研　究　速　報

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A METHOD OF PATTERN RECOGNITION BY REGION COUNTER

—FREE FROM SIZE, DEFORMATION AND ROTATION OF THE PATTERN—

領域カウンタによるパターン認識の一方法

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§1. Introduction

Recently, optical hand-written character readers have been developed and applied on a large scale level, for example such as a mail-automation. In such a device, the pattern must be treated as various in quality. It is required that these devices adopt the feature parameters which are little varying with size, deformation and rotation of the patterns. In order to satisfy the above requirement, various methods have been considered and proposed by some authors. However, these are not always convenient to practical uses.

In this report, the author presents a unique method of extracting the distinct feature parameters. This is a method of pattern recognition by a region counter, and in order to realize this method, the author proposes a device which counts the number of regions divided by the pattern, and calls it region counter. Furthermore, the author will demonstrate the result of simulation for optical hand-written numeral character reader.

§2. A Method of Extracting the Distinct Feature of the Patterns by the Region Counter.

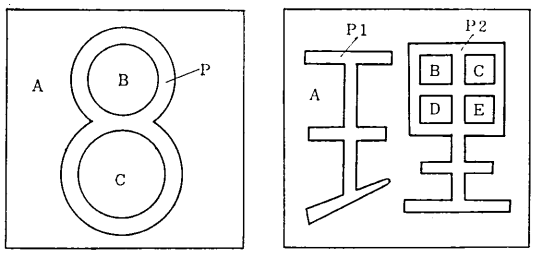
A method of extracting the distinct feature parameters will be illustrated as follows.

Generally, it is difficult to extract the whole features of a pattern, for instance, the number of closed loops, the number of blobs and so on. By this method, it is achieved easily to extract the feature parameters concerning to the closed loops, the blobs and other some overall features of the pattern. In this report, some terms are used in the following senses.

1) "Region Number" is the number of regions which are divided by a pattern.

2) "Blob Number" is the number of blobs which construct a pattern, and it is equal to Region Number of the negative pattern.

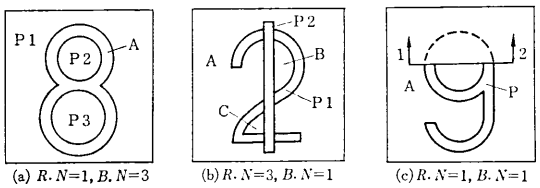
3) Transformation of a pattern means either of following processes; (1) to put a pattern segment on the original pattern, for instance, as shown in Fig. 2 (b), (2) to erase proper section of a pattern, as shown in Fig. 2 (c), (3) to make a pattern negative, (4) to pick up particular section of a pattern, as shown in Fig. 3, and (5) combined operation of (1), (2), (3) and/or (4). The topological or graphical properties of the pattern are extracted directly by counting Region Number or Blob Number of the original pattern



(a) $R.N=3, B.N=1$　　(b) $R.N=5, B.N=2$

RN; Region Number.　　BN; Blob Number.
P, P1, P2; Pattern (Blob).　　A, B, C, D, E; Region.

Fig. 1 Some examples of the regions and the blobs.



(a) $R.N=1, B.N=3$　　(b) $R.N=3, B.N=1$　　(c) $R.N=1, B.N=1$

Notations are the same in Fig. 1

(a) Negative pattern.　　(b) Put a segment of pattern.
(c) Erase some section of pattern.

Fig. 2 Some examples of the pattern transformation.

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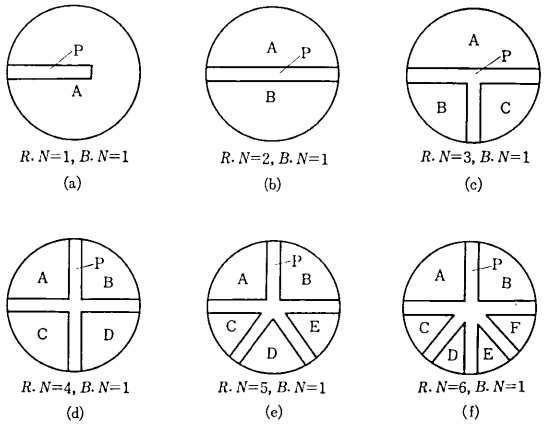


RN: Region Number. BN: Blob Number.
P: Pattern (Blob). A, B, C, D, E, F: Region.
(a) Edge of pattern. (b) Simple line. (c) Cross point of three lines. (d) Cross point of four lines. (e) Cross point of five lines. (f) Cross point of six lines.

Fig. 3 A method of extracting the partial feature, using region counter.

