The HERON Project — Multimedia Database Support for History and Human Sciences

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Abstract. The interdisciplinary HERON project investigates the impact of multimedia applications from the humanities, in particular heraldry, on future database technology. We present first evaluation results of querying image databases by visual content. Also the requirements of a digital workbench for art historians are described. Here we present an approach how to tackle the complex problem of exchanging multimedia documents over the internet.

1 Introduction

Images were always used to bear complex information. Though they tend to be even the most intuitive kind of information, image interpretation requires a lot of semantic knowledge and consequently is a time-consuming, difficult task. According to their complexity, so far little database support for image retrieval and evaluation has been established. Currently research efforts draw upon two orthogonal approaches for the retrieval of images based on their content: The conservative way is to manually index an image's content using predefined vocabulary. Queries then are specified using the predefined vocabulary [8, 3]. A more recent approach attempts an automatic content-based image retrieval based on generic features like color, texture, shape or spatial layout. There are numerous projects and (commercial) systems dealing with database support for multimedia data and content-based retrieval, such as QBIC [5], Photobook [9] or Virage [6]. This emerging technology opens up the opportunity for challenging applications in the humanities, where large and precious collections of images exist.

At the University of Augsburg computer scientists and art historians have initiated the interdisciplinary research project HERON[1] (HERaldry ONline). Today the use of digital libraries in arts, history and humanities is still exceptional. Though images are essential in almost all historic sciences, their use in heraldry is outstanding. The HERON project is set up with the target of building a very large multimedia database for heraldic research in art history. Heraldry

[1] Since the beginning of 1998 HERON is funded by the DFG (Deutsche Forschungsgemeinschaft) as part of the DFG program "Verteilte Verarbeitung und Vermittlung digitaler Dokumente".

is one of the oldest ancillary sciences and useful for the classification of a wide variety of medieval historical documents, epitaphs, paintings or other pieces of art. Especially when it comes to the identification of particular persons or personal possessions, results can often only be achieved by the means of heraldry. To classify coats of arms depicted on historical objects, historians still have to go through various large works of reference, some containing more than 100,000 different shields [11, 10]. Thus existing technologies for content-based image retrieval have to be evaluated seriously w.r.t. the requirements of heraldry.

The integration into the internet together with efficient online access is crucial for HERON. From an art historian's viewpoint the WWW can be characterized as a world wide compound of multimedia document servers delivering historical documents relevant to his/her work. However, the art historian's requirements dramatically influence the profile of online multimedia databases: The intensive use of multimedia documents in a variety of formats and at different levels of quality demands an optimized storage of multimedia documents, together with the integration of knowledge on multimedia formats into web servers and clients.

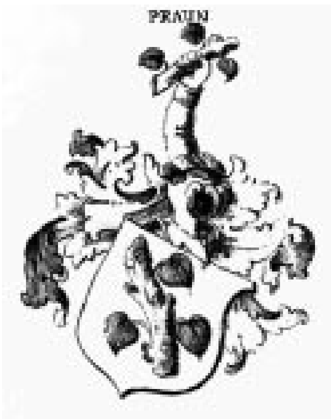
The rest of this paper is organized as follows: An overview of the science of heraldry together with new challenges for heraldic databases is presented in Sect. 2. First results on the retrieval by image content are presented in Sect. 3. Section 4 discusses the impact of an art historian's requirements on the design of HERON's prospective server architecture and its integration into a networked environment. We will draw conclusions in Sect. 5 and point out future research directions of the HERON project.

2 Heraldic Databases

2.1 Basic Issues in heraldry

The beginnings of heraldry date back to the late eleventh century when nobles began to fight in armour. As it became more and more impossible to recognize strongly armoured fighters, pictorial representations were used to identify individuals, and later on entire families (cf. Fig. 1). By the Middle Ages heraldry had blossomed into a complex system with the growing tendency to crystallize vague guiding principles into exact rules [4].

