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RECOGNITION OF CORRELATED PATTERNS WITH SPIN GLASS-LIKE MODELS

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ՍՊԻՆԱՅԻՆ ԱՊԱԿՈՒ ՏԻՊԻ ՄՈԴԵԼՆԵՐԻ ՕԳՆՈՒԹՅԱՄԲ ԿՈՌԵԼԱՑՎԱԾ ՊԱՏԿԵՐՆԵՐԻ ՃԱՆԱՉՈՒՄԸ

Աշխատանքում հետազոտված են նեյրոնային ցանցերի մաթեմատիկական մոդելների վրա հիմնված/սպինային ապակու տիպի մոդելներ/պատկերների ճանաչման համակարգեր: Կոռելացված պատկերների ճանաչման համար նախատեսված Հոպֆիլդի ալգորիթմը համեմատված է առաջարկվող ալգորիթմի հետ, որտեղ այդ սահմանափակումը հանված է: Ցույց է տրված, որ նոր ալգորիթմը, բացի այդ, բնութագրվում է հրապուրող տիրույթի և ունակության մեծացմամբ:

Հաշվողական փորձերը կատարվել են 10 10 և 20 20 չափերի ցանցերի վրա ռուսական այբուբենի 15 տառերից և հակադիր կողմնորոշման 50%-անոց ներկայացմամբ բնութագրվող 20 պատահական պատկերներից կազմված այբուբենով:

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RECOGNITION OF CORRELATED PATTERNS WITH SPIN GLASS-LIKE MODELS

The pattern-recognition systems based on the mathematical model of neural networks (the models of spin-glass type) are studied. A comparison is carried out between the Hopfield algorithm intended for recognition of uncorrelated patterns and one without this restriction. The new algorithm is shown to be characterized by the increase of the attractivity region and capacity. Simulations were carried out with an alphabet consisting of 15 Russian letters and 20 random patterns characterized by 50% representation of opposite orientations, on 10x10 and 20x20 lattices.

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Yerevan 1987

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Г.В.ЗАЗЯН, Д.Б.СААКЯН, А.А.ЧИЛИНГАРЯН,
Н.О.ХУДОНЯН

РАСПОЗНАВАНИЕ КОРРЕЛИРОВАННЫХ ОБРАЗОВ С ПОМОЩЬЮ МОДЕЛИ ТИПА СПИНОВОГО СТЕКЛА

В работе исследуются системы распознавания образов, основанные на математической модели нейронных сетей (модели типа спинового стекла). Проводится сравнение алгоритма Хопфилда, предназначенного для распознавания некоррелированных образов, и алгоритмы, в которых это ограничение снято. Показано, что новый алгоритм, кроме того, характеризуется увеличением области аттрактивности и емкости. Вычислительные эксперименты проводились с алфавитом, состоящим из 15 русских букв и из 20 случайных образов, характеризуемых 50 % представительством противоположных ориентаций, на решетках размерами 10 х 10 и 20 х 20.

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1. Introduction

In recent years the pattern-recognition systems based on the mathematical models of the spin-glass type have become increasingly popular. These systems are connected with the problems of creation of artificial intelligence (associative memory and the 6-th generation computers) and study of higher nervous activity (neural networks). Besides, already at the achieved stage of development these systems are capable of solving specific technical problems like recognition of symbols of some prescribed alphabet. However, as shown by the simulations with the system working on the basis of the first algorithm suggested [1, 2], only uncorrelated patterns can be recognized with sufficient confidence. And since most symbols of any alphabet are constructed of identical blocks, the application of such systems is rather limited. Our purpose was to construct a recognition system capable of recognizing any symbols. Our second aim was to increase the recognition capacity. Both problems were solved through the orthogonalizing transformation of the pattern space, using the algorithm suggested in Ref. 3,4 .

2. Method

Consider a two-dimensional lattice. In the lattice nodes we place the hypothetic particles characterized by a "spin" ± 1 . By the "spin" we imply some orientation and predetermine certain terminology associated with the Ising model, e.g. "spin-flip". One should, however, keep in mind that such a "materialization" of the model is introduced only for the sake of convenience, and in the general case the values ± 1 may be identified with the white or black colour of the pattern cell or with the neuron activity in the network. The relaxation of such cellular structure is determined by the interaction between the spins. We write down the energy of exchange interaction in the form:

$$E_{ij} = T_{ij} S_i S_j . \tag{1}$$

The coefficients T_{ij} in the Ising model are negative, so the configuration with parallel spins S_i and S_j corresponds to the minimum of energy. For the spin-glass model T_{ij} are distributed by some random law, namely:

$$p(T) \sim \exp\left[-1/2\,(T/\sqrt{M})^2\right], \tag{2}$$

where M is the number of prototypes [3] .

The randomness of T_{ij} brings to the existence of many spi orientations corresponding to local minima of energy, and the initial configuration will relax to one of these stationary states. Thus the spin glass is capable of recognizing patterns, but a random interaction results in a random alphabet. This drawback was overcome by Hopfield 1 who suggested to take the exchange integrals in the form:

$$T_{ij} = - \sum_{\alpha=1}^{M} S_i^{\alpha} S_j^{\alpha} , \tag{3}$$

where S^{α} - prototype patterns - alphabet written on lattices with dimensions N (the number of nodes). Then for not very large number of patterns ($M/N < 0.14$) the asynchronous relaxation of the system will result in a prototype state, namely in one to which the initial pattern is closer, say, in the terms of the Hamming distance. At $M/N > 0.14$ the system behaviour will be characterized by the interaction of the (2) type, and the attractivity region of the prototypes will sharply decrease.

