Master Thesis Abstract

Study on Some Key Issues of Synergetic Neural Network

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Neural Network can be used as associative memory. Synergetic Associative Memory, or Synergetic Neural Network is one kind of recently developed associative memory. Compared with traditional associative memory, it has remarkable advantages as closing to biological pattern, short training time, low space complexity, low time complexity in recall process, no fault states, and good associative effect.

Synergetic associative memory network includes several different models such as Haken Model, Diffusive Haken Model, and Extended Symmetric Diffusion Network. Although it has been studied in detail, synergetic associative network is still a new research field and needs more attention in both theory and application.

In this paper, we discussed the basic and integrated theory of synergetic neural network, and studied on the optimization for the two sub networks of synergetic neural network.

First, we introduced the structure and important concepts of the classical model of synergetic neural network: Haken model. The work process of Haken model is

* Computes adjacent vectors which orthogonal to original vectors;

* Computes the inner production of input patterns and adjacent vectors, which is also the decomposition values of input patterns on original vectors, or the order parameters;

* The order parameters compete in a dynamic evolution function under the influence of selective attention from attention parameters. The final winner among all order parameters stands for the recognized pattern.

Then we proposed that synergetic neural network is a certain kind of competitive neural network and can be divided into two parts: matching sub-network and competitive sub-network. In the matching sub-network, the weight values from the input layer to the order parameter layer just are the adjacent vectors, and they should satisfy the requirement of minimizing the distances between weights and input original patterns. In the competitive sub-network, we can find special feature of competitive network, such as lateral suppression, winner takes all, and selective attention.

Finally, we proposed that the study and improvement of synergetic neural network could be conducted relatively independently for matching sub-network and competitive sub-network based on this dividing. We also gave some principles in the improvement

of matching sub-network and competitive sub-network. Further more, this kind of dividing is also advantageous for applying synergetic neural network in some special problems. For example, matching layer is not necessary in combinational optimization problem, we can use competitive sub-network alone in this case.

Key issue of constructing matching layer is to find a transformation to measure the similarity between input patterns and original vectors and obtain the initial value of order parameters. Such transformation should meet those conditions:

1) Transformation is one to one, that's, one original pattern is corresponding to an adjacent pattern (or to an order parameter) directly.
2) Order parameter stands for the similarity between input pattern and original pattern.
3) The remnant vector of input pattern after decomposing it on original pattern should be as small as possible.

Order parameter stands for the similarity between input pattern and original pattern. Classic Pseudo-Inverse Method can obtain precise order parameter in the sense of inner production, but is greatly limited on comptutaional ability and the adaptability.

1) High limitation on the dimension N and the number M of input patterns;
2) Those M original vectors must be linear irrelative;
3) All samples must be recomputed to get new pseudo-inverse when new pattern is appended. It is very disadvantageous for dynamic recognition.
4) Cannot represent the distance between input pattern and original pattern.

We proposed that order parameter can be obtained by other methods under the criterion of Minimial Remnant Vector and gave expriments with Mean Square Error Method, Correlation Coefficient Method, and Distance Method. The result shows:

1) From the view of Minimial Remnant Vector, those methods all can obtain fine result. Their remnant vectors all have smaller mode value than that of pseudo-inverse method, and re-rebulit vectors are closer to input pattern.
2) Training time is greatly reduced
3) The absoblute value of order parameter is "shrinked" while their relative size still remain as smiliarity.
4) They are all sutiable for dynamic recognition problem (with variable sample number) without re-training for new original patterns. Pseudo-inverse method has no such feature.

Then we studied the ordering measurement of synergetic neural network: the entropy and global coupling. We analyzed the concept of synergetic information, and claimed that to compute the synergetic information, we need to calculate the possibility distribution of input pattern set. If we want to observe the orderization during the running of network, we need a new definition related to time. So the entropy of synergetic neural network is defined based on the relative distribution of order parameters, and is proved that it never decreases during the running of network. It shows that the work processing of synergetic neural network is a self-organizing processing.

In the study of competitive sub-network, we mainly analyzed the improvement on the time performance of classic Haken network. Classic Haken model requires resolving high-dimension nonlinear equation groups when the number of patterns is very large. This iterating procedure requires large time and memory resource. With detailed analysis for potential function, we can understand that when the attention parameters are determined, potential function, all attractor and attractive domains are determined, too. Because the characteristic structure of synergetic neural network, the shape of attractive domains of all attractors are regular (especially when the attention parameters are balanced or far greater than the initial values of order parameters), so the evolutionary locus of order parameter with certain initial value can be full determined by the initial value of order parameter and the attention parameter. This method can greatly reduce the required time for iteration. That's the basic idea of **Quick Haken network**.

When the attention parameters are balanced (equal), the order parameter with biggest initial value will win eventually. In this case, the competition result is determined by the difference among attention parameters and the logarithm of relative difference of order parameters. That's, the competition result is determined not by the absolute difference, but by the relative difference of order parameters.

We design the basic structure for implement classical Haken model and quick Haken model by optical-electronic method and using it in shape recognition system. The proposed system had combined the strongpoint of feature extracting based on Hough transformation and the synergetic pattern recognition based on Haken model. Hough transformation can extract invariant feature efficiently and reduce the feature dimension to provide reliable initial vectors for synergetic pattern recognition, and the synergetic pattern recognition can eliminate fault states to insure the correctness of recognition. So they are complementary each other in overcoming own shortcomings. This system is not sensitive to noise, and strongly robust to shape and shifting transformation of object.

In the study of competitive sub-network, some problems that couldn't be solved by Quick Haken Network are analyzed. We discussed how to use synergetic neural network to solve high dimensional problem and claimed some general principles for constructing potential function and order parameter in high dimensional competition.

1) Each minimal value of potential function is corresponding to a validate pattern without any fault state;
2) For balanced attention parameter, all attractors have equal attractive effect, in another word, the depths of potential wells in potential functions are also equal. For unbalanced attention parameters, the magnitudes of attention parameters will determine the depths of potential wells;
3) The evolution function of order parameters can be obtained by the gradient of potential function;
4) The evolution function of order parameters should include three parts:
   - One order term with attention parameter as self-exciting item
   - Cubic order term with negative parameter as self-suppressive item
   - Lateral suppressive item between an order parameter and other order

parameters. It stands for constrain in the evolution process.

Finally, we proposed a stratagem based on hierarchical competition for the pattern recognition of huge-capacity dataset