Stereo vision system with the grouping process of multiple reaction-diffusion models

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1. Summary

The present study proposes a stereo vision system that detects a disparity map from random-dot stereograms[1]. The proposed model consists of the following steps.

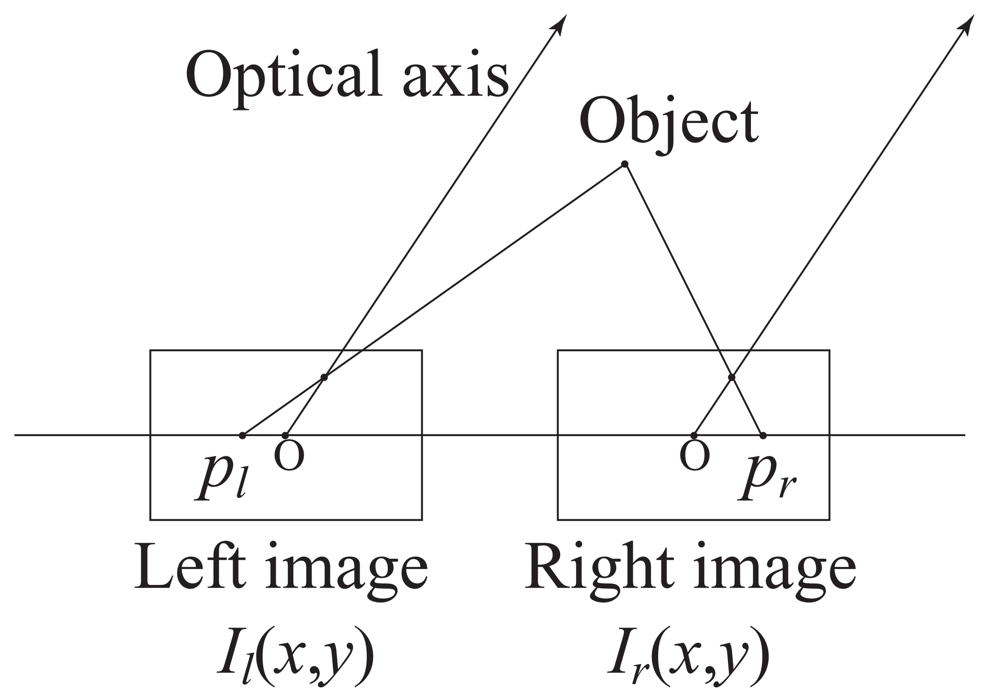
(1)Convert the stereo correspondence problem into the segmentation problem with the XNOR logic operation[2].

(2)Solve the segmentation problem with the grouping process consisting of multiple reaction-diffusion models.

(3)Build a disparity map from the outputs of the reaction-diffusion models.

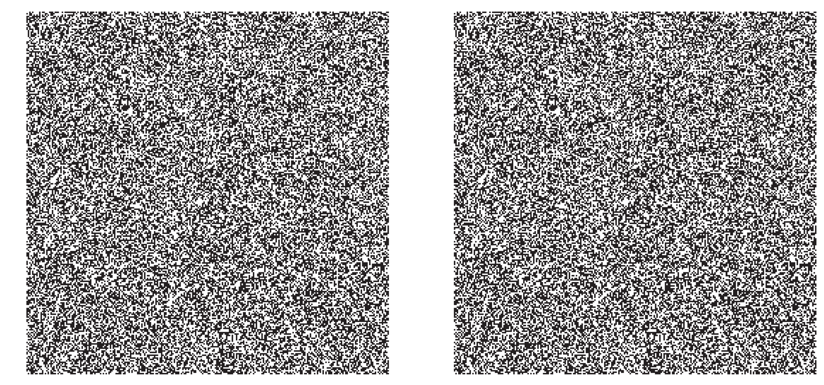
The performance of the proposed model is confirmed through the analysis of a random-dot stereogram and real stereo images.

