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Collection guiding: review of the main strategies for multimedia collection browsing

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1 Introduction

This report describes the state of the art in the development of image collection browsing and overviewing. This is motivated by the fact that such activities are complementary to search operations and may provide efficient solutions where search tools are deficient due to the lack of representative semantics within the documents.

2 Image Collection Browsing

Many current information management systems are centered on the notion of a query. This is true over the Web (with all classical Web Search Engines), and for Digital Libraries. In the domain of multimedia, available commercial applications propose rather simple management services whereas research prototypes are also looking at responding to queries (see section 4 for details and examples). The notion of browsing comes as a complement or as an alternative to query-based operations in several possible contexts that we detail in the following sections.

2.1 Browsing as extension of the query formulation mechanism

In the most general case, multimedia browsing is designed to supplement search operations. This comes from the fact that the multimedia querying systems largely demonstrate their capabilities using the Query-by-Example (QBE) scenario, which hardly corresponds to a usable scenario. Multimedia search systems are mostly based on content similarity. Hence, to fulfill an information need, the user must express it with respect to relevant (positive) and non-relevant (negative) examples [39]. From there, some form of learning is performed, in order to retrieve the documents that are the most similar to the combination of relevant examples and dissimilar to the combination of non-relevant examples. The question then arises of how to find the initial examples themselves. Researchers have therefore investigated new tools and protocols for the discovery of relevant bootstrapping examples. These tools often take the form of browsing interfaces whose aim is to help the user exploring the information space in order to locate the sought items.

The initial query step of most QBE-based systems consists in showing images in random sequential order over a 2D grid [39]. This follows the idea that a random sampling will be representative of the collection content and allow for choosing relevant examples. However, the chance for gathering sufficient relevant examples is low and much effort must be spent in guiding the system towards the relevant region of information space where the sought items may lie. Similarity-based visualization [8, 9, 24, 27, 29–31, 36, 43] organizes images with respect to their perceived similarities. Similarity is mapped onto the notion of distance (section 3.1) so that a dimension reduction technique (see section 3.2) may generate a 2D or 3D space representation where images may be organized. Figure 1 illustrates the organization of 500 images based on color information using the MDS dimension reduction [36].

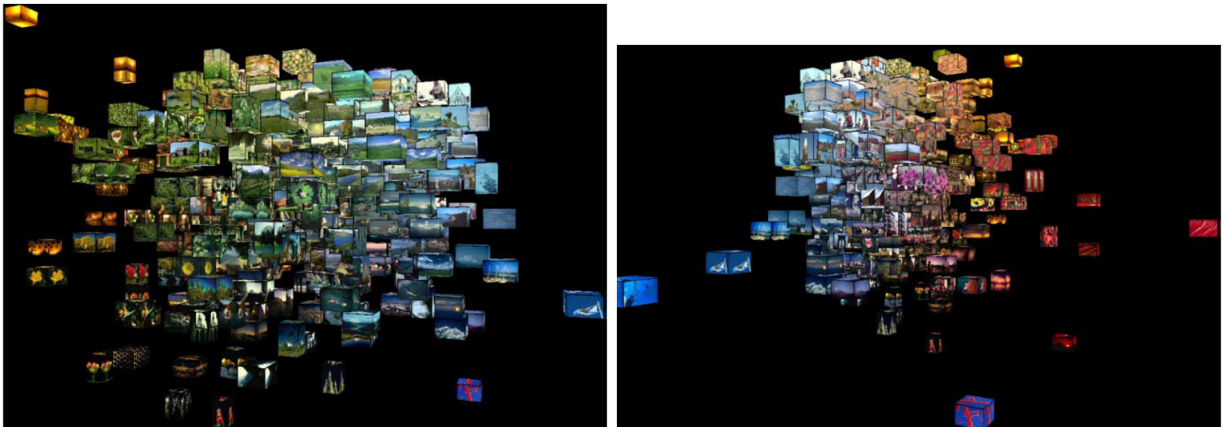


Figure 1: Two views of the MDS mapping of 500 images based on color information

This type of display may be used to capture feedback by letting the user re-organise or validate the displayed images. Figure 2 shows a screenshot of the interface of El Niño [37].