Three principal elements characterize a coat of arms: the field, tinctures and charges. The field is the ground of the shield and may be divided by horizontal, perpendicular or diagonal lines and by any combination of these. Thus smaller partitions arise that can be divided or emblazoned with charges like the original shield. Each partition or charge is of a specific tincture. The tinctures comprise two metals – gold and silver (often represented by yellow and white), seven colors – red, blue, green, purple, black, orange and brown and three furs – ermine, vair and potent. In drawings or engravings tinctures are mostly represented by dots or differently arranged lines (hatchings). There are lots of charges or symbols that can emblazon a shield, even overlaying several partitions. The art of correct descriptions of bearings (blazonings) is a very complex matter requiring a specific



Praun (Tafel 125)
schweizerischer Uradel, hiessen dort »die Prunen von Schenwerd« und sassen bereits im XIII. Jahrhundert im Rathe der Stadt Zürch. Einer des Geschlechts siedelte im XIV. Jahrhundert nach Nürnberg über, wo das Geschlecht mit der Zeit auch ins Patriziat kam.

Ihr Stammwappen zeigte in S. einen r. Stern, und auf dem Helm einen ebensolchen, an den Spitzen mit g. Kugeln besteckt. Dies Wappen wurde den Nürnberger Praun i. J. 1474 von Kaiser Friedrich verändert, aus welchen Ursachen unbewusst, und bildet diese Umänderung ein merkwürdiges Beispiel in der Geschichte der Heraldik.

Das neue, jezt noch übliche Wappen zeigt in S. einen abgehauenen Ast mit drei r. Lindenblättern, oben 2, unten 1. — Auf dem Helm ein r. und s. Wulst, daraus hervorwachsend ein s. Arm, mit dem Ast in der Hand. — Decken: r. und s. Im vorigen Jahrhundert führte die Familie auch die beiden Wappen vereint in einem gevierteten Schilde mit zwei Helmen, wie die Abbildung auf der Tafel zeigt.

Fig. 1. Image of a shield with blazoning from [11]

vocabulary. Not only partitions, colors and charges are named individually, but also particular postures and several ways of depiction.

Considering the portrait shown in Fig. 2, the identity of the person portrayed is not apparent. The only realizable hint is given by the coat of arms painted in the upper right corner, which is supposed to be the bearing of the person depicted. Using one of the main works of reference [11] for German heraldry, the manual search for this bearing produced the result shown in Fig. 1. Though the form of the shield differs, the charge and colors used are the same. Besides the illustration of the arms, there is a short text containing genealogical information as well as the blazoning. Finding particular coat of arms in works of reference has been a difficult matter so far, because most works are ordered by topographic aspects, i.e. any volume only contains arms of a regionally restricted area. Furthermore there are far too many different collections of arms, preventing a complete sequential scan. For instance [11] consists of more than a hundred volumes, together containing about 130,000 different arms. So it is easy to verify assumptions, but finding arms without any knowledge of their provenance or the bearer's name is far too often - despite time consuming searches - unsuccessful.

2.2 Querying Heraldic Databases

Traditional digital image archives have in common that they only allow conventional query by keyword or full text search on only a few categories (name of the artist, iconographic subject, depository or even physical attributes like format or size). From the beginning of image processing standardized grammars like [13] have been used for description of almost any kind of images, but for any searches using unanticipated keywords or subjective descriptions – e.g. shades of colors – good results cannot be expected. Though blazonings are standardized by particular rules and use a special vocabulary of graphical elements occurring that could be translated into a grammar, major experiences in describing images correctly would be necessary, due to the complexity of art historical sciences.

Fig. 2. 17^{th} Century portrait and magnification of the upper right corner

Moreover, using language-bound descriptions only is far too obstructive to interdisciplinary research as well as to queries in other languages. In most cases the descriptions are done without using a standard vocabulary or thesaurus and even if so, the problem of specialized terminology in each discipline as well as often missing multilingual descriptions remain as a barrier to interdisciplinary communication. Retrieval by image content has the potential to make archives accessible to a far larger group of users, as only the visual impression and not the exact definition of what is shown is needed to retrieve certain images. However, experts in the field may still want to use traditional retrieval capabilities as full text search on blazonings. Therefore a combination of both conventional and visual approaches of retrieval is going to be adopted by the HERON project.

3 Query by Image Content in Heraldic Databases

3.1 Building a Heraldic Database

One problem in content-based querying is to determine the exact set of appropriate attributes or features that describes the content of each image in the database adequately. The complete process of querying is illustrated in Fig. 3.

