(Semi-) Automatic Segmentation in Historic Collections of Heraldic Images

Jürgen Vogel, Wolf-Tilo Balke, Werner Kießling
Institut für Informatik, Universität Augsburg
{vogel,balke,kiessling}@informatik.uni-augsburg.de

Abstract

A modern approach to manage multimedia databases is content-based retrieval. Especially in image databases graphical features like color, texture or shape can be used efficiently instead of expensive manual annotations. Due to the large number of image archives and the enormous costs of annotations it is most important to extract adequate features automatically by means of digital image processing. Using the image processing tool MVTec Halcon we propose a preprocessing for heraldic image segmentation that can automatically derive color information from monochrome images as well as semiautomatically segment heraldic bearings. We claim that exploiting application semantics leads to successful image segmentation in digital libraries.

1. Introduction

In the framework of the interdisciplinary HERON project [8] a historical collection of heraldic images is made accessible to both art-historical experts and the interested public. *Content-based retrieval* of digitized image material seems a most intuitive way to open up historic archives without conservatory objections whilst providing powerful tools to support a wide variety of applications [2,6]. However, content-based retrieval strongly suffers from the lack of commercially available shape-based retrieval techniques, which are of major interest not only for art-historical applications.

The major problem in shape-based retrieval is not the appropriate set of features, but rather the segmentation of object contours in images collections that has not yet been solved for the general case [1]. The image processing tool MVTec Halcon [5] provides a large variety of modern segmentation algorithms and is thus useful to build preprocessing applications for image segmentation. We claim that in order to provide an effective segmentation, the *application semantics* has to be exploited. As a first application field for HERON heraldry [3] was chosen.

The objects on coats of arms can differ from abstract geometrical shape to everyday's objects as for instance stars, animals or plants. Heraldic images are characterized by standardized image representations, which provide both stylized images and a grammar for image descriptions (so called blazonings). Unfortunately, these blazonings cannot exclusively be used for retrieval purposes as their usage would prevent non-experts from accessing heraldic image collections. But blazoning-based fulltext retrieval can be used to verify the correctness of (semi-) automatically segmented objects.

2. Application semantics

In heraldry there are only nine colors [3]: Gold, silver, red, blue, green, purple, black, brown and orange, of which the last two are hardly ever used. However, these colors cannot directly be analyzed, as all standard volumes of heraldry are based on medieval collections. Those were printed with monochrome images, where colors were encoded by different kinds of shadings (cf. fig. 1). Thus colored became shaded areas, that pose a severe problem to most segmentation algorithms (e.g. watershed transformation, boundary tracking), as they merge with object contours and strongly differ in width and print quality.

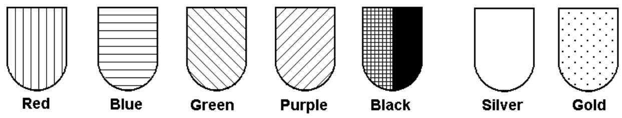

Figure 1: In heraldry, colors are encoded by shadings

Though coats of arms may show different fields with different background colors, it is quite easy to distinguish between them. Thus the problem of heraldic segmentation can be broken down to outlining (shaded) objects on a uniform (shaded) background. As the shadings have a distinct semantics, two main ideas can be used:

- To **recolor shaded areas** accordingly and segment objects by e.g. thresholding techniques
- To **remove shadings** and segment objects by e.g. morphological techniques

3. Segmentation by recoloring

A suitable segmentation can be based on the directions and kinds of shadings. Any shading is a texture that is directed and shows a regular pattern of parallel lines with a certain distance (shading frequency) from each other. If the shaded areas are recolored properly, the colored image can simply be segmented by thresholding techniques.

3.1. Filtering techniques in local environments

As the detection of silver, golden and black areas has proven to be quite simple, we will focus on the other colors. Since shadings are local properties, an operator window has to be used for detection. A direction-sensitive filter is applied to every image part within this window filtering different directions of 0° (blue), 45° (purple), 90° (red) and 135° (green). Thus a degree of correlation between filter direction and directionality of the image part can be determined and the appropriate colour is attached to each image part.

