Reducing Computation Time in a Reaction-Diffusion Stereo Algorithm

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1. Abstract

A reaction-diffusion stereo algorithm consists of multiple systems of reaction-diffusion equations. Since the equations are described with time-evolving partial-differential equations, they require much computation time. In addition, the previous reaction-diffusion stereo 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 reaction-diffusion stereo algorithm, we propose a criterion for convergence judgement and implement the algorithm on a multi-processor computer system.

2. Reaction-Diffusion System

The FitzHugh-Nagumo Reaction-Diffusion Equations[1,2)]

$$\begin{cases} \partial_t u = D_u \nabla^2 u + [u(u-a)(1-u) - v]/\varepsilon \\ \partial_t v = D_v \nabla^2 v + u - bv \end{cases}$$

u,v: variables defined in space and time
D_u, D_v: diffusion coefficients
a, b, ε: constants
$\partial_t = \partial/\partial t$, ∇: Laplacian operator

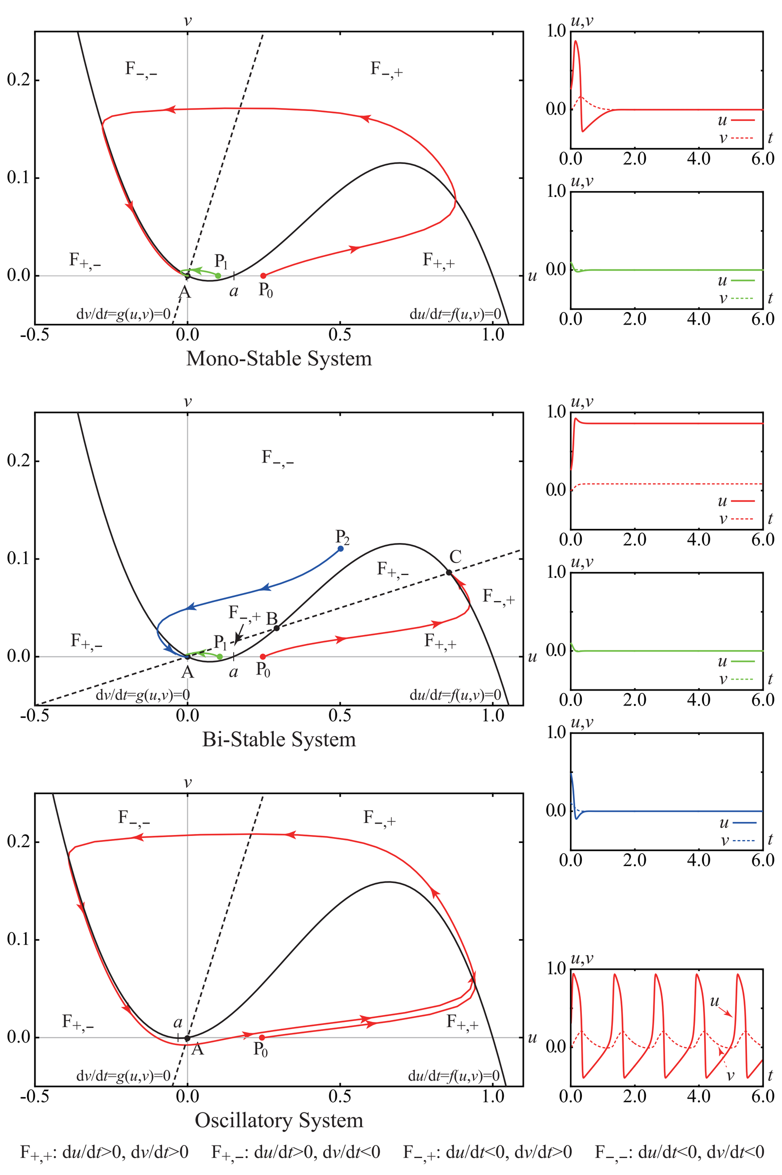

Fig. 1: Phase plots and temporal developments of ordinary differential system.

