A Critical Overview of Image Segmentation Techniques Based on Transition Region

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INTRODUCTION

Image segmentation is the key step from image processing to image analysis, and is an important technique of image engineering (Zhang, 2009). It refers to the general procedures and processes for dividing an image into regions with each has some particular characteristics and extracting the target region of interest. Since there is no general theory for image segmentation itself, yet, the image segmentation has always been in-depth study of attention. A large variations of theories and technologies have been applied to solve the image segmentation problem (Zhang, 2006). According to a study based on EI Compendex, the first segmentation algorithm is proposed in 1962, the number of literatures on image segmentation has reached 77,000 half-century late (Zhang, 2015b). According to the increasing tendency, it is estimated that this number should be around 100,000 now.

Image segmentation based on transition region is a special or distinctive type of techniques that are different from traditional boundary-based or region-based techniques. Its strategy is first detecting a transition region between object regions and background regions, then segmenting image into object region and background region based on the properties of transition region. The first technique using transition region is often referred to effective average gradient (EAG) that in fact is just the name of the core parameter of this technique. EAG has raised more than a quarter of a century ago (Zhang, 1989). Journal paper (Zhang, 1991) introduced this technique in detail, and journal paper (Zhang, 1996) further extended this technique to more general situations. Since then, there are many subsequent related researches and applications, and a series of papers in the literature citing (Zhang, 1991) and/or (Zhang, 1996) are published worldwide (Zhang, 2015a).

Using Google Scholar, a number of papers citing (Zhang, 1991) and/or (Zhang, 1996) are searched and selected, a study on the statistics of these papers is conducted, an analysis of these papers is performed, and discussions on these results are provided.

BACKGROUND

The main contributions of the original journal papers (Zhang, 1991) and (Zhang, 1996) can be summarized into five points:

1. **They Clarified the Three Evidences for the Existing of Transition Region:** Firstly it can prove that, according to Shannon sampling theorem, the discrete edge obtained by sampling a continuous image has always a transition region of at least one pixel wide (Gerbrands, 1988). Secondly the transition region in the actual image can be directly observed. Finally, the transition region can be generated by means of smoothing property inherent in the nature of image capturing.
2. **They Analyzed the Rationality and Feasibility of Using the Transition Region for Segmentation:** The transition region is spatially located between the object and

DOI: 10.4018/978-1-5225-2255-3.ch112

the background, so the boundary separating the object and background should be in the transition region. Moreover, the gray-values of transition region are in the middle of the gray-values of object pixels and background pixels, so if the thresholding techniques is used for segmentation, the appropriate threshold values should be belong to the value set of the transition region pixels. In addition, selecting the threshold value from the transition region must be more reliable than selecting the threshold value from the full image.

3. **They Put Forward a Specific Method for Determining the Transition Region:** Although the existing of transition regions is an objective reality, the effective detection method is required. To determine the transition region in actual images, a method consisting of clip transformation of images, computation of the EAG curves, determination of the optimal dynamic range, and thereby extracting the transition region is proposed. This method converts the problem of determining the transition region into an optimization problem, without any preset parameter to be adjusted in the determination. This fully automatic method has the iterative nature and uses the global information of images, so it is relatively stable and robust. Finally, according to the characteristics of the EAG curve, a fast realization way is designed to improve the computational efficiency.
4. **They Proved Three Properties of the Two Gray-Values Defining the Transition Region:** Depending on the aforementioned computation method for the transition region, the dynamic range of transition region is defined by two gray-values (i.e., L_{low} and L_{high}) obtained from EAG curve. With the help of mathematical analysis, three properties of these two values are formally proved: 1) They always exist and only one for each transition region; 2) They can make both corresponding functions EAG(L_{low}) and EAG(L_{high}) reaching the maximum values; 3) They satisfy $L_{low} < L_{high}$ in practical situations. In (Zhang, 1996), these three properties are also proved for images having more than one transition region.
5. **They Discussed How to Use the Transition Region Further to Segment Image:** On the basis of the transition region extracted, according to the property that the gray-value range of transition region is between gray-values of object and background, a suitable threshold value can be determined with the help of gray-values of the transition region, for example, this threshold value can be the average value or the mode value of the gray-value ranges of the transition region.

SURVEY ON THE FOLLOW-UP LITERATURE

A large number of follow-up researches for (Zhang, 1991) and/or (Zhang, 1996) have been conducted, many new papers have been published in referring/citing them. With the help of Google Scholar, many of them (most of them are journal papers) can be found.

Citation-Statistics Over the Years

According to the search results from Google Scholar, so far the number of records citing (Zhang, 1991) is 87, the distribution of these records for each year is shown in Figure 1; and the number of records citing (Zhang, 1996) is 59, the distribution of these records for each year is shown in Figure 2.

The total number of records citing these two papers reaches 146. However, after a careful reading and checking of all these records, it is found that 7 of them are incorrectly picked up by Google Scholar (3 records for citing (Zhang, 1991), 4 records for citing (Zhang, 1996)). On the other side, there are 13 records citing both (Zhang, 1991) and (Zhang, 1996). After screening, there are totally 126 papers citing (Zhang, 1991)