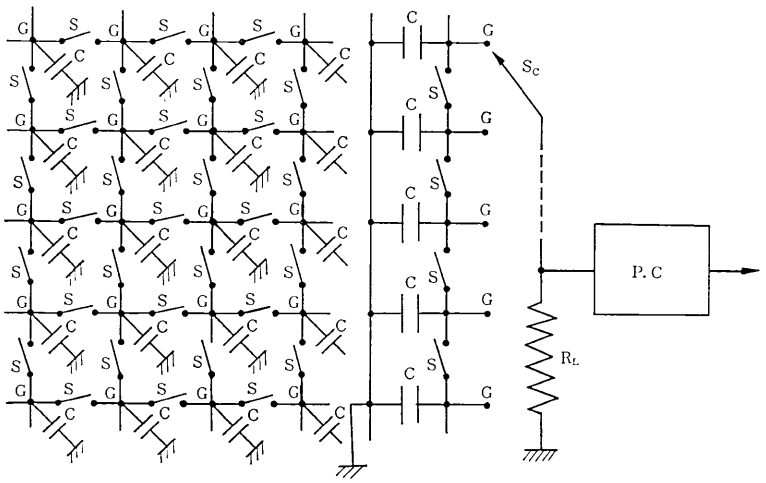
and the transformed patterns. For example, from Region Number of the original pattern and that of the transformed pattern as shown in Fig. 2 (c), we obtain the closed property of the pattern and the location of the closed loop roughly. Furthermore, we can also obtain a partial properties of a pattern from Region Number and Blob Number of a transformed pattern as shown in Fig. 3.

§3. Principle of Region Counter

The author proposes a device which realizes a method of extracting the ferture parameters of the patterns, described in §2, it is called "Region Counter".

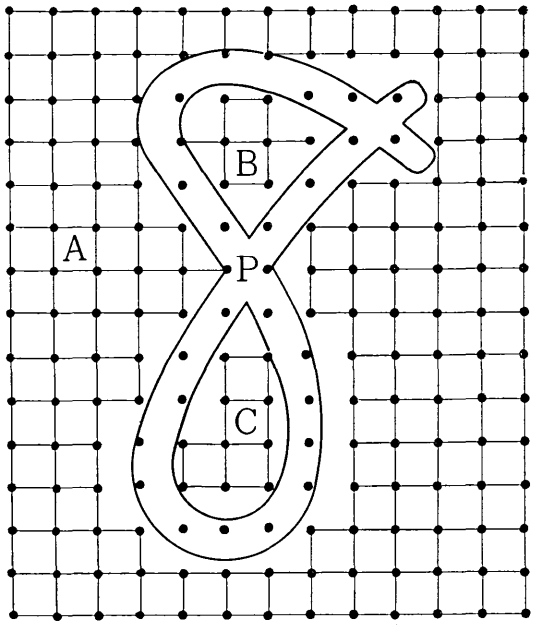
Principle of the region counter is shown in Fig. 4. Outline of this region counter is as follows.

It is constist of many electrical capacitors placed at all grid points, many switches which connect the adjoining grid points with each other, scanning switch which scans along all grid points, resistor and pulse counter which count only the pulse corresponding to simultaneous discharge of more than two capacitors. Switches, which connect the adjoining grid points, are controlled by the signals from the pattern recepter, and also controlled simultaneously by other proper signals. At first, all of the capacitors are charged. If any pattern is projected on the pattern recepter, the switches become make on or make off correspondingly to the pattern. For example, states of the switches corresponding to numeral 8 is shown in Fig. 5. In Fig. 5, the capacitors in each region corresponding to A, B, and C are connected parallel each other and form a group respectively, and in the region shown by P, switches are make



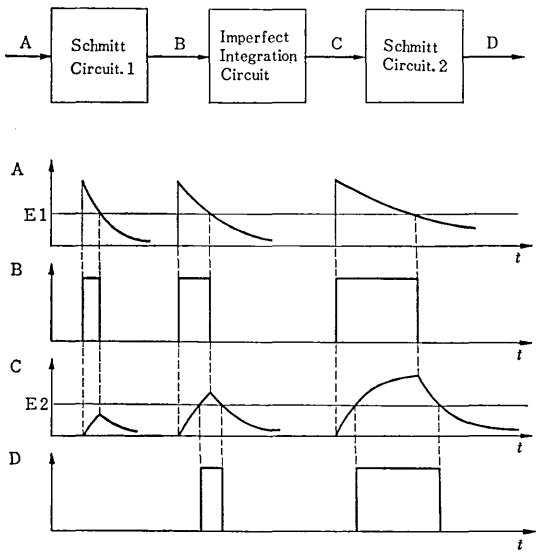
G; Grid point. C; Capacitor. S; Switch which is controled by the signal from pattern recepter. Sc; Scanning switch. RL; Resistor. P. C; Pulse Counter which counts the pulse only when more than two copacitors are discharged at once.

