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A Picture-based Document Retrieval Service for the Electronic Visualization Library

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Abstract

This report describes the development of an experimental service for picture-based document retrieval for the Electronic Visualization Library (EVlib). The EVlib is a digital library for scientific visualization, established at the Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB). The picture-based retrieval service allows users to look for documents by describing the pictures they contain. This query method was developed based on the assumption that (1) pictures often represent relevant parts of the contents of a document, and (2) pictures are often remembered well. A picture-based approach provides a new quality of accessing and exploring scientific literature.

Motivation, concepts and realization of our service are outlined. Results of a user test are presented, too. The results indicate that this service can be used for searching and browsing the document collection in principle. On the other hand, problems were detected which can give fruitful hints for future work concerning document and image retrieval.

Keywords: information retrieval, document retrieval, image retrieval, digital library, picture memory, visualization, user interface

1 Introduction

In this report we outline the motivations, concepts, development and a user test of an experimental image retrieval service (IRS for short) as an example for a picture-based access to scientific literature. The development of this service was part of the project "Information services for Scientific Visualization" (VisInfo)[1]. The IRS is described in a german master's thesis [7] in more detail. Here, a summary of this work is presented.

Pictures are of great importance in human communication processes. Pictures can represent knowledge [38], and they often represent a fact much better than verbal descriptions [8]. Usually, they can be quickly interpreted [25].

Thus, pictures are regarded valuable in didactic and scientific literature. Indeed, in literature on some subject areas one can find a huge number of pictures or figures. Especially, this is true for scientific visualization and computer

[1] See `http://visinfo.zib.de`.

graphics (see table 1). There, one can find about eight figures in each article. For other subject areas this might be true, too.

	Proc. ACM SIGGRAPH			*Proc. IEEE Visualization*	
	1997	1992	1986	1997	1992
Fig. per article	9.5	7.8	11.7	7.0	7.0
Fig. per page	1.2	1.1	1.4	1.1	1.0
Articles with figures	90%	75%	100%	95%	88%
Pages with figures	70%	57%	65%	61%	47%

Table 1: Numbers of figures or pictures in articles of the Proceedings IEEE Visualization and ACM SIGGRAPH. On the average, each article contains about eight figures.

Scientists often have to look for documents (literature). In libraries, this search is usually done using verbal descriptions, e.g. keywords. This is the main approach for document retrieval though some problems might occur. Uncertain semantic representations of documents, ambiguous words, or people forgetting specific keywords may cause problems. In addition, it is often quite annoying to read a long list of titles in a result set of a query.

Looking for documents on the basis of pictures may be viewed as an alternative and complementary search method. In addition, it provides a more "sensuous" access to literature than a pure text-based approach. Furthermore, Entlich et al. report that users "particularly like looking at pictures" and "make extensive use of thumbnail-sized versions of the figures in the articles for browsing" [10].

In some projects this method has already been realized. The Chemical Abstracts Service (CAS) provides a tool for searching for chemical information by drawing chemical structures [5][2]. In [23] the authors describe the DocBrowse system which allows queries for office documents by pictures (logos, emblems). Aho et al. [2] describe the "Columbia Digital News Project" where — among other things — images may lead users to related (multimedia) documents.

The service described here (IRS) provides an alternative access to documents stored in the Electronic Visualization Library (EVlib). The EVlib is a digital library for scientific and data visualization [29][3] developed at the Konrad-Zuse-Zentrum für Informationstechnik Berlin (ZIB).

The IRS allows users to browse through all the pictures extracted from documents of the EVlib. Each picture provides a link to its document. To submit a query, users describe remembered or desired pictures by specifying (only) visual features using "query-by-image-example" or a drawing. Thus, a user may find related documents by looking for similar pictures.

Section 2 of this report first deals with pictures and the human visual memory. Studying phenomena of picture memory and visual perception may give fruitful hints and motivations for the development of an image and document retrieval system. In section 3 we outline the realization of our system. Section 4 reports the results of a user test. It was especially interesting whether it is

[2]See `http://www.cas.org/`.
[3]See `http://visinfo.zib.de/EVlib`.

possible to find pictures — and hence documents — only on the basis of visual features of pictures. A summary and a discussion are following in section 5. Section 6 mentions plans for future work.

