International Congress Series 1301 (2007) 282 – 285

www.ics-elsevier.com

Adaptive network structure for texture discrimination by a 1-D oscillator system

Yoshinori Nagai [a,*], Ted Maddess [b]

[a] Center for Information Science, Kokushikan University, 4-28-1 Setagaya, Tokyo 154-8515, Japan
[b] ARC Centre of Excellence in Visual Science, RSBS Australian National University, Australia

Abstract. We investigated 1-D oscillator networks that can discriminate isotrigon textures as humans and bees do. The triangular network system investigated discriminated isotrigon texture pairs in the sense of differences in response dynamics for different textures. © 2007 Elsevier B.V. All rights reserved.

Keywords: 1-D oscillator; Texture; Discrimination; Box; Random; Nonlinear dynamics; Oscillator networks; Isotrigon; Triangular network

1. Introduction

Our previous work investigating sensory receptive fields of 1-D oscillator networks with receptor inputs showed that 1-D oscillators can follow the shape of temporally rectangular inputs [1]. This implies that these 1-D oscillator networks can imitate input shapes. The subject of the present paper is whether the 1-D oscillator networks are able to discriminate the combination of inputs from photoreceptor outputs whose expected magnitudes differ. We have been investigating how humans discriminate *isotrigon textures* from random textures: such pairings differ only in their 4th and higher order spatial correlations [2,3]. Here we investigate whether oscillator networks can discriminate isotrigon textures. We postulate that information gained from studying the dynamics of these networks [4,5] may indicate how humans use higher order structure to discriminate isotrigon textures and similar structure in natural images.

When the 1-D oscillator networks imitate input shapes, sensory receptive fields will be realized in the 1-D oscillator networks [1]. These types of *receptive fields* are applicable for modelling texture discrimination by 1-D oscillator networks. The isotrigon textures have the statistical characteristics of zero ensemble averages of their first through third order

* Corresponding author. Tel.: +81 3 5481 3220; fax: +81 3 5481 3227.
E-mail address: nagai@kokushikan.ac.jp (Y. Nagai).

doi:10.1016/j.ics.2006.12.103

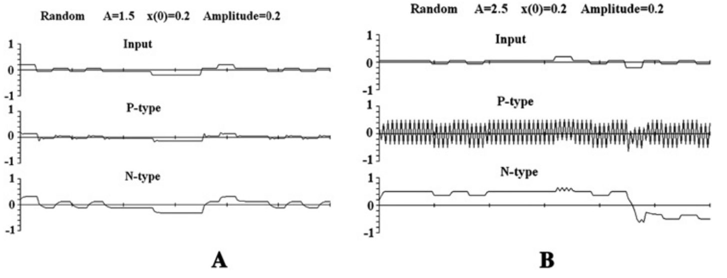

Fig. 1. The elementary responses to the three pixel averaged inputs from isotrigon texture.

spatial correlation functions. Thus, it is expected that the average responses will provide null temporal development in a statistical sense. We therefore investigated some kinds of nonlinear responses to the isotrigon textures that yield differences between superposed responses from a statistical viewpoint.

2. Isotrigon texture discrimination on triangular network system

2.1. Elementary responses of 1-D oscillators to the inputs

The responses of elementary 1-D oscillators to locally averaged inputs from isotrigon texture fields are shown in Fig. 1. We employ two kinds of 1-D oscillators: P-type and N-type [6]. As seen from Fig. 1, both types of 1-D oscillators imitate the inputs when the parameter A is lower than 2, while values higher than 2 yield nonlinear responses exhibiting *gap* behaviour as seen in Fig. 1B. The inputs shown in Fig. 1 are averaged over domains of three vertically neighbouring pixels that are distributed along the horizontal direction of the input texture field (Fig. 2A).

2.2. The 1-D oscillator network for tasking texture discrimination

A network system for testing texture discrimination is shown in Fig. 2A. The receptors in the network system shown in Fig. 2A average three pixels from the texture field, and each sends their output to a 1-D oscillator connected to it.

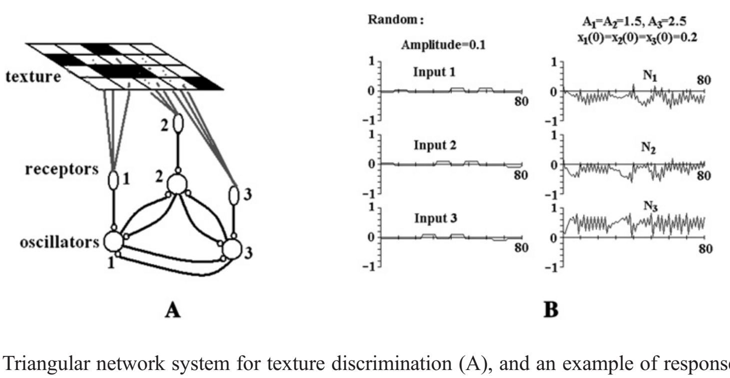

Fig. 2. Triangular network system for texture discrimination (A), and an example of response (B).

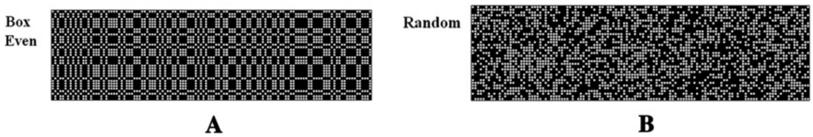

Fig. 3. Even box texture (A) and random texture (B).

