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Noise-like Coding in Associative Memories

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Abstract

There have been several independent approaches to the mathematical modeling of associative memories. The models produced by these approaches are essentially of two types: the so-called matrix models (see Steinbuch, 1961; Kohonen, 1972); and the convolution-correlation models (see Gabor, 1968; Bottini, 1980), which originated from the optical holographic models of memory. Despite the independence of their origins, all these models are based on a common principle. In every case, in fact, the success in recalling stored information depends on the degree of correlation between the recall key and the key used, on storage, for coding that information.

Sometimes, in these models, nonlinear mathematics is used to improve the capability of choice of the memory system. Moreover, a feedback connection can be introduced to produce either a dynamic improvement in the quality of the recall of a single item, or a sequential recall of a chain of different items.

Dynamic recalls from an associative memory can also be described using the language of statistical mechanics (Hopfield, 1982).

Such associative memories achieve the maximum of the storage capacity when the coding keys are of noise-like type, i.e. quasi-orthogonal. In the most favourable case in which the recall keys are complete, a noise-like coding of the information being stored gives a storage capacity of about 0.7 or 0.5 bits per storage element, according to whether the storage elements are binary, i.e. they can be turned on once only during the storage of all the traces (Palm, 1980), or they have many levels, i.e. can change their value many times, within a given range, during the whole memorization process (Bottini, 1987). The lack of orthogonality between the keys drastically reduces the system performance.

In the model proposed by Bottini (1980), each of two associated items codes the other, on storage, by means of a noise-like key which must be obtained from the item itself through a randomizing preprocessing (in an autoassociative memory scheme, the single item should produce its own coding basis).

In this paper, we will show how such a correspondence

between items and noise-like keys can be established for the important case in which the information items are described by means of sets of features belonging to a given repertoire. This correspondence satisfies the condition that any sufficiently-large feature subset, which partially describes a given stored item, yields a noise-like key (i.e. recall key) which still correlates sharply with the key corresponding to the complete item (i.e. storage coding key). Thus, the memory system will produce complete recalls from fragmentary keys.

From a relatively-small number of features, suitably arranged in different classes, it will be possible to obtain a large number of (orthogonal) noise-like keys, following a combinatorial scheme.

Finally, the storage capacity of this memory system will be measured as a function of the (permitted) incompleteness of the recall key, for high values of the recall efficiency, i.e. with small error probabilities in the recall.

References

Steinbuch K. (1961) Die lernmatrix. Kybernetik 1: 36-45

Kohonen T. (1972) Correlation matrix memories. IEEE Trans. on Computer C-21: 353-359

Gabor D. (1968) Holographic model of temporal recall. Nature (London) 217: 548

Bottini S. (1980) An algebraic model of an associative noise-like coding memory. Biological Cybernetics 36: 221-228

Hopfield J.J. (1982) Neural networks and physical systems with emergent collective computational abilities. Proc. Natl. Acad. Sci. USA (Biophisics) 79: 2554-2558

Palm G. (1980) On associative memory. Biological cybernetics 36: 19-31

Bottini S. (1987) An after-Shannon measure of the storage capacity of an associative noise-like coding memory. Submitted to Biological Cybernetics

Network Architectures II

Monday, June 22, 1987 1:00 to 4:45 PM

Grand Ballroom

Chair: Shun-ichi Amari

1:00–1:30	Research Challenges and Opportunities in Electronic Neural Systems *C. Lau*
1:30–1:45	Efficient Method for Estimating Kinetic Constants from Single Channel Patch Clamp Recordings *T.R. Chay*
1:45–2:00	A Procedure for Mapping the Architecture of a Living Neural Network into a Machine *R.L. Dawes*
2:00–2:15	Multiplexed Multi-Electrode Semiconductor Brain Electrode Implant *M. Kabrisky, S.K. Rogers, J.P. Mills & E. Kolesar*
2:15–2:30	Noise-like Coding in Associative Memories *S. Bottini*
2:30–2:45	Neural Net Associative Memories Based on Convex Set Projections *K. Cheung, R.J. Marks II & L.E. Atlas*
2:45–3:00	Comparison of Information Capacity of Hebbian Neural Networks *J.D. Keeler*
3:00–3:15	Some Asymptotic Results for Learning in Single Hidden Layer Feedforward Network Models *H. White*
3:15–3:30	Temporal Behaviour of Neural Networks *E. Gelenbe & A. Stafylopatis*
3:30–3:45	Self-Organization of Cooperative and Competitive Networks *K. Matsuo*
3:45–4:00	Stochastic Processing in a Neural Network Application *D. Nguyen & F. Holt*
4:00–4:15	Error Correcting System Based on Neural Circuits *Y. Takefuji, P. Hollis & Y.P. Foo*
4:15–4:30	The Most Complicated Networks of Formal Neurons *E. Labos*