Study on Some Key Issues of Synergetic Neural Network

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

Main Work:

1、Structure Dividing of Network

2、Generating Order Parameters

3、Order Measurement of Network

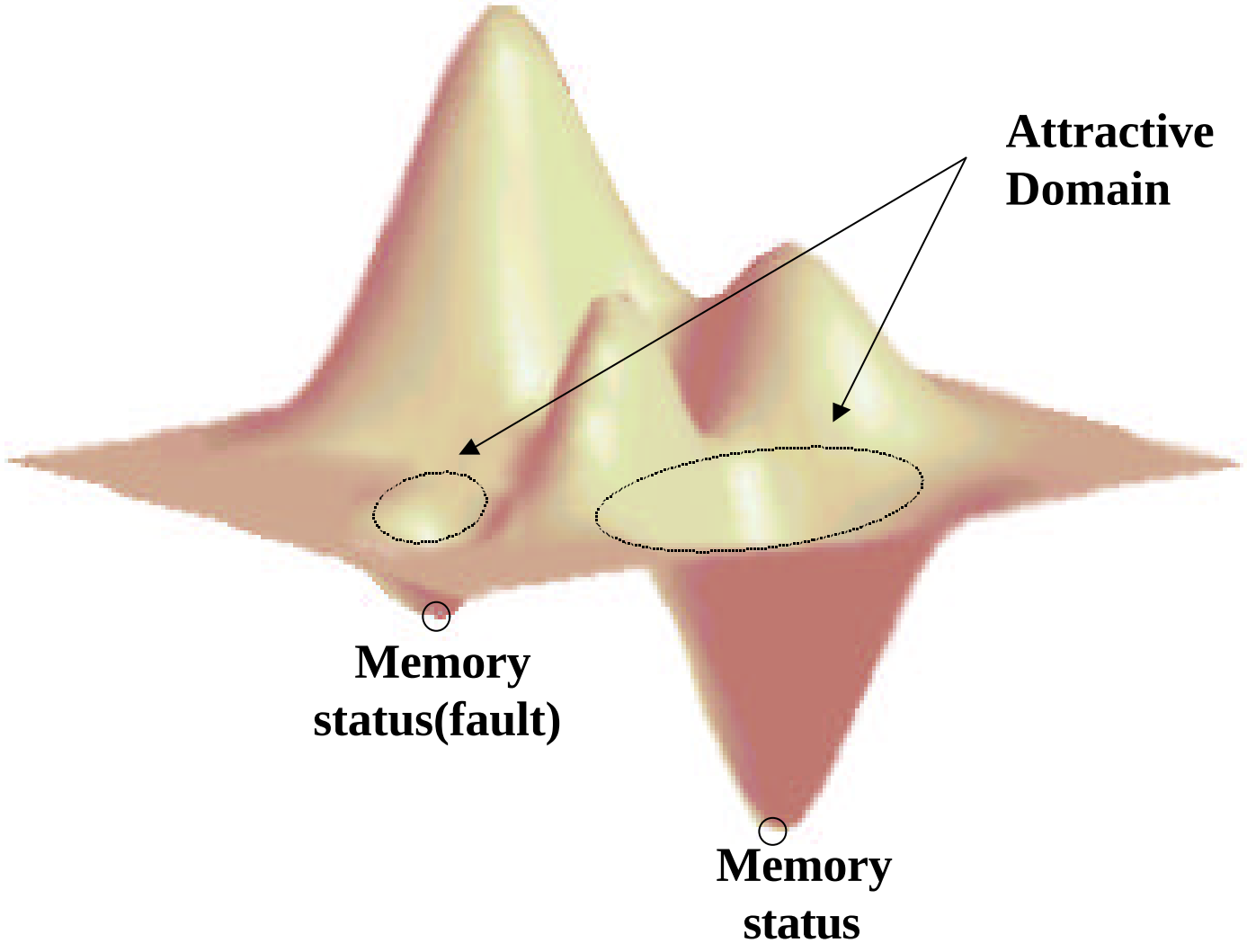
4、Quick Haken Network

Synergetics and Synergetic Information Processing

Synergetic Information Processing is a new concept proposed by Hermann Haken (Germany) in 1980s by applying Synergetics in information science

