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A Neural Network system to Adjust a Strain of Patterns

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Abstract—In this paper, I describe a new neural network system to transform a pattern so that the distance from the transformed pattern to the reference pattern is reduced. Some application of this new neural network such as the character recognition and the stereogram recognition is presented.

1. Introduction

Generally, the preprocessing of the recognition system is very important. Because of noise, strained and/or shifted, recognition systems misunderstand. It is required to adjust them at the preprocessing process to avoid this problem. For example, a character recognition system compares the input pattern and the reference patterns. But it sometime misunderstand because the input pattern may be shifted, rotated or strained. When a hand written character is recognized, it is very big problem. The system which adjusts the strain or sliding is required to solve the problem. Other hand, when stereogram is calculated from a right eye picture and a left eye picture, their strain is very important. The difficulty is finding correspondence point of the pictures. These problem is solved with presented new system too.

From these backgrounds, I present a new system which adjusts the strain or sliding. This system consists of analog processing units, registers and shifter. The operation is executed with the parallel processing and it can be realized by the cellar neural network implementation technique. I expect that this system can be applied for a lot of a recognition system such as a character recognition, a voice recognition and so on.

In this paper, I show the simulation result of one-dimensional system and two-dimensional system. And I show an application for the stereogram. From these simulation results, this system is very useful and powerful.

2. One-dimensional system

2.1. The adjusting the strain pattern for one-dimensional pattern

In this section, the adjusting the strain pattern for one-dimensional pattern is discussed. Two-dimensional system will be discussed at a later section.

Now I define two data $\{a(x)|0 < x < x_m\}$ and $\{b(x)|0 < x < x_m\}$ which are one dimensional data. For an example, $a(x)$ is original data and $b(x)$ is strained data. For another example, $a(x)$ is right eye data and $b(x)$ is left eye data for stereogram.

In this paper, I define *strain* means expansion or contraction for X direction. I show you the example of *strained* data in fig. 1. $a(x)$ is original data and $b(x)$ is *strained* data. $b(x)$ is expanded around center. $c(x)$ is shifted to right, it is considered that "left side of the data is expanded.". Then it is one of the sample of *strained* data.

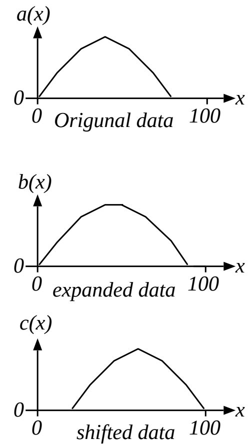


Fig. 1 example of *strained* data

Now I describe the relation of $a(x)$ and $b(x)$ as

$$a(x) = b(x + z(x)) \tag{1}$$

where $a(x)$ and $b(x)$ are input data and $z(x)$ is strain of their data. When $a(x)$ and $b(x)$ are practice data, there are meny kind of noise $n(x)$ and strain $n(x)$. Including the noise, the equation is replaced with

$$a(x) = b(x + z(x)) + n(x) \tag{2}$$

One of the goal of this paper is to obtain the $z(x)$. If I assume $n(x)$ is small and $z(x)$ is optimal, cross correlation S must be maximum where

$$S = \int a(x)b(x + z(x))dx \tag{3}$$

Now I define the energy of the noise $\epsilon = \int n(x)^2 dx$. To substitute (2) to this definition, the following equation is obtained.

$$\epsilon = \int a(x)^2 dx + \int b(x + z(x))^2 dx - 2S \qquad (4)$$

Because the first term is constant and the second term is almost constant, when S is maximum ϵ should be minimum. Then we can obtain $z(x)$ from following equation.

$$\epsilon_{min} = min(\epsilon) = min(\int (a(x) - b(z(x) + x))^2 dx) \quad (5)$$

In this paper, I apply the the steepest descent method to solve the equation. When apply the steepest descent method, we have to quantize the $a(x)$ and $b(x)$ and apply numerical integration. Then I define that $\{x_i | i = 1, n\}$,$a(x_i) = a_i$, $b(x_i) = b_i$ and $z(x_i) = z_i$ are quantized x, $a(x)$, $b(x)$ and $z(x)$, respectively.

The equation (5) is replaced with following equation using these definition.

$$\begin{aligned} \epsilon_{min} &= min(\sum (a(x_i) - b(x_i + z(x_i)))^2) \\ &= \sum \epsilon_i \end{aligned}$$

where

$$\epsilon_i = min((a(x_i) - b(x_i + z(x_i)))^2) \qquad (6)$$

Then we can obtain $z(x_i)$ from equation (6).

