

## PREFACE

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Thinning is a technique widely used in the preprocessing stage of a pattern recognition system to compress data and to enhance feature extraction in the subsequent stage. It is a process which reduces a digitized pattern to a skeleton so that all resulting branches are of only 1 pixel thickness. The advantages of thinning are many, for example (i) It provides a significant reduction in the amount of data which need to be processed. Usually the compression ratio between the original data and the processed data is about 4:1. (ii) It facilitates subsequent extraction of distinctive features from the pattern, e.g. endpoints of lines, intersection points, positions, lengths, and directions of line segments. This is especially useful for computer recognition of characters, fingerprints, line-drawings, circuit diagrams, and others.

At the onset, thinning looks like an easy task and human beings seem to be able to do that without much effort by simply drawing the centre lines of the strokes. However, after two decades of intensive research, the proposition of numerous thinning algorithms and the publication of over 300 papers, it is clear that thinning is indeed a very challenging subject. The great difficulties in programming computers to skeletonize a digital pattern stem from the major reasons listed below:

- (a) In contrast to human beings, the thinning algorithms usually know neither the identity of the input pattern, nor its shape and stroke formations. Hence it is extremely difficult for a thinning algorithm to produce perfect skeletons which will reflect the true shape of the original pattern.
- (b) Many algorithms thin patterns by continuously eroding their outer contours which may result in uneven edges and possibly the destruction of certain parts of the pattern, especially at the junctions and turning points.
- (c) The thinning process may produce small bumps and extraneous branches to the pattern, some of which may seriously affect the recognition process.
- (d) Connectivity between pixels may be broken by the thinning process, leading to changes in the topology of the input pattern.
- (e) Except through subjective assessments, presently there are no standard test patterns and methodologies for the measurement of the performance of thinning algorithms.

This book contains a collection of papers by distinguished scientists who have been working in this area for a number of years. The papers deal with both the theoretical and experimental aspects of thinning methodologies. In preparing this book, the authors were encouraged to address some of the problems mentioned above, to compare the performance of their results with others, and to assess the challenges ahead of us. It is hoped that this book will shed some light on them and stimulate further research in this exciting area.

There are altogether 15 papers in this book which can be divided into the following categories:

## 1. NEW THINNING ALGORITHMS

The paper by Dimauro *et al.* presents a new thinning algorithm which is based on an iteratively controlled procedure which deletes the edges of all regions of the digitized pattern. This process produces skeletons which retain the important specifications of the pattern useful for robust structural descriptions. The next paper by Arumugam *et al.* describes another new thinning algorithm which is based on the well-known concept of the force of attraction or repulsion between charged particles. This algorithm generates connected skeletons which preserve the shape and endpoints of the original patterns. Suzuki *et al.*'s paper proposes a new method which produces natural line patterns by suppressing shape distortion and false feature points. Hu and Li's paper presents a noniterative method which can deal with the difficulty associated with the thinning of line intersections. Suzuki and Mori's paper propose the Cross Section Sequence Graph which describes line images in a simple and well-structured form so that singular regions can be analyzed to find the endpoints, corners, branches, crosses, and other features.

## 2. PARALLEL THINNING

Five papers fall into this category. Arcelli *et al.*'s paper proposes a 4-subiteration parallel thinning algorithm which takes into account bidirectional compression in each subiteration to remove pixels which belong to a pair of successive contours. Using the octagonal metric, the medial line is centered in a pattern in a quasi-Euclidean sense and is found to be less sensitive to pattern rotation. The next paper by Ubeda describes a parallel thinning algorithm which uses the bounding boxes to keep the regularity of thinning processes while reducing the amount of standard parallel operations. The original picture is partitioned and the range of the full-parallel operation in the subpictures is reduced dynamically. Eckhardt and Maderlechner's paper shows that the natural requirement of invariance leads nearly automatically to a method which is genuinely parallel and well-defined so that it is possible to investigate it theoretically. Jang and Chin's paper describes a reconstructable thinning process which is based on one-pass parallel thinning and the morphological skeleton transformation. It uses thinning templates to iteratively remove boundary pixels and structuring templates of the morphological skeleton transformation to retain critical feature pixels for reconstruction. Another Ubeda's

paper uses a  $k \times k$  mask to achieve faster parallel thinning speed by increasing window size.

### 3. EVALUATION OF THINNING ALGORITHMS

The first paper by Lee *et al.* presents the results of extensive experiments conducted to evaluate the performance of 19 skeletonization algorithms which have been implemented in the C language and tested with a large number of binarized patterns. A systematic comparison of the algorithms has been made based on criteria such as similarity to reference skeleton, quality of skeleton, connectivity, degree of parallelism, speed, and reconstructibility. Zhang and Wang use a heuristic, hybrid approach to analyze the differences between thinning algorithms using iteration and subiteration, and thinning by coordinates and by edges. A serial model thinning algorithm is also proposed. Plamondon *et al.*'s paper investigates three different methods of comparing preference structures for thinning algorithms involving a series of experiments with human subjects, neural networks, and distance measurements. Several statistical tests have also been performed to analyze the preference structures exhibited by the data. Lam and Suen's paper summarizes the results of an attempt to develop a methodology to automatically evaluate the quality of skeletons. It makes use of distance measures based on 3 shape-matching methods to compare the skeletons produced by these methods.

### 4. SKELETONIZATION OF GREY-VALUE PATTERNS

The last paper by Verwer *et al.* deals with both binary and grey-value thinning. The authors propose and demonstrate skeletonization using path-based metrics which are a better approximation of the Euclidean metric.

The papers in this book are also published in a special issue of the *International Journal of Pattern Recognition and Artificial Intelligence* (Volume 7, Number 5, 1993).

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