reproduces the content of one or several distant sites. It can generally be accessed far more rapidly than them by users situated on the same local system, or even in the same geographical zone (country, continent. ..). However mirrors generally replicate the information on the basis of the site where it is found and not of its content. Many documents that are not found on main sites are thus not replicated.

The selection by the content of these composite documents necessitates methods of filtering adapted to images, to the sounds and to videos. Beside methods that depend on the media and

an expertise of the user, we also propose methods of research by concepts, in which this expertise is realized by learning modules and automatic assistance.

On the other hand, current selection methods are often too poor to give optimal results with all documents types [5-7]. Efficient methods of selection by content only begin to appear for the new types of documents, as images or sounds. Other approaches (sentence parsing [8], research by implicit concepts, etc.) are often very expensive in their parsing or learning phase. Cooperative methods are very promising, and are implicitly used in collective caches. We propose the realization of thematic mirrors, that replicate data according to their content, and to users long-term profiles. These replicates will pre-fetch relevant documents, before their consultation by the user. Prefetch will be done incrementally, and will deal only with new or modified documents. Efficient access to documents by a group of users on a long period will be allowed by archiving them in tertiary memory (cd-rom juke-boxes). Thematic mirrors will specialize by areas, and will cooperate between themselves. The service will be invoiced by subscription or according to others modes.

We consider composite documents, including structured text components, still images, sounds, videos, and in the future VRML presentations. Videos are not yet commonly accessed on the Internet. However the development of new compression techniques, and the network evolution, make this a realistic prospect [9, 10].

From this point of view, the quality of retrieval methods is essential in order to load documents that will be useful to users. We will validate our approach by an effective experimentation.

In this paper, we will present first a brief state of the art of document access and selection techniques. Then we will present the functionalities and the architecture of our system. Finally we will conclude by presenting experimentation perspectives and the most original aspects of our research.

2. State of the art

The purpose of documents filtering and access methods is to reduce the response time and to improve the quality of service, and to allow the access to relevant documents. Filtering reduces the number of documents proposed to the user. Access methods will enable us to reduce transfer times on the network.

HTTP, Hyper-G, Harvest, the Tapestry [11, 3, 4, 12, 13] are protocols and systems that manage access methods to documents. These systems and new indexation methods enable filtering improvement.

2.1. methods of access

HTTP protocol

HTTP is a lightweight and stateless client-server protocol for the communication in an hypermedia distributed network. It leans on the utilization of universal object identifiers, named URLs. The HTML language enables users to incorporate hyperlinks formed by URLs in a structured text.

The protocol explicitly allows proxies management, gateways and or individual collective caches (i.e. common to several clients). Proxies are intermediate servers between a client and a final server. The proxies and location servers, as Lycos [14], are related to the brokers of CORBA [15], i.e. to servers used as relay between the client and the final server.

The absence of state of the protocol does not allow to directly manage transactions composed of several successive actions. The proxies generally lean on caches that preserve documents

only in a provisional manner (some days). Public annotations, essential to cooperative work, are not specified in the protocol.

Hyper - G

Hyper - G is an hypermedia document management system that is intended to be of "second generation" , and whose purpose is to propose a session oriented, stateful protocol, public annotations, and multimedia access (from structured texts to VRML presentations). URL links become bi-directional.

However documents indexing is essentially text-based, and data are managed in caches where they are not filed in the long term.

Harvest

Harvest is a system of servers and brokers whose purpose is to extract summaries from documents (with the help of the Essence summarizer), to most often limit the transfers on the network to transfers of summaries, and to select documents in the brokers from summaries.

This system does not process annotations or cooperative research. Currently the Essence summarizer and the proposed indexers are mainly text-based. Finally if the selection of the document is facilitated, final access to the former uses a classic cache system, with its limitations.

Tapestry

The purpose of the Tapestry from Xerox Palo Alto is to filter documents (News, etc. ..) on the Internet, notably on cooperative criteria (annotations of the other users), and to transfer relevant documents to the user. The system interface is the Mail, or the TQL language, derived from SQL.