2 Pictures and Picture Memory

First, we assume that pictures and figures in scientific literature are perceived by readers. They usually show certain contents of the subject not adequately represented in the text, and authors are frequently asked to mention them explicitly.[4] Furthermore, pictures are an eye catcher. Readers are usually looking at the pictures first (cf. [28, p.134] and [25, p.15]).

Intraub [18] and Paivio and Codes [34] show that a fraction of a second of perception may be sufficient to remember and recognize pictures. Haber states that humans have a "vast memory" for pictures which seems to be almost limitless [48, 13].

Nevertheless, — and this is important for image retrieval in general — there are significant differences in the ability to recognize and to recall pictures.

Many studies [13, 15, 16, 17, 18, 27, 30, 31, 48, 47] indicate that pictures can be recognized with a probability of up to 90% [31, 48]. For example, Standing, Conezio, and Haber report a study where subjects looked at 2560 pictures (photographs) for only a few seconds. In a recognition test they were asked to decide which one of two shown pictures they recognize. About 90% of the answers were correct [48]. Standing experimented with 10.000 photographs and after two days subjects recognized up to 66% correctly [47].

In some studies the recognition of words and phrases were tested in parallel. The authors report that pictures are recognized better than words or phrases [24, 42, 47]. This result also motivates a picture-based approach to document retrieval.

The high ability of humans to recognize pictures requires that an image retrieval system ought to provide a browsing facility. Users may find pictures by browsing through the repository and recognizing the desired ones, or they may detect other interesting pictures related to their topic.

In a large repository, this is too time-consuming, and users have to describe the pictures they look for somehow. They have to recall them or at least some features.

Recalling pictures is a much more difficult task. There are many studies dealing with picture recall. Most of them describe experiments where subjects had to recall the semantic features of pictures by describing the shown objects verbally [9, 11, 17, 34, 35, 41]. Similar to the recognition task, some authors conclude that pictures are superior to words: "Clearly, pictures are not only recognized better but are also recalled better than words" [47].

Only few authors report experiments where subjects had to draw a remembered picture [13, 21, 26, 19, 20]. Results of such studies could be valuable for the development of image retrieval systems because they show some more details about what is remembered and how, e.g. which visual features. Unfortunately, there are only a few drawings of subjects presented [13, 21, 20], and there are only a few remarks on colors.

[4] See "instructions for authors" e.g. provided by the publisher Springer Verlag as described in the *International Journal on Digital Libraries* 1(4), Dec. 1997, p.A2.

One important phenomenon of perception and/or picture memory in this context is the "boundary extension" reported by Intraub et al. [19, 21, 20]. Humans tend to remember and draw central objects smaller than they were physically presented. The boundaries of the represented scene are extended.

For image retrieval systems based on visual features and drawings of users this may cause problems.

Another interesting phenomenon is reported by Prinzmetal et al. [37]. They realized that a shift occurs in the memory for colors. Humans tend to remember a slightly shifted hue than was physically presented. But, on the other hand, the uncertainty of memory can be reduced by higher attention to the presented stimulus. This is also true for features like location and orientation of objects.

Some authors state that colors of pictures or objects can be remembered quite well. Spatial relations and orientation of visual objects are said to be remembered well, too [39]. This may justify to regard colors and the layout of pictures in an image retrieval system.

3 System Overview

The "image retrieval service" (IRS) was first of all designed as a tool for image browsing and searching with a WWW user interface. Each image provides a link to the respective document stored in the Electronic Visualization Library (EVlib). Thus, picture-based document retrieval is done by first looking for relevant pictures and then following the respective link.

3.1 System Structure

The Electronic Visualization Library stores Postscript or PDF versions of documents as far as available, otherwise the bibliographic data only. At the moment, there are about 1000 documents collected, about 50% with Postscript or PDF files.

The acquisition of these documents is done by registered users — no librarian. We do not expect these users to provide additional information about the pictures. Thus, no verbal description for them is available and hence no keyword search possible. Therefore we extract visual features of the pictures and store information about their position within the document.

Pictures — we consider colored or black–and–white ones, sketches, graphics, and tables — are extracted from the rendered Postscript versions automatically using page segmentation algorithms.

The extracted pictures are stored in a picture database. Currently, this database stores about 5000 pictures. Visual features are extracted and indexed. Currently, we are using the QBIC software [3, 12, 14] as the basis for visual feature indexing and retrieval. The version of QBIC software we are using provides functions for indexing and retrieval regarding "mean color", "color distribution", "color layout" and "texture". It provides a programming interface for own extensions. We added two additional features: (1) The aspect ratio of a picture, and (2) a feature we call "composition". This is based on a haar wavelet decomposition similar to the one described in [22].