Now I apply the steepest descent method for equation (6). Then I obtain following equation,

$$\frac{dz_i}{dt} = -2(a(x_i) - b(x_i + z_i))\frac{db(x_i + z_i)}{dz_i} \qquad (7)$$

The solution of (6) is stable point of the differential equation. The equation (7) can be replaced with following equation by applying quantized method.

$$\begin{aligned} \frac{dz_i}{dt} \;=\; & -\frac{2}{\Delta z}(a(x_i) - b(x_i + z(x_i))) \\ & (b(x_{i+1} + z(x_{i+1})) - b(x_i + z(x_i))) \quad (8) \end{aligned}$$

where $\Delta z = z(x_{i+1}) - z(x_i)$

Finally, following equation is obtained and solution z(x) is stable point of the equation.

$$z_j = \int \gamma(a_j - b_{j+z_j})(b_{j+z_{j-1}} - b_{j+1+z_{j+1}})dt \qquad (9)$$

where $\gamma = 2/\Delta z$.

But we can not solve the equation (9). Because there is no relation between $z(x_i)$ and $z(x_{i+1})$. Then I assume that the strain $z(x_i)$ is smooth and continues function and I apply low pass filter for $z(x_i)$. There are a lot of low pass filter, but I apply a low pass filter which is application of CNN[1] because of simple structure.

So equation (9) is replaced with

$$v_j = Sig(\int \gamma(a_j - b_{j+z_j})(b_{j+z_{j-1}} - b_{j+1+z_{j+1}})dt) \quad (10)$$

and

$$z_j = \alpha(z_{j-1} + z_{j+1}) + (1 - 2\alpha)z_j + \beta v_j \qquad (11)$$

The second equation realize low pass filter[1] where α and β are parameter of the low pass filter and $Sig(x)$ is sigmoid function.

2.2. Example

Fig.2 shows you a sample of the strain. Pattern $a(x)$ and pattern $b(x)$ are same shape, but slided. I simulated the presented system with the sample pattern. z_j present the sliding of the point and pattern $b(x + z(x))$ is adjusted pattern. I can confirm that pattern $b(x + z(x))$ are almost same as pattern A.

Fig. 3 shows you a sample of different pattern. Pattern $b(x + z(x))$ is output of the presented system. In this case, pattern $b(x+z(x))$ is NOT similar to pattern A, because there are not sliding pattern.

From these simulations, we can conform that if pattern $b(x)$ are slided or strained pattern, pattern $b(x)$ is adjusted by this system. Then, we can calculate the distance of patterns after adjusted the shift or the strain.

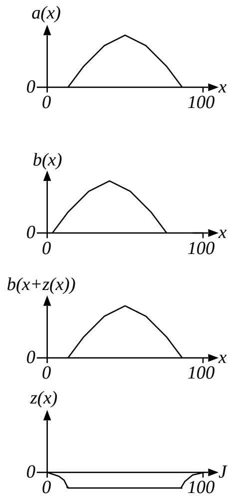


Fig 2 Sample pattern 1.

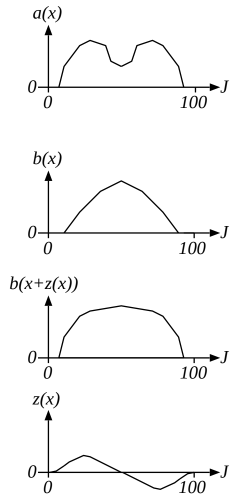


Fig 3 Sample pattern 2.

I can expect that this technique can be applied for a pattern matching, because one of the biggest problems for the pattern matching is strain and slid. If strain problem is solved with this system, the ability of pattern matching must improve.

2.3. System architecture

I show you the new system that adjusts the strain of pattern in fig. 4. The circle symbols are indicated the processing units.

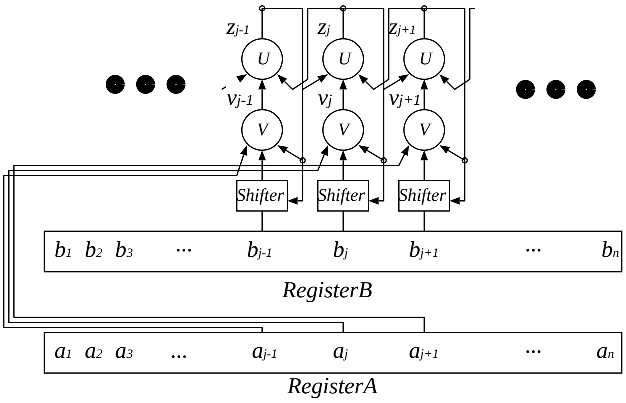


Fig. 4 System architecture for one-dimensional pattern.