A contribution of the Tapestry is to define conditions for incremental query execution, i.e. each execution should only deal with new documents. In order that the request have a monotony property, all documents included in the result at a given time have to remain part of the result at any further date. This necessitates long term documents archiving.

The filtering is only text-based. If a document is consulted by several users at successive dates, it is not preserved during this period in a common archive.

2.2. methods of selection

selection by content

selection by textual content

Selection by textual content has been widely studied by Salton and al. [5], it leans on boolean queries, on vectorial queries (which lead to a documents classification), and on the automatic enrichment of the request. In the later, significant document words selected in a first step, serve as keywords lists for an ulterior step of the query. These methods can also concentrate on a summary extracted from the document structure (for example, paragraph titles).

These methods suppose an expertise on keywords to use, or a first selection step with a user participation to the result evaluation.

selection by image content

Selection by image content can lean on the specification of a color distribution in selected images, or on the research of textures or simple shapes. These different approaches can give very good results (QBIC, Chabot) [16,17] if the user has enough expertise in query formulation and in the database content. For example the retrieval by color in Chabot allows to find easily images of sunsets or prairies with flowers.

However shape retrieval in QBIC leans on an intervention of the user to separate shapes from the background. QBIC does not use 3-D indices provided for example by the projective geometry, to segment objects contained in images [18-22].

selection by sounds content

The selection by sounds content can lean on a recognition of the speaker or the type of sound of a sound sequence (word, silence, music, noise), or on the translation of spoken sentences into text (vocal dictation).

Speaker recognition gives very good results if samples of word of the different speakers are known (Orphée) [23-25]. The case of non supervised segmentation is still a subject of open research. Vocal dictation from continuous speaking gives good results if the vocabulary is limited and known (currently up to 64000 words) [26,27], as it is the case with scripts of videos. Techniques as word spotting also allow to retrieve isolated words from continuous sentences, but this technique is less powerful than the vocal dictation.

selection by video content

The two main problems in the selection of videos is the segmentation of the video into scenes, generally composed of several plans, and the mapping of indexable content (text, images, speakers, spoken text, etc. ..) with each scene. The "Interactive Cinema" team at Media Lab (MIT) studies a selection of scenes in view of the video authoring, mainly from manually created annotations [28]. Automatic video indexing remains an open problem [29,30, 37, 38].

selection by concepts

In the research by content, an expertise on the application field is often necessary. For example for image retrieval by the color histograms, it is necessary to know the desired color distribution.

When using domain and media-independent concepts, content based retrieval is possible to non expert users [31,32]. For example, if one seeks "a prairie of poppies" , an assistance module can determine that it concerns red spots on a green bottom. Similarly for videos, one will be able to research "sad scenes" or "outside scenes during the night" . The Alex system in the Netherlands experiments this approach. It is applied to structured texts and to images of faces. For structured texts for example, the method consists in partitioning a representation space with a very large number of dimensions (more than 100 000) to represent it by a space of concepts to a number of weaker dimensions.

For the moment the Alex approach is not applied to animated images, and its learning mechanisms remain expensive.

cooperative selection

Cooperative retrieval is another very powerful means to improve the pertinence of retrieved documents. It leans on the existence of a group work, in which some users agree to provide a notice to the other users. The efficiency of these mechanisms has been demonstrated by the experience of the Tapestry [12].

3. Functionalities of UDoc.

UDoc is conceived as a collection tools that facilitate access to documents on the Internet as well as document administration.

3.1. Access to documents

content-based indexation of sounds, images and video

Indexation allows to retrieve a document from its content or that of its summary. The index also constitutes a condensed information that can be transfered to a distant site (other UDoc site), in order to facilitate the research on a site network as in Harvest.

Index in UDoc are partially dependent from the field. It is possible to find keywords which are present in a structured text, in a spoken text, or to find the name of a speaker who is present in a scene. From percentages of colors, it is possible to find visual atmospheres. For example by researching "some red in a lot of green" one will find images of poppy prairies.