However, as already mentioned, such a system is unable to recognize correlated patterns, perhaps for the reason that every prototype acts as an independent training element. In the algorithm we use, there are stored the "orthogonalized" patterns, i.e., a preliminary processing with a choice of discriminative elements is carried out. In this case

$$\begin{gathered} T_{ij} = \sum_{\alpha,\beta}^{M} (R^{-1})^{\alpha\beta} S_i^{\alpha} S_j^{\beta} , \\ R^{\alpha\beta} = N^{-1} \sum_{i=1}^{N} S_i^{\alpha} S_i^{\beta} . \end{gathered} \tag{4}$$

3. Experiment

The recognition system was studied with two alphabets on the lattices 10x10 and 20x20. The Russian symbols (15 letters) were used as well as random patterns - up to 20 configurations, characterized by $\approx 50\%$ representation of opposite orientations. In contrast to previous works, the quality of recognition was characterized not by the Hamming distance R_H between relaxed and prototype patterns but by a fraction of correctly recognized patterns (for which $R_H = 0$). All the letters in various combinations were submitted for the recognition, the level of noise was brought up to 90%. After three iterations or earlier, during which the lattice was successfully passed round and the spin-flip occurred according to the interaction laws 3 and 4, the initial state relaxed either to some prototype or to metastable state, and further change had no longer taken place.

Table 1 shows the quality of recognition of the symbols versus both random noise and the number of prototypes. A comparison with the Hopfield algorithm is not presented since correlated symbols were not recognized even for the number of prototypes 3 and insignificant noise. Fig. 1 presents a few metastable states the initial patterns (И, Н, Г ,... letters) relaxed to when being recognized with the use of interaction 3.

Table 2 shows a comparison of algorithms 3 and 4 on random (uncorrelated) patterns. The new algorithm is shown to be much more stable to noise, and its capacity is higher.

In Fig. 2 we have shown distorted patterns that are then recognized by this algorithm.

Conclusion

We have shown a possibility to recognize correlated patterns with the help of the decorrelated transformation (4).

The results presented show also the increase of the attractivity region of prototypes. The algorithm under study may become a basis for the construction of the physical information analysis systems, say, data on scanning the roentgen-emulsion films exposed on the mountains and containing information about high-energy particles. For that aim, one should develop approaches ensuring the recognition of both white-black and "coloured" patterns.

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Table 1

Correctly recognized symbols by the algorithm 4 (%).

M - number of prototypes,

S - random noise

S\M	2	5	7
10	100	100	100
30	100	100	43
50	100	100	28
70	100	40	14
90	50	20	8

Table 2

Correctly recognized random patterns by the algorithms 3 and 4 (%).

M - number of patterns,

S - random noise

S\M	14		16		18		20	
	3	4	3	4	3	4	3	4
0	64	100	48	100	22	100	14	100
50	28	100	25	100	17	72	0	48

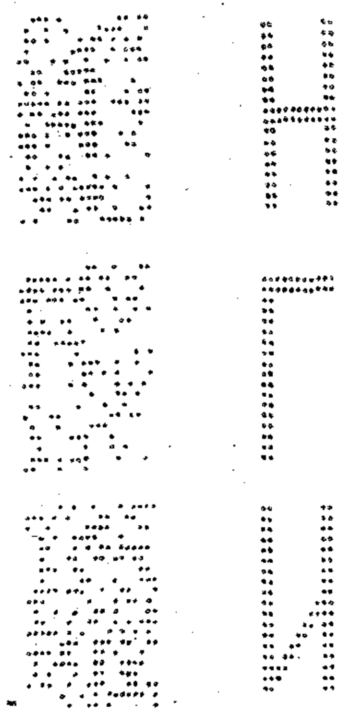

Fig.2

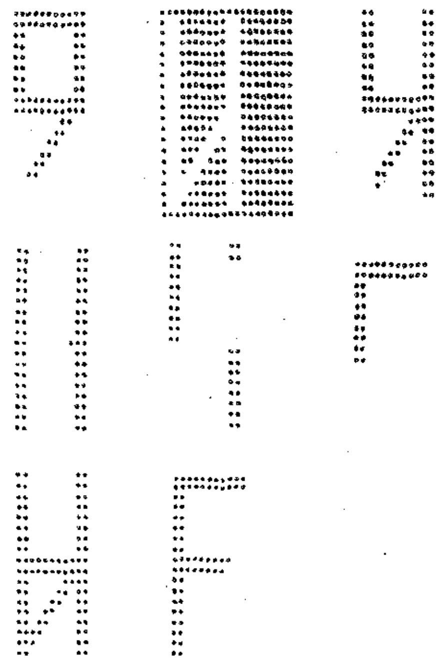

Fig.1

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(на английском языке, перевод Асланян З.Н.)

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