CONTENT-BASED RETRIEVAL OF DIGITAL ARCHIVES USING STATISTICAL OBJECT MODELING TECHNIQUES

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Abstract

The efficient archival and retrieval of digitized images is a demanding task due to e.g. the increasing popularity of digital imaging and the emerging application of image databases in various areas. Apart from technical databases, digital image archives are used as commercial product catalogs or in art galleries and historical museums. This paper presents two experimental image retrieval systems, both using a statistical framework which allows a flexible matching of shapes as well as the possibility to integrate features from different visual cues such as shape, color and – in future – texture in an integrated way. The first system applies the "query by user sketch" paradigm rather than the commonly used "query by example" method and is able to retrieve images from archives of isolated objects. Our experimental database consists of 120 color-images of common objects such as light-bulbs, hands, forks, etc. Although our experimental system has been evaluated on this database, the system can due to automatic learning capabilities easily be adapted to art or historical databases containing isolated objects. Examples for archives of isolated objects in this context are e.g. sculptures, *Readymades* or ancient objects of historical importance. A second experimental system described in this paper deals with the retrieval of historical watermarks, where those images are retrieved which contain user defined details. This watermark retrieval system uses the same statistical framework as the first system (so called Hidden Markov Models), which again leads to a deformation tolerant behavior, but applies a two-dimensional variant which fits more naturally to images.

1 Introduction

By far the largest image archive available is the World Wide Web (WWW), which contains images taken from all areas ranging from digitized paintings to cartoons. In order to efficiently retrieve pictorial data from very large databases, such as e.g. the WWW, content based methods are an attractive alternative to the traditionally used method of manual textual indexing. Text-based retrieval of images requires a time consuming and thus expensive manual indexing of the entire database. Furthermore, the query may lead to inaccurate retrieval results, if the query text does not match any of the stored keywords, due to different interpretations of the image contents. Moreover, the use of textual queries is not intuitive for humans and many users demand man-machine interfaces such as computer mouse or digitizer boards, rather than keyboards. In order to overcome these limitations of textual queries, two experimental systems which allow a content-based access to image libraries are presented in the following sections.

2 Retrieval by Sketch

Content-based retrieval by sketch allows a user to search an image database intuitively by applying simple drawings. By specifying the shape of an object by a sketch, it is often much easier to retrieve a

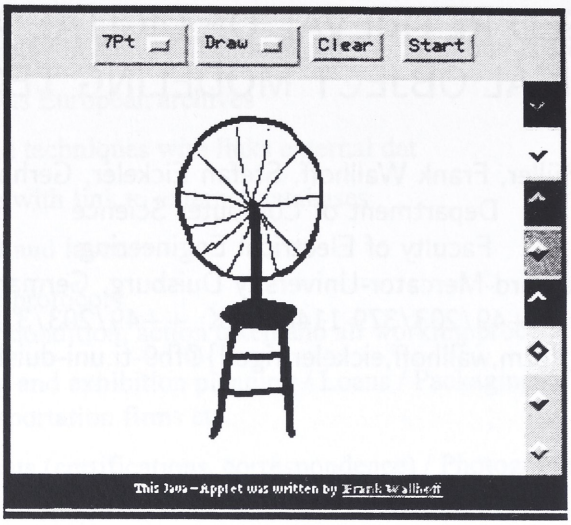

Figure 1: Java applet for presenting query sketches to our image retrieval system. This rough sketch could be used in order to retrieve an image of Marcel Duchamp's *Readymade* "The Bicycle Wheel".

specific object. It is for example possible to express height to width ratios or complex forms, which is quite difficult to express using a textual query. Imagine a textual description of the shape shown in Fig. 1, where a rough sketch of M. Duchamp's *Readymade* "The Bicycle Wheel" is shown. The sketch has been drawn using the WWW interface of our experimental retrieval system, which can be found at `http://www.fb9-ti.uni-duisburg/demos/query.html`. Note that although it would be possible to retrieve e.g. sculptures, the system currently retrieves images of common objects such as light-bulbs, forks, etc. Due to automatic learning capabilities, the system can be adapted to different databases. The Figs. 2 and 3 illustrate the polar sampling of a shape or sketch (feature extraction) and a diagram of the statistical model (Hidden Markov Model), respectively. The Hidden Markov Model (HMM) is used in order to represent the shape. HMMs are widely used in speech recognition, where they proved to be highly flexible and are able to deal with variations in pronunciation as well as (talking-)speed (see [7] for details). More recently, these models became also popular in online handwriting recognition (see e.g. [6]). In this research area the elastic matching capabilities are needed in order to deal with the large variations in the handwriting of even a single person. The examples given above demonstrate the usability of HMMs for the elastic matching of patterns and thus these models can be applied to the image retrieval by sketch. The polar sampling step illustrated in Fig. 2 generates the important features from an object and those features are used to train an individual HMM for every element in the database. Note that a very detailed explanation of the training procedure for HMMs in given by Rabiner in [7]. The particular topology of the