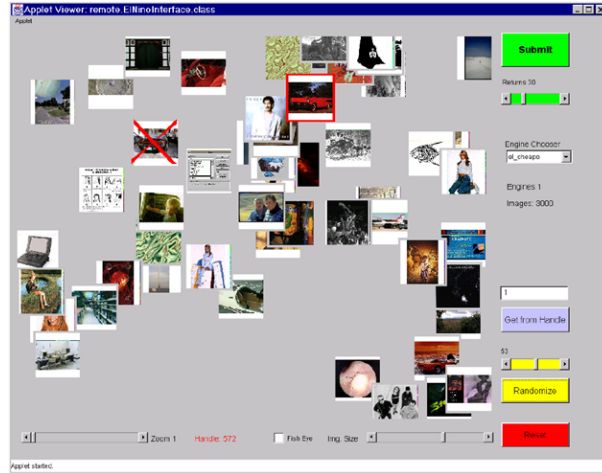


Figure 2: Interface of the El Niño system [37] where image similarity is mapped onto planar distance

Specific devices may be used to perform such operations. Figure 3 shows operators sitting around an interactive table for handling personal photo collections [27].



Figure 3: The PDH table and its artistic rendering (from [27])

In Figure 4, an operator is manipulating images in front of a large multi-touch display¹.



Figure 4: Manipulating images over touch-enabled devices

Alternative item organizations are also proposed such as the Ostensive Browsers (see Figure 5 and [42]) and interfaces associated to the NN^k paradigm [19].

All these interfaces have in common the fact of placing multimedia retrieval much closer to human factors and therefore require specific evaluation procedures, as detailed in Section 5.

¹From <http://www.perceptivepixel.com>

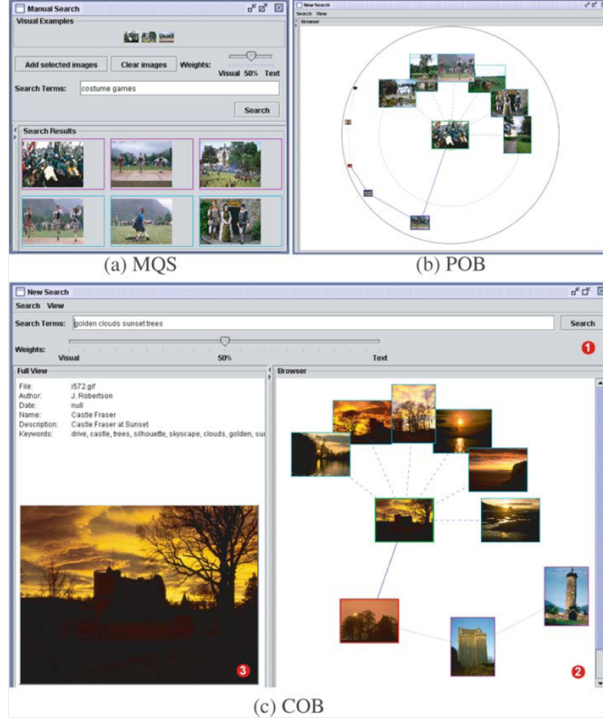


Figure 5: The Ostensive Browsers [42]

Although somewhat different, it is worth mentioning here the development of the Target Search browsers. Whereas using QBE-based search a user may formulate a query of the type show me everything that is similar to this (and not similar to that) and thus characterize a set of images, using Target Search, the user is looking for a specific image (s)he knows is in the collection. By iteratively providing relative feedback on whether some of the current images are closer to the target than others, the user is guided to the target image. This departs from the QBE-based search where the feedback is absolute (this image is similar to what I look for, whatever the context). In that sense, Bayesian search tools may be considered as focused collection browsers. In this category, the PicHunter Bayesian browser [12] is one the initial developments. It has been enhanced with refocusing capabilities in [28] via the development of the Tracker system.

