Image Halftoning with Turing Patterns

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Abstract

This poster presents an image halftoning algorithm that converts a gray level image to a binary image[1]. A reaction-diffusion system generates a spatial heterogeneous pattern[2,3], in which wave length depends on its parameter settings. The algorithm proposed here utilizes the Schnakenberg type reaction-diffusion system[2] and achieves image halftoning by modulating a parameter setting of the system according to a gray level distribution of image. The algorithm was tested for several images and compared with other previous algorithms.

The Algorithm

Schnakenberg type reaction-diffusion[2)]

$$\frac{\partial u}{\partial t} = \nabla^2 u + \gamma(a - u + u^2 v)$$

$$\frac{\partial v}{\partial t} = D\nabla^2 v + \gamma(b - u^2 v)$$

Initial conditions:

$$u(x,y,t=0) = a + b + n_1$$

$$v(x,y,t=0) = \frac{b}{(a+b)^2} + n_2$$

n_1 and n_2 are noise

Parameter modulation:

$$b(x,y) = b_{\min} + (b_{\max} - b_{\min}) \underbrace{I(x,y)}_{\text{original image}}$$

Halftone image:

$$H(x,y,t) = \begin{cases} 1 & \text{if } u(x,y,t) \geq v(x,y,t) \\ 0 & \text{otherwise} \end{cases}$$

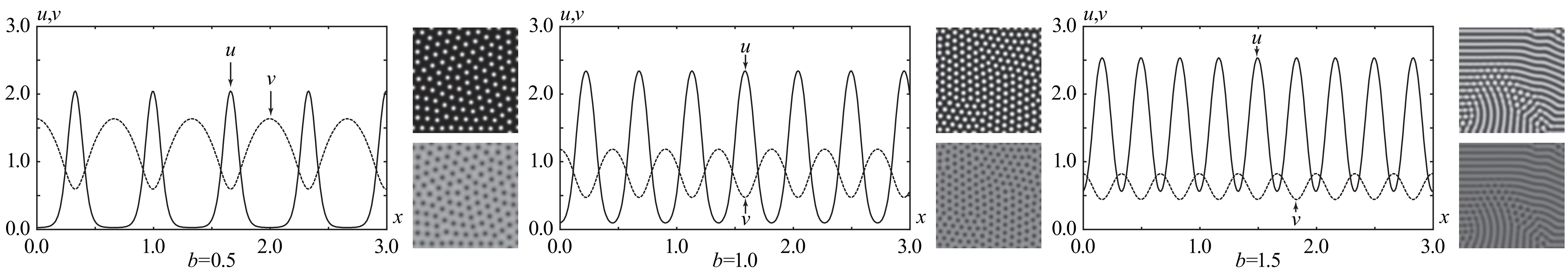

Fig. 1 Typical examples of Turing patterns in the Schnakenberg type reaction-diffusion system[2)].