Fig. 4 Principle of region counter.



● ; Grid Point.　●——● ; Switch on.　● ● ; Switch off

Fig. 5 An example of switch-states on the region counter corresponding to numeral 8.



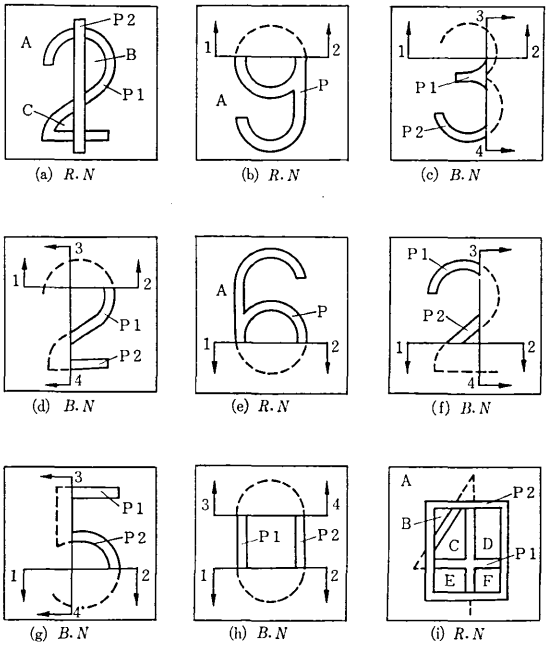
E1: Driving voltage of schmitt circuit 1.
E2: Driving voltage of schmitt cricuit 2.

Fig. 6 An example of pulse transformation for the pulse counter which counts the pulse only when more than two condensers are discharged at once.

off and capacitors are exist separately. Then all the grid points are scanned by a scanning switch the capacitors are discharged one after another. When scanning switch reachs the first grid point belonging to group A, all the capacitors belonging to it are discharged, and after this moment, discharge could not occur even if scanning switch proceeds any grid point belonging to it. It is the same for group B and C. Therefore, counting the pulses corresponding to simultaneous discharge more than two capacitors, and we obtain Region Number. If we project a negative pattern or control the switches in opposition, we obtain Blob Number. These are the same for the transformed patterns. Controling the switches by other proper signals simultaneously, we can achieve the pattern transformations easily.

The pulse counter, which counts the pulse only when more than two capacitors are discharged at once, could be realized, for instance as in Fig. 6. Time constant of discharging, when the capacitors are discharged through the same resister, is proportional to the number of parallel connected capacitors. If we make the discharge pulses input of the Schmitt circuit, we obtain the pulses which have the width proportional to the time constants of the pulses. Furthermore, if we make the obtained pulses input for the imperfect integration circuit, we obtain the pulses which have different peak values, and pulse is the wider, peak is the higher. Making the pulses obtained above input for the Schmitt circuit again, and setting the driving point of the Schmitt circuit between the voltage corresponding to one capacitor's discharge and the voltage corresponding to the dischage of two capacitors, we obtain the pulses only when more than two capacitors are discharged simultaneously. Making it input for ordinary pulse counter, we have a required pulse counter.

The author has obtained a satisfactory result in basic experiment of "Region Counter" by the way described above.



(a) *R.N* (b) *R.N* (c) *B.N*

(d) *B.N* (e) *R.N* (f) *B.N*

(g) *B.N* (h) *B.N* (i) *R.N*

Fig. 7 Adopted transformations of the pattern in this simulation of hand-written numerals reader.

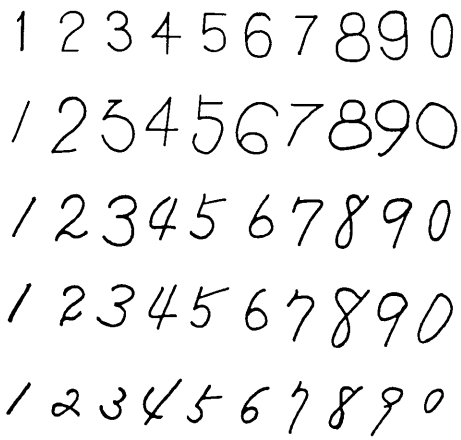


Fig. 8 Numerals treated in this simulation.

§4. Simulation of the Hand-Written Numeral Reader by This Method

The author performed the simulation of hand-written numeral reader by the method of region counter, and obtained a satisfactory result. Outline of this experiment is as follows.