2.2 Browsing for the exploration of the content space

In the above cited works, browsing is seen as an alternative to the random picking of initial examples for the QBE paradigm. Here, we look at browsing from a different point of view. In this setup, the user aims at overviews the collection with no specific information need. Simply, (s)he wishes to acquire a representative view on the collection. In some respect, the above developments may be included into this category as overviews of the sub-collection representative to the query in question. In [23], specific presentation layouts are proposed and evaluated (see also section 5). The interface aims at enhancing the classical grid layout by organising related image groups around a central group (see Figure 6).

Somewhat similar is the earlier development of PhotoMesa [2] which aims at browsing image hierarchies using treemaps (Figure 7).

Hierarchies are also studied in depth in the Muvis system, both for indexing and browsing via the Hierarchical Cluster Tree (HCT) structure [22]. In figure 8, an example of hierarchical browsing of a relatively small image collection (1000 images).

In [13], the alternative idea of linearising the image collection is presented. The collection is spanned by two space-filling curves that allow for aligning the images along two intersecting 1D path. The reason for allowing two paths is that while two neighboring points on a space-filling curve



Figure 6: Bi-level radial layout [23]

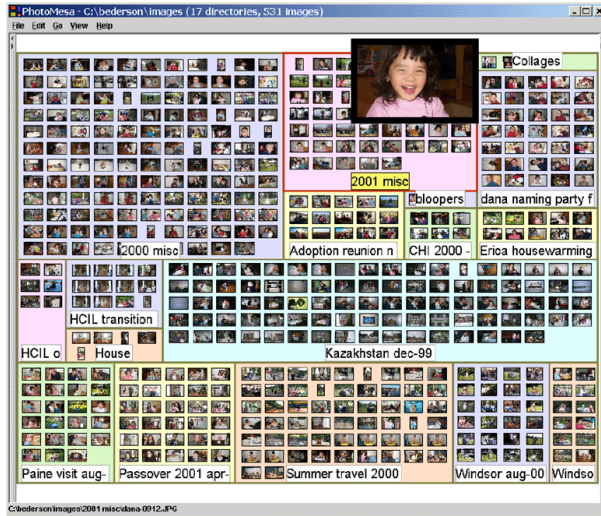


Figure 7: Screenshot of PhotoMesa, based on TreeMaps [2]

are neighbors in the original, the converse is not guaranteed to be true. Hence, two neighboring points in the original space may end up far apart on the path. The use of two interweaved curves may alleviate this shortcoming.

At every image, each of the two paths may be followed in either of the two directions so that at every image, 4 directions are allowed. A browser shown in Figure 9 is proposed to materialize this visit.

In [25], the principle of Collection Guiding is introduced. Given the collection of images, a path is created so as to guide the visit of the collection. For that purpose, image inter-similarity is computed and the path is created via a Travelling Salesman tour of the collection. The aim is to provide the user with an exploration strategy based on a minimal variation of content at every step. This implicitly provides a dimension reduction method from a high-dimensional feature space to a linear ordering. In turn, this allows for emulating sort operations on the collection, as illustrated in Figure 10.

The Collection Guide provides also several multi-dimensional arrangements (see Figure 11). However, it is clear that these (as the ones presented in the above section) are conditioned to the quality of the dimension reduction strategy. In [40], the underlying data cluster structure is accounted for so as to deploy valid dimension reduction operations (see section 3 below for more details).