Parameter settings: D=20, a=0.025, γ=1000, δh=1.0X10^{-2}, δt=1.0X10^{-5}

Results

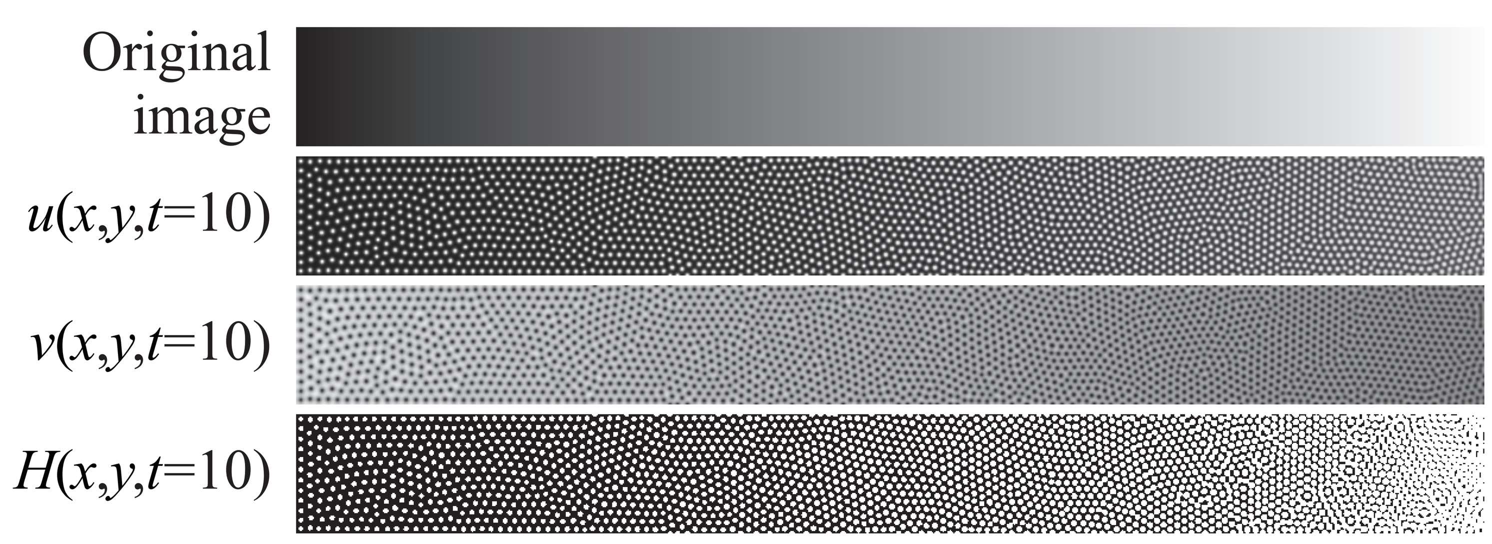

Fig. 2 Simple example for a gray level image.

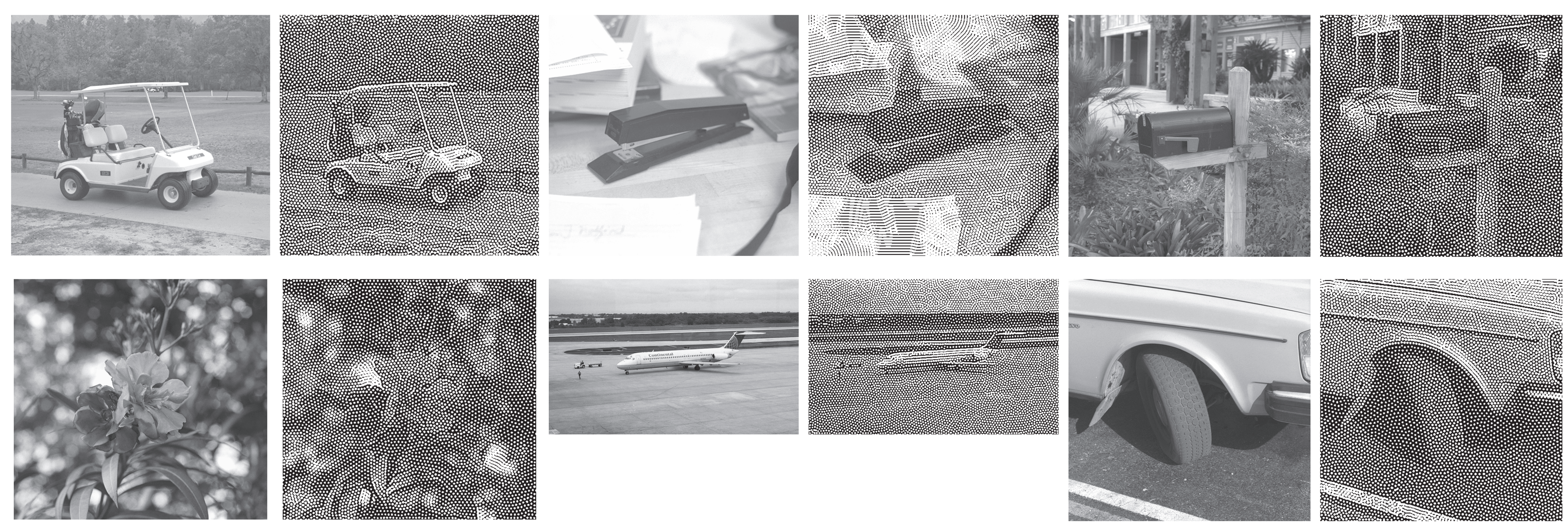

Fig. 3 Variety of examples for real images.