The future HERON database will consist of images of about 32,000 coat of arms. High quality scanners are used for the monochrome digitization of images. As it is not necessary to have high quality for just fastly browsing the images, low quality images or thumbnails are sufficient to choose the relevant ones. Due to important details of the original, it is necessary to get at least an average quality image on the screen, which must also be available in high quality for zooming or printing. The high quality images (original size about 1.5×2 inches)

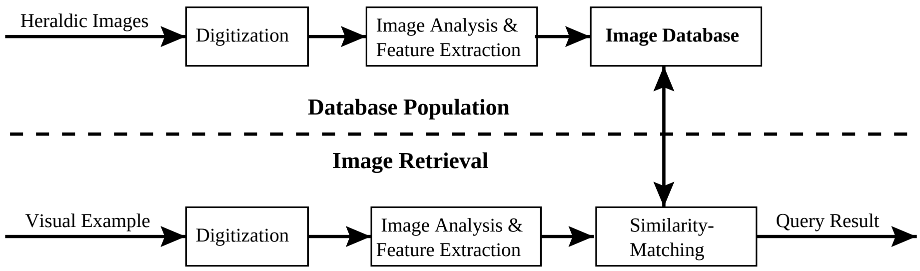


Fig. 3. Image processing and retrieval

are scanned at 600dpi using TIFF5.0 format. Every coat of arms is divided in two heraldic images, one showing the complete coat of arms, the other one presenting the shield only. About twelve coat of arms per person and hour can be scanned and postprocessed on the average. Furthermore thumbnails (50dpi) and the images in medium quality (300dpi) of all those images showing shields only, will be stored in the online retrieval database together with full text blazonings of the corresponding coat of arms resulting in a database at the total size of approximately 9GB. For the purpose of zooming, the high quality images can be stored in a nearline CD-ROM database with a size of about 50GB.

3.2 First Results

There are lots of different features, algorithms and similarity measures that have been proposed, but an optimal set can only be chosen considering the field of application. To get a first feeling about the specific problems in heraldry, a small database containing 100 shields has been created using IBM's Ultimedia Manager [5] that offers a variety of different features including color – histograms as well as average color –, texture, position and shape of images and the objects they contain. Since charges are essential to compare coats of arms, shape has proven to be the by far most important feature. Secondary are colors and textures that are both used to determine tinctures and position features that can be used to compare regionally restricted areas of shields. In [1] these features have been analyzed with respect to heraldry.

Shape Features: Retrieval by shape is known to be one of the most complex problems in image retrieval. A wide variety of shape features have been proposed in machine vision literature, but similarity strongly depends on the particular field of application. The Ultimedia Manager determines shape features by area, circularity, eccentricity and major axis orientation as well as a set of algebraic moment invariants [12]. The resulting feature vectors are accessed using conventional R*-trees [2] as feature indexes. To retrieve similar images a weighted Euclidean distance is computed for matching the query vector with all the vectors in the database. We have studied the retrieval of both simple geometric structures (circles, rectangles, etc.) and complex shapes (lions, eagles, etc.).

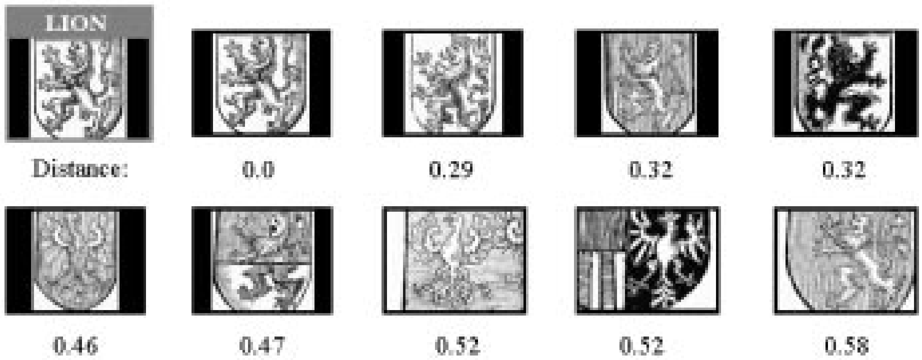


Fig. 4. Query by shape: complex shape

Of course, the quality of retrieval may differ with the sample chosen. A query result for complex shapes is shown in Fig. 4. The visual example is shown in the upper left corner. Obviously there are many false retrievals here. But all images of lions in the database are retrieved within a tolerable distance that is determined matching the features of each image in the database to the visual example.

Though there are lots of quite similar, but different charges in heraldry to emblazon a shield, their planarity, stylized depiction and clear recognizable borders encourage the further use of query by shape.