Relations between pictures and the pages and documents on/in which they appear are stored in a separate database.

A query module performs the retrieval using QBIC functions as basic operations. The results of these operations are combined in complex queries (see below). The picture–page–document relation is used to exclude documents which do not match certain query criteria.

The functionality of this query module was defined by a textual query language. A graphical user interface for the WWW then provides a more natural way to formulate queries. Those queries are translated to queries written in the textual language of the query module. Thus, different user interfaces may be designed for the same query module.

3.2 Query Facilities

One can distinguish between two major purposes of users of a library:

1. Retrieval of a document they have viewed before ("exact queries").
2. Search for documents related to a certain topic ("vague queries").

We focused on the first one, but the search methods we provide may be applied for the second kind of queries, too.

With regard to retrieval, we assume that readers of a document are able to remember (1) some semantic and visual features of pictures, (2) some information about their positions, and (3) possibly some information about the number of pictures in the document ("there was exactly one") or on some pages ("there was a combination of eight pictures on one page"). Whether this is true — and to which extent — has to be examined in future work.

The query module and the textual query language of the IRS were designed to enable queries which regard these features. A user may describe and look for pictures only ("simple query"). A textual query for a picture may be written like the following example:

```
PIC (Colors = Picture1, AspectRatio = Picture2)
```

In natural language, this means "Look for pictures with colors like `Picture1` and an aspect ratio like `Picture2`". One may also describe a document by specifying one or more pictures and pages and the above mentioned features. For example, the "advanced query"

```
DOC (N>5, PAGE (PIC (Colors = Picture1),
                PIC (AspectRatio = Picture2) ) )
```

represents a request which reflects the memory for "a document with more than five pictures where there was a page with (at least) two pictures; the colors of the first one were similar to `Picture1` and the aspect ratio of the second one was similar to `Picture2`".

The result of such a query will consist of list of documents ordered by similarity to this description. The similarity measure is computed from the similarity values of the single feature–picture-queries. Each document containing less than five pictures is removed from the list.

As one can see, the main technique for describing (desired) pictures is through "query-by-image-example". A user describes a desired picture by giving examples which are similar to it in some way. "Query-by-drawing" is almost the same since a drawing can be used as an example.

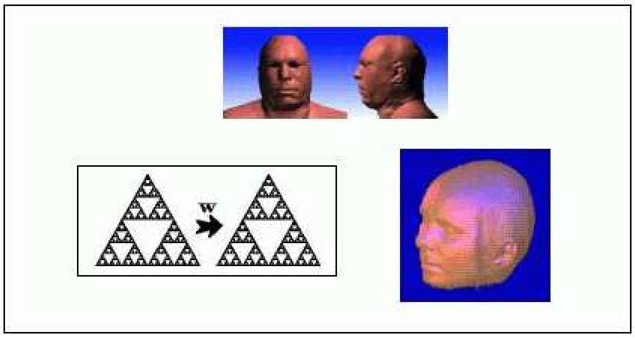

Figure 1: Example for using more than one picture to specify a desired picture.

Query-by-image-example is a common technique used for image retrieval. Well-known image retrieval systems provide this method, e.g. the interfaces to QBIC [12], VisualSEEk [43, 44], or the Virage Image Engine [4].

Usually, this can be done only by selecting one picture and one visual feature at a time. In some cases, this might not be sufficient to specify what a user wants to look for. If there is not "the one example" but some others, which resemble the desired picture in some visual features each, a user might want to be able to use more than one example in the query formulation. Let the upper picture in figure 1 be the desired one, below, two of those available as examples. The language of our query module allows to formulate a query like this: "Look for a picture which is similar to the one on the left regarding aspect ratio and similar to the one on the right regarding colors."

3.3 User Interface

The graphical user interface provides methods for query formulation in a more natural way than the textual language explained above. It can be accessed via WWW[5].

Though the textual language is quite powerful, we decided to offer only a subset of the possibilities in the first version of the user interface.

Query formulation is done as follows. A user first selects pictures from a random set (figure 2) which are similar in any way to the desired ones. In a second step the actual query is specified. To submit a "simple query" (figure 3) for each of the selected pictures a user tells the system which visual features have to be considered. The result of the query in figure 3 is shown in figure 4.