The 1-D oscillators in the triangular network are connected to each other and each oscillator receives an input from a receptor. In the present model, the receptor only plays the role of averaging the local pixel states of a texture. The triangle 1-D oscillator networks we used were classified into 4 types as determined by the included combinations of different oscillator types, namely NNN, PNN, PPN, and PPP [4,5]. Each oscillator has a parameter A that regulates the temporal development of its variable, $x_i(t)$, and so the parameter set (A_1, A_2, A_3) was also considered in classifying the response dynamics to texture inputs. The dynamics, i.e. the temporal development of oscillator variables ($x_1(t)$, $x_2(t)$, $x_3(3)$), were governed by the following recurrence equation of discrete time:

$$x_j(t+1) = \pm A_j(x_j^2(t)-1)x_j(t) \pm x_j(t) \pm \frac{1}{2}\sum_{k=1}^{3} x_k(t)(1-\delta_{k,j}) \pm R_j(t), \qquad j = 1, 2, 3,$$

$$R_j(t) = \sum_{y=\xi(t)}^{\xi(t)+2} S(x = \mu(t), y)$$

where (x, y) are coordinates on the texture surface. The texture inputs were moved in the x-direction of the texture with an appropriate, constant, step speed.

An example of the oscillator dynamics of an NNN triangular oscillator network is shown in Fig. 2B. Compared with the case of isolated oscillators, the working area [1] of the inputs to the networks was confined to lower values of the parameter A.

2.3. Composed oscillator dynamics of network for discriminating texture

Texture discrimination by the oscillator networks was judged on the component oscillator dynamics. If different network dynamics appeared when scanning the texture fields

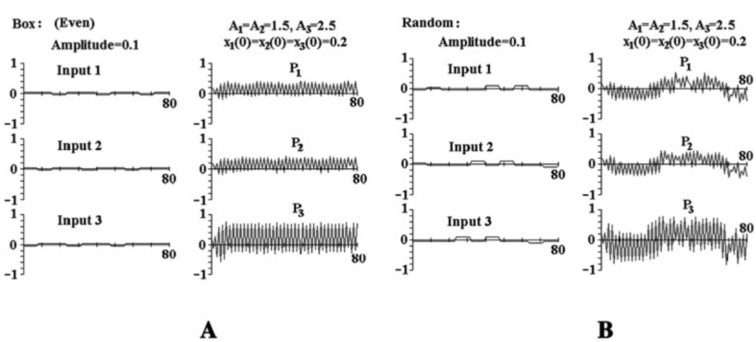

Fig. 4. Oscillator responses for even box texture (A) and random texture (B).

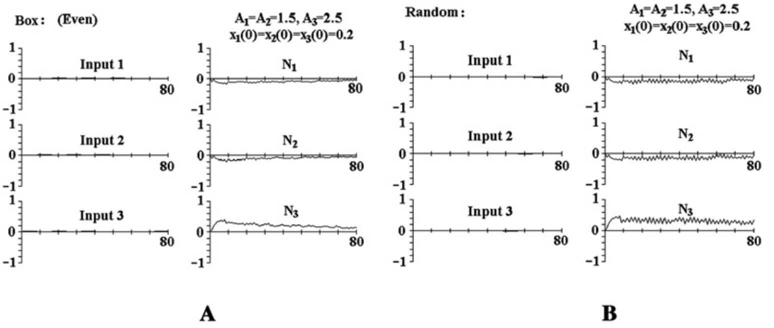

Fig. 5. Superposed responses of 50 samples for even box texture (A) and random texture (B).

compared with random fields then it can be said that the triangular network discriminated the texture. Given the limitation of 4 pages, we illustrate a single type of texture *versus* random discrimination. Randomly seeded isotrigon textures made by the Box glider and the even Box rule are shown in Fig. 3. The three receptors of the triangular oscillator network system scanned the texture pixel field in 3 × 3 *minitexture* domains. The 1st receptor averages over the first column of the 3 × 3 minitexture, the 2nd averages over the second column, and so on. The receptors stay at the same place for 8 iteration steps, while the network moves to the next column line on each step. The response dynamics of the scanning inputs imply the network can discriminate the textures (Fig. 4).

3. Statistical significance of texture discrimination in the triangular network

The isotrigon textures have the property of randomness. It is possible that there is discrimination even if the response dynamics are different between two textures for every isotrigon texture so we needed a statistical method to judge discrimination. One simple method is to superpose the responses. The discrimination example shown in Fig. 4 uses a PPP triangular network. The discrimination Box *versus* random was also performed by NNN networks. The PPP network yielded null results while the NNN network realizes a difference in 50 superposed cases as shown in Fig. 5.

References

[1] Y. Nagai, T. Maddess, Input effects and sensory receptor responses of triangular oscillator networks, Mem. Kokushikan U. Cent. Infor. Sci. 27 (2006) 1–13.
[2] T. Maddess, Y. Nagai, Discriminating isotrigon textures, Vision Res. 41 (2001) 3837–3860.
[3] T. Maddess, Y. Nagai, J.D. Victor, R.R.L. Taylor, Multi-level isotrigon textures, J. Opt. Soc. Am. A, 24 (2007) 278–293.
[4] Y. Nagai, T. Maddess, Nearest neighbour coupled systems of four 1 = d oscillators, ICS 1269 (2004) 129–132.
[5] Y. Nagai, T. Maddess, S. Hyde, The oscillatory features of triangular and square prism oscillator networks, Mem. Kokushikan U. Cent. Infor. Sci. 26 (2005) 1–16.
[6] Y. Nagai, T. Maddess, Mechanics of control dynamics, Mem. Kokushikan U. Cent. Infor. Sci. 25 (2004) 21–45.