Color Features: In many applications best content-based query results have been achieved using color features. But whereas histogram color has proven to be rather useful, average color has no real application in heraldic databases, because it is impossible to distinguish clearly between shields only using their average color, e.g. a crest containing red and blue parts may have the same average color values as a purple one. Though comparing histograms is an effective way to distinguish between even similar shields, the relevancy of mere colors in heraldry is quite limited. Thus queries by color will only be useful in combination with additional features, such as shape or texture. Unfortunately colors cannot be used directly for querying, as most books of reference merely reproduce monochrome prints of shields, where each color is shown as a certain hatching. Therefore the problem of segmentation - in particular the distinction between areas of different color - is going to become more and more important, since this is the only way to take advantage of queries by color in heraldic applications.

Texture Features: The main application of texture features in heraldry is to find areas covered by furs. In the case of the Ultimedia Manager contrast, coarseness and directionality features are evaluated to represent textures of images. A sample query result is shown in Fig. 5. A visual example of an area covered with ermine (upper left) is compared to all images of the database. Since the example was taken from the database, the original image has been found first, followed by all those containing areas covered with ermine. The last image shown does not contain any ermine. Note that the distance measured for the last retrievals

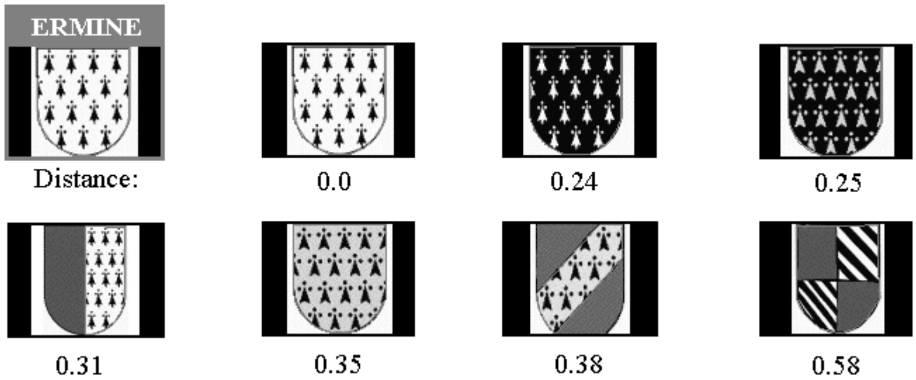


Fig. 5. Query by texture

displayed in Fig. 4 and Fig. 5 have the same value. But the latter image is a false retrieval, whereas the former image is relevant. This is due to the meaning of absolute values of distances strongly differing w.r.t. the particular feature.

Contour of Objects: Whereas color and texture features are extracted automatically, in most present systems the contour of any object has to be outlined manually to extract shapes or any other feature restricted to a specific object. This manual identification is time-consuming, expensive and an inhibition to a more widespread use of digital image libraries. To segment shields by manually outlining the shape of charges, an average of merely 3-4 shields can be processed per person and hour. Thus advanced capabilities of auto-segmentation of shields are absolutely necessary. Especially when it comes to segmentation of monochrome prints of crests, the representation of different colors by particular hatchings prevents the use of conventional algorithms for auto-segmentation.

Invariance to Rotation: Parallel to human perception both texture and shape features have generally been implemented invariant with respect to affine transformations such as translation, scaling and rotation [5]. Though invariance to scaling and translation is necessary in heraldic applications, invariance to rotation causes some serious problems, as neither the direction of hatchings nor the orientation of ordinaries and subordinaries or the specific posture of animals, etc. that are relevant parts in retrieving most similar images, can be recognized. Considering for instance the moon as a charge, unless the moon is shown full, the horns can point in different directions as shown in Fig. 6.

Positional Aspects: It is a necessity to determine the position of specific charges towards each other, since their exact topological arrangement is important to distinguish between coats of arms, e.g. there are different ways to arrange three lions: they may be arranged one above two, two above one or three in a row. All these coats of arms would be different, although showing three lions.

Aggregational Aspects: Charges often have to be counted. For instance, shields containing five stars have strictly to be distinguished from those con-

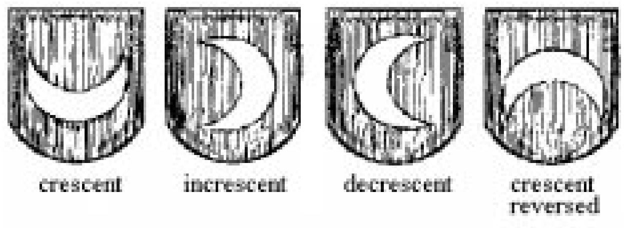


Fig. 6. Different bearings due to rotation of a charge

taining only three or even just a single star. Therefore additional aggregation capabilities on all images retrieved are required.