Though tests [9] showed good color recognition results for larger image sizes, the quality of recognition decreases with declining window sizes. If small window sizes (near the shading frequency) are chosen, the detection is doomed to failure. Larger window sizes on the other hand lead to a coarse resolution of the colored images arising and thus prevent an effective segmentation.

3.2. Segmentation results

Though segmenting image objects by recoloring has failed due to the coarse color images, the *ratio* between the colors occuring has proven to be correct for a large majority of images. Tests showed that the absolute size of colored areas is heavily dependent on the scan quality, but the percentage of colors in almost every image can be determined quite precisely (cf. fig. 2). Thus the use of recoloring is twofold:

- The precise information of color percentages can be used by other segmentation approaches (cf. section 4)
- The automatic extraction of color percentage histograms and the coarse positional color layout enables users to pose color-based queries to monochrome collections of heraldic images. The color layout may even be used as graphical index for query by visual example or query by sketch [7].

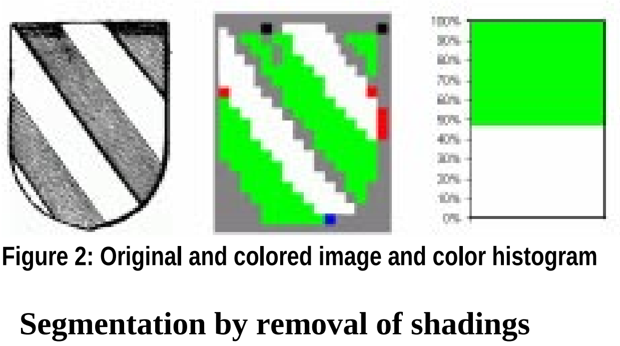

Figure 2: Original and colored image and color histogram

4. Segmentation by removal of shadings

A second approach is the removal of shadings to prepare object contours for morphological segmentation. The main scenario is one or more (shaded) objects that overlie a background showing a different but regular shading. As a removal always affects the image contours, the removal should be restricted to the background shading. To get better segmentation results a postprocessing is necessary, in which for example small holes can be filled up or edges can be completed or smoothed.

4.1. Five kinds of background shadings

Considering the application semantics (cf. section 2) there are five different kinds of background colors to remove. Each kind of background needs a particular algorithm for removal resulting in five main scenarios:

1. **Silver**: The object contours overlie a plain white shield and can easily be prepared, e.g. for morphological segmentation.
2. **Black**: On a plain black shield there are light objects.
3. **Cross hatch:** A black background can also be shown as cross hatched area with light objects (cf. figure 1).
4. **Gold**: A golden background is represented by a region spread with small dots.
5. **Simple shading**: The background is shaded regularly. The directionality of the shading is indicating the particular color.

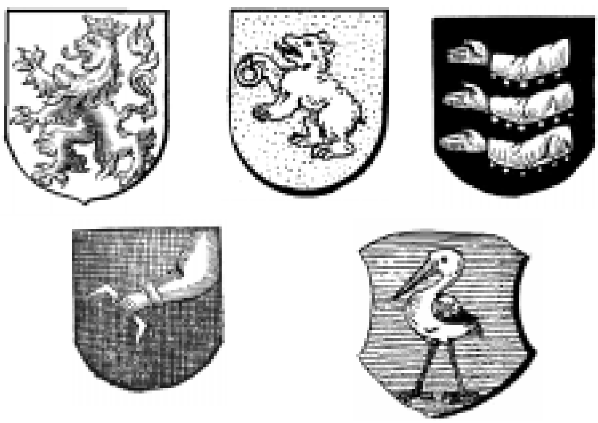

Figure 3: Examples for the five cases

4.2. Detection of background colors

To choose the right removal algorithm, the background color has to be determined. In heraldry objects are shown near the centre of the shield and borders are mostly free of objects. Nevertheless dependent on artistic styles the borders of coats of arms may strongly differ. To compensate these differences a *self-adapting algorithm* has been implemented removing the shield border and guiding an operator window over the border regions of the shield. If a recoloring strategy as in section 3 is applied to the border areas only, the background color can mostly be detected.