The most complex type of structured document managed by UDoc is constituted by videos, that contain animated images, sounds, and optional text (subtitles, script).

The problem of video indexing is the mapping of scenes of the script (when the script exists) with scenes of the image channel, and the "sentences" of the sound channel. To stall the script on the video we recognize speakers in the sound channel, we translate spoken sentences into text, and we recognize visual atmospheres (for example: "outside night") in the image channel. For each scene or each plan we isolate characteristic still images. For each still image, we research a visual atmosphere as in Chabot and QBIC. This atmosphere is characterized by a color histogram.

The index is constituted of the mapping between scenes of the video, names of speakers, characteristic images, color histograms, scenes of the script, keywords from these scenes, etc.

research by concepts

The purpose of research by concepts is to map domain-independent and qualitative queries to more precise, domain-dependent queries based on text, colors and sounds. For example a research on the " "mobile computing" concept will be able to lead to more specific queries on "GSM" and "portable computers".

In a multimedia document such as a video, the system will retrieve "a happy atmosphere with Lauren Bacall" by deriving from this request domain-dependent queries on the color distribution, the speaker name, and the corresponding scenes of the script. The mapping between concepts and domain-dependent queries will result from a learning phase (based on scripts and index) which will teach UDoc the correlations between concepts and derived queries.

For still images and sound documents other than videos, we use part of these techniques.

cooperative selection and long term queries

Relevant document selection also leans on two other techniques that are cooperative selection, based on annotations, and users profiling.

Annotations allow a cooperative selection based on document evaluation by other users. These annotations can be textual comments on a document, a numerical note or a boolean evaluation. This one can be obtained either explicitly (the user tells the system that the document is relevant) or implicitly (the document is consulted). For a cooperative utilization, annotations have to be public and nominal. This approach is used to filter the News in the Tapestry.

Profiles characterize fields of interest of a user. They can be used to precise a user query, or to anticipate it by permanent queries. Profiles can be acquired from short term requests made by the users, and transformed into long term queries by a learning process, or explicitly in the form of long term queries formulated by the user.

Speeding-up document access

We implement a thematic mirror whose content depends on profiles of the mirror users. This mirror replicates relevant documents, and summaries of a priori less relevant documents, by a pre-fetch of these summaries and documents. Documents are loaded when communication networks are the less loaded, which optimizes the system throughput. Documents and summaries are analyzed in more detail after their reception. If a summary appears particularly relevant, the corresponding document is retrieved on the network. When the document appears itself relevant, it is filed in the long term in a tertiary memory, constituted of juke-box of CDROMS. This memory has a large capacity for a very low storage cost by document. When the user asks to access a document, it is transferred in the mirror collective cache. The

archiving and cache policy takes into account the access probability of the document and its size.

For example, if a UDOC server comprises 100 users, and each of them reads on the average 10 documents of 600 KB per week (for example PostScript files), the server will file on the average 600 Megabytes per week, i.e. 30 Gigabytes per year. In fact, a document will be able to be used by several users, but part of the transferred documents part will probably not be read by addressees. As a result the volume of data proposed to users by the system will possibly be superior to 30 gigabytes per year, in order to guarantee a sufficient readable volume.

The archiving of documents on the server during several months or several years will allow to research them outside incrementally, and to insure their consultation by several users at very spaced intervals. The very low tertiary memory cost (less than 400 FF / 80 USD by gigabyte), allows to implement this storage for an acceptable cost. In the case of videos, the index alone will be durably stored on the server. The video itself will reside on an external video server (video to demand or other). Thereafter if techniques for more efficient compression develop (a factor 1000 to 10000 is proposed with Generic Video for some types of videos [9]), local video archiving will become foreseeable.

external interface

To facilitate accesses to documents on the net three tools will be put at users disposal: MailAccess, SGQL [33] and DQBE.