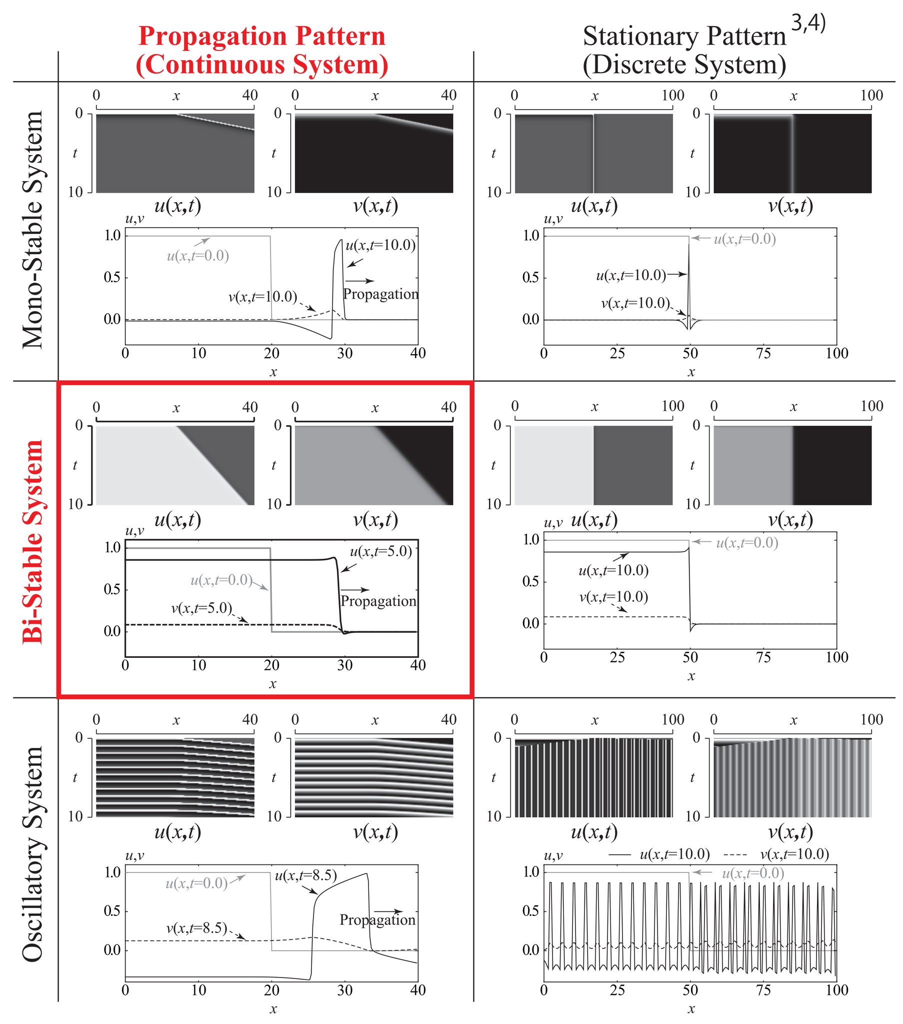

Fig.2: Spatio-temporal plots and spatial distribution on one-dimensional system.

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1) FitzHugh, R.: Impulses and physiological states in theoretical models of nerve membrane. Biophys. Journal, Vol.1, 445–466 (1961)

2) Nagumo, J., Arimoto, S., Yoshizawa, S.: An active pulse transmission line simulating nerve axon. Proc. IRE, Vol.50, 2061–2070 (1962)

3) Nomura, A., Ichikawa, M., Miike, H., Ebihara, M., Mahara, H., Sakurai, T.: Realizing visual functions with the reaction-diffusion mechanism. Journal of the Physical Society of Japan, Vol.72, 2385-2395 (2003)

4) Kurata, N., Kitahata, H., Mahara, H., Nomura, A., Miike, H., Sakurai, T.: Stationary pattern formation in a discrete excitable system with strong inhibitory coupling. Physical Review E, Vol. 79, 056203 (2009)

3. Reaction-Diffusion Stereo Algorithm[5)]

Multiple Reaction-Diffusion Systems

$$\begin{cases} \partial_t u_d = D_u \nabla^2 u_d + f(u_d, v_d, u_{\max}) + \mu C(x,y,d) \\ \partial_t v_d = D_v \nabla^2 v_d + g(u_d, v_d) \end{cases}$$

