Edge Strength Evaluation with Reaction-Diffusion Systems

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1. Abstract

Edge strength[1)] refers to the sharpness of spatial brightness change at an edge position. In this presentation, we propose an algorithm evaluating edge strength as well as edge positions from image brightness distribution. The proposed algorithm utilises multiple systems, each of which consists of two subsystems of the **FitzHugh-Nagumo reaction-diffusion equations**[2,3)] coupled with a diffusion equation. Integration of the outputs of the multiple systems provides edge strength distribution.

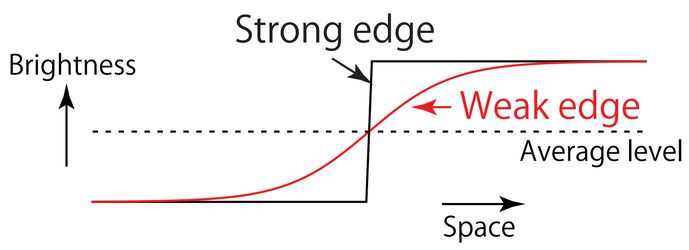


Fig. 1: One-dimensional example of a strong edge and a weak edge.

References:

1) Elder, J. H., Zucker, S. W.: Local scale control for edge detection and blur estimation, IEEE Transactions on Pattern Analysis and Machine Intelligence. Vol. 20, 699–716 (1998)

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

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

2. Reaction-Diffusion System

The FitzHugh-Nagumo Reaction-Diffusion Equations[2,3)]

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

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

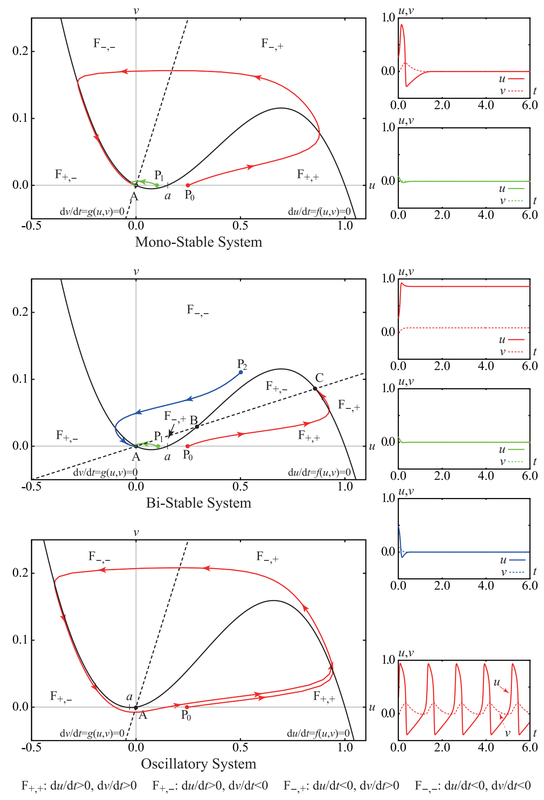


Fig. 2: Phase plots and temporal developments of the ordinary differential system.

