Half Century for Image Segmentation

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INTRODUCTION

Image (and video) segmentation is an important image technique, and is often described as the process that subdivides an image (or a clip of frames) into its constituent parts and extracts those parts of interest (objects). It is well known by its utility, since for extracting the useful information from images or a group/sequence of images, to separate the objects from background is an inevitable step/task. It is also well known by its complexity, as there is no general theory for image segmentation, yet. Therefore, the development of image segmentation techniques is still an *ad hoc* process.

Image segmentation is one of the most critical tasks in automatic image analysis, which is at the middle layer of image engineering (IE). Image Engineering (which is composed of three layers from bottom to top: image processing, image analysis and image understanding) is a new discipline and a general framework for all image techniques (Zhang, 2008d).

According to the statistics gathered from a yearly bibliography survey on image engineering (Zhang 2013), the journal publication on image segmentation is ranked the first among the current 16 groups/branches of research techniques of image engineering. The comprehensive survey has been made consecutively for 18 years, and the totally involved papers are more than 40000, in which 8243 are related to the different technique groups of image engineering. The statistics for the distribution of these papers in each group are listed in Table 1. It is seen that the group of image segmentation is the one that attracts the most attentions and achieve the most results among a complete list of technique groups.

In this article, after an introduction about three levels of research on image segmentation, the statistics for the number of developed algorithms in these years are provided; the scheme for classifying different segmentation algorithms is discussed, and a summary of existing survey papers for image segmentation is presented. All these representations and discussions provide a general picture of research and development of image segmentation in the last 50 years.

BACKGROUND

The history of segmentation of digital images using computers can be traced back to 50 years' ago. The earliest proposed method for image segmentation, which is a global thresholding technique, should be the

Table 1. Journal papers in different technique groups

No	Technique Group	# of Papers	No	Technique Group	# of Papers
1	Segmentation and edge detection	1238	9	Content-based image retrieval	347
2	Enhancement and filtering	974	10	Reconstruction from projections	303
3	Coding/decoding	896	11	Analysis and feature measurement	287
4	Object extraction and recognition	832	12	Object representation and description	233
5	Registration, matching and fusion	810	13	3-D modeling and scene recovery	231
6	Biometrics	643	14	Multiple-resolution processing	158
7	Watermarking, and information hiding	599	15	Spatial-temporal technology	90
8	Capturing and storage	523	16	Image perception and interpretation	79

DOI: 10.4018/978-1-4666-5888-2.ch584

"p-tile" method (Doyle, 1962). This method needs to know the percentage (p%, the name comes) of object pixels in the whole image, and chooses the gray level as threshold that could map p% pixels to the object region. As an example, suppose one image consists of a lighter object on a darker background, then the threshold level should separate the whole pixels into two parts: one with p% pixels for the object while another with $(100 - p)$% pixels for the background. In digital images, the exact percentage might not be achieved, so a most closed percentage could be selected.

Since then, the field of image segmentation has evolved very quickly and has undergone great change (Zhang, 2001a; Zhang, 2006). The cumulative effort makes this field becoming the most active and most fruitful one in all fields of image engineering, as demonstrated by Table 1.

Though many efforts have been devoted to the research of segmentation techniques, there is no general theory for image segmentation, yet. Therefore, the development of segmentation algorithms has traditionally been an *ad hoc* process. As a result, many research directions have been exploited, some very different principles have been adopted, and wide varieties of segmentation algorithms have appeared in the related literatures. It was noted by many people that none of the developed segmentation algorithms are generally applicable to all kinds of images and different algorithms are not equally suitable for a particular application (Zhang, 2006).

With the increase of the number of algorithms for image segmentation, how to evaluate the performance of these algorithms becomes indispensable in the study of segmentation. Considering the various modalities for acquiring different images and the large number of applications requiring image segmentation, how to select appropriate algorithms for segmentation turns into an important task. A number of evaluation techniques have been proposed, for those published in the last century, see survey papers (Zhang, 1996; Zhang, 2001b), while for those published in this century, see (Zhang, 2008a).

While the evaluation of segmentation techniques has gained more and more attention, with numerous evaluation methods frequently designed, how to characterize the different existing methods for evaluation has also attracted some interest in recent years (Zhang, 2001a). In fact, different evaluation criteria and procedures, their applicability, advantages and limitations need to be studied carefully and systematically (Zhang, 2006).

According to the above discussion, the research for image segmentation is carried on in three levels (Zhang, 2006). The first one and the basic one is the level of algorithm development. The second one is the level of algorithm evaluation. The third one is the level of systematic study of evaluation methods. This present article will mainly concentrate on the first level.

GENERAL PROGRESS STATUS

After 50 years of development, the current progress status of image segmentation could not be totally covered by only a few of pages. Instead, three aspects are presented to give a general idea:

1. A worldwide statistics about the number of segmentation algorithms already developed.
2. A general scheme for classifying different segmentation techniques into groups.
3. An overview of survey papers for segmentation, published in the last 50 years.

Amount of Developed Segmentation Algorithms

Over the last 50 years, the research and development of segmentation algorithms are going on and making very rapid progress. A great number of segmentation algorithms have been developed and this number continually increases each year. Table 2 gives a list of the numbers of records (for every 5 years) found in EI Compendex (the most comprehensive bibliographic database of engineering research available today, see http://www.

Table 2. List of records found in EI Compendex

Period	62-66	67-71	72-76	77-81	82-86	87-91	92-96	97-01	02-06	07-11	Total
Number	7	8	61	353	1036	2086	4901	9672	18425	37098	73647