Contour Extraction of Watermarks in Old Manuscripts

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Abstract

The comparison of watermarks in old paper is the major technique for dating undated medieval manuscripts. The extraction of watermarks as contours is the crucial task in digitalization and building a watermark database. In this paper the method of object delineation by active curves (snakes) is modified and applied to the contour tracing and skeletonization of watermarks.

Keywords: active contours, watermarks, snakes, cultural heritage

1. Introduction

Medieval handwritten books and incunabula represent an important part of our cultural heritage. Investigation, cataloging, and restoration of these books are necessary to preserve this heritage for the future. Often, these books are not dated, but the knowledge about the date when the book was written or printed is essential for research. The comparison of dated watermarks with undated ones is a major method for dating undated mediaeval handwritten (paper) documents and incunabula. For this purpose there exist several standard catalogues[1,2] containing thousands of hand-drawn sketches of watermarks. The identity of a watermark with one in the standard catalogues is a good indicator for the age of the watermark and the codex in question.

2. Problems

There are some essential drawbacks to the precise dating of the watermarks in a codex using the standard catalogues. In many cases the watermarks of a document are covered by the written text such that it is quite impossible to produce unique hand-drawn sketches. But even if it is possible to make a perfect sketch of the watermark, it is time-consuming and tedious to find an identical watermark among hundreds of watermarks of the same motif. Furthermore, it appeared that the proof of the watermark identity is not sufficient for a reliable dating result. The identity of the sieve has to be demonstrated, too. Computers are ideal tools for cataloging and retrieval of huge amount of data and considerable work has been done already to develop and fill watermark databases[3,4,5].

All paper marks including watermarks are small deviations in the thickness of paper. Prior to inputting the watermark, a hardcopy made e.g. by hand, rubdown, X-rays, or betaradiography has to be produced. Betaradiography has been chosen among the methods for a unique recording of the watermarks because of the good quality of these recordings. Small deviations in density of the paper are recorded sufficiently well after an exposure time of four to six hours. These hardcopies have low contrast except some very bright or very dark spots and areas caused by holes in the paper or special color ink (Figure 1). A drum scanner or a sensitive flatbed scanner with a transparency extension can do the scanning. The recordings are scanned, digitally processed, contrast enhanced, and stored in a database as images.

For comparison and classification, it is necessary to extract the watermark as skeleton (sequence of strokes). This is the most demanding step in the watermark-processing pipeline. All attempts to fully automate the procedure for skeletonization failed, especially because of the low contrasts in the watermark recordings and many artifacts, which produce incomplete figures. Furthermore, the

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watermarks are overlapped by other structures such as sieve marks. Manual tracing is not acceptable because of the huge amount of watermarks and the subjectivity of tracing the contours by hand.

3. Solution

A semi-automatic procedure has been chosen, as all attempts to trace or segment the watermarks automatically did not work properly due to the quality of the images. But a main design goal of the semi-automatic procedure is to minimize the user interaction and to optimize the quality of tracing.

Figure 1: *Contrast enhanced image (betaradiography) with watermark (bell), sieve marks (dark vertical and horizontal lines) and artifacts (white areas).*

At first, the watermark motif, which defines the overall watermark shape, is determined by user interaction. The motif is selected from a list of some dozen possibilities (e.g. bell, scales, bow and arrow, oxhead etc.) and lays down the number and positions of control points, which are necessary to be marked manually. This number is kept minimal (typical between five and ten). Furthermore the motif also sets geometric restrictions for the variability of the skeleton.

Each two consecutive control points are connected by piecewise (cubic) splines fitting the watermark contour as good as possible. For achieving this, tracing or delineation methods used in application areas like medical imaging[6] are applied and adopted. After identification of the motif and marking the positions of the control points (landmarks), constrained active contour models, also called snakes, are used to find the optimal position of the contour between the control points.

Active contour models were originally introduced by Kass et al.[7] as curves that minimize energy functional. An active contour is influenced by image forces that attract it towards features like lines and edges and by external constraint forces provided by input from higher level processes or user interaction.

In our case, two consecutive control points are connected by a cubic or higher-order parametric spline $s(t,p)$, where t is the parameter and p are the coefficients of the spline. The spline coefficients p are varied such that the energy functional, which can be written as[8]:

$$E(p) = \int_t (E_{int}(s(t,p)) + E_{img}(s) + E_{con}(s))dt$$

is minimal. E_{int} is called the internal energy and it specifies the elasticity and stiffness controlling the deformations of the curve. It restricts the elongation and bending, and depends mainly on the first and second derivatives of the curve. In most cases the extremal motif shape extensions are known and these extreme values are used to formulate constraints. This apriori knowledge can be coded also into the internal energy. E_{img} is that part of the energy functional which determines the effect of the image on the form of the spline. It is chosen as the negative magnitude of the image gradient being a good indicator for the existence of an edge. The final term E_{con} controls the effect of user interaction on the snake, which is necessary when the snake is attracted to wrong areas in the image.

The spline coefficients are independent from the position and orientation of the watermark. They describe the watermark completely, allow the search for existing identical or similar watermarks in the database, and yield also a very comprehensive coding.

Figure 2 shows all contours (black curve and straight lines) that are essential for comparison and dating of watermarks. A mean contour is calculated for each motif by simple averaging the coefficients of the splines. This mean contour is used as initial value for the minimization.

The proposed procedure proved to be successful in nearly all cases. The procedure fails only in those cases were large artifacts overlap the watermark with gray values in the same range as the watermarks. Another drawback is that the procedure detects only contours, but sometimes watermarks or parts of them have a width of some

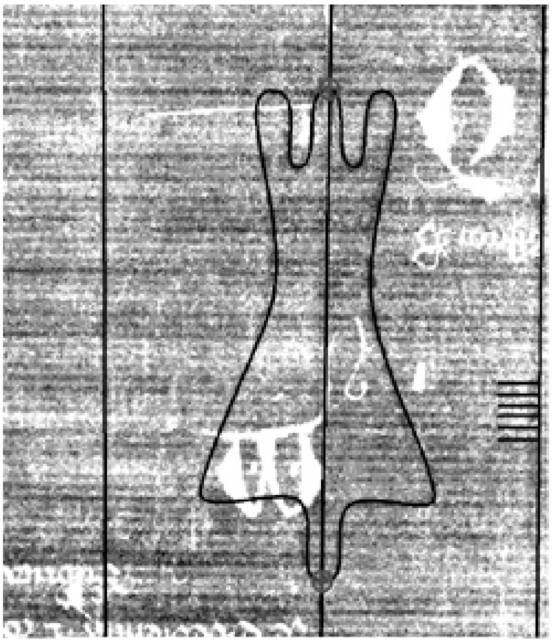

Figure 2: *Traced contours of the watermark and manually marked sieve wires (3 long vertical and 6 short horizontal lines)*

pixels and hence two contours can be generated. In this case, the skeleton is calculated as the midline of both contours.

4. Future work

In future work, we will improve the handling of artifacts. Analyses and classification of artifacts should allow detecting most of the artifacts automatically. The study of different image energy functions should help to improve the quality of contour detection.

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