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Hidden Markov Random Fields and Swarm Particles: a Winning Combination in Image Segmentation

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Abstract

Segmenting an image, by splitting this latter into distinctive regions, is a crucial task in many nowadays ubiquitous applications. Several methods have been developed to perform segmentation. We present a method that combines Hidden Markov Random Fields (HMRF) and Particle Swarm Optimisation (PSO) to perform segmentation. HMRF is used for modelling the segmentation problem. This elegant model leads to an optimization problem. The latter is solved using PSO method whose parameters setting is a task in itself. We conduct a study for the choice of parameters that give a good segmentation. The quality of segmentation is evaluated on grounds truths images using Misclassification Error criterion. We use the NDT (Non Destructive Testing) image dataset to evaluate several segmentation methods. These results show a supremacy of the HMRF-PSO method over threshold based techniques.

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Keywords: Image segmentation, Hidden Markov Random Field, Swarm Particles Optimization, Misclassification Error.

1. Introduction

Image segmentation, a process used to partition images into distinctive and meaningful regions, is a crucial task in many nowadays ubiquitous applications. More specifically, in image segmentation, a label is assigned to each pixel in an image such that pixels having the same label have some common characteristics. Various

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techniques have been explored for image segmentation. We can classify these methods in six broad classes: edge detection based methods, clustering methods, threshold based methods, Markov random fields methods, Region growing and deformable models. Among these methods, Hidden Markov Random Field (HMRF) provides an elegant way to model the segmentation problem. Geman and Geman [7] were among the precursors using Markov Random Fields (MRF) models in segmentation [3,8,9]. Our work focuses on image segmentation using HMRF model. This monetization results in an energy function minimization [2] under the MAP criterion (Maximum A Posteriori). For this purpose, we have used Particle Swarm Optimization (PSO) technique. PSO optimization is a class of metaheuristics formalized in 1995 by Eberhart and Kennedy [4]. This technique [6] is drawn from moving swarm social behaviour as flocking bird or schooling fish. An individual of the swarm is only aware of the position and speed of its nearest neighbours. Each particle modifies its behaviour on the basis of its experience and the experience of its neighbours to build a solution to a problem like a sardine shoal trying to escape tuna fishes. The performance of the swarm is greater than the sum of the performance of its parts. The selection of PSO parameters in the algorithm simulation is a problem in itself [5,11]. A bad choice of parameters can lead to a chaotic behaviour of the optimization algorithm. We conduct an evaluative study for the choice of parameters that give a good segmentation. The quality of segmentation is evaluated on ground truth images using the Misclassification Error criterion. We have used NDT (Non Destructive Testing) image dataset [10] to evaluate several segmentation methods. The results show the supremacy of the HMRF-PSO method over threshold based techniques.

This paper consists of six sections. In section 2, we provide some concepts of Markov Random Field model. Section 3 is devoted to Hidden Markov Field model and its use in image segmentation. In section 4, we explain the Particle Swarm Optimization technique. We give in section 5 experimental results on sample images with ground truth. Section 6 is dedicated to conclusions.

2. Markov Random Field model

2.1 Neighbourhood system and cliques

Image pixels are represented as a lattice denoted S of M=nxm sites. $S=\{s_1,s_2,\ldots,s_M\}$ The sites or pixels in *S* are related by a neighbourhood system *V(S)* satisfying:

$$\forall s \in S,\ s \notin Vs(S),\ \forall\{s,t\} \in S,\ s \in Vt(S) \Leftrightarrow t \in Vs(S) \qquad (2.1)$$

The relationship V(S) represents a neighbourhood tie between sites. An r-order neighbourhood system denoted $V^r(S)$ is defined by:

$$V^r s(S)=\{t \in S \mid distance(s,t)^2 \leq r^2,\ s \neq t\} \qquad (2.2)$$

A clique *c* is a subassembly of sites with regard to a neighbourhood system. The clique *c* is a singleton or all the different sites of *c* are neighbours. If *c* is not a singleton, then:

$$\forall\{s,t\} \in c,\ t \in Vs(S) \qquad (2.3)$$

2.2 Markov Random Field

Let $X=\{X_1,X_2,\ldots,X_M\}$ be a set of random variables on *S*. Every random variable takes its values in the space $\Lambda=\{1,2,\ldots,K\}$. The set *X* is a random field with the configuration set $\Omega = \Lambda^M$. A random field *X* is said to be a Markov Random Field on S with regard to a neighbourhood system *V(S)* if the formula given hereafter holds:

$$\forall x \in \Omega,\ P(x) > 0,\ \forall s \in S,\ \forall x \in \Omega, P(Xs=xs/Xt=xt,t \neq s)=P(Xs=xs/Xt=xt,t \in Vs(S)) \qquad (2.4)$$