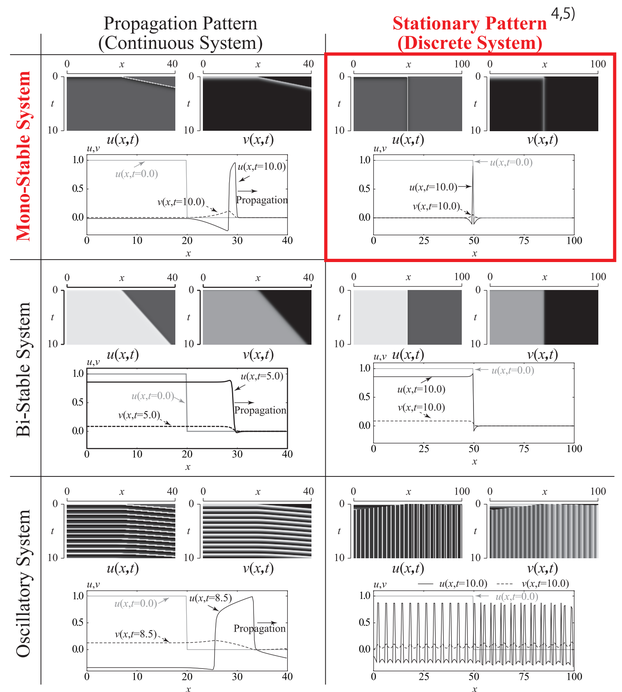


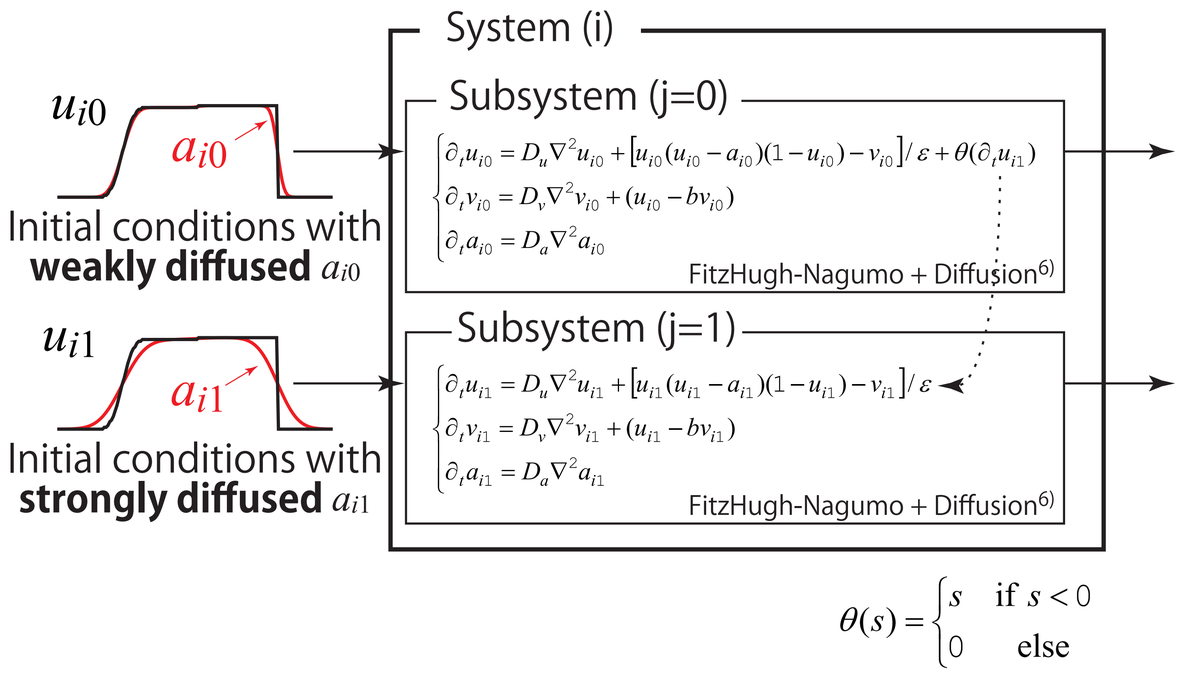
Fig.3: Spatio-temporal plots and spatial distributions of the one-dimensional system.

References:

4) 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)

5) 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. Proposed Algorithm



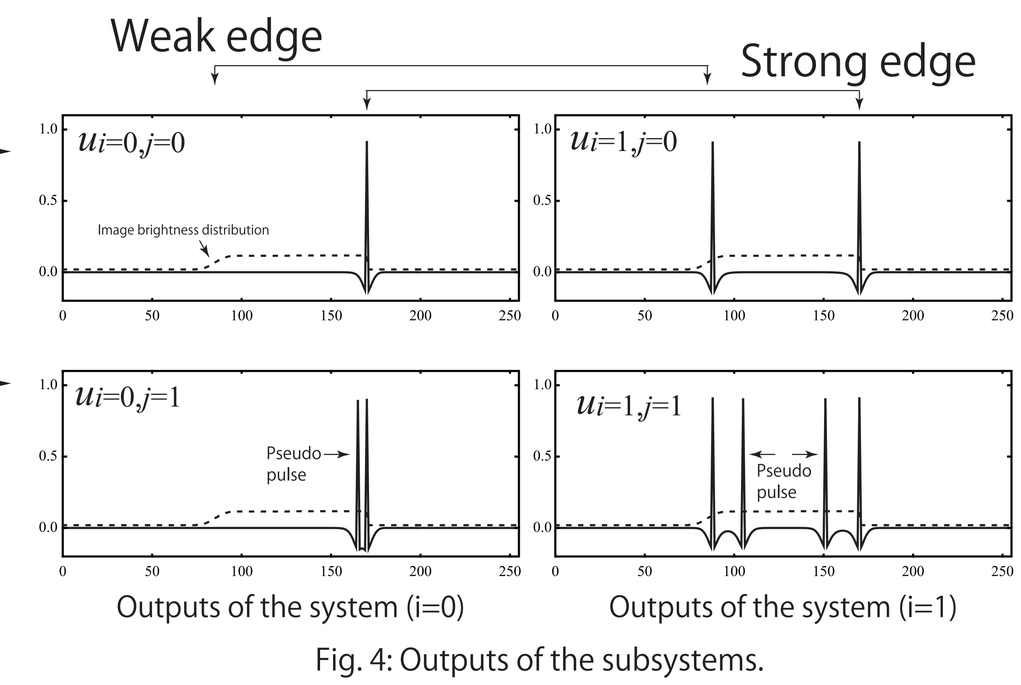


Fig. 4: Outputs of the subsystems.