An "advanced query" — describing a document in more detail — is specified as follows. Users select pictures like they do for a "simple query". In the second step, they describe (only) up to three pictures which are supposed to appear in a document (figure 5). Additionally, they can define whether two or all the three pictures appear on the same page. The result of the example query in figure 5 is shown in figure 6.

This interface may serve simply as an image browser. It allows to explore the "visual contents" of the document database. This represents an alternative access to the literature collected in the EVlib. If a user is just looking for

[5] See `http://visinfo.zib.de/IRS`.

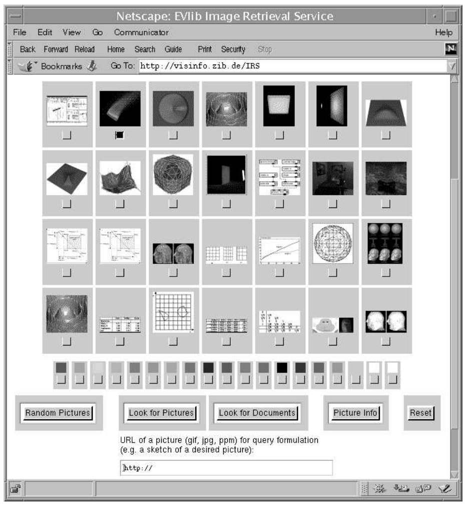

Figure 2: Image browser of the image retrieval service.

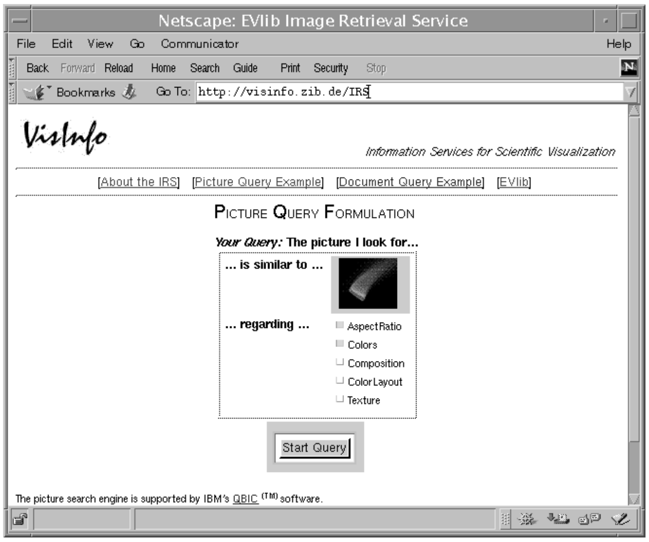

Figure 3: Simple query formulation. For each selected picture a user specifies which features are relevant.

pictures, he or she might use other example pictures to describe what kind of picture he or she wants to retrieve. This will often be sufficient to retrieve a document. If a user is able to remember some more details of a document he or she wants to retrieve, there is the "advanced query" possibility, which allows to refine and restrict the search.

A search based on picture similarity might also serve as a method for finding related documents ("vague queries"), assuming that in some cases visually similar pictures represent similar semantic content. This is naturally not always the case. Nevertheless, we observed that it is often true for pictures in literature concerning scientific visualization.

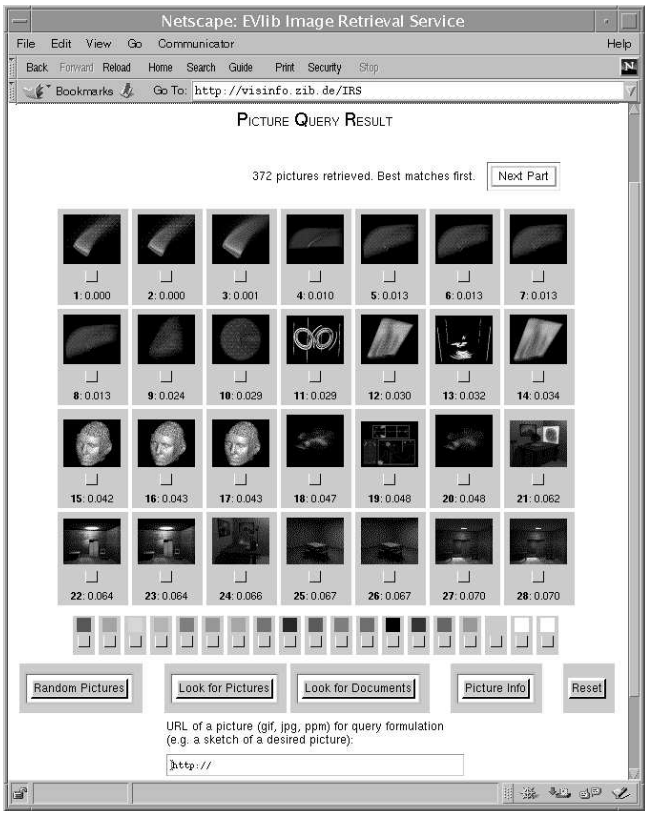

Figure 4: Result set of a simple query.