MailAccess is an extension of the mail tool, which is widely spread among users. It allows them to send queries, to receive bibliographies and documents and to annotate them.

SGQL - Structured Generalized Document Query Language - is a query language for structured documents, derived from SQL. As in Chabot this language will allow to query the document on concepts, keywords, color histograms, etc. It will also allow to retrieve a scene in a video based on the speaker name.

The DQBE language (Document Query By Example) is a language for structured document query which is derived from QBE [34] and form-based languages. It allows to specify colors or textures of an image from colors and texture paddles, sounds from samples, etc...It also makes possible to help authoring new videos, by summarizing existing ones while keeping the narrative continuity of the story.

The basic idea of these languages is that they recognize the document structure, such that it is defined by its syntax in the case of SGML documents, and by its semantics. Thus the language will recognize notions of title, authors, abstract, bibliography, subheads, paragraphs, tables, for structured texts, or notions of images, plans, sequences, canal, for videos.

The interrogation by keywords must be applicable to documents written in a foreign language. To allow this access, we will use bilingual dictionaries and automatic translation tools.

3.2. Documents administration

documents modelisation according to SGML and Hytime

To guarantee the durability of documents and to facilitate some accesses, documents in UDoc will be able to be modelised and stored according to the SGML standard [35], while the real time part will be modelized according to HyTime [36]. This approach is facilitated by the fact that currently available documents on the WEB use the HTML standard, that is simply an instance of SGML.

For existing documents that are not in SGML, we will optionaly use the ESSENCE [6] approach, that maps each file type with a representation model and a behavior.

billing

Billing is an important issue for any documents access system on the Internet, and particularly for a system of proxies with prefetch. We envisage three billing types: by subscription, by service, and by document.

Billing by service consists in proposing to the user a subscription for each long term query that it submits to the system, or that the system proposes him. The subscription fare can depend on an estimation of the number of documents accessed with this profile.

Finally the user can be invoiced on the basis of the volume of received documents. In this case the user must be able to refuse some documents before to consult them. This approach risks to result in a diversion of access to documents, the user being able to get the document for free on the Internet, after the document selection by the system.

4. Architecture

4.1. general presentation of the architecture

The architecture is characterized by two data paths (fig.1). Requests are transmitted by the client to UDoc external interface (mailer or DQBE). The former transmits them in internal format to several successive modules. The concepts manager derives domain-dependent and precise queries (requests on colors, on the sounds, etc. ..) derived from more general queries. The indexer researches corresponding documents in the local document database. The profiler extracts long term profiles from of immediate queries. The examiner addresses immediate client requests and permanent requests, produced by the profiler, to external location servers, and evaluates the resulting titles and summaries.