2. Stereo vision



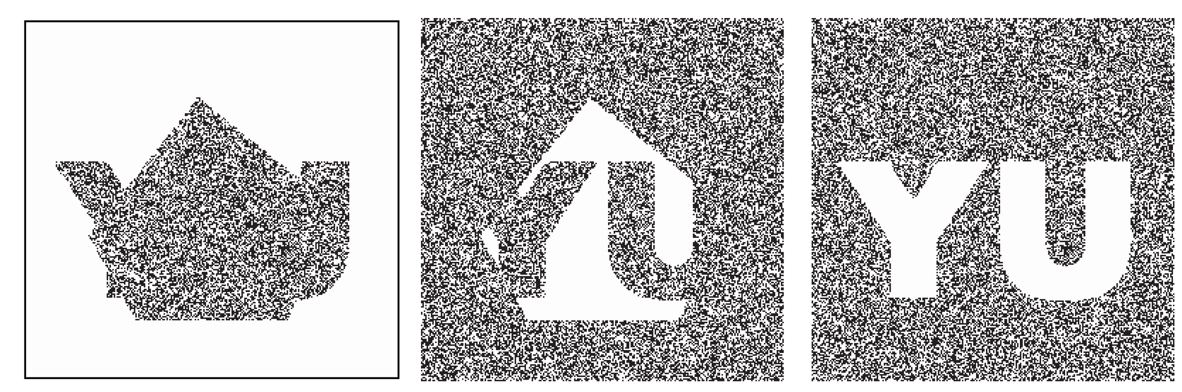
Stereo disparity: $d = p_l - p_r$

3. Random-dot stereogram[1)]



$I_l(x,y)$ $I_r(x,y)$

XNOR[2)]: $L(x,y;d) = \overline{I_l(x,y) \oplus I_r(x+d,y)}$



$L(x,y;d{=}0)$ $L(x,y;d{=}1)$ $L(x,y;d{=}2)$

Stereo correspondence problem => Segmentation problem

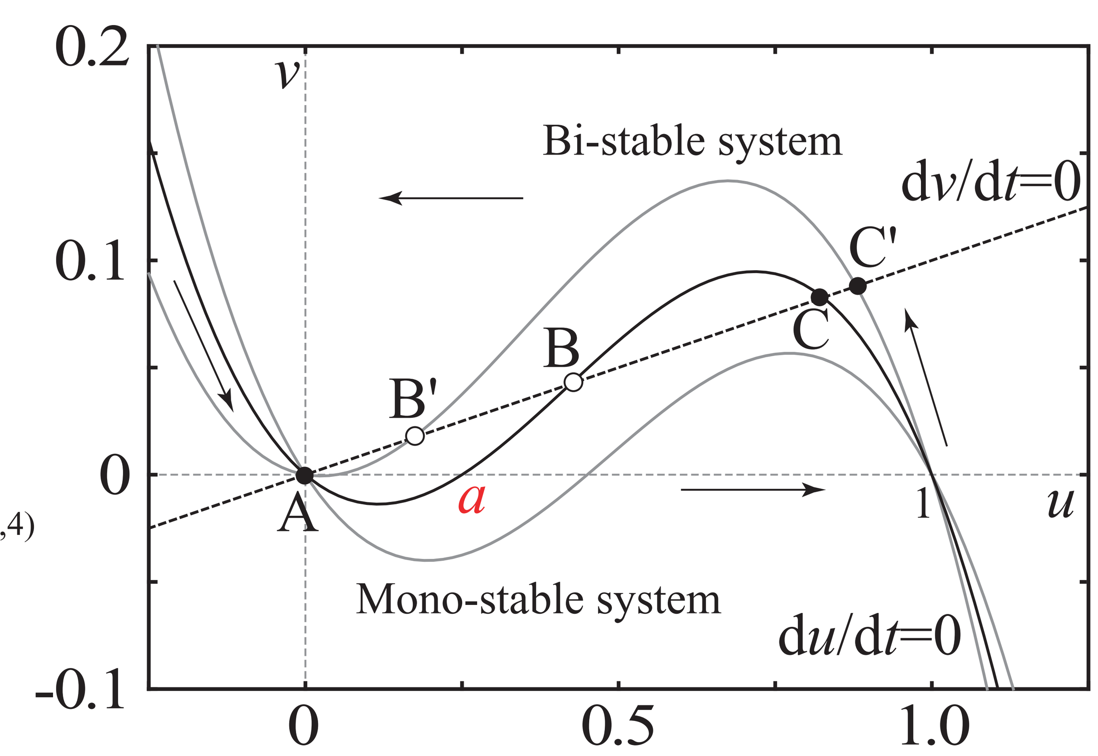
4. Reaction-diffusion model

Reaction-diffusion eq. with (u,v)

$$\begin{cases} \dfrac{\partial u}{\partial t} = D_u \Delta u + \dfrac{1}{\varepsilon} f(u,v) \\ \dfrac{\partial v}{\partial t} = D_v \Delta v + g(u,v) \end{cases}$$

FitzHugh-Nagumo reaction terms[3,4]