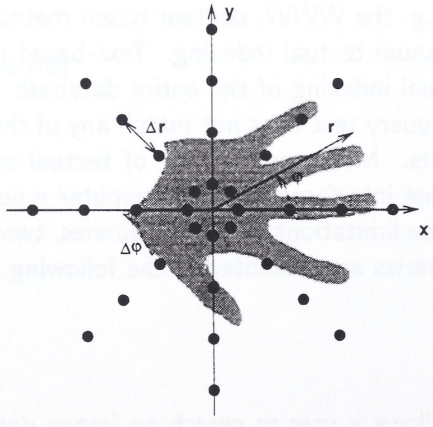

Figure 2: Polar sampling raster

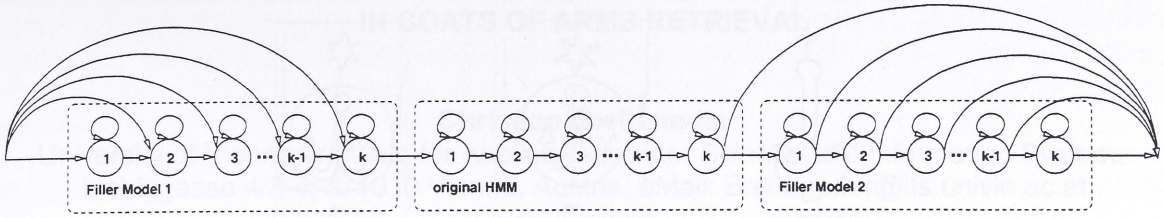

Figure 3: HMM structure for the modeling of shapes

HMM shown in Fig. 2 has mainly been chosen in order to achieve the desired rotation invariance. Rotation, scaling and translation are those affine transformations which, by definition, do not change the shape of an object. Detailed explanations about the applied feature extraction and statistical modeling techniques can be found in [2, 5]. The HMM-framework allows the use of different visual cues such as shape and color in an integrated way. In order to generate the color features, the sampling as illustrated in Fig. 2 is performed for each of the RGB-channels. Fig. 4 presents some results achieved with our system, where in every row the query-sketch is shown first, followed by those four images (out of 120) with the highest similarity measure (see also [3]).

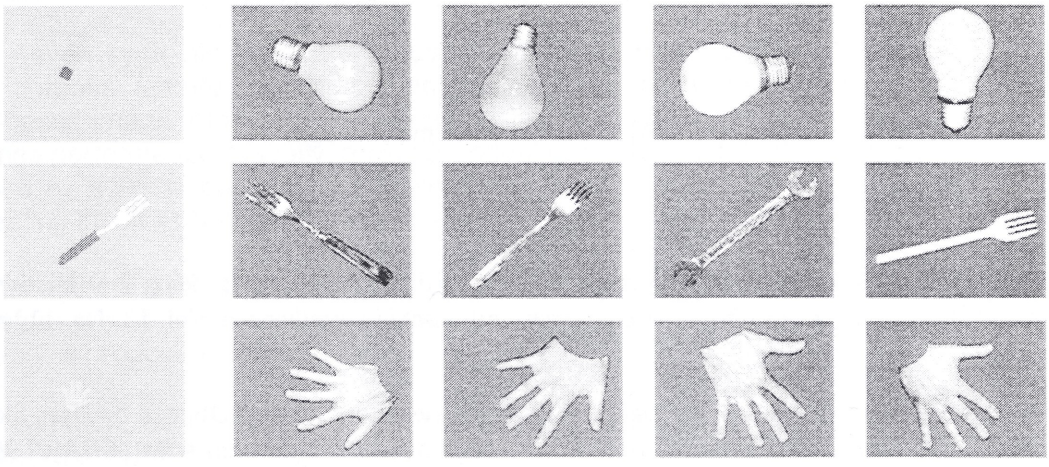

Figure 4: Query sketches and retrieved images

3 Finding details in historical watermark images

The second approach presented in this paper aims to retrieve historical watermark images [8] containing certain details, such as e.g. anchors, eagles, hands, etc., even in cases where the query shape is embedded in e.g. hatching or is connected to other parts in the image. The query-shape is represented by a two-dimensional statistical model (P2D-HMM) rather than a one-dimensional model as shown in Fig. 3 and is surrounded by so-called *filler states* which generate the remaining part of the image. This leads to an integrated approach which assigns probability scores to the elements of the archive and also locates the query shape in the database images. P2D-HMMs have been introduced by Kuo and Agazzi in [1]. Fig. 5 illustrates a query result, where the query shape (anchor) is shown in the upper left corner followed by those eight images (out of 50) with the highest similarity score (ordered left to right and top to bottom, with decreasing score). A detailed description of the system can be found in [4], however note that in [4] the system is evaluated on an engineering drawing database.

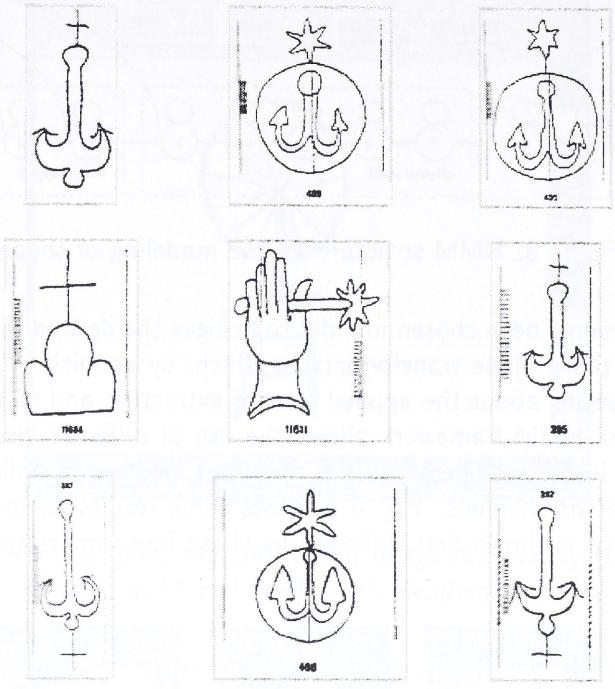

Figure 5: Retrieval of watermark images

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