Disparity map: $$M(x,y,t) = \arg\max_d u_d(x,y,t)$$

$C(x,y,d)$: Matching cost function with a disparity level d.

$$f(u_d, v_d, u_{\max}) = [u_d(u_d - a_d)(1-u_d) - v_d]/\varepsilon$$
$$g(u_d, v_d) = u_d - b v_d$$
$$u_{\max} = \max_{d' \in \Theta} u_{d'}$$
$$d_a = \left| d_n - \arg\max_{d' \in \Theta} u_{d'} \right|$$
$$a_d = A_0 + u_{\max} \times [1 + \tanh(d_a - A_1)]$$

μ, A_0, A_1, b, ε: constants
N_d: number of possible disparity levels
Θ: inhibition area for uniqueness constraint.

Two constraints for the stereo correspondence problem:

- Continuity constraint:
  Wave propagation
- Uniqueness constraint:
  Mutual inhibition mechanism due to a_d.

Reference:

5) Nomura, A., Ichikawa, M., Miike, H.: Reaction-diffusion algorithm for stereo disparity detection. Machine Vision and Applications, Vol. 20, 175-187 (2009)

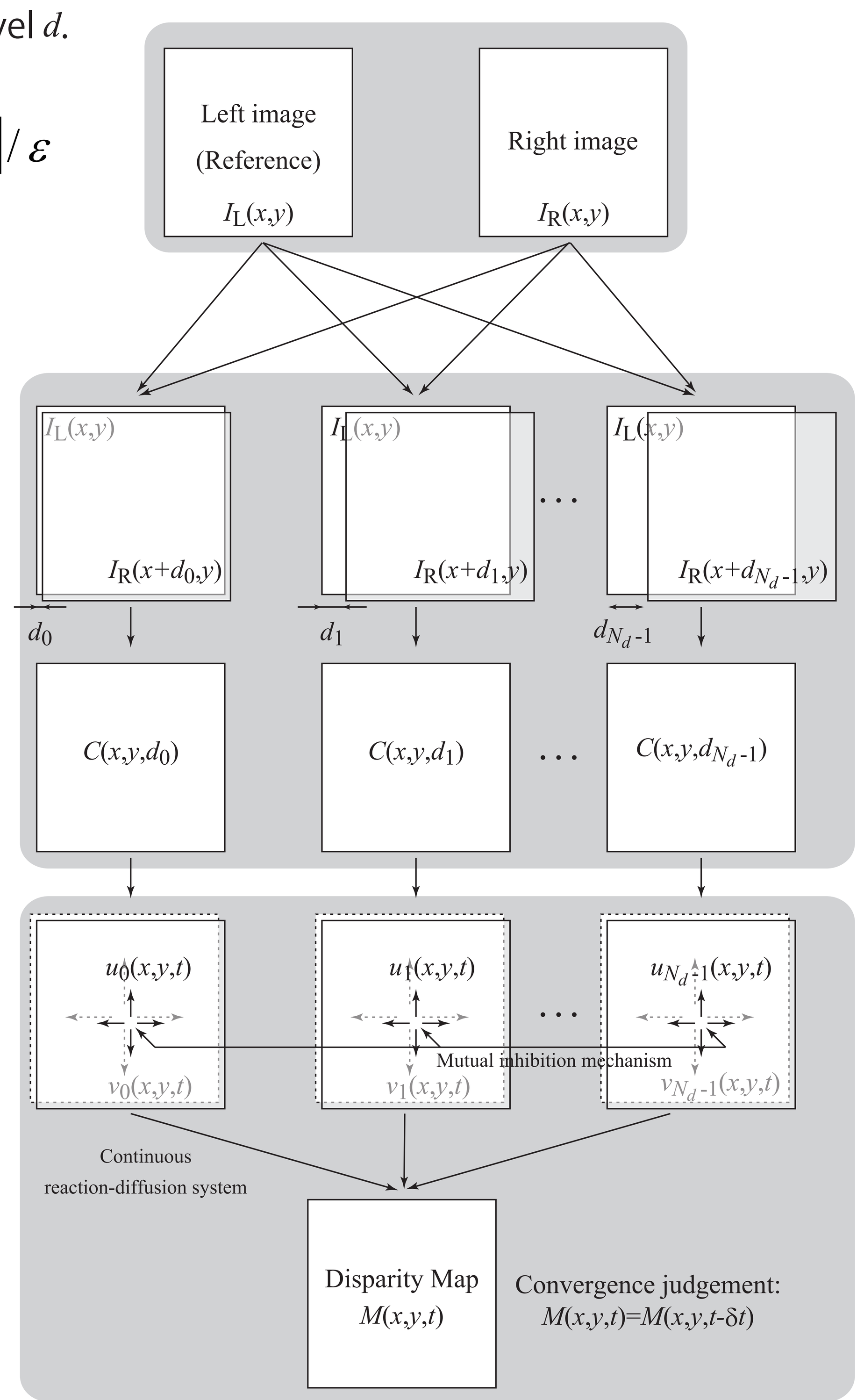

Fig.3: System structure of the reaction-diffusion stereo algorithm.

4. Convergence Judgement & Parallel Implementation

- Criterion for convergence judgement:
  $M(x,y,t)=M(x,y,t-\delta t)$
  δt: a finite difference in time
- Parallel implementation of multiple reaction-diffusion systems on a multi-processor comuter system.