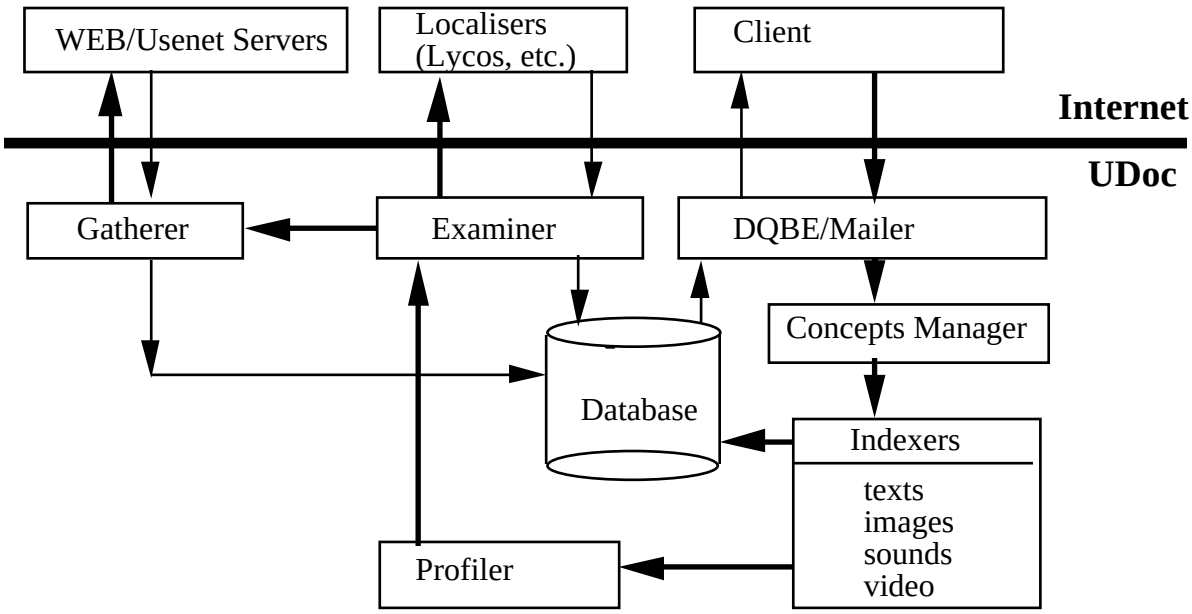

figure 1. Architecture of UDOC

The gatherer researches documents that have been favorably evaluated by the examiner. Resulting documents are sent to the storage system, then to the user (return path).

The storage system memorizes documents, summaries and annotations in a cache and in tertiary memory. The thesaurus manages a corpus of reference documents (for example of articles of a review preliminarily chosen to describe the area), and undertakes the learning of concept correlations in this corpus.

4.2. concepts manager

The concept manager exploits knowledge learned in the thesaurus, on the correlation between general concepts and domain-dependent queries. For example from concept "outside night" the concepts manager generates a research of dark images with brilliant yellow lights.

4.3. thesaurus manager

Concepts are maintained in the thesaurus in the form of a semantic network or correlation coefficients. In the example of the concept of "outside night", this concept is explicitly present in the script and associates a certain number of scenes with a corpus of videos. A statistic is undertaken on the color histograms of these scenes. The thesaurus manager derives a correlation between the concept and some values of this histogram. The representation of the thesaurus is one of the problems under study.

4.4. Indexer

indexer of structured texts

This indexer leans on text summaries extracted from the structure which is modelized in SGML (see Essence). Leaves of the index describe key words or key sentences and the element of the structure to which they belong (title, etc. ..).

Annotations are also indexed, which allows to retrieve a document from a numerical note or a textual appreciation.

image indexer

For each image the indexer builds one or several color histograms, possibly a low definition image(icon), as well as an index of simple segmented objects.

sounds indexer

We start with signatures of the different types of sounds presents in the sound channel. These signatures can be established with or without user assistance. The system localizes time intervals corresponding to each speaker or each type of non spoken sound (animals, music, hummed, silences). With the vocal dictation, we map each sound sequence with the text pronounced in this sequence.

video indexer

The purpose of this indexation is on the one hand to segment the video in scenes, each composed of one or several plans, on the other hand to map each scene with representative still images, lists of objects in movement, speakers of the scene, and the text of the script.

4.5. Profiler

The role of the profiler is to extract permanent textual requests, or profiles, from immediate user requests. Permanent requests are also transformed in such a way to become monotonous and incremental. In a first time, long term requests will be composed of the most frequently present keywords in immediate requests. These keywords can be derived from more specific ones (for example a keyword"architecture of computers" will be derived of short-term queries on " microprocessors " "AS400" "DSP").

4.6. Examiner

The examiner chooses an external location server, formulates the request in the language of this server, collects results, evaluates these results. A reference provided by a location server is usually accompanied by a title, name of authors, URL, summary, etc. .. These data are analyzed to verify the document relevance. The learning of relevance criteria can be made on the thesaurus or from users appreciations.

4.7. Gatherer

The gatherer researches documents that are favorably evaluated by the examiner. It simultaneously retrieves documents from several documents servers, as a function of transfer throughputs. Obtained documents are transferred to the storage system, which possibly notifies them to the user.