Synergetics is a research inter-disciplinary field. It studies the cooperation among “synergized” individuals and the formation of new space structure , time structure or functional structure by cooperation

The concept of synergetic computer is come from Synergetics. It utilizes the similarity between the pattern formation and pattern recognition and its most pronounced feature is that it can strictly control the behavior of the network on the mathematic meaning, so we can know its feature precisely and get no “fault status” The construction of synergetic computer is a top-down method: we recognize the expected feature first and then create the algorithm to avoid the dis-uniqueness and uncontrollability of dynamic behavior.


Attractive
Domain
Memory
status(fault)
Memory
status

The progress of pattern recognition is also the progress of pattern formation. When the feature sets are given, order parameters will compete. The order parameter with the strongest initial support will win eventually and force the system to resume the absent features. This progress is corresponding to the transformation from experiment sample to basic sample.

$$\dot{x}_k = l_k x_k - B\sum_{k'\neq k} x_{k'}^2 x_k - C\left(\sum_{k'=1}^{M} x_{k'}^2\right) x_k$$

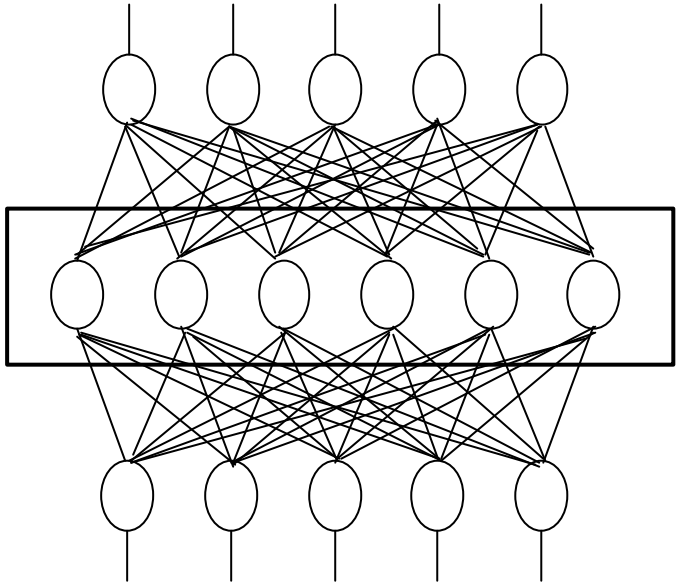
$$V = -\frac{1}{2}\sum_{k=1}^{M} l_k x_k^2 + \frac{1}{4} B \sum_{k'\neq k} x_{k'}^2 x_k^2 + \frac{1}{4} C\left(\sum_{k'=1}^{M} x_{k'}^2\right)^2$$

1 Division of synergetic neural network

In this chapter, we proposed that synergetic neural network is conformed to the general construction of competition neural network and can be divided into matching subnet and competition subnet. This division is helpful to better understand and improve the generation and dynamic evolution progress of synergetic neural network, and is also advantageous for applying it in some special problems 。

Explanation of some key concepts in Haken Model

- Adjacent Vector and Original Vector
- Order parameter
- Attention parameter
- Energy Function
- Evolution Progress