Finally, at the border between exploration and search, opportunistic search is characterised by uncertainty in users initial information needs and subsequent modification of search queries to improve on the results [21, 33]. In [33], the authors present a visual interface using semantic fisheye

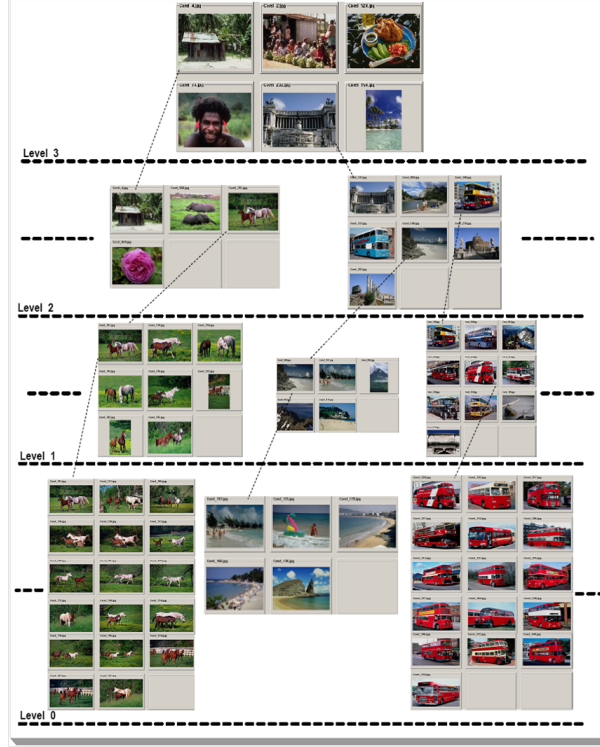


Figure 8: An example of HCT-based hierarchical navigation [22] on the 1k Corel image collection

views to allow the interaction over a collection of annotated images. Figure 12 displays interfaces associated with this concept.

Faceted browsing [17], oriented towards search is also at the limit between exploration and querying as it also for filtering a collection while smoothly and interactively constructing complex queries. Figure 13 displays an example application of Faceted Search using the Flamenco toolbox for a collection of annotated images.

2.3 Browsing to aid content description

While retrieval and browsing are in general passive to the collection (ie the collection stays at it is), these operations may also be used to enrich the collection content. In (Kosinov, 2003), authors have reviewed and proposed several models that allow for the semantic augmentation of multimedia collections via interacting with them. This follows the line of the Semantic Web and associated domains of knowledge management. In this line, the work proposed in [38] relates ontology management and image description.

3 Multimedia Space Representation

From a multimedia (image, in our case) collection, one should derive a representation that is both easy to handle via mathematical tools but which also account for the intrinsic meaning (semantics) of the content. From there, operations such as sampling and visualization are made possible. We overview briefly the possibilities in the next sections.

3.1 Generic feature space representation

There are well-known image representation techniques in the image compression and retrieval literature [39]. Among them, features such as color, texture and shape emerge as the most global

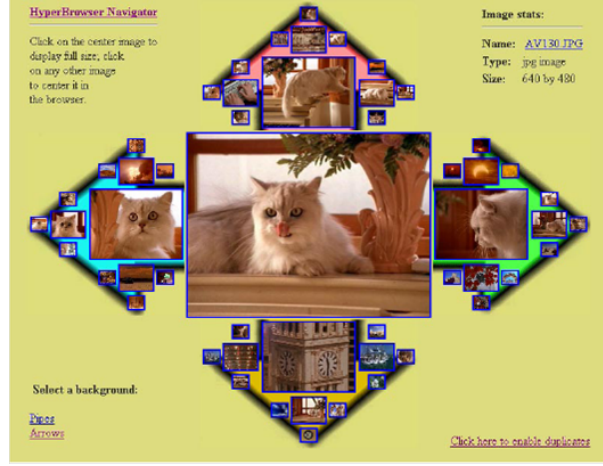


Figure 9: Multi-linearisation browser [13]

