

Chapter 8

Indian River Watershed Image Analysis Using Fuzzy– CA Hybrid Approach

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ABSTRACT

Image segmentation among overlapping land cover areas in satellite images is a very crucial task. Detection of belongingness is the important problem for classifying mixed pixels. This paper proposes an approach for pixel classification using a hybrid approach of Fuzzy C-Means and Cellular automata methods. This new unsupervised method is able to detect clusters using 2-Dimensional Cellular Automata model based on fuzzy segmentations. This approach detects the overlapping regions in remote sensing images by uncertainties using fuzzy set membership values. As a discrete, dynamical system, cellular automaton explores uniformly interconnected cells with states. In the second phase of our method, we utilize a 2-dimensional cellular automata to prioritize allocations of mixed pixels among overlapping land cover areas. We experiment our method on Indian Ajoy river watershed area. The clustered regions are compared with well-known FCM and K-Means methods and also with the ground truth knowledge. The results show the superiority of our new method.

INTRODUCTION

Cogalton and Green in 1999 defined Remote sensing as “the art and science of obtaining information about an object without being in direct physical contact with the object” (Cogalton, 1999). Canopy of methods exist for classifying pixels into known classes (for example, an urban area or turbid water) in satellite images. Theoretically, a remote sensing image can be defined as a set,

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$$P = \{p_{ijk} \mid 1 \leq i \leq r, 1 \leq j \leq s, 1 \leq k \leq n\} \quad (1)$$

of $r \times s \times n$ information units for pixels, where $p_{ij} \in \{p_{ij1}, p_{ij2}, \dots, p_{ijk}\}$ is the set of spectral band values for n bands related with the pixel of coordinate (i, j) . In order to find similar regions, this image has been segmented by fuzzy sets, that consider both the spatial image objects and the imprecision attached to them.

Let P (usually $d_F(x, y)$ or \mathbb{Z}^n) denotes the space of the remote sensing image. Consequently, the points of P (pixels or voxels) are the spatial variables x, y . Let $d_p(x, y)$ denotes the spatial distance between two pixels $\{x, y\} \in P$. In existing works, d_p is taken as the Euclidean distance on P (Maulik, 2012), (Bandyopadhyay, 2005).

In the remote sensing image, a crisp object C is a subset of $P, C \subseteq P$. Henceforth, a fuzzy object is defined as a fuzzy subset F of $P, F \subseteq P$. This fuzzy object F is defined bi-univoquely by its membership function, $\mu \cdot \mu_F(x) \in (0, 1]$, which represents the membership degree of the point x to the fuzzy set F . When the value of $\mu_F(x)$ is closer to 1, the degree of membership of x in F will be higher. Such a representation allows for a direct mapping of mixed pixels in overlapping land cover regions in remote sensing images. Let F denotes the set of all fuzzy sets defined on P . For any two pixels x, y , $d_F(x, y)$ is denoted by their distance in fuzzy perspective. The definition of a new method utilizing the cellular automata over fuzzy segmentation solutions is the scope of this chapter.

Clustering is an unsupervised classification method, based on maximum intra-class similarity and minimum inter-class similarity. State-of-the-art clustering methods for pixel classification in remote sensing images are - self-organizing map (SOM) (Spang, 2003), K-Means clustering (Tavazoie, 2001), (Hoon, 2004), simulated annealing (Lukashin, 1999), graph theoretic approach (Xu, 1999), fuzzy c-means clustering (Dembele, 2003) and scattered object clustering (de Souto, 2008). Different similar approaches like clustering based on symmetry (Maulik, 2009) or supervised multi-objective learning approach (Maulik, 2012), also efficiently detect arbitrary shaped land cover regions in satellite images.

The membership functions of soft computing approaches like rough sets and fuzzy sets, also efficiently detect overlapping partitions. Therefore, recently rough set theory is being used for clustering (Bandyopadhyay, 2008), (Cordasco, 2007), (Gonzalez, 1992), (Dembele, 2003), (Qin, 2003). Hirano and Tsumoto (Cordasco, 2007) proposed an indiscernibility based clustering method to handle relative proximity. Lingras and others (Xu, 1999), (Dembele, 2003), (Qin, 2003) used rough set theory to develop interval representation of clusters without crisp boundaries.

Fuzzy set theory is a methodology to illustrate how to handle uncertainty and imprecise information in the dataset. The fuzzy models have been experimented for land cover detection of remote sensing images and pattern recognitions (Bandyopadhyay, 2005), (Dave, 1989). Applying the concepts of fuzzy membership function (Wang, 1997), (Pappis, 1993), fuzzy clustering (Huang, 2008), fuzzy-rule based systems (Bardossy, 2002), fuzzy entropy (De Luca, 1972) and fuzzy integrals (Kumar, 1997) in algorithms, the remote sensing image identification becomes more feasible.

In the literature, earlier distances proposed comparing fuzzy membership functions do not include spatial information and therefore were not used in remote sensing (Chen, 1995) (Jain, 1995). The be-

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