Initial value of input pattern

Order Parameter

Original Parameter

Synergetic Neural Network is a kind of Competitive Neural Network

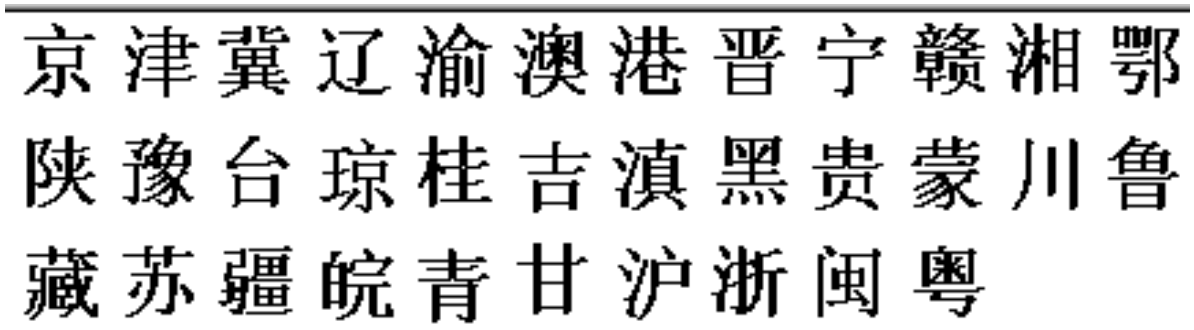
Matching Layer: Order parameter stands for the similarity between patterns.

Competition layer:

- lateral suppression
- winner takes all
- selective attention

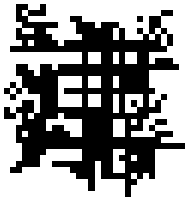
2 Generation of Order Parameter

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. Classic Pseudo-Inverse Method can obtain precise order parameter in the sense of inner production, but is greatly limited on computational ability and the adaptability. We proposed that order parameter can be obtained by other methods under the criterion of Minimal Remnant Vector and gave experiments with Mean Square Error Method, Correlation Coefficient Method, Distance Method and Absolute Value Distance Method to overcome those problems