4 Tests and Results

The use and benefits of the current implementation and user interface were examined using "usability inspection" methods as described e.g. in [32, 33, 36]. We chose to log some interaction data ("interaction logging") and a user test with observing and "thinking-aloud".

4.1 Interaction Logging

First, we wanted to get information about how the service is used in general. It was especially interesting what kind of queries and which features users mainly apply. This might give some hints for a redesign.

The service is online since Septemper 10, 1998. Interaction protocols were evaluated from 43 days. Interactions like query formulations were logged.

Mainly, users applied the "simple query". Only a few times the "advanced query" was tried, but here some errors were made. This is obviously a weakness of the interface to allow erroneous queries.

Most of the time "query-by-image-example" was done using only one picture (see table 2) and only one visual feature (see table 3). The features which were mostly chosen were "composition" and "colors" (see table 4). "Composition" may have been viewed as an overall similarity measure regarding objects and

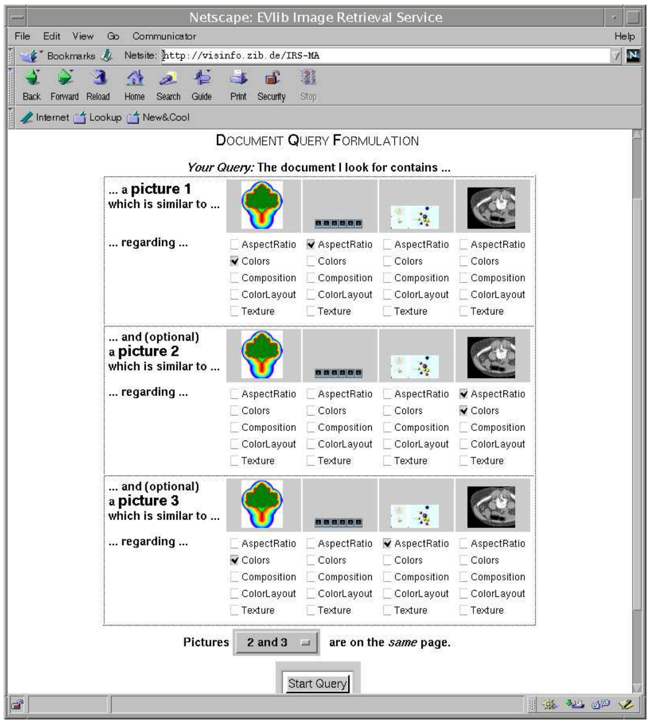

Figure 5: Advanced query formulation. A user can describe up to three pictures by specifying similar features.

spatial relations. Actually, it implied the feature derived through a wavelet decomposition [22] but, unfortunately, this was not mentioned anywhere.

Pictures per query	Frequency
1	127
2	35
3	21
4	9
5	1
6	3
7	1
10	1
14	1

Table 2: Frequency of the number of selected pictures per query.

One might conclude that users tend to apply only a small and simple subset of query possibilities. The WWW page showing the form for an "advanced query" might have been too "scary" and misleading because of complexity.

