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Wenyin Liu
Josep Lladós (Eds.)

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Ten Years Review and Future Perspectives

6th International Workshop, GREC 2005
Hong Kong, China, August 2005
Revised Selected Papers

IAPR

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Preface

This book contains refereed and improved papers presented at the 6th IAPR Workshop on Graphics Recognition (GREC 2005). This year is the tenth anniversary of GREC, which was started in 1995 and has been held every 2 years: GREC 1995 in Penn State University, USA (LNCS Volume 1072, Springer, 1996); GREC 1997 in Nancy, France (LNCS Volume 1389, Springer, 1998); GREC 1999 in Jaipur, India (LNCS Volume 1941, Springer, 2000); GREC 2001 in Kingston, Canada (LNCS Volume 2390, Springer, 2002); and GREC 2003 in Barcelona, Spain (LNCS Volume 3088, Springer, 2004).

GREC is the main event of IAPR TC-10 (the Technical Committee on Graphics Recognition within the International Association for Pattern Recognition) and provides an excellent opportunity for researchers and practitioners at all levels of experience to meet colleagues and to share new ideas and knowledge about graphics recognition methods. Graphics recognition is a particular field in the domain of document analysis, which combines pattern recognition and image processing techniques for the analysis of any kind of graphical information in documents from either paper or electronic formats. In its 10 year history, the graphics recognition community has extended its research topics from the analysis and understanding of graphic documents (including engineering drawings vectorization and recognition), to graphics-based information retrieval and symbol recognition, to new media analysis, and even stepped into research areas of other communities, e.g., sketchy interfaces and on-line graphics recognition, so as to face up to new challenges. These continuous changes show that we are a dynamic, active, and promising scientific community.

The program of GREC 2005 was organized in a single-track 2-day workshop. It comprised several sessions dedicated to specific topics. For each session, there was an overview talk, followed by a number of short presentations and concluded by a panel discussion. Session topics included "Engineering Drawings Vectorization and Recognition," "Symbol Recognition," "Graphic Image Analysis," "Structural Document Analysis," "Sketching and On-Line Graphics Recognition," and "Curve and Shape Processing." In addition, a special session of panel discussion was dedicated to the 10th anniversary of GREC, which focused on the summary of the achievements of GREC in the past 10 years and the planning of GREC in the next 10 years.

Continuing with the tradition of past GREC workshops, the program of GREC 2005 also included two graphics recognition contests: a symbol recognition contest, organized by Ernest Valveny and Philippe Dosch, and an arc segmentation contest, organized by Liu Wenyin. In these contests, test images and ground truths are prepared in order for contestants to have objective performance evaluation conclusions on their methods.

After the workshop, all the authors were invited to submit enhanced versions of their papers for this edited volume. The authors were encouraged to include ideas and suggestions that arose in the panel discussions of the workshop. Every paper was evaluated by two or three reviewers. At least one reviewer was assigned from the attendees of the workshop. Papers appearing in this volume were selected and most of them were thoroughly revised and improved based on the reviewers' comments. The structure of this volume is organized in eight sections, reflecting the workshop session topics.

We want to thank all paper authors and reviewers, contest organizers and participants, and workshop attendees for their contributions to the workshop and this volume. Special thanks go to the following people: Miranda Lee for her great efforts in managing all logistic work; Wan Zhang, Tianyong Hao, and Wei Chen for their help in preparing the workshop proceedings and this volume; Karl Tombre for leading the panel discussion session dedicated to the tenth anniversary of GREC and providing an insightful summary of the discussion. Finally, we gratefully acknowledge the support of our sponsors: The City University of Hong Kong, IAPR, K. C. Wong Education Foundation, and The Hong Kong Web Society.

During the review process, we received the extremely sad news of the unexpected passing away of Adnan Amin. Adnan was an active researcher in the graphics recognition community. He participated in several GREC Workshops and was a member of the Program Committee of GREC 2005. He will be sorely missed by all of us. We would like to dedicate this book to the memory of Adnan.

The 7th IAPR Workshop on Graphics Recognition (GREC 2007) is planned to be held in Curitiba, Brazil, together with ICDAR 2007.

April 2006

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Vectorization and Parity Errors

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Abstract. In the paper, we analyze the vectorization methods and errors of vectorization of monochrome images obtained by scanning line drawings. We focused our attention on widespread errors inherent in many commercial and academic universal vectorization systems. This error, an error of parity, depends on scanning resolution, thickness of line, and the type of vectorization method. The method of removal of parity errors is suggested. The problems of accuracy, required storage capacity, and admissible slowing of vectorization are discussed in the conclusion.

Keywords: Raster Image, Vectorization, Medial Axis, Centerline, Accuracy, Error of Parity.