This detection can be represented by a formal decision process using not only the color information detected, but also the color histogram for the entire image:

1. If the detection shows high percentages of silver, gold, black or cross hatch these colours can be assigned to the background.
2. Simple shadings can often not be detected properly in border regions due to ornaments near the borders. In this case a matching with the color histogram for the entire image is necessary. If the dominant direction is part of the histogram its color can be assigned.
3. In about 20% of all cases the previous steps do not yield a result. Then the maximum value of the color histogram should be chosen as background color, as ornaments on the border in general indicate that there are not many objects on the shield. Thus a large percentage of background color can be assumed.

Using this decision process for genuine historic collections of bearings [4] tests showed that for more than 95% the background color has been determined correctly [9].

4.3. Removal of shadings

Having determined the correct background color an adequate method for the removal of background shadings can be chosen. The ideal case is a plain background that shows no shadings at all and allows segmentation of clearly distinguishable object contours. All other cases have to be reduced to this case.

Silver: This is the simplest case with a plain white background. Morphological operators may access all the occurring shapes, complete boundaries and fill up holes.

Black: The case of a plain black background is inverse to the case of silver. If the grey values are inverted, dark objects on aplain white background arise. Thus the image can easily be segmented.

Cross hatch: The second representation of black areas raises problems with light spots between the shading lines. Though the sizes of these spots may differ in image collections, it is quite constant in each image and spots are very compact and numerous, too. To remove the spots the grey values of an image again have to be inverted and all unconnected, compact areas of a certain size have to be removed. Therefore an algorithm was implemented collecting all objects and determining the size of frequently occuring compact objects.

Gold: The golden background is inverse to the cross hatched. Again unconnected compact objects have to be removed after determining their characteristic size.

Simple shadings: This case has proven to be the most difficult one. In general there are three requirements for removal algorithms:

- *direction sensitivity*: All objects that are not part of the background shading must be preserved.
- *shading frequency*: Within each image the background shading shows a characteristic distance between its parallel lines.
- *minimum number of lines*: As shadings consist of several parallel lines, isolated lines or parallel lines which are closer than the shading frequency may belong to an object contour.

In [9] several algorithms for the removal have been compared varying from simple gradient approaches to extended line descriptors. A broad perceptual analysis of segmentation results showed fourier filters as the most effective choice. To filter images in the frequency space an apropriate mask had to be designed taking the direction of the shading and its frequency into account. After the retransformation of the image the background shading has become a rather uniform grey area that can be removed by thresholding techniques again leaving clearly distinguishable objects on a plain white background.

Figure 4: Segmented objects after removal

4.4. Postprocessing

After the segmentation on silver, black or golden backgrounds, there are in general satisfactory results in the form of binary masks. If on the other hand a simple shading had to be removed, the object contours have almost always been affected. Those boundaries are heavily fragmented and have to be closed and completed before a morphological segmentation can take place. A completion can be obtained by traditional line completion algorithms as e.g. Hough transform or boundary tracking. The completed boundary can always be matched with the original image, thus providing a possibility of evaluating the correctness of the completions.

Obviously the segmentation quality strongly depends not only on the kind of removal algorithm, but also on the quality of the historical image material. Generally speaking it is hardly possible to segment heavily fragmented object contours on irregular background shadings, whereas images of good quality could be segmented rather successfully. Nevertheless a manual postprocessing was still needed. Tests with genuine historical collections (e.g. [4]) showed that 50%-60% of all images have been adequately segmented. For these images the postprocessing was restricted to accepting or rejecting the segmented objects. In the other cases some postprocessing as joining or seperating parts of objects, filling up larger holes or even reconstructing partially damaged object boundaries is needed. Considerable difficulties occurred by occluded or overlapping objects, that generally cannot be solved without knowledge about the kind of objects shown [1].