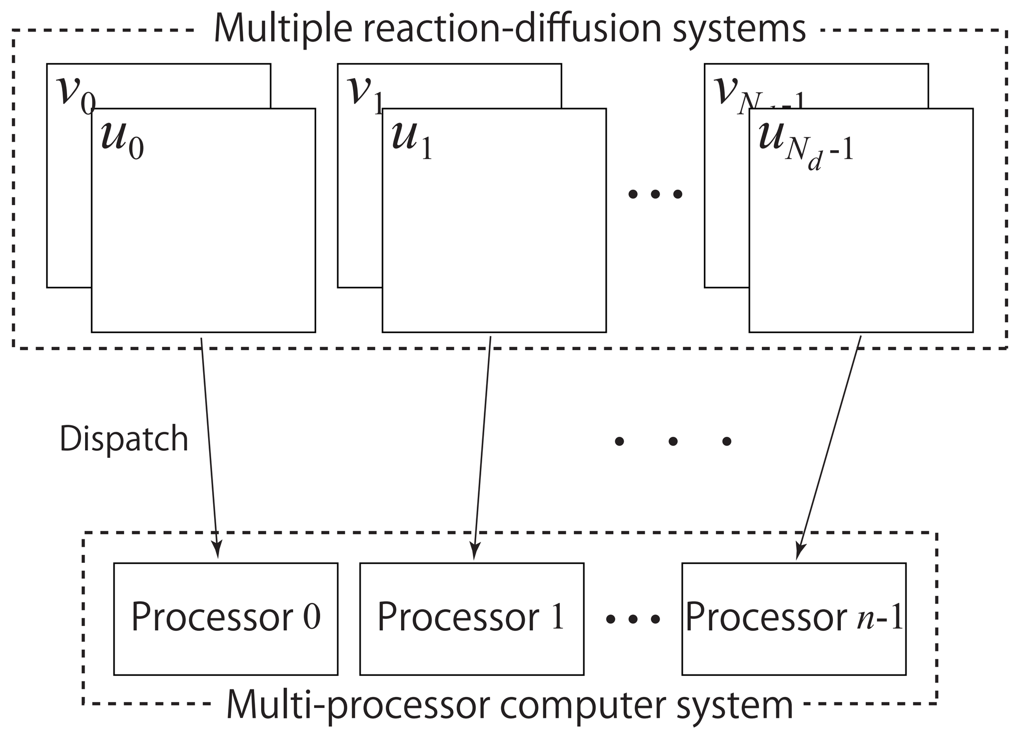

Fig. 4: Parallel Implementation

5. Results

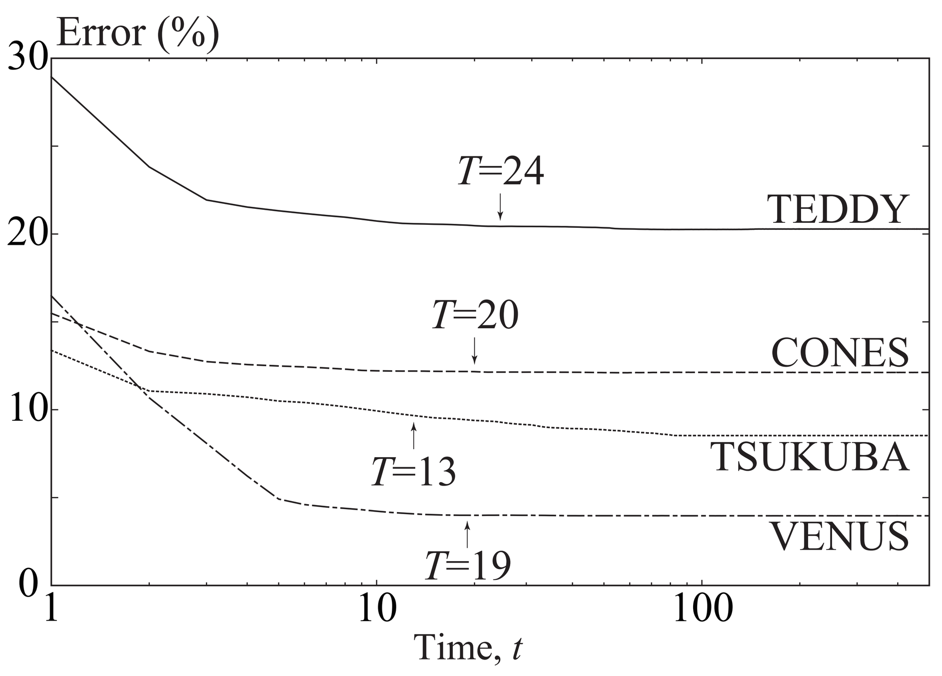

Fig. 5: Convergence of the reaction-diffusion stereo