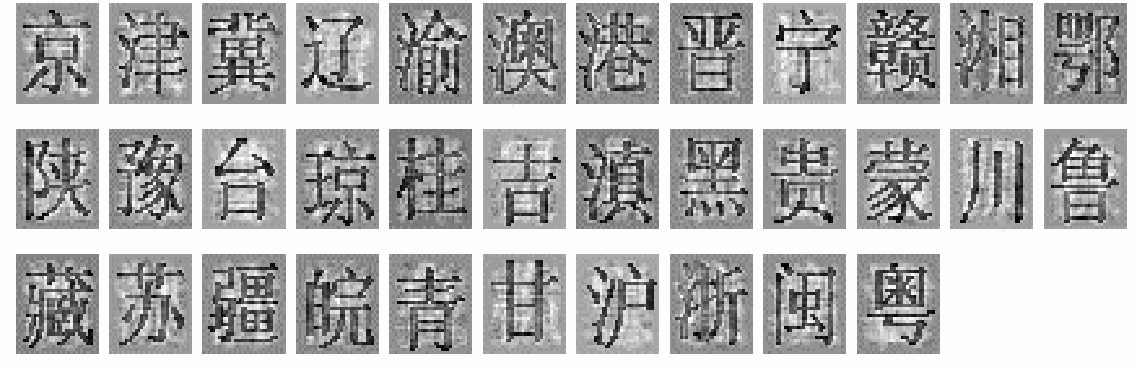


京 津 冀 辽 渝 澳 港 晋 宁 赣 湘 鄂
陕 豫 台 琼 桂 吉 滇 黑 贵 蒙 川 鲁
藏 苏 疆 皖 青 甘 沪 浙 闽 粤

Original Pattern



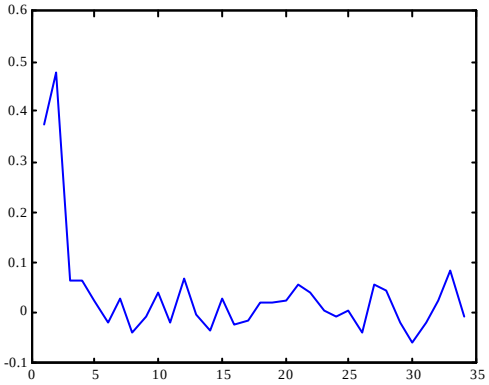
Pattern to be recognized

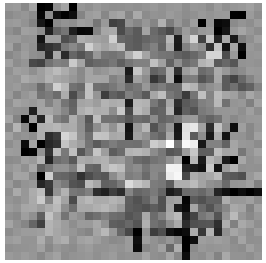


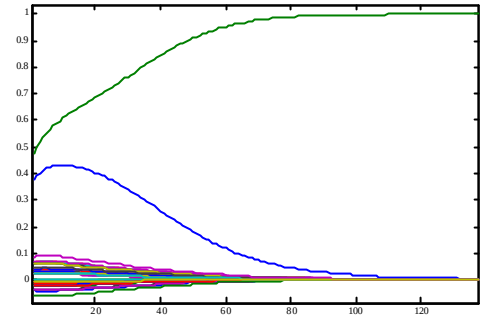
Adjacent Pattern

$$w = q - \sum_{k} x_k v_k$$

Remnant Vector







Method： Order Parameter, Remnant Vector, Evolutional Processing

$$(v_k^+, v_{k'}^T) = v_k^+ \cdot v_{k'} = d_{kk'} = \begin{cases} 1 & k = k' \\ 0 & k \neq k' \end{cases}$$

Definition of Pseudo-Inverse

The shortcomings of Pseudo-Inverse Method:

- 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.

Construct order parameter based on its basic meaning

- Distance

$$x_k(0) = 1 - \frac{\|v_k(0) - q\|}{2}$$

- Mean Square Error

$$x_k(0) = s / e^2$$

- Correlative coefficient

$$x_k(0) = \frac{\sum_i v_{ki} q_i}{\sqrt{\sum_i v_{ki}^2} \sqrt{\sum_i q_i^2}}$$

- Absolute Value Difference

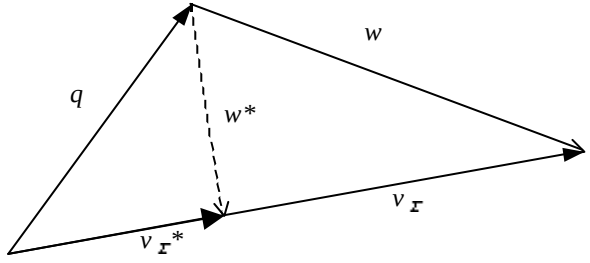
$$x_k = 1 - \sum_i |v_{ki} - q_i| / h$$

Strength and weakness of new methods

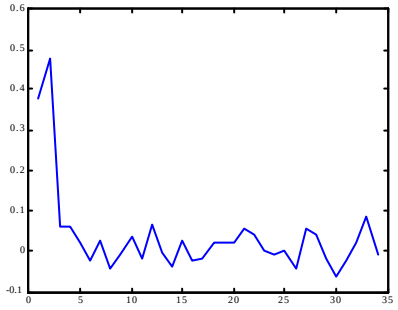
•Don’ t need Pseudo-Inversion

• Also stand for the similarity between input pattern and original pattern

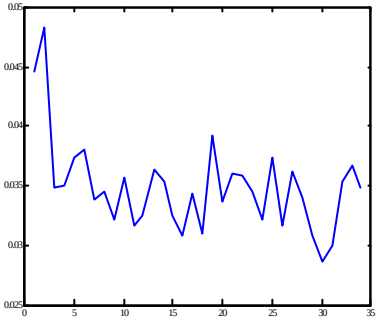
• They all can’ t meet the requirement of zero remnant vector, so we need more work on minimizing remnant vector