1 Introduction

The vectorization of monochrome images obtained by scanning line drawings consists of finding:

a) Mathematical lines (lines with zero thickness) describing appropriate raster linear objects (their location and topology)
b) Nodes (points of intersection of raster linear objects)
c) Shape functions that define the local thickness of the source raster lines.

The results of vectorization contain enough information for restoring the source image with a given accuracy.[1]

Authors of many papers use the term "skeleton" for the set of mathematical lines that are the result of the vectorization. We prefer the term "centerline", because the term "skeleton" often is used as a synonym for medial axes.

Medial axes are the locus of centers of maximal discs inscribed into the shape [1]. There is another definition equal to the previous one: medial axes of a form are a set of points internal to a form where each point is equidistant and closest to at least two points of the form boundary.

Each protrusion on the border of the geometrical form (in our case a form is a set of intersected raster lines) causes medial axis deviations. Even very small protrusions

[1] The vectorization task contains also dividing an image into linear objects and solids. The result of solid vectorization is a vector description of solid borders. But this part of the task of vectorization is beyond the scope of the paper.

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cause new branches and branching points (nodes). If we interpret each branch of a medial axis as a centerline, then the branches and appropriate nodes produced by deviations of borders have to be interpreted as erroneous or parasitic ones (see Fig. 1).

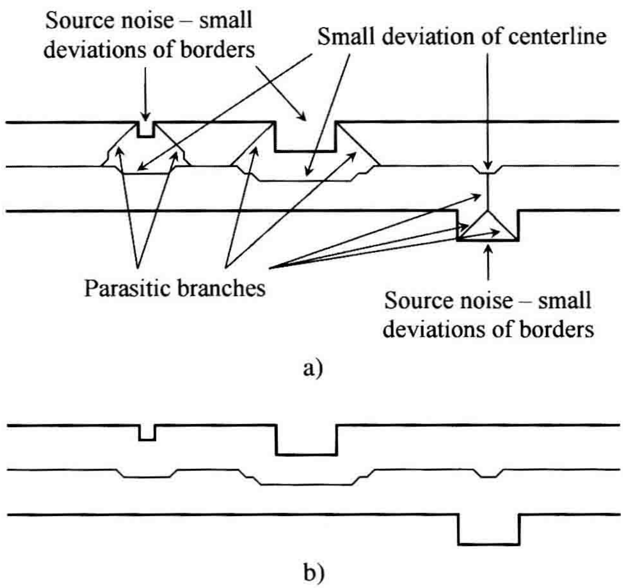

Fig. 1. Horizontal raster line with deviations of borders. a) Medial axis with parasitic branches, b) Medial axis without parasitic branches.

Medial axes have a strict geometrical definition, so they can be built without control parameters, thresholds, or any additional information except the borders of shapes.

Medial axes were suggested for a vector description of shapes. It is possible to use them for vectorization, but in no circumstances are they the results of vectorization because of parasitic branches and nodes.

There are methods of vectorization that build centerlines from medial axes by removing parasitic branches. We have already mentioned that parasitic branches are the results of noises, which are deviations of borders of raster lines from the true borders. Usually these noises have a probabilistic nature, so for building centerlines it is necessary to have some information about statistics of noises and desired signal.

So centerlines, as opposed to medial axes, do not have a strict deterministic definition [2, 3]. What part of a medial axis forms a centerline depends on the application domain, the type of line drawing, the resolving task, and many other reasons. This uncertainty is the main difficulty of the problem of vectorization and vectorization accuracy evaluation.

Nevertheless, it is obvious that in the simplest cases of horizontal and vertical raster lines with constant thickness, the centerlines have to be its axes of the symmetry. So in these cases we can easily evaluate errors of vectorization.

Fig. 2 and 3 show the results of vectorization obtained by two well-known commercial universal vectorization systems. It is easy to see that the results of vectorization have the following errors:

a) Centerlines of raster lines with thickness 2 and 4 pixels are shifted from axes of symmetry. We will call this error a parity error.
b) Many centerlines do not reach the ends of appropriate raster lines.
c) The ends of some centerlines essentially shifted from axes of symmetry.
d) A centerline showed on Fig. 3c is not horizontal.

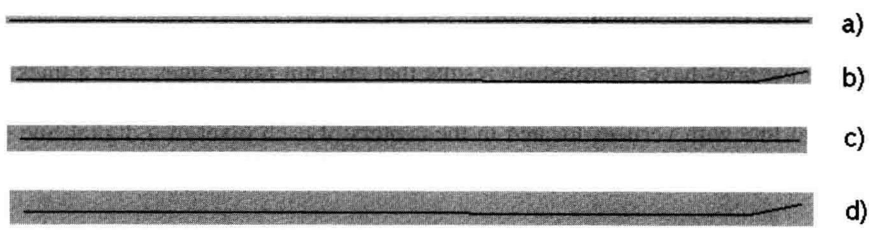

Fig. 2. Source raster lines and centerlines obtained with universal vectorization system A. Thickness of lines: a) 1 pixel, b) 2 pixels, c) 3 pixels, d) 4 pixels.