algorithm. Error was evaluated with the Bad-Match-Percentage (BMP) error measure.[6)]
T: convergence time.

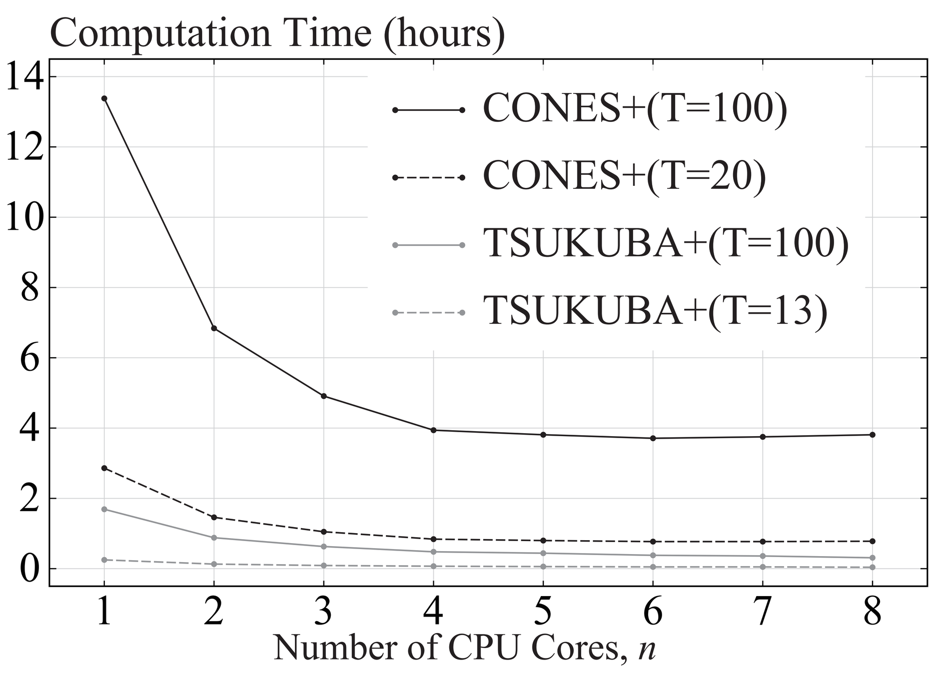

Fig. 6: Consumed computation time.