$$\begin{cases} f(u,v) = u(u-a)(1-u) - v \\ g(u,v) = u - bv \end{cases}$$



Phase plot of the FitzHugh-Nagumo model.
(The parameter *a* works as a threshold value.)

5. Proposed model

Grouping process with multiple reaction-diffusion models[5)]

$$\begin{cases} \dfrac{\partial u_i}{\partial t} = D_u \Delta u_i + \dfrac{1}{\varepsilon} f(u_i, u_j, v_i) + \mu s_i \\ \dfrac{\partial v_i}{\partial t} = D_v \Delta v_i + g(u_i, v_i) \end{cases}$$

$$i = 0,1,\cdots,(N-1); \quad u_j = \max(u_0, u_1, \cdots, u_{N-1}),\ j \neq i$$

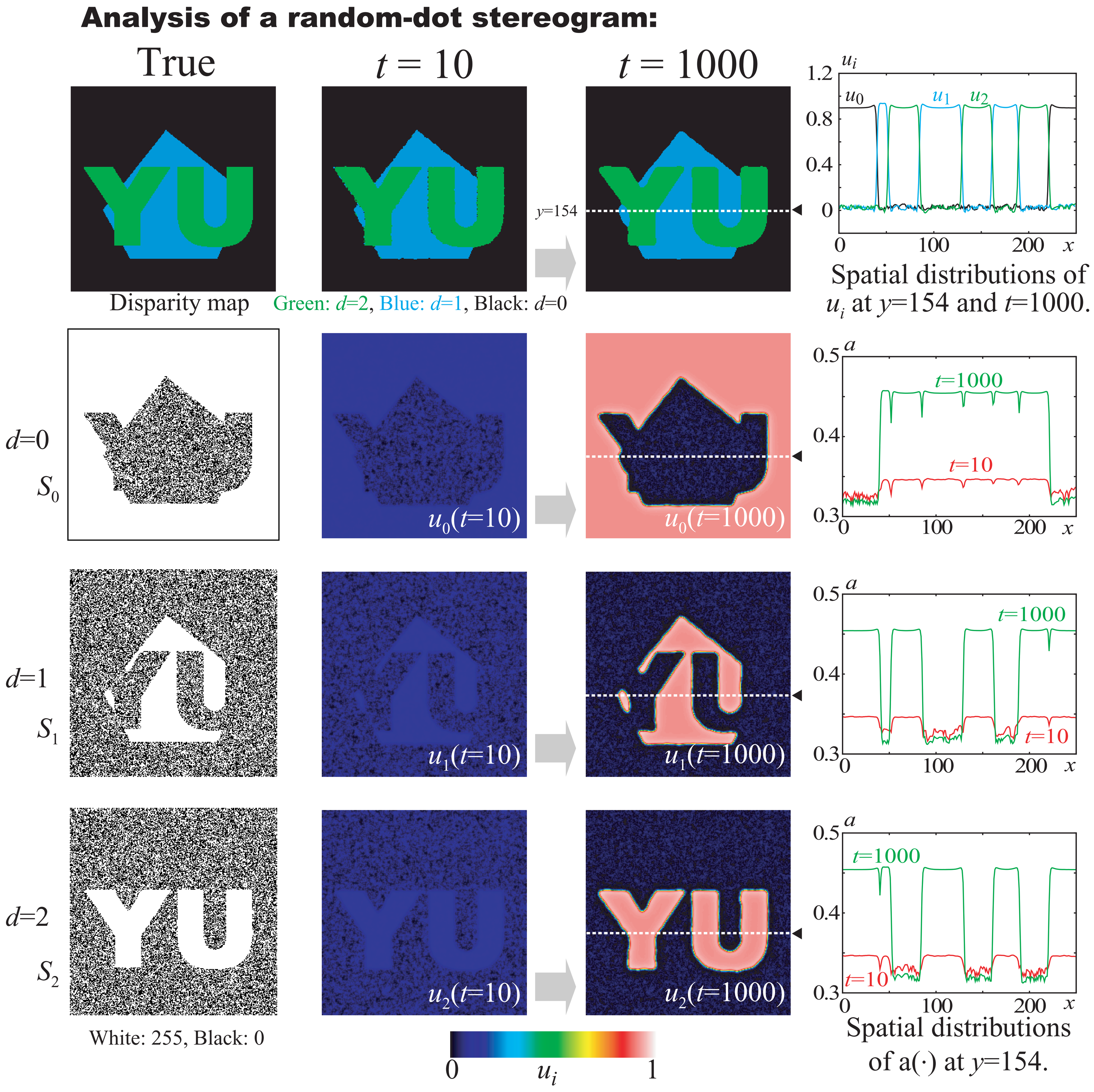
$$\begin{cases} f(u_i, u_j, v_i) = u_i(u_i - a(u_j))(1-u_i) - v_i \\ g(u_i, v_i) = u - bv \end{cases}$$