5. Summary and outlook

The HERON project is committed to content-based image retrieval in digital libraries especially in the field of art history. As field of application for HERON heraldry has been chosen. Shape-based retrieval is of major importance in art-historical applications, but currently not commercially available due to severe segmentation problems for general image archives. Thus our aim was to provide effective algorithms for the segmentation in heraldic image collections.

As –despite intensive research– effective segmentation approaches for general image archives are still lacking, the particular application semantics of heraldry was exploited. The problem could be reduced to segmenting (shaded) objects which overlay a regularly shaded background in monochrome images, where different kinds of shadings represented particular colors. The algorithms considered are part of the image processing tool MVTec Halcon that proved to be adequate for image segmentation tasks.

Two approaches towards segmentation have been presented. The first tried to recolor shaded image regions with the appropriate color and then segment objects by thresholding techniques. Unfortunately due to the coarse resolution of the arising color images the segmentation failed. But the approach proved to be very useful for automatically extracting accurate color histograms from monochrome image collections. The coarse result images can also be used as a graphical index for query by visual example or query by sketch. Thus our algorithm enables users to pose color-based queries to monochrome heraldic image collections. The second approach tried to remove background shadings in order to segment objects using effective morphological algorithms. After developing algorithms to determine the background shading and designing adequate fourier filters, tests with practical data showed that segmentation also in this case could only be performed semi-automatically.

Severe problems arised from poor quality of the historic image material. Shading frequency and line width may strongly differ within the same image. Parameters like operator window size are dependent on the particular collection and have to be tuned, if a new heraldic collection is accessed. Object contours may be fragmented and are even more affected by the removal of the background shadings. Here line completion algorithms have proven to be very useful but still need adaption to the specific field of application.

Adressing severe problems of todays digital libraries the approach for segmentation of heraldic images developed within the HERON project resulted in a semi-automatic algorithm. The enormous costs of preparing image archives for retrieval by providing descriptive verbal annotations or even manual outlining of object contours have been cut considerably. The human interaction in more than half of all cases in different medieval collections could indeed be reduced to accepting or rejecting automatically segmented image objects. In all cases also adequate color histograms could automatically be generated. Thus the overall digitization costs for high quality data sources in digital libraries could be essentially reduced. The results make us confident that our semantic-based approach can be extended to broader application areas beyond heraldry.

6. References

[1] Ashley, Barber, et al. *Automatic and Semi-Automatic Methods for Image Annotation and Retrieval in QBIC*. Tech. Report RJ-9951. IBM Almaden Research Center 1995

[2] Bach, Fuller, et al. *Virage Image Search Engine: An Open Framework for Image Management*. In: Storage and Retrieval for Image and Video Databases (SPIE), pp. 76-87, 1996

[3] Boutell. *Heraldry*. Frederick Warne&Co. Ltd., London UK, rev. Ed. by j. p. brooke-little edition, 1958

[4] Bucelin. *Germania Topo-Chrono-Stemmatographica Sacra et Profana*. Vol. 1-4. Görlinus. Ulm 1660-1678

[5] Eckstein, Steger. *The Halcon Vision System: An Example for flexible Software Architecture*. In: 3. Meet. of Pract. Appl. on Real-Time Image Processing (org. by JSPE). Tsukuba. Ibaraki. Japan 1999

[6] Faloutsos, Barber, Flickner, Hafner, Niblack, Petkovic, Equitz. *Efficient and Effective Querying by Image Content*, J. of Intelligent Inform. Syst., Vol.3 (1994), pp. 231-262

[7] Hirata, Kato. *Query by Visual Example*, Advances in Database Technology EDBT ’92, pp. 56-71, Heidelberg 1992

[8] Kießling, Erber-Urch, Balke, Birke, Wagner. *The HERON Project – Multimedia Database Support for History and Human Sciences*. INFORMATIK’98. Published in Dassow, Kruse (edit.). Informatik '98: pp. 309-318, Heidelberg 1998

[9] Vogel, Balke, Kießling. *Automatische Segmentierung in Wappensammlungen mittels MVTec Halcon*. Tech. Report 1999-3, Institut für Informatik. Universität Augsburg 1999