Before this system is operated, two n-bit pattern $A = \{a_i\}$,$B = \{b_i\}$ are set into the register A and register B.

At the processing unit V, the equation (10) is calculated. The strain of the point is calculated at the processing unites U. The calculation is described by the equation (11).

The shifters shift the pattern of the register B using the result of the processing unit U. If z_j is not integer, output of the shifter is calculated using the linear interpolation. All processing elements are calculated parallelly, and the stable state is the result.

We can expected that eliminate the strain of the pattern in register B with this operation, and I can obtain distance of 2 pattern without strain.

Because the functions of the processing unit can be realized using the neural network element, presented system can be realized by the neural network. Because this system require only local connection, the technique of the cellar neural network system can be applied for the presented system.

3. Two-dimensional system

3.1. Extension for two-dimensional pattern

In this section, I discuss the extension of presented system for two-dimensional pattern. Now, I define the $z^X_{x,y}$, $z^Y_{x,y}$, $v^X_{x,y}$ and $v^Y_{x,y}$ which are extended z_j and V_j of one-dimensional system, respectively.

$A = \{a_{xy}\}$,$B = \{b_{xy}\}$ are the two-dimensional pattern which are stored register A and register B. $z^X_{x,y}$ is strain of x direction at (x, y), $z^Y_{x,y}$ is strain of y direction at (x, y). $v^X_{x,y}$ is input data for the low pass filter to caliculate $z^X_{x,y}$ and $v^Y_{x,y}$ is input data for the low pass filter to caliculate $z^Y_{x,y}$.

Using these parameters, Eq. (10) and Eq. (11) are extended for two-dimensional pattern as follow.

$$
\begin{aligned}
v^X_{x,y} &= Sig\Big(\int \gamma(a_{x,y} - b_{x+z^X_{x,y},y+z^Y_{x,y}}) \\
&\quad \cdot(b_{x+z^X_{x,y}+1,y+z^Y_{x,y}} - b_{x+z^X_{x,y},y+z^Y_{x,y}})dt\Big) \quad (12)\\
v^Y_{x,y} &= Sig\Big(\int \gamma(a_{x,y} - b_{x+z^X_{x,y},y+z^Y_{x,y}}) \\
&\quad \cdot(b_{x+z^X_{x,y},y+z^Y_{x,y}+1} - b_{x+z^X_{x,y},y+z^Y_{x,y}})dt\Big) \quad (13)\\
z^X_{x,y} &= \alpha(z^X_{x,y-1} + z^X_{x,y+1} + z^X u_{x-1,y} + z^X_{x+1,y}) \\
&\quad +(1-4\alpha)z^X_{x,j} + \beta v^X_{x,y} \quad (14)\\
z^Y_{x,y} &= \alpha(z^Y_{x,y-1} + z^Y_{x,y+1} + z^Y_{x-1,y} + z^Y_{x+1,y}) \\
&\quad +(1-4\alpha)z^Y_{x,j} + \beta v^Y_{x,y} \quad (15)
\end{aligned}
$$

where i is imaginary unit.

3.2. System architecture

System architecture to operate this equation is described fig. 5. This system require only local connection, we can expect that the cellular neural network system technique is applied for this system.

