Reducing Computation Time in a Reaction-Diffusion Stereo Algorithm

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Abstract

A reaction-diffusion stereo algorithm consists of multi-sets of reaction-diffusion equations. Since the equations are described with time-evolving partial-differential equations, they require much computation time. In addition, the previous algorithm does not state any criterion for convergence judgement; we need to compute the equations for enough duration of time until their solutions converge. In this work, for reducing computation time in the algorithm, we propose a criterion for convergence judgement and implement the algorithm on a multi-processor computer system.

1 Introduction

Reaction-diffusion algorithms designed for image processing and computer vision tasks consume much computation time. The algorithms utilise multi-sets of reaction-diffusion equations; each of the sets consists of time-evolving partial differential equations having diffusion terms, non-linear reaction terms and source terms. We need to solve discretised reaction-diffusion equations for enough duration of time until their solutions converge.

Previous reaction-diffusion algorithms do not state any criterion for convergence judgement. Mrázek and Navara proposed a criterion for an optimal stopping time on time-evolving computation; their criterion is mainly intended for diffusion algorithms including anisotropic diffusion and non-linear diffusion [1]. We need to propose a criterion for convergence judgement in reaction-diffusion algorithms, in order to reduce computation time.

In this work, focusing on a reaction-diffusion algorithm designed for stereo disparity detection [2], we propose a criterion for convergence judgement and implement the algorithm on a multi-processor system. By applying the algorithm to several stereo image pairs, we confirm the performance of the algorithm with respect to consumed computation time and accuracy of stereo disparity, in comparison to the original reaction-diffusion stereo algorithm performed on a uni-processor system. As a result, we have successfully achieved huge reduction of computation time under keeping accuracy of stereo disparity.

2 Algorithm and Implementation

A reaction-diffusion stereo algorithm consists of multi-sets of the following equations [2]:

$$\partial_t u_d = D_u \nabla^2 u_d + f(u_d, v_d, u_{\max}) + \mu C_d, \quad (1)$$

$$\partial_t v_d = D_v \nabla^2 v_d + g(u_d, v_d), \quad (2)$$

where variables $u_d(x,y,t)$ and $v_d(x,y,t)$ are defined at an image position (x,y) and time $t \geq 0$; $\partial_t = \partial/\partial t$ and $\nabla^2 = \partial^2/\partial x^2 + \partial^2/\partial y^2$, D_u and D_v are diffusion coefficients, $f(\cdot,\cdot,\cdot)$ and $g(\cdot,\cdot)$ are reaction terms, μ is a constant and C_d is a source term of a matching cost function computed for a disparity level $d \in \{0, 1, \cdots, N_d - 1\}$. Each of the multi-sets is linked with others via $u_{\max} = \max_{d' \in \{0,1,\cdots,N_d-1\} \setminus \{d\}} u_{d'}$. The algorithm provides a tentative disparity map $M(x,y,t)$ at t as

$$M(x,y,t) = \mathop{\arg\max}_{d \in \{0,1,\cdots,N_d-1\}} u_d(x,y,t). \quad (3)$$

We need to compute N_d sets of Eqs. (1) and (2) until the solutions u_d and v_d converge, that is, until $\partial_t u_d$ and $\partial_t v_d$ become zero.

We propose a criterion for convergence judgement of the reaction-diffusion stereo algorithm.

Each set of solutions (u_d, v_d) spontaneously converges at a stable steady state. However, it takes quite long time until the convergence is achieved. Thus, we judge convergence of the disparity map and terminate computation of the reaction-diffusion equations at $t = T$, when two successive disparity map $M(x, y, t)$ and $M(x, y, t - \delta t)$ satisfies the following criterion at any position (x, y):

$$M(x, y, T) - M(x, y, T - \delta t) = 0, \quad (4)$$

where δt denotes the time difference utilised for discretisation of Eqs. (1) and (2).

When implementing the reaction-diffusion algorithm on a computer system, we can reduce computation time by utilising parallel processing on a multi-processor system. Although multi-sets of Eqs. (1) and (2) are linked via $u_{\max}$, each of the discretised sets can be solved independently from others. Thus, we can easily realise the algorithm performing on a multi-processor system.

3 Results and Discussions

We implemented the reaction-diffusion algorithm with the proposed criterion Eq. (4) on a multi-processor system and confirmed its performance. Figure 1 shows computation time and temporal changes of accuracy. As shown in Fig. 1(a), we can confirm that computation time highly decreases as the number of working processors n increases in the range of $n \leq 4$. In addition, from Figs. 1(a) and 1(b), we can also confirm that the criterion Eq. (4) for convergence judgement is quite effective on reduction of computation time. For example, the accuracy evaluated for the result of CONES with the evaluated $T = 20$ is almost same as that for the result of CONES with $T = 100$. Thus, these results show that the proposed algorithm has successfully reduced computation time under keeping accuracy of obtained stereo disparity maps.

As the future work, we have a plan to implement reaction-diffusion algorithms on a computer system having many processors such as GPU. We would like to build more efficient vision system in realistic situations, by utilising more complex structure of reaction-diffusion equations.

Acknowledgement: This research has been supported in part by the Grant-in-Aid for Scientific Research (C) (No. 20500206) from the Japan Society for the Promotion of Science.

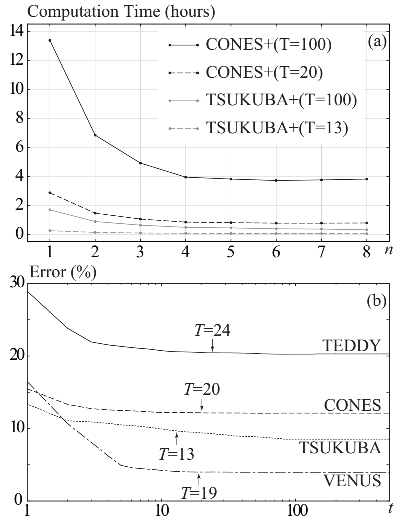

Figure 1: Experimental results on computation time and bad-match-percentage error of the reaction-diffusion stereo algorithm. (a) Computation time required for the image pairs CONES and TSUKUBA, in the case of the fixed $T = 100$ and in the case of T evaluated by Eq. (4). We obtained the results by increasing the number of working processors n. (b) Temporal changes of error evaluated for disparity maps obtained by the algorithm for the image pairs CONES, TEDDY, TSUKUBA and VENUS. The figure also indicates the time duration T evaluated by Eq. (4). The Middlebury website [3] provides the stereo image pairs CONES, TEDDY, TSUKUBA and VENUS (see the website [3] for image sizes and disparity ranges). We fixed parameter values of the algorithm except N_d and T across the experiments.

References

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