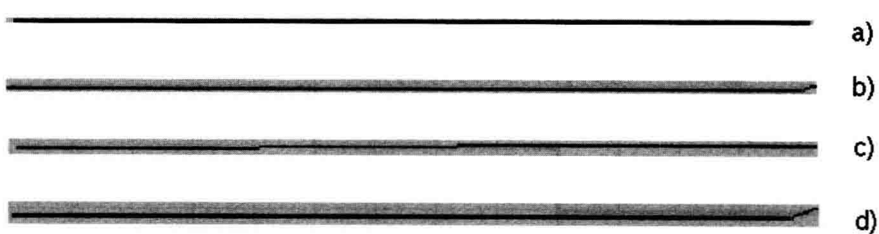

Fig. 3. Source raster lines and centerlines obtained with universal vectorization system B. Thickness of lines: a) 1 pixel, b) 2 pixels, c) 3 pixels, d) 4 pixels.

2 Three Classes of Methods of Raster Lines Vectorization

Many of the vectorization methods implemented in universal vectorization systems can be conditionally represented as three successive stages: pre-processing, raw vectorization, and post-processing.

The first stage consists of editing raster images (raster-to-raster conversion) to suppress of noises and improving the quality of the images. This stage is optional.

The second stage is a raster-to-vector conversion or raw vectorization. It can include removing parasitic branches. The result of this stage is a set of raw centerlines, which are represented with polygonal lines. The length of each segment of raw centerlines is about one pixel.

The third stage (vector-to-vector conversion) consists of processing raw centerlines to increase accuracy and data compression. Usually it includes gap closure, smoothing, geometrical recognition, line type recognition, beautification, and compression.

Below, we will analyze only those methods of vectorization which include the stage of the raw vectorization (explicitly or implicitly).

Divide all vectorization methods into three classes:

A. Vertices of raw centerlines can be located only in the centers of pixels.
B. Vertices of raw centerlines can be located only in corners of pixels.
C. Vertices of raw centerlines can be located in arbitrary points.

Class A contains many methods based on thinning, distance transformation, and veinerization (see, for example, [3–6]).

This is not a full list of vectorization methods of class A. It is important only that all these methods have intermediate results that are thin raster lines with a thickness of 1 pixel. Such thin raster lines are often called digital lines. A raw centerline is a polygonal line with vertices located in the centers of each pixel of a digital line (see Fig. 4).

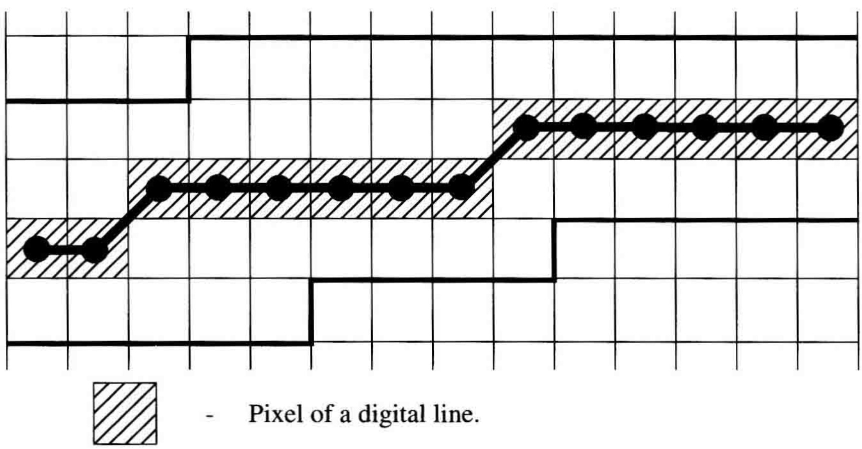

Fig. 4. Raw centerline with vertices in pixel centers

Class B contains a method that uses raster approximation of extended Voronoi cells [7]. In this method, a centerline follows between cells (along edges of cells), which are equidistant or almost equidistant from opposite sides of the raster line border.

Class C contains methods based on finding cross sections of raster lines. These cross sections pass through conjugated points on the opposite sides of the border of the raster line. The angle between a centerline and cross segments has to be as close as possible to 90 degrees and at least not less than 45 degrees. Connecting the middle points of these cross segments, it is possible to build lines that approximate the branches of the median axes. One such method is described in [8]. Another example of the vectorization method of class C is based on Voronoi tessellation [9].