http://marathon.csee.usf.edu/edge/

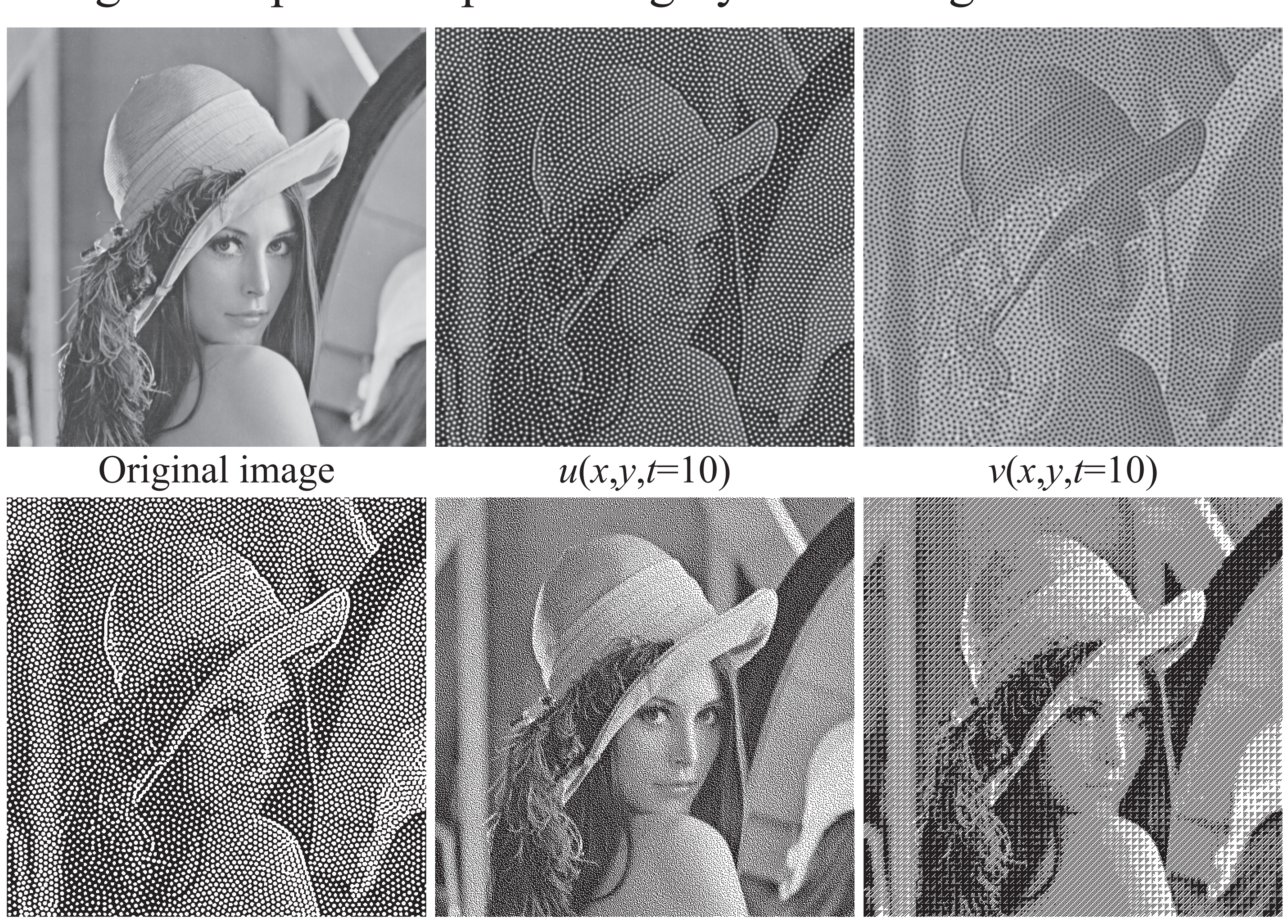

Fig. 4 Results for the test image LENA.

