On The Random Walks Algorithms for Image Processing

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1 Introduction

Random walks are time-reversible and finite special Markov chains. They are used to model different phenomena in mathematics and physics widely applied in many fields as economics, ecology, biology, computer science, etc.

In this paper, we present a review of the use of random walks algorithm in images processing, called, random walks on graphs [7]. The basic concept of this algorithm remains in considering a given undirected graph $\boldsymbol{G} = (\boldsymbol{V}, \boldsymbol{E})$, the random walk is a stochastic process that starts at a given vertex and move to a randomly selected neighbour, from which a similar process will be executed. The sequence of selected vertices defines a random walk on the graph. Random walks was used widely to solve several image processing problems, we cite here, image enhancement, image segmentation and image registration.

2 Random Walks for Image Segmentation

Image segmentation is the problem of partitioning the image into different regions, based on pixels similarities (colours, intensities, texture...) which can be used to detect different objects in the image.

A supervised method for image segmentation using random walks was introduced by Grady [6], where for a given set of K user defined seeds (s), indicating K regions, the algorithm will compute for every unlabelled pixel I_{ij}, in the image, the probability that a random walker starting at this pixel will first reach each primarily defined seeds I_s (**1<s<K**). The seed that is reached with the highest probability, share its label to the pixel I_{ij} Fortunately, the analogy between Random Walks and potential theory gives a more practical alternative for implementation. An image is viewed as a discrete weighted, connected and undirected graph. The problem of finding the random walker probabilities have the same solution as the combinatorial Dirichlet problem, which is the problem of finding a harmonic function subject to its boundary values. The harmonic function (which satisfies the Laplace equation $\boldsymbol{\nabla^2 u = 0}$) minimizes the Dirichlet integral as the Laplace equation is the Euler-Lagrange equation for this integral. Grady's algorithm is simple, as its solution only requires to solve a sparse and positive-definite, symmetric system of equations. Besides, the results show that the algorithm provides a quality solution that is unique [6] [10] [11]. In [9] the authors used random walks algorithm to segment images based on histogram.

3 Random Walks for Image enhancement

Image enhancement methods are an important step in low level image processing, which aims to improve the image, such as denoising or contrast enhancement, what makes the image more appropriate to be processed by a computer system.

In the work of Smolka [1], the authors present different algorithms using random walks in image contrast enhancement and noise reduction. The idea is based on computing the probability that a virtual particle performing a random walk on the graph starting at a point will arrive at a different point after a fixed number of steps. Given that the probability of a particle to walk from a point to a neighbouring one is determined by the Gibbs statistical distribution. While for the image denoising, a probabilistic smoothing transformation is calculated for each pixel $(\boldsymbol{i},\boldsymbol{j})$ as $\sum_{(\boldsymbol{k},\boldsymbol{l})} \boldsymbol{P}\{\boldsymbol{n},(\boldsymbol{i},\boldsymbol{j}),(\boldsymbol{k},\boldsymbol{l})\}\boldsymbol{I}(\boldsymbol{k},\boldsymbol{l})$ where $\boldsymbol{P}$ is the probability of a particle starting at point $(\boldsymbol{i},\boldsymbol{j})$ performing a random walk and arriving to the ending point $(\boldsymbol{k},\boldsymbol{l})$ after $\boldsymbol{n}$ steps. This method of denoising was also used in mesh denoising in [8].

4 Random Walks for Image registration

Image registration is a fundamental problem, especially in the medical imaging field. It is based on overlaying different images (two or more) of one scene, which are taken from different points, different timing or even different sensors. The process of image registration is to align source image with target one, according to feature detection, feature matching, mapping function design or image transformation. [2]. In a recent work [3], random walk was used in a discrete formulation of the image registration problem, which is finding an optimal transformation between the source and the target image. Transformation can be expressed as the minimum of energy functional, described as: $\boldsymbol{E} = \boldsymbol{E_D} + \boldsymbol{E_R}$; where E_D, the data-related term measures the similarities between images, and E_R, is a regularisation term. A transformation of the registration problem into a labelling problem was done, and was presented by the Markov Random Field, in order to assign an optimal label to each pixel in the image. At this stage, random walks were introduced by the authors as modification of the energy functional, by adding the probability of a pixel to have a specific label and the graph edges weights function. The method details were relaxed in [3].

In this paper a brief review about the random walks algorithms use in solving image processing problems, especially: image segmentation, image enhancement and image registration is presented. Nevertheless, this algorithm is used in other applications, as texture discrimination [4] and object shape characterization [5] ..

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