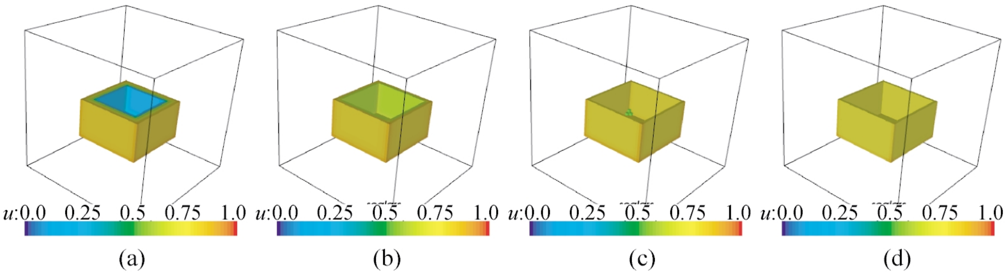

Fig. 6. A time series of the edge plane structure found at $D_u = 1.5 \times 10^{-4}$ and $D_v = 6.0 \times 10^{-4}$. The lower half of distributions of u at the 1600th step (a), 1700th step (b), 1900th step (c), and 5000th step (d) are visualized. The other parameters were $a = 0.1$, $b = 1.0$, $\epsilon = 1.0 \times 10^{-4}$, $\Delta x = 0.01$, and $\Delta t = 1.0 \times 10^{-4}$.

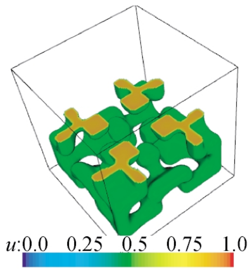

Fig. 7. A three-dimensional Turing pattern found at $a = 0.2$, $b = 5.0$, $\epsilon = 1.0 \times 10^{-3}$, $\Delta x = 0.01$, $\Delta t = 1.0 \times 10^{-5}$, $D_u = 1.0 \times 10^{-2}$, $D_v = 4.0 \times 10^{-2}$, and $N = 100$. The lower half of the isosurface $u = 0.5$ at the 300000th step is visualized.

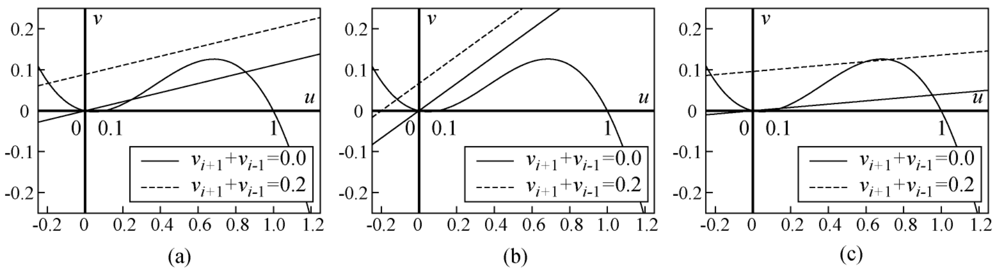

Fig. 8. Nullclines of Eqs. (3) and (4) at $D_v = 1.0$ (a), $D_v = 4.0$ (b), and $D_v = 12.0$ (c). $\Delta x = 0.01$ and $a = 0.1$ in each case. The solid lines indicate that $v_{i+1} + v_{i-1}$ is small (0.0), and the dashed lines show that $v_{i+1} + v_{i-1}$ is sufficiently large (0.2). Sufficiently large discreteness results in a non-uniform number of stable points in space according to distributions of the inhibitor value v, which almost depends on the activator value u (a). The number of stable points is identical in space in (b) and (c).

system (see details in Kitamori and Kitamura (1996)). If a dynamic system shows an exponential decay, the quantitative state of the system becomes $1/e$ after τ passes. In the FitzHugh–Nagumo model (Eqs. (1) and (2)), the estimated value of characteristic τ is 0.1 for parameters that yield both edge detection (Figs. 4 to 6) and a Turing pattern (Fig. 7). We also estimated τ for a Turing pattern generated by the Oregonetor model (refer figure 12 in Nomura *et al.*, 1997) and obtained $\tau = 1.0$. In each case (edge detection, the Turing pattern of the FitzHugh–Nagumo model, and that of the Oregonetor models), states of the patterns were still non-stationary just as τ passed, but settled into steady patterns after around tens of times τ passed in each case.

4.2 A brief theory of extracting the edge structures in the FitzHugh–Nagumo model

Here, we consider the FitzHugh–Nagumo system in one spatial dimension, for better understanding of the discussion. It seems that the generality of the theory of the one-dimensional system is retained when it is adopted in three dimensions. In addition, we assume that D_u is zero. We have confirmed that edge structures also appear in this case. First, we adopt a central difference in space and obtain the following Eqs. (3) and (4),

$$\frac{du_i}{dt} = \frac{1}{\epsilon}\{u_i(u_i - a)(1 - u_i) - v_i\}, \tag{3}$$

$$\frac{dv_i}{dt} = r'(v_{i+1} - 2v_i + v_{i-1}) + u_i - bv_i, \tag{4}$$

where r' represents $D_v/(\Delta x)^2$. The subscript $i = 1, 2, \ldots, N$ is a spatial index. Equations (5) and (6) represent nullclines of Eqs. (3) and (4), respectively (see also Fig. 8),

$$v_i = u_i(u_i - a)(1 - u_i), \tag{5}$$

$$v_i = \frac{1}{b + 2r'}u_i + \frac{r'(v_{i+1} + v_{i-1})}{b + 2r'}, \tag{6}$$

where b, r', v_{i+1}, and v_{i-1} are positive.