4.8. storage system

naming mechanisms

Documents are referenced in secondary memory by a file name derived from the URL, and in tertiary memory by a physical identifier (name of the cd-rom and address in the CDROM). There are three file types: documents, annotations, summaries. An annotation file contains all annotations of a document. A summary file can be a directory containing different summary types (textual summary, histogram, etc. ..).

For example for a document with URL MyURL, derived files are the following:

/ UDOC / doc / MyURL	for the document himself
/ UDOC /summary / MyURL	for the summary
/ UDOC / note / MyURL	for the list of annotations.

The URLs dictionary will insure the mapping between URL and physical address, and will allow to research if an URL already exists in the database.

cache and archive manager

To allow an efficient placement in tertiary memory, documents are grouped in the cache by user or profile and by access date. The documents of a same user constitutes a cluster.

The archive is stored in a tertiary memory (juke-box of CDROMs), and preserves documents in the long term. Documents of a cluster are stored in contiguous pages of a same CDROM.

Videos will be stored in the system only during their indexation.

5. Project status

A rapid prototype of the U-Doc server is presently being implemented, in order to evaluate some of the main issues of the architecture. The prototype can store distant, composite documents, and local documents, including MPEG videos, PostScript files, and textual annotations. Main issues are concept based filtering of the retrieved documents in order to eliminate irrelevant ones, extraction of profiles from immediate queries, scenes or "paragraph" indexing in videos, adequate use of textual annotations for cooperative retrieval, joint retrieval of textual and video documents. The corresponding results will be the subject of further papers.

The prototype is implemented in Perl for most external interfaces (examiner, gatherer, mailer), and in C++ for the internal modules. Visual C++ is used for DBQE. The text indexer is based on a version of Glimpse, from the University of Colorado. This is appropriate for

rapid prototyping. Due to the moderate performance of Glimpse, it will be necessary to study more performing indexers for the final prototype. Glimpse response times for average databases and index sizes are about tens of seconds. They may be appropriate for a local server with hundreds of connections per day, not for a real-scale document server with distant access and several queries per second.

In the present prototype, video indexing is based on calculation of Euclidian distances on a 256-element color histogram, using the RGB color representation. Distances are calculated between representative frames of the current shot and of several previous shots. Representative shots are defined by their place in the shot (first frame plus x frames, last frame minus x frames, intermediate frame). More elaborate color histograms, with a very large color space and Munsell color representation, are under study. Video indexing enables us to automatically retrieve video paragraphs, based on sparse annotations. Performances of scenes video indexing will be published in another paper. Use of speaker recognition is also under study in collaboration with another team. Speaker recognition returns a mapping of speaker names on various time intervals.

External access to the prototype will be first limited to researchers from our laboratories. We should begin to populate the server with real distant documents by the end of 1996. A major issue for populating the database is access rights on the videos. Presently the video database is for local use within the member laboratories.

6. Conclusion

In this article, we have presented the UDoc architecture, that describes a thematic mirror based on the filtering of composite documents which are present on the Internet or on others large networks. This architecture allows to access documents of the Internet, that represent the planetary database, and data of the Intranet, constituted by private user documents and by annotations of the other documents.

The project started in 1995, as an answer to a call for proposals on the "Information Highways" from the French Government. The main innovations of the project concern the integration of content based retrieval in images, sounds and videos, retrieval by domain-independent concepts, the thematic mirror architecture, and the development of adapted techniques for the placement in tertiary memory. The disposition of new technical means of multimedia document indexation will allow a more massive utilization of these documents, whose utilization is currently limited on the large networks.

Our approach will be validated, in terms of utilization rate of the UDOC system , as well as in terms of gains in response time and relevance of accessed multimedia documents, by an experimentation in true magnitude, with panels of users from the campus of the participating universities.

Currently we are prototyping UDOC, with simplified functionalities (limited to structured texts and permanent images), and we study the indexing of sounds and videos, in collaboration with others research teams, working on images and sounds (Heudiasyc, Laforia) and an industrial partner (STSI).

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