A threshold value depends on other group's state.

$$a(u_j) = \frac{1}{4}\left\{1 + \tanh(u_j + a_0)\right\}$$

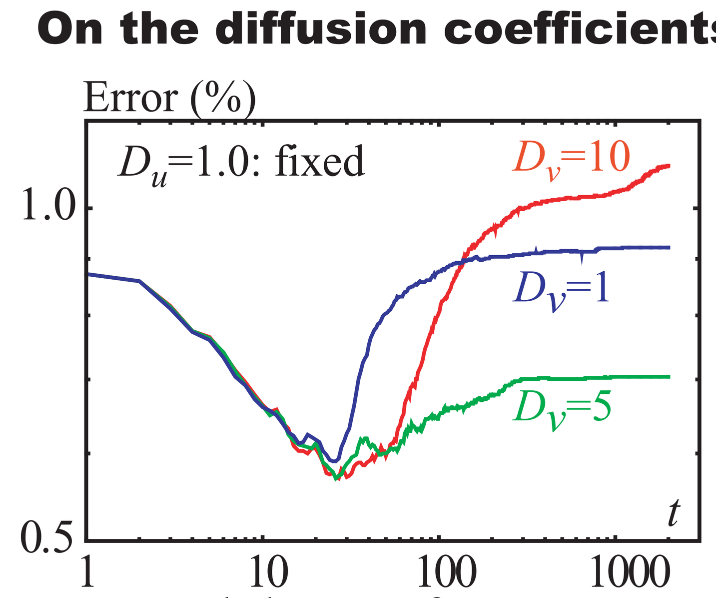
6. Experiments

Analysis of a random-dot stereogram:



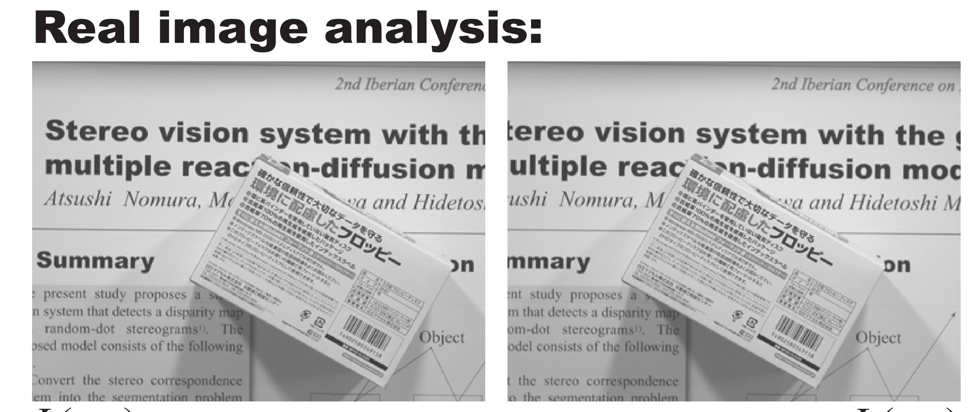
Parameters: D_u=1.0, D_v=5.0, a_0=0.25, b=10, ε=10[-2], μ=10[-5], Image size: 250x250 (pixels), N=3

On the diffusion coefficients:



Temporal changes of error measures for different values of D_v.

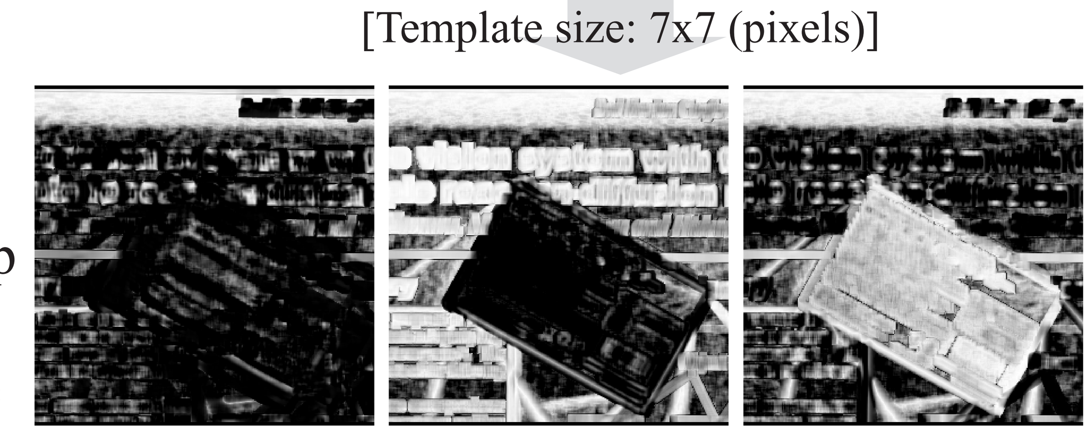
Real image analysis:



$I_l(x,y)$ $I_r(x,y)$

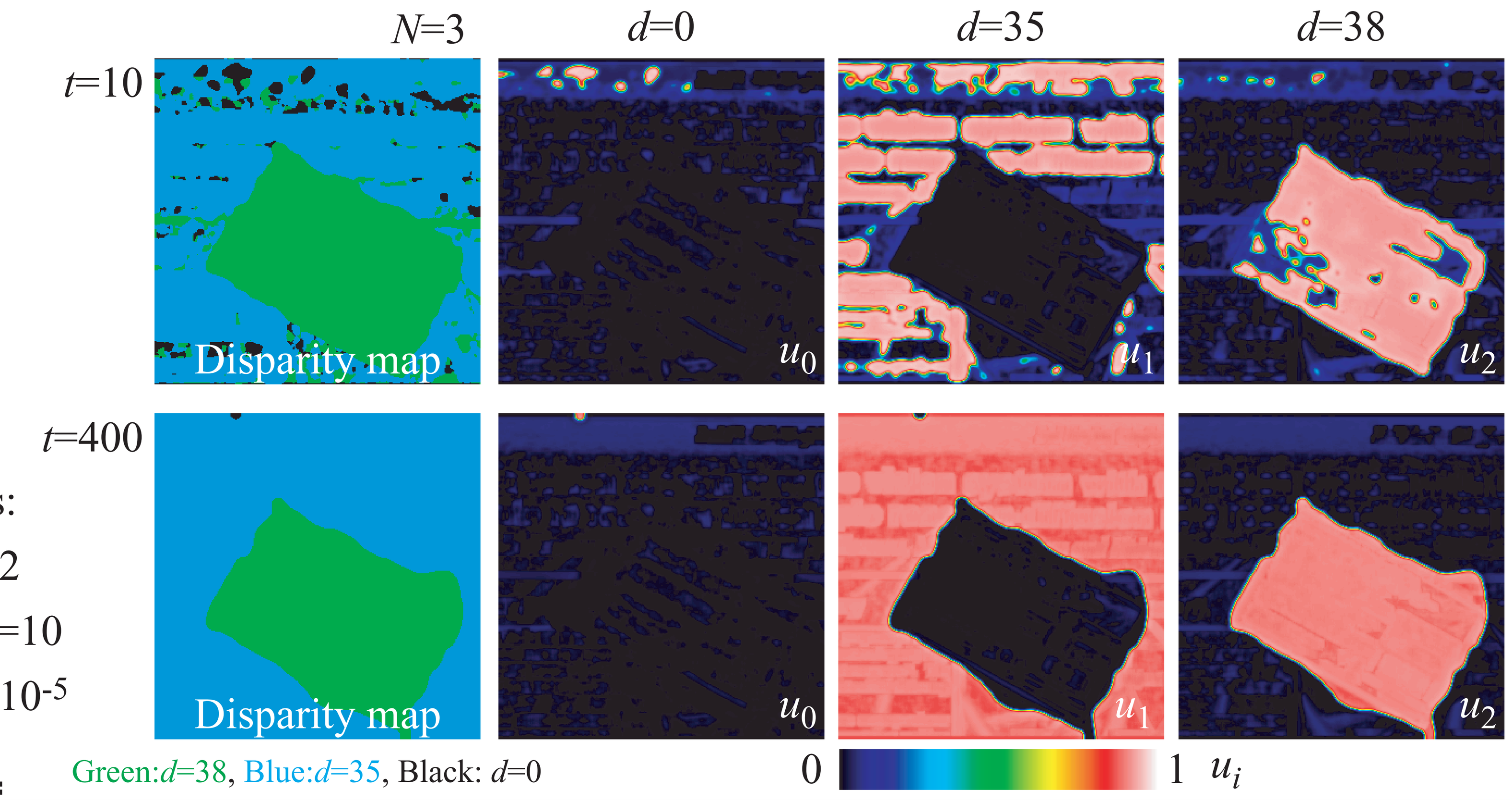
Mutual correlation
[Template size: 7x7 (pixels)]

Correlation map



d=0 d=35 d=38

Image size: 300x300 (pixels)



Parameters:
D_u=1, D_v=2
a_0=0.25, b=10
ε=10[-2], μ=10[-5]

Green: d=38, Blue: d=35, Black: d=0

References:

1) Julesz: Binocular depth perception of computer-generated patterns. *The Bell System Tech. J.* **39** (1960) 1125--1162
2) Nomura et al.: Realizing visual functions with the reaction-diffusion mechanism, *J. Phy. Soc. Jpn.* **72** (2003) 2385-2395
3) FitzHugh: Impulses and physiological states in theoretical models of nerve membrane. *Biophysical J.* **1** (1961) 445-466
4) Nagumo, Arimoto, Yoshizawa: An active pulse transmission line simulating nerve axon. *Proc. IRE* **50** (1962) 2061-2070
5) Nomura, Ichikawa, Miike: Realizing the grouping process with the reaction-diffusion model. *IPSJ Trans. Computer Vision and Image Media* **45** (2004) 26-39 (in Japanese)