Chapter 13
Fuzzy Clustering Based Image Segmentation Algorithms

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ABSTRACT

Image segmentation especially fuzzy based image segmentation techniques are widely used due to effective segmentation performance. For this reason, a huge number of algorithms are proposed in the literature. This chapter presents a survey report of different types of classical and shape based fuzzy clustering algorithms which are available in the literature.

1. INTRODUCTION

The application of digital images is rapidly expanding due to the ever-increasing demand of computer, Internet and multimedia technologies in all aspect of human lives, which makes digital image processing a most important research area. Digital image processing encompasses a wide and varied field of applications from medical science to document processing and generally refers to the manipulation and analysis of pictorial information. Image processing is mainly divided into six distinct classes: i) Representation and modelling, ii) Enhancement, iii) Restoration, iv) Analysis, v) Reconstruction, and vi) Compression. Image analysis embraces feature extraction, segmentation and object classification (Baxes, 1994; Duda & Hart, 1973; Gonzalez & Woods, 2002; Jahne, 1997; Jain, 1989), with segmentation for instance, being applied to separate desired objects in an image so that measurements can subsequently be made upon them.

Segmentation is particularly important as it is often the pre-processing step in many image processing algorithms. In general, image segmentation refers to the practice of separating mutually exclusive homogeneous regions (objects) of interest in an image. The objects are partitioned into a number of

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non-intersecting regions in such a way that each region is homogeneous and the union of two adjacent regions is always non-homogeneous. Most natural objects are non-homogeneous however, and the definition of what exactly constitutes an object depends very much on the application and the user, which contradicts the above generic image segmentation definition (Gonzalez & Woods, 2002; Karmakar, Dooley, & Rahman, 2001; Spirkovska, 1993; Haralick & Shapiro, 1985; Fu & Mui, 1981).

Segmentation has been used in a wide range of applications, with some of the most popular being, though not limited to: automatic car assembling in robotic vision, airport identification from aerial photographs, security systems, object-based image identification and retrieval, object recognition, second generation image coding, criminal investigation, computer graphic, pattern recognition, and diverse applications in medical science such as cancerous cell detection, segmentation of brain images, skin treatment, intrathoracic airway trees, and abnormality detection of heart ventricles (Karmakar, Dooley, & Rahman, 2001; Pham & Prince, 1999; Liu, et al, 1997; Pal & Pal, 1993).

Different applications require different types of digital image. The most commonly used images are light intensity (LI), range (depth) image (RI), computerized tomography (CT), thermal and magnetic resonance images (MRI). The research published to date on image segmentation is highly dependent on the image type, its dimensions and application domain and so for this reason, there is no single generalized technique that is suitable for all images (Pal & Pal, 1993; Karmakar, 2002).

There are numerous image segmentation techniques in the literature, which can be broadly classified into two categories (Pal & Pal, 1993) namely: i) classical and ii) fuzzy mathematical. The former (Canny, 1986; Basu, 1987) comprises the five main classes (Pal & Pal, 1993) shown in Figure 1: i) Gray level thresholding (Otsu, 1980; Taxt, Flynn, & Jain, 1989; Yanowitz & Bruckstein, 1988), ii) Iterative pixel classification (e.g. relaxation, Markov random fields and neural network based techniques) (Andrey & Tarroux, 1998; Gosh, Pal, & Pal, 1993; Geman & Geman, 1984), iii) Surface-based segmentation (Besl & Jain, 1988), iv) Colour segmentation (Overheim & Wagner, 1982), and v) Edge detection (Canny, 1986; Haddon, 1988). Fuzzy mathematical techniques are widely used in multifarious computer vision applications as they are far better able to handle and segment images, particularly noisy images, by using fuzzy membership values. The various fuzzy mathematical techniques identified in Figure 1 will be examined in greater detail in Section 2. There are also other image segmentation techniques which are not classified in either category, including those based upon Markov random models, Bayesian principles and the Gibbs distribution, with further details being given in (Geman & Geman, 1984; Derin & Elliot, 1987; Derin et al, 1984; Hansen & Elliot, 1982; Jain, 1981).

Segmentation is certainly one of the most challenging tasks in image processing and computer vision for many reasons, some of which are (Karmakar, Dooley, & Rahman, 2001; Spirkovska. 1993; Haralick & Shapiro, 1985; Pal & Pal, 1993):

- Image types such as MRI, CT or Single Photon Emission Computed Tomography (SPECT) contain inherent constraints that make the resulting image noisy and may include or introduce some visual artefacts.
- Image data can be ambiguous and susceptible to noise and high frequency distortion as in SPECT imaging for instance, where object edges become fuzzy and ill-defined.
- The shape of the same object can differ from image to image due to having different domain and capturing techniques as well as various orientations. An object’s structure may not be well defined in many natural images and can also be very hard to accurately locate the contour of an object.