4 Heraldry Online

4.1 A Digital Workbench for Art Historians

What sets the research of art historians apart from other humanities is an intensive and varied use of images. Art historical research is based on voluminous reference works containing high quality reproductions of art collections like museum catalogues or on numerous monographies. Additionally photographic material in various forms (transparencies, reverse prints, etc.), either collected and archived by the individual researcher himself or by public art institutions, represent an important source. Scientific analysis of works of art is not conceivable without permanent use of reproductions primarily for the purpose of comparison. Therefore, it seems promising to use the possibilities of new media in art research at a large scale: a plurality of different material either printed, photographic or on continuous media can be stored in online multimedia databases.

Today large systematically arranged image archives especially addressed to art historians or historians, which allow research at any computer with internet-connection, are built up just to a small extent. They are available more often offline (CD-ROM) than online. The future "digital workbench" for art historians, consisting of a personal computer usually fed with digitized material from traditional sources which is connected to a network of (multimedia) databases, is depicted in Fig. 7. HERON is intended to line up with existing online databases, but it is strongly tailored to the needs of art historians by providing an intuitive visual query engine for the retrieval of a very large stock of historical multimedia documents together with a storage optimization for the digitized material aiming at a good quality of service.

4.2 Optimization of Document Delivery Costs

Future HERON users will extensively use image material in a large variety of formats. As mentioned above, multimedia objects in several formats and at different levels of quality are required. However, image formats are not independent from

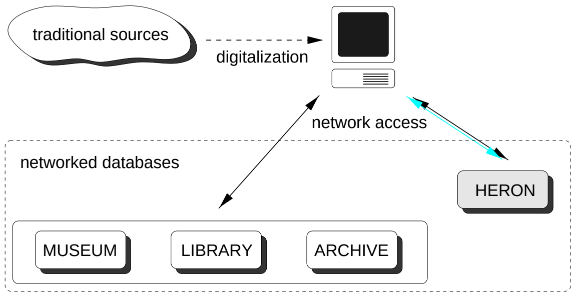


Fig. 7. A digital networked workbench for art historians

each other but interrelated by conversion tools and may differ in some aspects such as compression, color depth and resolution.

The Optimization Problem: To determine an optimal choice of stored image formats is a non-trivial optimization problem subject to parameters such as query profile, available disk storage, server load and network bandwidth. In [7] we have addressed this problem formally and proposed to integrate the conversion tools into database and proxy servers aiming at a dynamic optimization of multimedia document exchange. Format interrelations between images are modelled as a graph of functional constraints. An acyclic graph of functional constraints, where every computed format has a unique functional composition, is called a functional base. These functional bases are used to model sequences of potential online conversions. Since the number of potential functional bases grows exponentially in the number of functional constraints, determining an optimal functional base is non-trivial. Functional bases allow storage optimization by partitioning multimedia formats into physically stored and computed ones.

A prototypical implementation using the most popular HTTP server Apache has shown first promising results in the reduction of multimedia storage costs and the increase of server performance. This result will be published elsewhere.

5 Summary and Outlook

In this paper we have outlined the goals of the interdisciplinary HERON project at the University of Augsburg. The necessity of combining database technology with advanced content-based query methods was pointed out regarding the requirements of art history. Given the capabilities of modern internet technology, an efficient integration of the HERON into the WWW is mandatory.

First results concerning heraldic queries by image content and client-server optimization of multimedia documents have been presented. Though especially the results in content-based retrieval are encouraging, the IBM Ultimedia Manager has some serious disadvantages due to a highly restricted range of possible queries or a missing database support. Currently other commercially available products like Excalibur Image DataBlade Module by INFORMIX Software Inc. and DB2 Relational Extender by IBM Inc. are evaluated on IBM RS6000/AIX.

Our further research will mainly focus on performance issues, scalability and advanced visual retrieval capabilities. Query by image content uses similarity measures, hence content based searches can only provide a ranked list of query results. This set of successful matches can get very large and will ultimately have to be refined by the user. Therefore another crucial aim will be to minimize false retrievals in query results by fully exploiting all semantic knowledge in heraldry.

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