References:

6) Nomura, A., Ichikawa, M., Sianipar, R. H. , Miike, H.: Edge detection with reaction-diffusion equations having a local average threshold. Pattern Recognition and Image Analysis, Vol. 18, 289–299 (2008)

4. Experimental Results

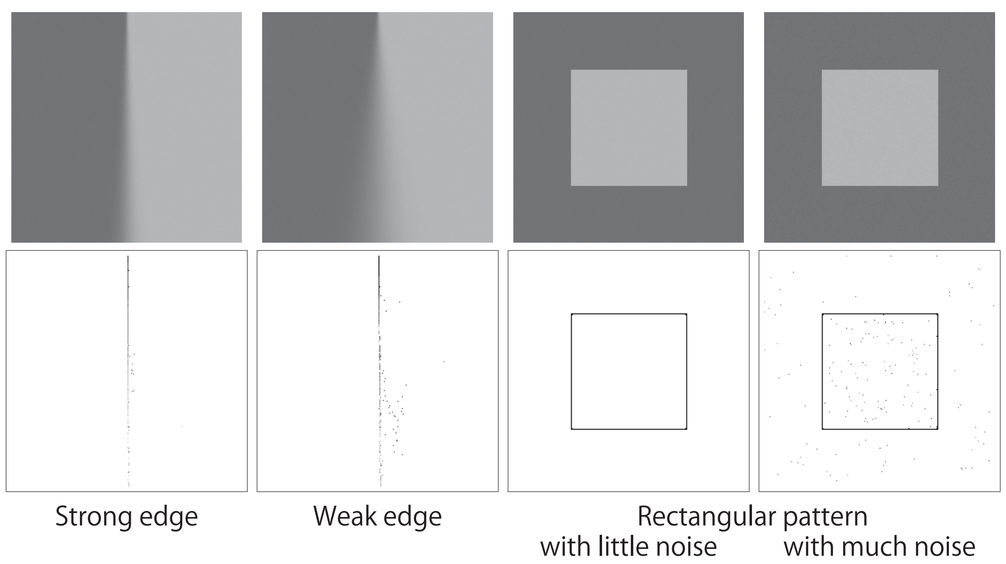
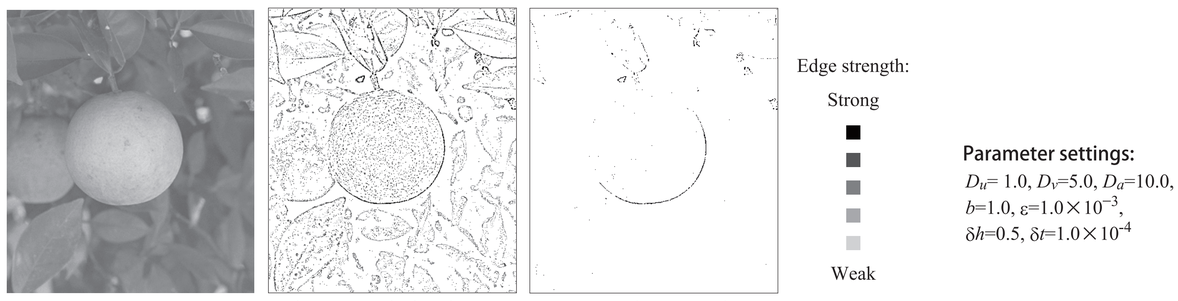


Fig. 5: Artificial images[1)] and their results of edge strength evaluation.



Parameter settings:
D_u= 1.0, D_v=5.0, D_a=10.0,
b=1.0, ε=1.0×10^{-3},
δh=0.5, δt=1.0×10^{-4}

Fig. 6: Results of edge strength evaluation for the real image Orange[7)].

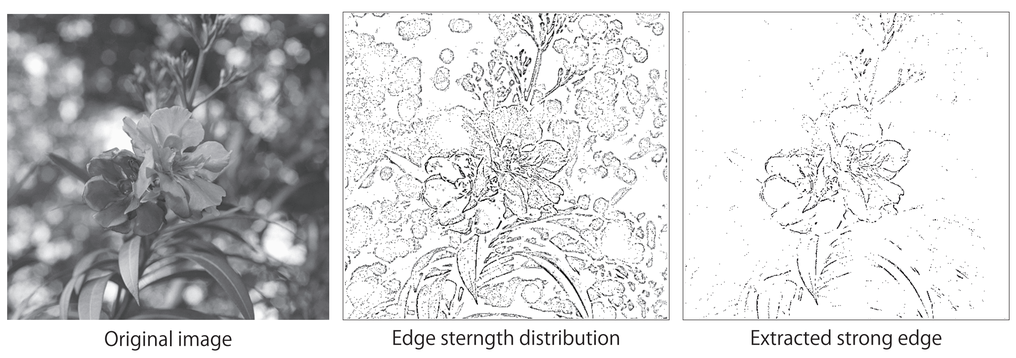


Fig. 7: Results of edge strength evaluation for the real image Flower[7)].

References:

7) Heath, M., Sarkar, S. , Sanocki, T., Bowyer, K. : Edge detector comparison. http://marathon.csee.usf.edu/edge/edge detection.html