http://www.ece.rice.edu/~wakin/images/

Parameter settings (fixed across all of the images):

D=20, a=0.025, b_{min}=0.5, b_{max}=1.5, γ=1000, δh=0.05, δt=1.0X10^{-5}

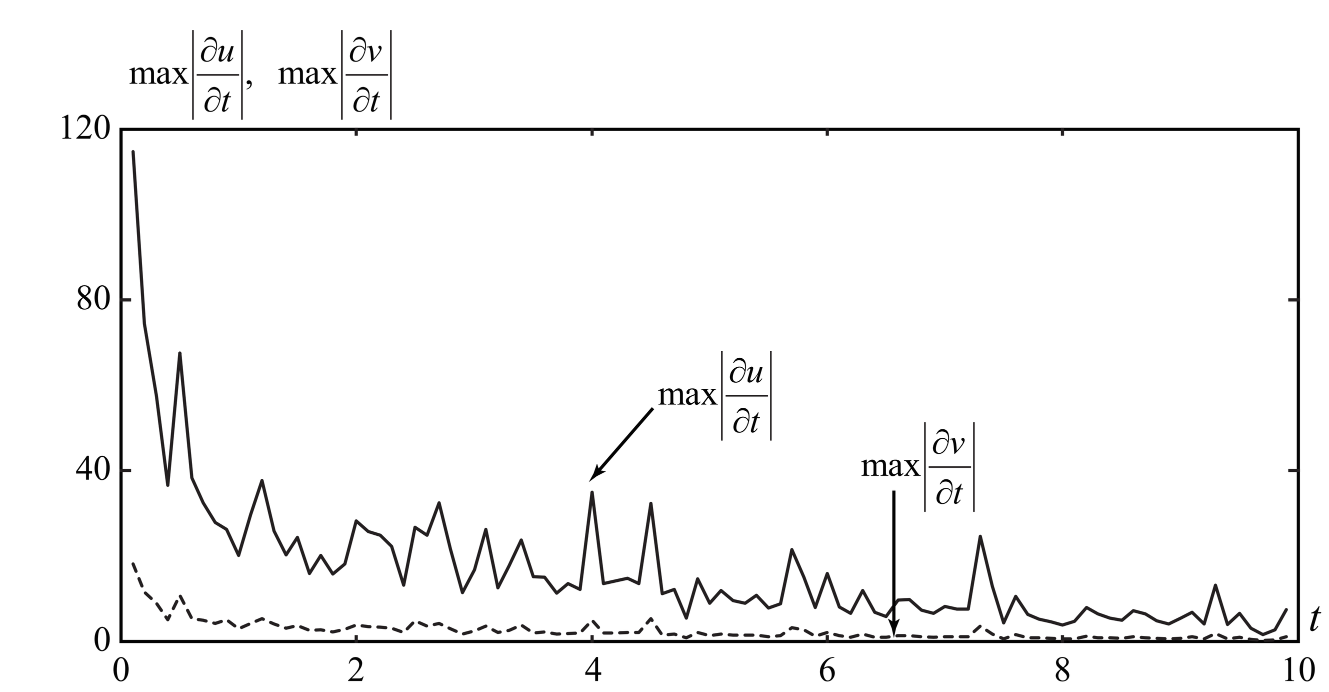

Fig. 5 Convergence of the algorithm for LENA.

Conclusion

This presentation demonstrated the prposed image halftoning algorithm consisting of the Schnakenberg type reaction-diffusion system[2)], which can generate Turing patterns[3)]. Through variety of experimental results, it was confirmed that binary images generated with Turing patterns in the algorithm approximately represent their original images except some artifacts. Convergence of the algorithm was also confirmed for a test image.

References

[1] Lau, D. L. and Arce, G. R. (2008). *Modern Digital Halftoning*. CRC Press.

[2] Schnakenberg, J. (1979). *Journal of Theoretical Biology*, **81**:389–400.

[3] Turing, A. M. (1952). *Phil. Trans. Roy. Soc. Lond. B, Biol. Sci.*, **237**:37–72.

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