Nature-Inspired Reaction-Diffusion Algorithm for Image Processing and Computer Vision Applications

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Keywords: reaction-diffusion model, image processing, computer vision

Abstract

Several chemical and biological systems self-organize spatio-temporal patterns. For example, the Belousov-Zhabotinsky reaction system self-organizes circular and spiral patterns of chemical reaction waves propagating over shallow-layered chemical solution [1]. The slim mold *Dictyostelium discoideum* self-organizes similar patterns as well as a streaming pattern in cell density distribution in an early vegetative stage of its life cycle [2].

The Oregonator model describes a spatio-temporal pattern formation process observed in the Belousov-Zhabotinsky reaction system [3]. The model consists of reaction terms describing non-linear chemical oscillation and diffusion terms of two chemical species. Thus, the model is a typical example of a reaction-diffusion model.

Kuhnert et al. found that the light sensitive Belousov-Zhabotinsky reaction system detects edges and segments from an intensity distribution initially provided to its solution surface [4]. That is, they successfully demonstrated image processing without any artificial or conventional computer system, but with the real chemical reaction. In those experiments the non-linearity of the reaction terms works as the function of detecting edges and segments of patterns; the diffusion terms help to remove small noisy and/or detailed pattern structures and to obtain appropriate edges and segments. Edge detection and segmentation algorithms are necessary for image processing and computer vision applications. Thus, the experimental results done by Kuhnert et al. imply that the non-linear reaction-diffusion system or its mathematical model works well in such the application areas.

Several researchers have tried to realize image processing algorithms with reaction-diffusion systems [5]. The authors have also developed image processing and computer vision algorithms such as edge detection, segmentation and stereo disparity detection with a reaction-diffusion model [6]. We call the class of the algorithms "reaction-diffusion algorithm". All of our reaction-diffusion

algorithms utilize the FitzHugh-Nagumo type reaction-diffusion model having two variables of activator and inhibitor under the Turing like condition. The FitzHugh-Nagumo model describes an information transmission wave along a nerve axon [7, 8]; the Turing condition is known as a condition that produces stable static patterns in chemical and biological reaction-diffusion systems [9]. The Turing like condition helps to obtain not transient but stable static patterns of edges and segments in the reaction-diffusion algorithms; it also helps to keep features such as sharp corners of patterns. Our edge detection algorithm consists of the reaction-diffusion model assisted by an additional diffusion equation being necessary to compute an average level of image brightness. That is, the algorithm consists of three partial differential equations. The idea coupling the reaction diffusion equation with the additional diffusion equation originates from a mathematical model of a streaming pattern formation process observed in the slime mold [2]. In order to apply the reaction-diffusion model to the stereo algorithm, our reaction-diffusion algorithm consists of multi-sets of reaction-diffusion models. The stereo algorithm needs to satisfy two constraints: the continuity constraint and the uniqueness one; the diffusion term works for the continuity constraint and the mutual inhibition mechanism built in the multi-sets works for the uniqueness constraint.

In this poster presentation, we again present our reaction-diffusion algorithms previously proposed [6]. Then, we confirm performance of our reaction-diffusion algorithms, compared to other image processing and computer vision algorithms.

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