The author adopted ten feature parameters of a pattern in this experiment. They are Region Number of a orginal pattern and nine parameters which are Region Number or Blob Number of the transformed patterns or their variations by a transformation of the pattern. Example of nine transformations of a pattern are shown in Fig. 7. Recognition is made by following decision function.

$$I_m=\min_i\left[\sum_{j=1}^{10} Q_{ij}\times(P_{sij}-P_{cj})^2\right]$$

if $I_m \leqq D$ recognize as i corresponding to I_m.

if $I_m > D$ reject.

where Q_{ij}; weighting function.

P_{sij}; standard feature parameter.

P_{cj}; extracted feature parameter.

D; constant.

At first, learning process has been performed for the numerals shown in Fig. 8. Outline of this learning process is as follows. Before starting the learning, P_{sij} and Q_{ij} are kept equal to zero, and

Table 1 P_{sij} obtained in learning

i \ j	1	2	3	4	5	6	7	8	9	10
1	1.0	1.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	1.8
2	1.2	2.8	3.6	0.2	1.0	0.0	0.0	0.0	0.8	2.0
3	1.0	3.0	3.8	0.0	1.0	0.0	0.0	1.0	0.0	2.2
4	1.6	2.4	5.0	0.6	0.2	0.0	0.0	0.6	1.0	3.4
5	1.0	2.7	3.2	0.0	0.0	0.0	0.0	1.0	0.2	1.8
6	2.0	3.2	4.0	1.0	0.0	0.0	0.0	0.0	0.2	2.0
7	1.0	2.0	2.6	0.0	1.0	0.0	0.0	0.0	0.0	2.0
8	3.0	4.0	4.6	1.0	0.6	0.0	1.2	0.8	0.4	2.2
9	2.0	3.6	4.0	0.2	0.4	0.0	1.0	0.8	0.0	2.2
0	2.0	3.0	3.6	0.1	0.2	0.0	1.0	0.2	0.6	2.6

Table 2 Q_{ij} obtained in learning

i \ j	1	2	3	4	5	6	7	8	9	10
1	10	10	1	10	10	10	10	10	10	1
2	1	1	1	1	10	10	10	10	1	1
3	10	10	1	10	10	10	10	10	1	1
4	1	1	10	1	1	10	1	1	10	1
5	10	1	1	10	10	10	10	10	1	1
6	10	1	1	10	10	10	10	10	1	10
7	10	10	1	10	10	10	10	10	10	10
8	10	1	1	10	1	10	1	1	1	1
9	10	1	1	1	1	10	10	1	10	1
0	10	10	1	10	1	10	10	1	1	1

proceeding the learning, made P_{sij} equal to the algebraical mean, and made Q_{ij} equal to 10, if P_{sij} were kept constant in learning period, and equal to 1, if P_{sij} were varied in learning period. And D was kept equal to 10 in this experiment. After learning, using the value of P_{sij} and Q_{ij} obtained by above learning process, shown in Table 1 and Table 2, recognition has been performed for the numerals shown in Fig 8, and all of these were recognized correctly.

§5. Conclusion and Acknowledgement

It should be emphasized that a method of pattern recognition by "Region Counter", described above, is a very effective method for extracting the overall properties of the pattern, for instance, closed property, rough location of closed loop, Blob Number and so on. Furtheremore, it should be emphasized that this method is also effective for extracting the partial topological or graphical properties, using the transformations of the pattern as shown in Fig. 3. Result of simulation described in §4 indicates the possibility of pattern recognition devices free from size, deformation and rotation of the pattern. Using this method parallel with other methods, we could realize a high performance level recognition. "Region Counter", presented in §3, is realized as the practical and very easy method. Capability of parallel processing of "Region Counter" indicates the possibility of high speed processing devices. Using "Region Counter," we could obtain the feature parameters in the numerical value directly, so after-processings become easy.

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REFFERENCES

1) S. Katsuragi, H. Genchi, K. Mori and S. Watanabe: "Recognition of Handwritten Numerals Using Decision Graph" *Proceeedings of the International Joint Conference on* [*ARTIFICAL INTERIGENCE*], Washington D.C. (1969, 5) p. 161.
2) M. Mori, K. Takase and H. Nishio; "A Dynamic Pattern Recognition Method Using The Preview Contorolled Saccadic Movement of The Detector" *Proceeding of the International Joint Conference on* [*ARTIFICIAL INTERIGENCE*], Washington D.C. (1969, 5) p. 141.
3) S. Leviadi; "CLOPAN [A CLOSED-PATTERN ANALYSER]". *Proc. of IEE.* Vol. 110, No. 6, (1968, 6) p. 879.
4) M. Idesawa; "Region Counter in Pattern Recognition and its Application", *Preprint of 8th Meeting of the Society of Instrument and Control Engineers,* (1969, 8) p. 359, (in Japanese).