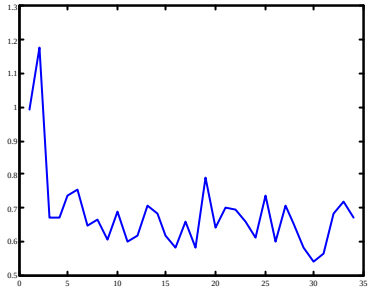
Experiment Result



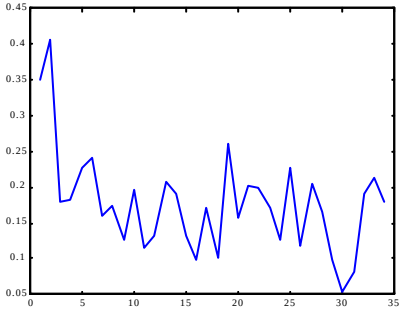
Pseudo-Inverse



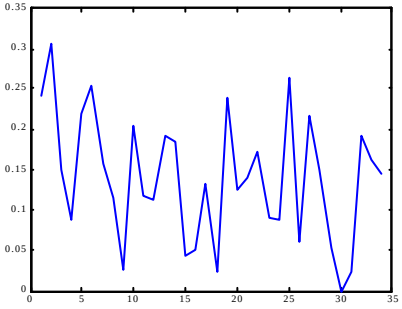
Distance Method



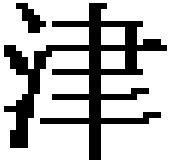
Mean Square Error Method



Correlation Coefficient Method



Absolute Value Distance Method



Correct recognized pattern

Running Cost

	flops	Comparing with PI
Pseudo-Inverse(PI)	155,528,036	1
Distance Method	174,148	1/893
Correlation Coefficient Method	69,632	1/2233
Absolute Value Distance Method	69,700	1/2231
Mean Square Error Method	313,514	1/496

3 ordering measurement of the network

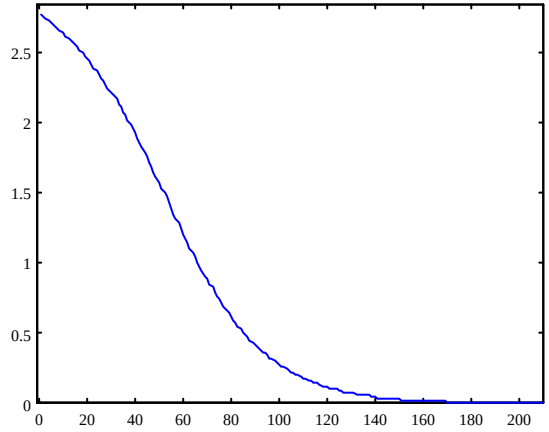
We proposed a ordering measurement of the network: Entropy, based on the relative distribution of order parameters. And it is proved that it never decreases during the running of network. It shows that the work processing of synergetic neural network is a self-organizing processing.

Definition:

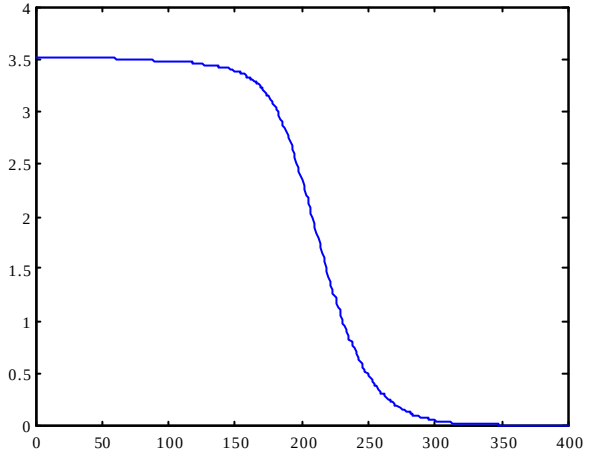
$$\tilde{x}_k = \frac{|x_k|}{\sum_i |x_i|}$$

$$H = -\sum_k \tilde{x}_k \ln \tilde{x}_k$$

Experiment:



Pseudo-Inverse



Correlation Coefficient Method

It can be proved that the entropy is non-decreasing during the evolution of synergetic neural network:

$$\frac{\partial H}{\partial t} \leq 0$$

4 Quick Haken Network

In the study of competitive sub-network, we mainly analyzed the improvement on the time performance of classic Haken network and proposed Quick Haken Network. With detailed analysis for potential function, 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 by classic Haken network.