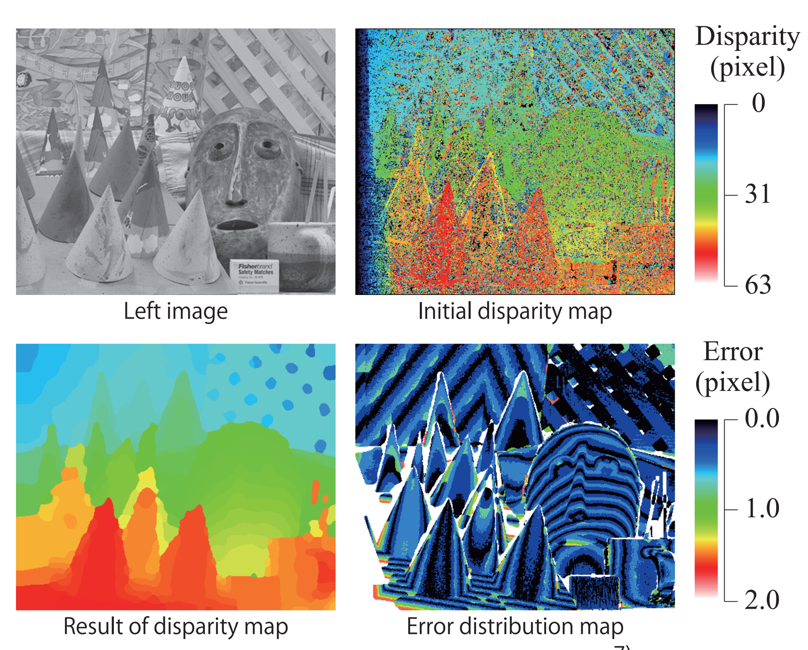

Fig. 7: Results for CONES.[7)]
Disparity levels: N_d=60. Error(BMP$_{all}$)=12.57(%)

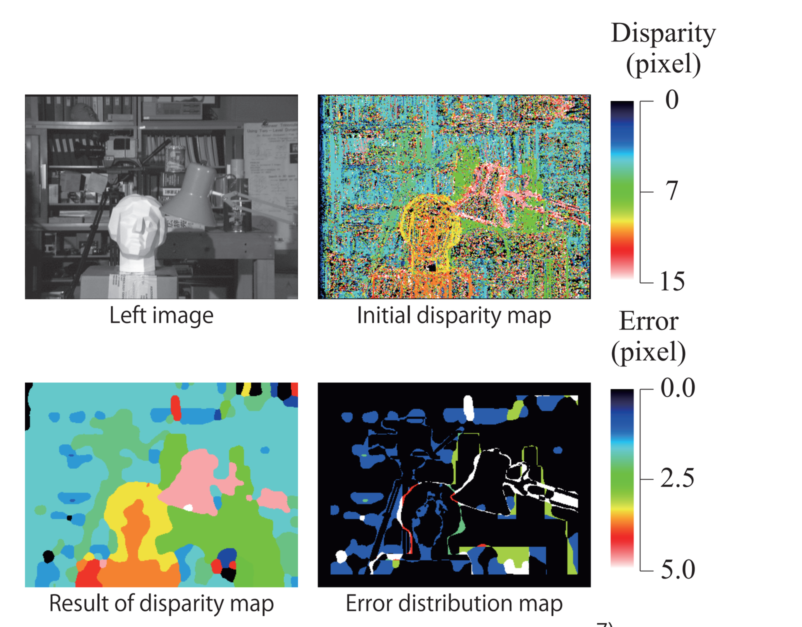

Fig. 8: Results for TSUKUBA.[7)]
Disparity levels: N_d=16. Error(BMP$_{all}$)=7.86

References:

6) Scharstein, D., Szeliski, R.: A taxonomy and evaluation of dense two-frame stereo correspondence algorithms. International Journal of Computer Vision, 47, 7-42 (2002)

7) Scharstein, D., Szeliski, R.: The Middlebury stereo vision page. http://vision.middlebury.edu/stereo/

Parameter settings:
δh=5, δt=100, D_u=1.0, D_v=3.0, a_0=0.13, a_1=1.5, b=10, ε=1.0×10^{-2}, μ=3.0