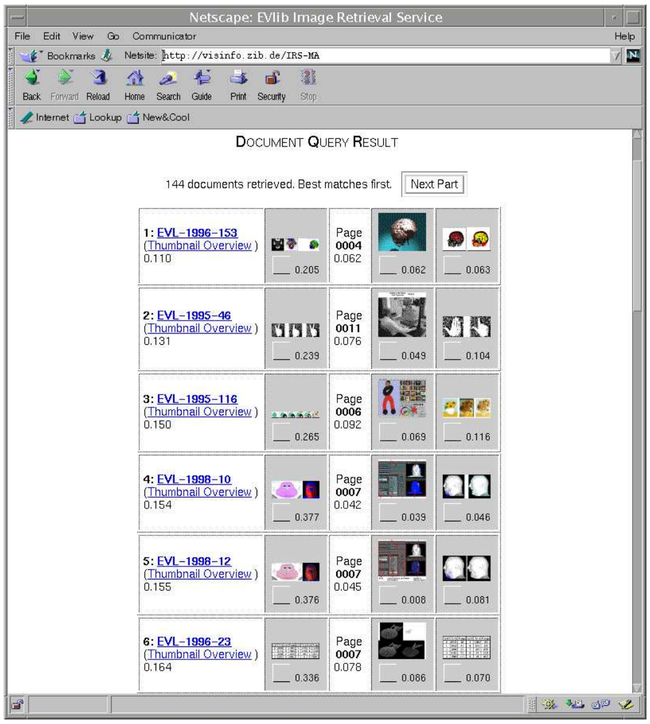

Figure 6: Result set of the advanced query in figure 5.

Number of features per query and picture	Frequency
1	213
2	81
3	29
4	14
5	13

Table 3: Frequency of the number of specified features of a picture.

Chosen feature	Frequency
Composition	180
Colors	150
Texture	117
Aspect Ratio	71
Color Layout	65

Table 4: Frequency of selected features.

4.2 User Tests

To get a deeper impression of how the IRS is actually used and which problems may occur, we performed a test with three potential users. Subjects were asked to retrieve three documents each. The three example documents were shown briefly, then the subjects had to search them using only the IRS. This an unrealistic and ideal situation. Nevertheless, valuable information was expected to be gained from this test, since "usability inspection" mainly aims to get hints on problems using a software system [36]. Subjects were asked to "think-aloud" and they were silently observed while performing their queries. They did not receive any help.

Main results were the following. Effective retrieval is possible but time-consuming. In eight out of the nine cases the documents were found. The formulation of a query using some pictures and some features was a little difficult to understand in general. But after learning this method, it could be used more effectively and efficiently. In two cases, pictures of the desired documents were displayed in the result set but were not recognized.

The "advanced query" was more difficult to understand and rarely used. One person stated that such a complex query will only be necessary to apply if the simple one is not succesful. Most of the time the simple query would be sufficient.

Often, subjects had problems recalling visual features instead of the semantic contents (objects, themes etc.). Apparently, it is sometimes difficult to seperate or identify distinct features.

In some cases subjects drawed a desired picture. It is noticeable how much these drawings differ from the originals while they had been viewed some minutes before. The drawings are shown in figures 7 a) through j) in comparison to the originals. It is also noticeable that some of the drawings clearly show the "boundary extension" phenomenon mentioned on page 4. In addition, colors sometimes could not be remembered anyway.

Eventually, it could be observed that browsing through the collection of pictures seemed to be an inspiring task, and the pictures often lead subjects to look for the respective documents.

5 Summary and Discussion

This report described an experimental and exemplary realization of a picture-based document retrieval tool (IRS). Our tool can be used to visually explore the contents of the Electronic Visualization Library. Since pictures are usually interpreted quite easily and users like to look at pictures [10], one can get a quick, comprehensive and "sensuous" overview of the repository. The probability of finding interesting documents while browsing through pictures may be higher than while browsing through a list of titles.

In addition, Users can look explicitly for pictures — and hence for documents — by applying simple or quite complex queries based on visual similarity of pictures.

We performed a user test which showed some problems which may affect future work for picture-based document retrieval and image retrieval in general.