Defect of classic Haken Model: 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.

Resolution:

1) Hierarchical Competition in Matching layer

2) Improvement in Competition Layer

2.1) From the view of time cost, determine the competitive result from the initial condition of the equation.

2.2) From the view space cost, convert differential function groups into sparse matrix and then solve.

We only discuss method 2.1 here.

Quick Haken Network

• Balanced attention parameter: the greatest order parameter will win eventually

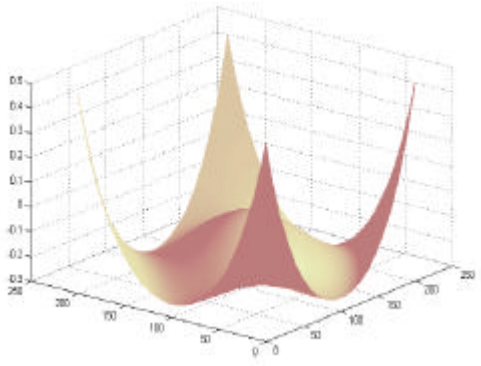
•Unbalanced attention parameter：

$$\lambda_j - \lambda_i > (1/t)\ln(x_i(0)/x_j(0))$$

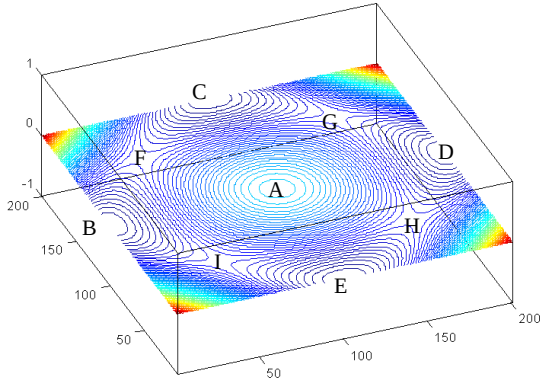
$$\Leftrightarrow x_j(0)e^{\lambda_j t} > x_i(0)e^{\lambda_i t} \Leftrightarrow x_j(t) > x_i(t)$$

Then the order parameter corresponding to pattern j will die away.

Potential Function Analysis : Balanced Attention Parameter

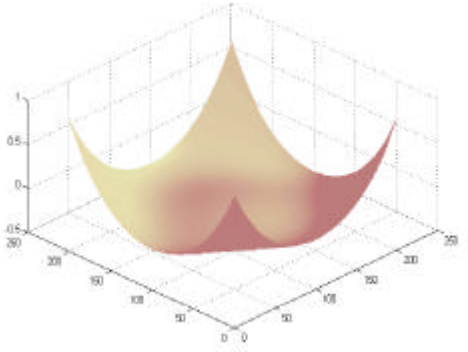


Potential function: 4 attractors can be found clearly in this figure and is axial symmetrical each other. The hill at original point is represented for instable equilibrium point . We can also find 4 saddle points on the diagonal direction.

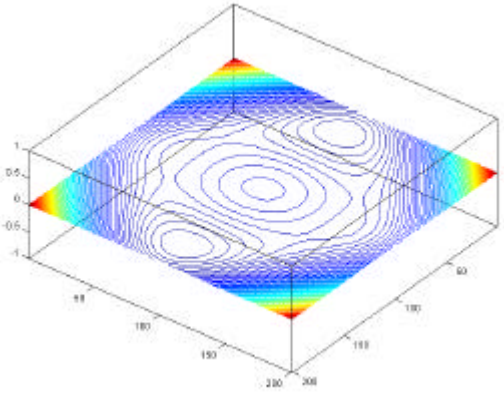


Note: there are 4 attractors (-0.25): B,C,D,E; 1 unstable stationary point (A),4 saddle points (F, G, H, I). And the shape of two attractor is same. It shows the meaning of “balanced” attention parameter.