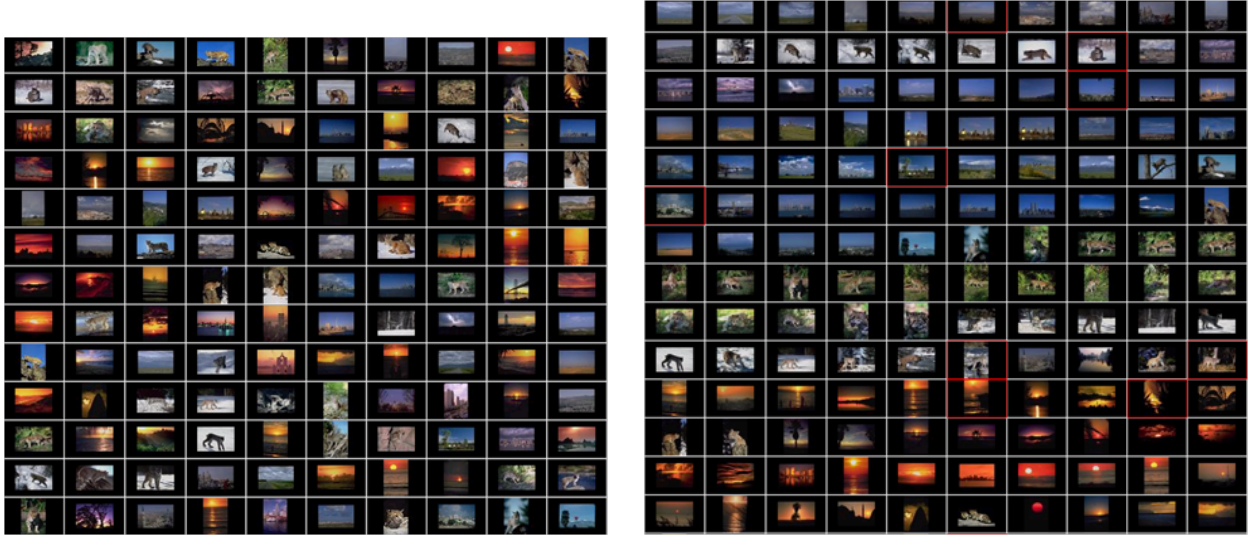


Figure 10: Image sorting via the Collection Guide (left) random order (right) sorted list

dominant cues for image content characterization. The task of feature selection is typically associated with data mining. In our context, one may perform feature selection base on several criteria. Typical reported work are based on a informative measures associated with predefined features or aim at optimizing a given criterion by the design of abstract feature sets.

3.1.1 Item similarity measurement

Distance measurement depends on the space within which information is immersed. In the case of color for example, it is known that distance measurements within the RGB color cube do no correspond to any perceptual similarity. To this end, the HSV, Luv and CIELa*b* color spaces have been proposed within which simple Euclidean measurement correspond to perceptual distances. A variety of distance functions exists and may be used for characterizing item proximity [16]. The simplest distance functions that may be used are that derived from the Minkowsky distance (L_k norm) formula. Here, all coordinates are taken equally, meaning that we assume the fact of an isotropic space. If we assume that coordinates are realizations of a random variable with a known covariance matrix, then the Mahalanobis distance may be used. More sophisticated distance functions exist, such as the Earth Mover's Distance [36].

