A NEW BIDIRECTIONAL ASSOCIATIVE MEMORY MODEL—HOMIBAM*

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Abstract A new bidirectional associative memory model named as HOMIBAM is introduced. The relationships of HOMIBAM with the models existed are pointed out. Both theoretical analysis and simulations show that the capacity and recall performance of HOMIBAM are superior to that of modified intraconnected BAM (MIBAM), higher-order BAM (HOBAM) greatly.

Key words Bidirectional associative memory; Recall; Capacity; Pattern pair; Intraconnection; Higher-order; Error-correcting capability

I. Introduction

The bidirectional associative memory (BAM) model proposed by Kosko\[1\] is attractive in many aspects, for it may be useful in intelligent system and database etc.. But it suffers from the low capacity and unsatisfactory recalling. Just as Kosko revealed, there should be two requirements: (1) BAM asks the pattern pairs to be stored satisfy continuous assumption. (2) In encoding \((X, Y)\), it encodes \((-X, -Y)\) at the same time, i.e. complement encoding problem. In order to relax these requirements and improve the performance of BAM, many models have been presented. Among these models, intraconnected BAM (IBAM)\[2\] and higher-order BAM (HOBAM)\[2,4\] are two typical ones. Although IBAM relax the continuous assumption to some extent, its capacity is still low. Contrarily, although HOBAM have a large capacity, it can not solve complement encoding problem and relax continuous assumption. It is known that the complement encoding problem and continuous assumption affect the capacity and recalling of memory largely. If the two previous problems of HOBAM are solved, a great improvement in capacity and recalling should be expected.

In this paper, we introduce a new bidirectional associative memory model—HOMIBAM, which is a realization of our previous idea. The relationship of this model with the modified intraconnected BAM (MIBAM)\[3\] and HOBAM are pointed out. The theoretical analysis and simulations show that HOMIBAM is superior to MIBAM and HOBAM in capacity and recalling.

II. MIBAM and HOBAM

Generally, a BAM model is composed of three aspects: (1) structure, (2) encoding, (3) recalling rule and recalling process. At present, Hebbian rule or its modifications are usually used to encode the pattern pairs. The structure and recalling rule are often different from case to case. In the following, we present the principles of MIBAM and HOBAM, some

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notations to be used are also given out.

(1) MIBAM:

\[ Y' = \text{sgn}(XM + YB) \]  
\[ X' = \text{sgn}(Y'M^T +XA) \]

where

\[ M = \sum_{i=1}^{m} (X^i)^TY^i, \quad A = \sum_{i=1}^{m} (X^i)^TX^i, \quad B = \sum_{i=1}^{m} (Y^i)^TY^i \]

\{(X^i, Y^i), X^i \in \{-1, +1\}^n, Y^i \in \{-1, +1\}^p, i = 1, 2, \ldots , m\} is the set of pattern pairs stored in the MIBAM, \( Y^i, X^i \) are row vectors. \( \text{sgn}(x) = 1 \) when \( x \geq 0 \), \( \text{sgn}(x) = -1 \) otherwise. \((X, Y)\) is the initial pattern pair to start the recall of the memory network. \((X', Y')\) is the state of network after one trial of recalling.

(2) HOBAM:

\[ Y' = \text{sgn}\left( \sum_{i=1}^{m} Y^i[(X^i)X^T]^s \right) \]  
\[ X' = \text{sgn}\left( \sum_{i=1}^{m} X^i[Y^i(Y')^T]^s \right) \]

In the previous equations, \( s \) is the order of the model.

The recalling process of bidirectional associative memory always starts from an initial or key pattern pair, after updating several cycles, it stays at a stable pair. The stable pair is taken as the result of recalling, i.e., \((X, Y) \rightarrow Y' \rightarrow X' \rightarrow Y'' \rightarrow \cdots \rightarrow Y^l \rightarrow X^l, (X^l, Y^l)\) is the stable pair.

III. A New Model—HOMIBAM

As a modification of IBAM, in fact, MIBAM differs from IBAM mainly in the level of parallel in recalling rule. That MIBAM uses the information of every cycle of recalling more efficiently makes MIBAM have better capability to deal with storing and recalling. The examples and experiments in Ref.[3] affirm it. Based upon the same principle, we add “parallel intraconnections” to HOBAM. By this way, a new bidirectional associative memory—HOMIBAM is proposed.

The recalling rule of HOMIBAM is as follows:

\[ Y' = \text{sgn}\left( \sum_{i=1}^{m} Y^i([X^iX^T]^s + [Y^iY^T]^s) \right) \]  
\[ X' = \text{sgn}\left( \sum_{i=1}^{m} X^i([X^iX^T]^s + [Y^i(Y')^T]^s) \right) \]

Comparing Eqs.(5), (6) with Eqs.(1), (2), we find that HOMIBAM looks like MIBAM, both have intraconnections running parallel with interconnections, but in HOMIBAM all connections (intra- or inter-) are of higher-order. So HOMIBAM can be thought as “higher-order MIBAM”.