A Neural Network Filter For Complex Spatio-Temporal Patterns*

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Abstract—This paper proposes a four-layer neural network filter for complex spatio-temporal pat- [redacted] **temporal pattern, it can be constructed according to the order of the spatio-temporal pattern. Moreover, it is demonstrated by the simulation results.**

I. INTRODUCTION

Filtering and recognition of spatio-temporal pat- [redacted]

temporal correlator network is proposed to solve the problem of spatio-temporal pattern learning, recogni- [redacted] on a Kohonen's self-organizing map and a fuzzy ART network. However, the number of the processing neurons in some layer varies with the complexity of spatio-temporal patterns, which makes difficult to implement the network.

In this paper, we propose a neural network based filter for any given complex spatio-temporal pattern [redacted]

$\mathcal{S}^c = P_1, \cdots, P_{m_0} P_1$. And m_0 is called the length of the spatio-temporal cycle.

Definition 2. *When a spatio-temporal pattern $\mathcal{S}$ is not periodic, the order of $\mathcal{S}$ is defined by*

$$r(\mathcal{S}) = min\{k : P_i P_{i+1} \cdots P_{i+k-1} \neq P_j P_{j+1} \cdots P_{j+k-1} \quad for \ all \ i, j \leq m-k+1, and \ i \neq j.\} \qquad (1)$$

Clearly, the order of $\mathcal{S}$ is the minimum of the number k which enable all the possible k-step blocks in $\mathcal{S}$ are different. Surely, it is a positive integer in the range $[1, m]$. For clarity, $r(\mathcal{S})$-step blocks of $\mathcal{S}$ are called basic blocks of $\mathcal{S}$. When the order of $\mathcal{S}$ is just one, it is called a simple spatio-temporal pattern. In this case, all the spatial patterns are different. When the order of $\mathcal{S}$ is larger than one, it is called a complex spatio-

The proof will be given in [11].

According to Theorem 1, we certainly have that the map from $\mathcal{S}$ to $\mathcal{B}_{\mathcal{S}}$ is one to one in the cases of both complex spatio-temporal pattern and cycle. That is, $\mathcal{B}_{\mathcal{S}}$ uniquely corresponds to its true spatio-temporal pattern or cycle when $\mathcal{S}$ is complex. Thus, a complex spatio-temporal pattern or cycle can be recognized from its basic blocks. We will use this idea to design the neural network spatio-temporal filter.

III. THE NEURAL NETWORK SPATIO-TEMPORAL FILTER

Suppose that $\mathcal{S}$ is a given complex spatio-temporal pattern of finite length (i.e., m is finite) or a given complex spatio-temporal cycle and its order is $k(>1)$.

a fixed n-dim binary pattern, we define

$$d_H(X,C)=\sum_{i=1}^{n}|x_i-c_i| \qquad (4)$$

as the Hamming distance between X and C. We then

define the t-neighborhood of C over the n-dim binary space $\{0,1\}^n$ as follows:

$$R_t(C)=\{X: d_H(X,C)\le t\}. \qquad (5)$$

The definition of the perceptive neuron is given as follows.

Definition 1 *If a binary neuron with a fixed weight*

value θ, satisfies the following input-output relation:

$$y(X)=Sgn(\sum_{i=1}^{n}w_ix_i-\theta)=\begin{cases}1 & \text{if } X\in R_t(C)\\ 0 & \text{otherwise}\end{cases} \qquad (6)$$

it is called a t-neighborhood perceptive neuron of (pat-

otherwise, the neuron is inhibited and we consider the input pattern cannot be recognized as SP_i. ε is selected according to the noise environment.

When the input pattern X and the spatial pattern

second order binary neuron, called matching neuron.

Actually, a second order binary neuron is defined by **W** which is an $(n+1)$-order real symmetric matrix. For an input signal pattern X, the output signal y of the second order binary neuron is computed by

$$y=Sgn(H(x))=\begin{cases}1 & \text{if } H(x)>0\\ 0 & \text{otherwise}\end{cases} \qquad (9)$$

$$H(X)=\sum_{i,j=0}^{n}w_{ij}x_ix_j, \qquad x_0=1.$$

Then, a matching neuron of the spatial pattern SP_i is defined by such a second order binary neuron that

At each time with an input pattern, if some U_{j_l} is activated, it sends a signal to the receiving box where

the first left block of the shift register. Otherwise, the

i.e., it has sent one or more positive signals to the output neuron, its contribution to the output neuron is

all the signals in the m times, the output neuron will

k-step blocks. The errors can be filtered by the output neuron if the threshold value is properly selected. Therefore, the neural network filter can recognize $\mathcal{S}$ in a noisy environment.

We further consider the case that $\mathcal{S}$ is a spatio-temporal cycle, i.e., $\mathcal{S} = P_1 \cdots P_{m_0} P_1$. In this situation, we design the neural network spatio-temporal filter as for the spatio-temporal pattern $\mathcal{S}' = P_1 \cdots P_{m_0} P_1 \cdots P_{k-1}$, i.e., $m = m_0 + k - 1$. Clearly, when the input spatio-temporal cycle enters the neural network spatio-temporal filter in such a way as $\mathcal{S}'$, we have the same result as above. Moreover, since the output neurons all check whether all or most of the basic

of the real number x). For a filtering or recognition system, only when the radius of the error-correcting hypersphere of each S_i is just t_i^*, the error probability of recognition reaches the minimum in a noisy environment.

Based on the Hamming distances between these sample patterns, we have

$$(t_1^*, t_2^*, t_3^*, t_4^*, t_5^*, t_6^*, t_7^*, t_8^*, t_9^*, t_10^*) = (3, 6, 5, 4, 9, 4, 5, 8, 3, 4).$$

Then, we can design the binary neuron U_i in the second layer of the neural network filter as the t_i^*-

period of m times and there is not any other require-

Theorem 2.

[2] C. Staneley and W.L. Kilmer, "A wave model of temporal sequence learning," *Int. J. Man-Machine Study*,