The reduction to visual features only may be a quite serious problem, since

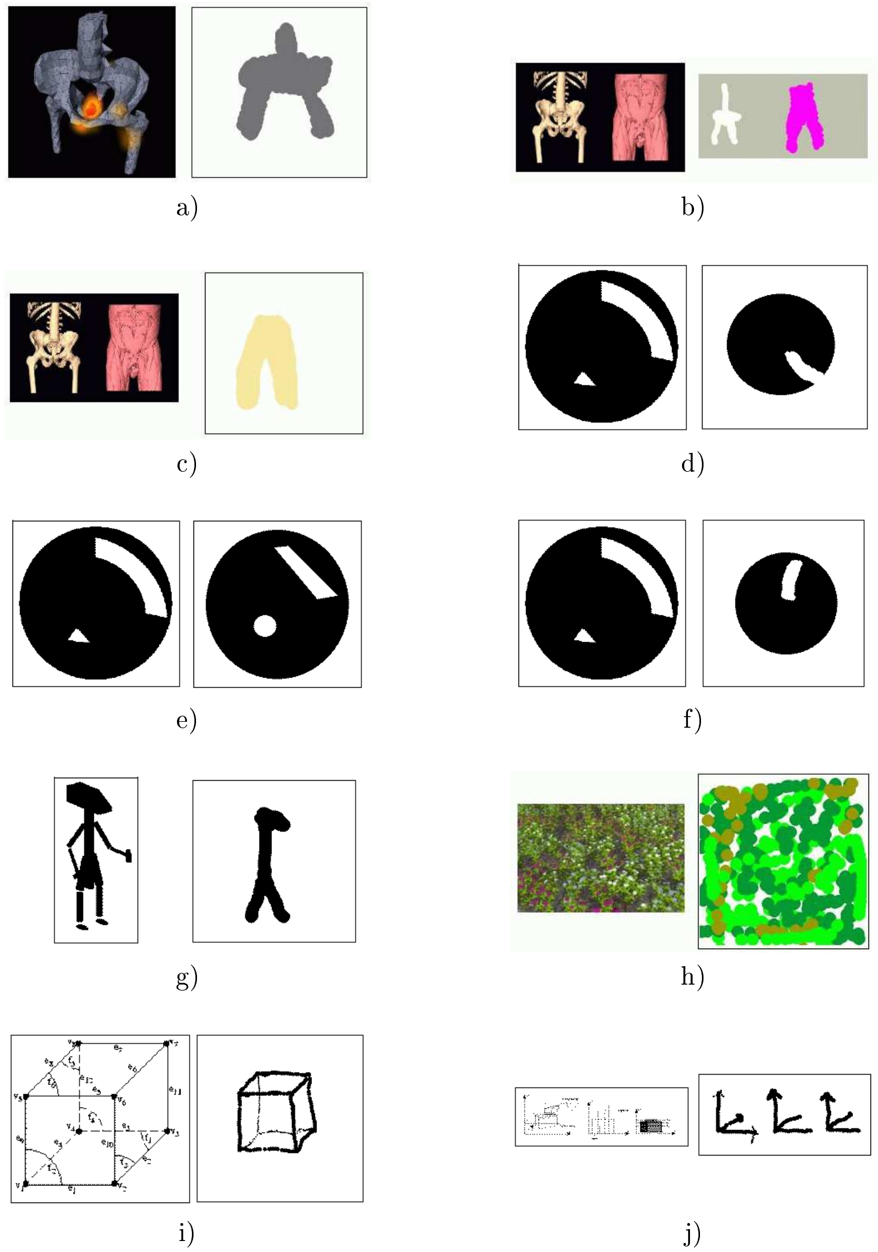

Figure 7: a) – j) Sought pictures (left of each in a–j) and drawing of a subject as a description of the sought picture (right).

apparently they often can not be recalled good enough to formulate an effective query. But while a user is browsing through the pictures he or she might recognize similar ones.

The query facilities of our service are quite powerful, though the current user interface only provides a subset of the query language. As a result of the tests, it seems questionable whether it would be reasonable to offer more detailed query facilities. One can conclude that the user interface has to be very simple.

Sometimes the search results are quite poor. This may be influenced by some search and comparison algorithms used in the IRS which refer to the absolute positions, sizes, and/or colors of visual objects. This is especially problematic if a picture is drawn with different sizes of objects — cf. the "boundary extension" problem. Algorithms which refer to relative positions and the relations between visual objects would possibly be of benefit.

Scientific visualization is a subject area where there are naturally many pictures found in the respective literature. Another subject area where a picture-based query method can be used (and is used) is chemistry, as mentioned in the introduction. For arts, such a system might be useful, too, provided there are really enough pictures in the respective literature.

Unfortunately, the EVlib provides full-text or Postscript versions only for a part of the document collection. But for other libraries which store full text versions for each document, a picture-based query service could be of great benefit.

A picture-based query for literature seems to be a quite new and uncommon but interesting approach. It leads to other results than text-based queries and provides a different quality in general. How and whether this quality really pays out has to be examined in future work.

6 Future work

Future work on our service will focus on a simple user interface and on the comparison algorithms used for evaluating queries. The current set of algorithms should be complemented by methods which try to regard phenomena of visual perception and memory as mentioned in section 2. Then, picture-based and text-based search methods could be combined.

Further empirical tests should be performed to evaluate and further improve the picture-based query approach.

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