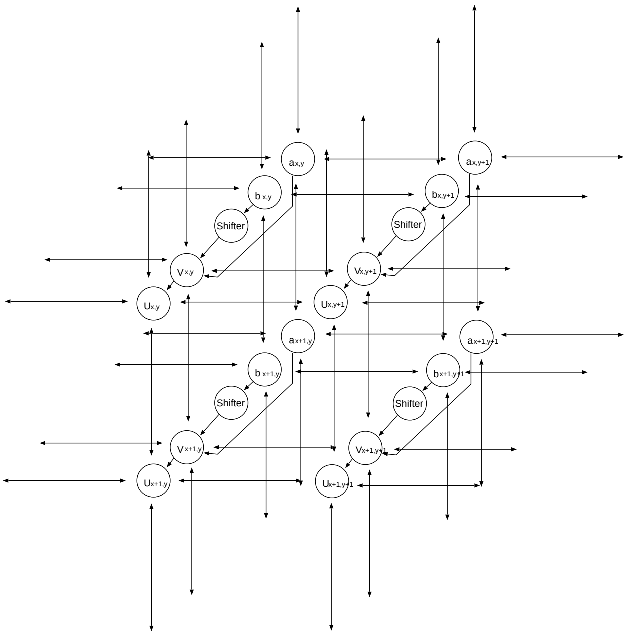
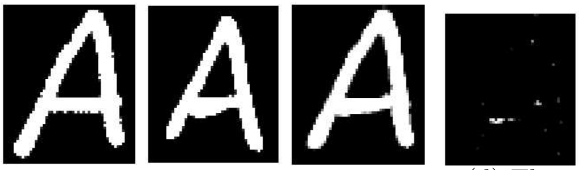


Fig.5 System architecture for two-dimensional pattern.

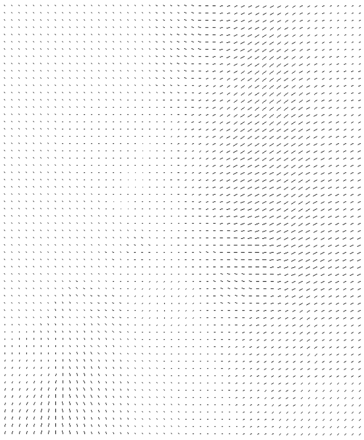
3.3. Application for character recognition

I simulate the two-dimensional system using two 'A' patterns. Fig. 6 (a) and (b) are patterns to be stored the registers A and B. Fig. 6(c) is adjusted pattern of fig. 6(b) by the presented system. Fig. 6(d) shows the difference of fig. 6(a) and Fig. 6(c), fig. 6 (e) shows you the amplitude and the direction of strain.

The distance of Fig. 6(a) and fig. 6(b) is 360, but one of Fig. 6(a) and fig. 6(c) is 46. It means that presented system adjust the strain.



(a) The pattern for register A (b) The pattern for register B (c) Adjusted pattern (d) The difference of (a) and (c)



(e) The amplitude and the direction of strain

Fig. 6 Simulation result.

I simulated characters recognition system with presented method and without it. From this simulation result, the recognition rate of presented system is 96%(=50/52) though one of the system without presented system is 71%(=37/52).

3.4. Application for the Stereogram

I apply presented system for the stereogram. The main problem of stereogram is to measure the distance of 2 pictures which are a right eye picture and a left eye picture.

Fig. 7 is a sample picture of the stereogram. The resolutions are 400x300. There is a box in the pictures. The most important problem is "how to find the corresponding point from these pictures".

The problem is solved with presented system. I can find the corresponding points and calculate distance from strain of these pictures. But because it is difficult calculate from these picture directory, I prepare low resolution pictures (100x75), (25x18),(8x6) of them. First, The result of the strain of (8x6) pictures is used as the initial condition to calculate the strain of (25x18) pictures. Next, the result of the strain of (25x18) pictures is used as initial condition to calculate the strain of (100x75) pictures, and so on. Finally, I can obtain strain of Fig.7. From this result I can calculate the distance of the object (box) as fig 12.

Fig. 7 Pictures for the stereogram.

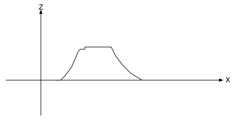


Fig. 8 The distance of the object.

4. Conclusion

In this paper, I presented new neural network system to adjust the strain of pattern. This system revises the strain between two pattern. It can be applied for the preprocessing of the recognition system. By the examples of this paper, this system can revise the strain of one-dimensional pattern and two-dimensional pattern.

By the simulation result for character recognition system, the character recognition rate improved from 71% to 96%. This simulation recognized using only Hamming distance. Then I believe that the recognition rate can improve again if smart character recognition techniques is applied.

By the simulation result for the stereogram, I can obtain distance of the object.

Future work is to implement new system for a recognition system such as a voice recognition system, an image recognition system and so on.

References

[1] Leon O. Chua and Lin Yang "Cellular Neural Networks: Theory" IEEE Trans. CAS, 35,10,pp. 1257-1272 (October 1988).

[2] Leon O. Chua and Lin Yang "Cellular Neural Networks: Applications" IEEE Trans. CAS, 35,10,pp. 1273-1288 (October 1988).