An Analog-Digital Hybrid Reaction-Diffusion Chip for Stripe and Spot Image Restoration

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Digital signal processors performing realtime image restoration consume huge amount of power when the target images are not clear or are damaged by extensive noises. On the other hand, every living thing efficiently restores (or cures) their 'spatial patterns' on the basis of reaction-diffusion (RD) processing. In this report, we propose a novel RD model that repairs Turing patterns; e.g., stripe and spot patterns observed in human fingerprints and marking patterns on various animals. Based on the model, we propose a novel LSI architecture, aiming at the development of compact and low-power silicon RD systems.

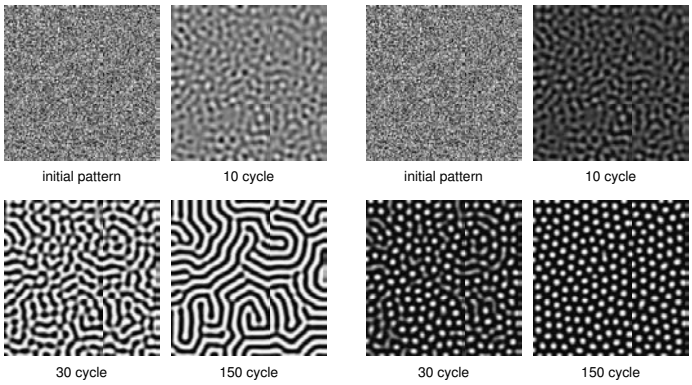
Conventional cellular-automaton RD models that generate Turing patterns are not suitable for LSI implementation because they required very complex transition functions [1] or distant neighbors [2] for the pattern generation. Our new RD model consists of two linear diffusion fields where chemical substances called activators and inhibitors diffuse on a 2-D space. Inhibitors diffuse much faster than activators. At every spatial point, both diffusion fields are initialized (or updated) step by step to the value of a sigmoid function. The input is the difference between the concentrations of the activators and inhibitors. A step convolutional operation corresponds 'difference of Gaussian' (DoG) filtering and subsequent initial values are set to the filtered values. By repeating this operation, localized clusters of activators and inhibitors appear on the RD field (Fig. 1). The shape of clusters can be controlled by changing offset values (c) of the sigmoid function ($c = 0$ for stripe, $c = \pm 0.16$ for spot patterns).

We designed an analog-digital hybrid CMOS circuit for the proposed model that consists of 2-D array of a cell circuit (Fig. 2) including i) 2-D diffusion circuits that operate in discrete time, ii) DoG circuits only with one diffusion layer and iii) variable-threshold sigmoid circuits. By extensive circuit simulations, we confirmed that the proposed LSI could restore stripe and spot images within 10,000 clock cycles, independently of the number of pixels in the image.

References

[1] Markus M. and Hess B., Isotropic cellular automaton for modeling excitable media, *Nature,* vol. 347, no. 6288, pp. 56-58 (1990).

[2] Young D.A., A local activator-inhibitor model of vertebrate skin patterns, *Math. Biosci.,* vol. 72, pp. 51-58 (1984).



(a) $c = 0$ Fig. 1 (b) $c = 0.16$

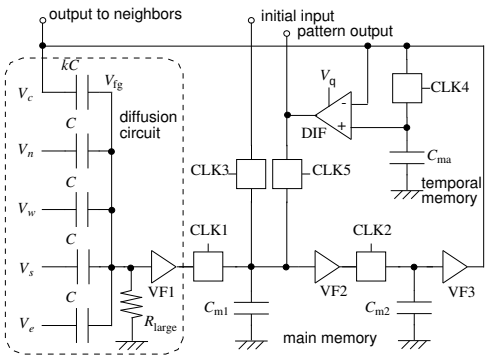


Fig. 2