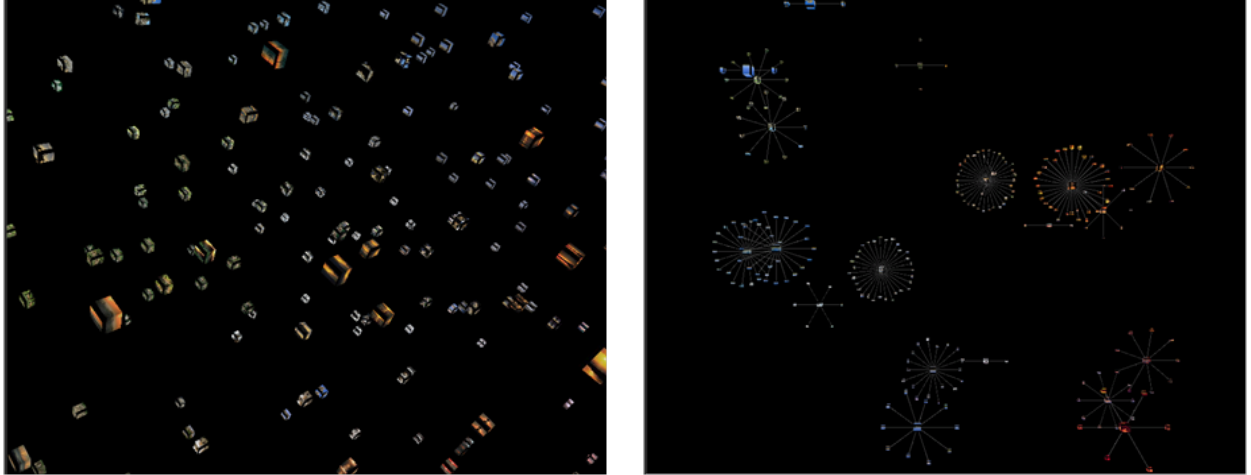


Figure 11: Examples of displays provided by the Collection Guide. (left) generic 3D mapping (right) planet metaphor

3.1.2 Collection subsampling

Associated with the concepts of exploration and browsing is the concept of summarization. Summarization is an approach commonly taken for presenting large content and involves a clear understanding of the collection diversity for performing sampling. The most common way of performing sampling is to use the underlying statistics of the collection. Typically, within the feature space, local density is analyzed. Dense regions of this space will be represented by several items whereas sparse regions will mostly be ignored within the representation. More formally, strategies such as Vector Quantization (VQ) may be used split the space into cells and only consider cell representatives. k-means clustering is one of the most popular VQ techniques. A geometrical interpretation of VQ is that of defining a Voronoi (Dirichlet) tessellation of the feature space such that each cell contains a cluster of data points and each centroid is the seed of the corresponding cell. This tessellation is optimal in terms of minimizing some given cost function, embedding the assumption over the properties of the similarity measurement function in the image representation space.

A radically different approach is to perform hierarchical clustering on the data. Initial data points form the leaves of a tree called dendrogram. The tree is built upon dependence relationships between data points. In the single-link algorithm, a point is agglomerated with its nearest neighbor, forming a new data point and a node within the tree. The algorithm stops when all points are gathered. Alternatives (complete-link and average-link) preserve the internal structure of clusters when merging. The dendrogram obtained may then be the base for sampling the collection, as each level of the dendrogram shows a view of the collection. By defining collection samples as closest to the tree nodes at one given level, one obtains an incremental description of the collection.

3.2 Dimension reduction

So far, we have considered items as represented by vectors in the feature space. However, two aspects of this mathematical modeling should be inspected. First, we have defined distances and similarity measures irrespectively of the feature space dimensionality. However, it is known that this dimensionality has an impact on the meaningfulness of the distances defined [1]. This is known as the curse of dimensionality and several results can be proven that show that there is a need for avoiding high-dimensional spaces, where possible. Further, typical visualization interfaces cannot handle more than 3 dimensions. Hence, there is a need for consistently representing items immersed in a high-dimensional space in lower dimensional spaces, while preserving neighboring properties. Dimension reduction techniques come as a solution to that problem. Methods for dimensionality reduction are employed each time high-dimensional data has to be reduced from a high to a low-dimensional space. The principle of the mapping process for methods based on distance matrices

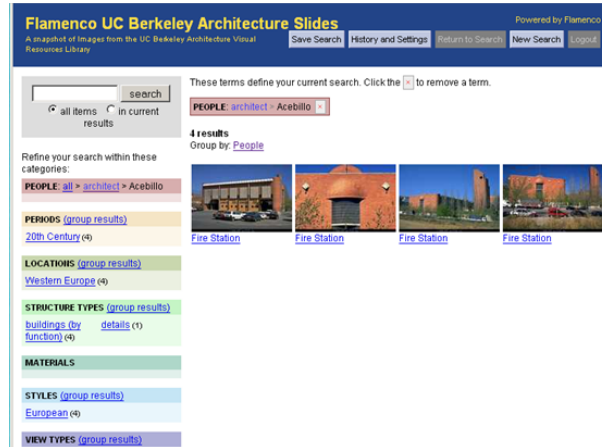


Figure 13: UC Berkeley Architecture Image Library (Flamenco toolbox)

An interesting feature is the near-1D organization whereby groups of pictures are arranged along the path (as opposed to aligning single pictures).

- Flickr's geotagged image browser exploits the planar nature of geographic data to arrange pictures.

4.2 Related patents

Image browsing is of high commercial interest since it provides a added value over a collection of data. The following are some US patents related to image browsing:

- 6233367 Multi-linearization data structure for image browsing
- 6636847 Exhaustive search system and method using space-filling curves
- 6907141 Image data sorting device and image data sorting method
- 7003518 Multimedia searching method using histogram
- 7016553 Linearized data structure ordering images based on their attributes
- 7131059 Scalably presenting a collection of media objects
- 7149755 Presenting a collection of media objects

4.3 Other media

Browsing may clearly apply to media other than images. While not detailing underlying strategies we give examples and pointers to multimedia browsers that we think provide interesting browsing functionalities.

- ViCoDE (Video Collection Description and Exploration [5]) is a video search engine interface implementing the QBE paradigm and allowing some exploration functionalities.
- The MediaMill browsers [15] allow time and similarity based video exploration. They have been tailored to the TRECVID challenge (interactive task) and thus are relevant for news content exploration.
- Islands of music [32] use Self Organising maps to arrange music pieces into a planar landscape, then used for browsing.
- Enronic [18] Email collection browsing, investigation. As emails represent communications between humans, this work is related to the domain of Social Network Analysis.



Figure 14: Dimension reduction over a database of images

- Scatter/Gather [17] is an early work on clustering retrieval results for their exploration by categories.

5 Evaluation

In [7], it is analyzed how browsing and the more general fact of providing a efficient interface to a information systems is often listed as one of Top-ten problems in several fields (eg, Information Retrieval [14], visualization and virtual reality). A new top-ten list of problems in the domain is created including benchmarking and evaluation. Firstly, the majority of browsing tools proposed in the literature organize their content using low-level features such as color or texture. [35] demonstrates via several user studies that this is relevant and that features may indeed be used as a basis for visualization and hence browsing. There are numerous efforts to benchmark information retrieval as a problem with a well-posed formulation. When including the quality of the interface or performance of the interaction with the information system, things are however less clear. The fact of embarking human factors in the context make the formulation less definite and prevents the automation of the performance measures (see eg [20]). Several attempts to propose evaluation protocols and frameworks have nevertheless taken place [3, 34, 41]. Some particular aspects such as zooming [11] and presentation [23, 34] have been the focus of attention for some works. While systematic retrieval performance evaluation is possible using ground truth and measures such as Precision and Recall, having reliable performance evaluation of interfaces and interactive tools requires long-term efforts and heavy protocols. It is certainly an area where developments should be made to formally validate findings. It is often a strong asset of private companies which carefully invest in user-based testing in order to validate tools that are simpler but more robust than most research prototypes.

6 The MultiMatch information browser

In the course of the MultiMATCH EU-FP6 STREP project², we have built from the analysis made in this state of the art and constructed an information browser as complement to the main search interface. We have followed the idea that searching and relevance feedback help in exploring local portions of the information space, whereas browsing should help the user getting both a global overview of the information space at hand and provide the user with a clear and efficient browsing strategy. We have therefore mixed the idea of the Collection Guide with that of linearization and faceted browsing to obtain an information browser starting from a specific document and linking, out of several possible dimensions [40], to other documents close to that dimension. By clicking on any of the non-central documents would bring it at the central place with its associated context.

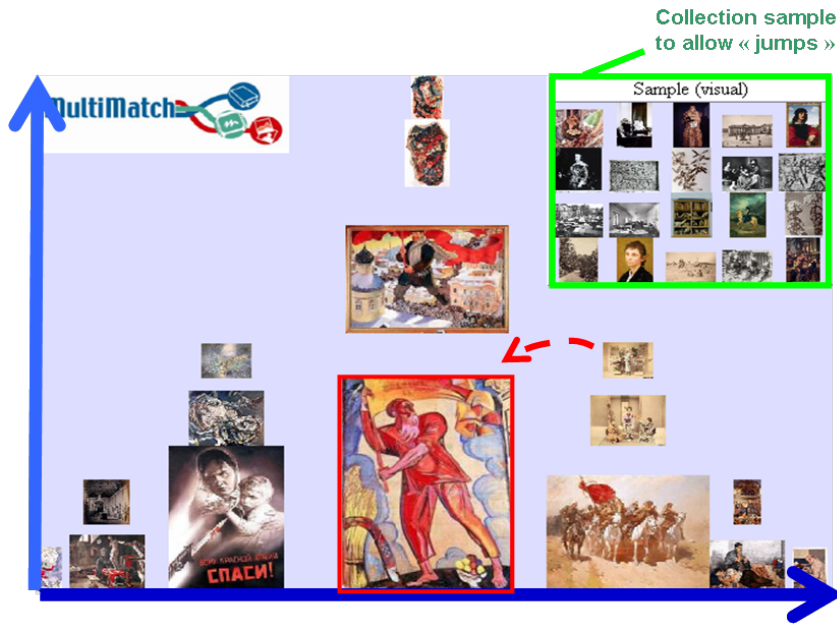


Figure 15: The MultiMATCH collection browser

Ordering set over horizontal and vertical dimensions may be modified and adapted at will. They may come from natural ordering (eg timeline over creation dates, alphabetical ordering of creators name, piece title) or be created using the Collection Guide methodology [25] out of content or metadata features (eg multimodal similarity).

7 Concluding remarks

Image browsing comes as a complement to query-based search. This is valuable, due to the imperfect nature of content understanding and representation, due principally to the so-called semantic gap. Browsing is also interesting to resolve the problem of the users uncertainty in formulating an information need. Opportunistic search and faceted browsing are example of principles and applications that bridge search and navigation. The above analysis shows that, as a complement to classical retrieval systems, browsing and navigation should be differentiated. It is suggested here that browsing is directed towards an objective (information need) and thus indirectly relates to searching and acts at the document scale. As such, browsing is seen as assistance within similarity-based search systems, where the QBE paradigm is often deficient. Browsing should be differentiated from navigating where the aim is the understanding of the collection content. Navigation-based systems thus use an absolute (global) modeling of the collection and include a global notion of similarity (ie that is driven by generic feature). This is to be opposed to browsing

²MultiLingual/Multimedia Access to Cultural Heritage <http://www.multimatch.eu>

systems, which use a notion of similarity based on the context of the neighborhood of the sought items (ie, the interpretation of the collection is made at the light of the sought items).

Image collection browsing imposes to focus on user interaction and thus the interface design and evaluation. This refers to the work done by the Human Factors (HCI) community, which is somewhat regrettably not enough inter-weaved with the Information Retrieval and management community. Finally, while browsing and navigation may be seen as an extension and complement to searching in image collections, it can also be applied to other media such as audio (music, eg [32]) and video (eg [10, 15]). These temporal media offer a temporal dimension that directly lends itself to exploration and thus makes browsing an obvious tool to use.

8 Acknowledgments

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