Potential Function Analysis: unbalanced attention parameter 0.6-0.4

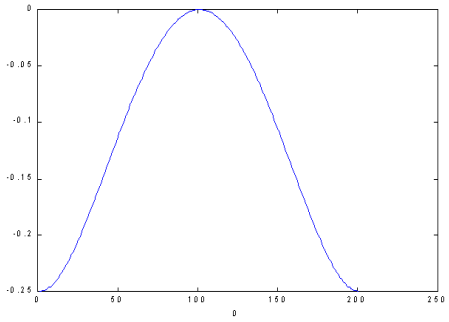
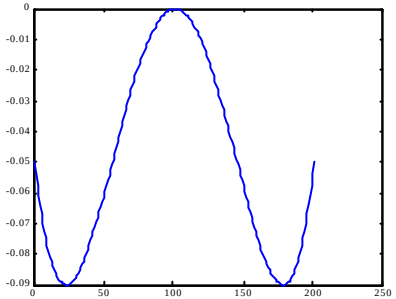
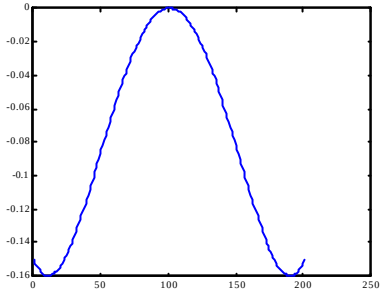
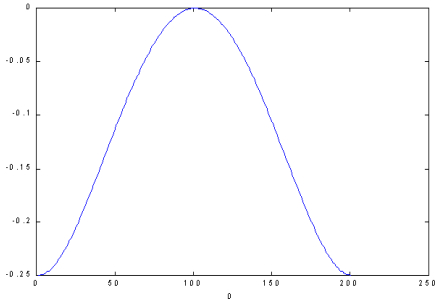
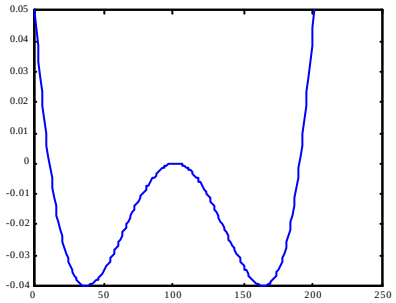
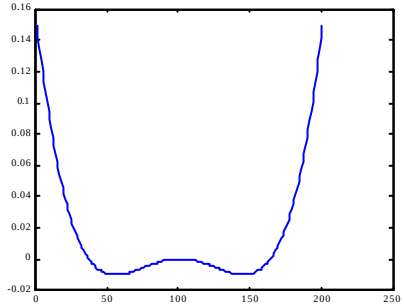


Potential function. Note that both the width and depth of attractive domain of pattern 2 are greatly reduced comparing with that of balanced parameters

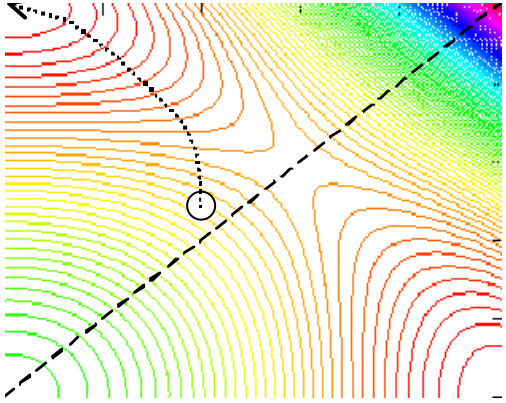


Note: Attractive domain of attractor 1 (pattern 1) is enlarged while that of pattern 2 is reduced. It shows that attention parameters have important influence on the attractive domain of patterns.

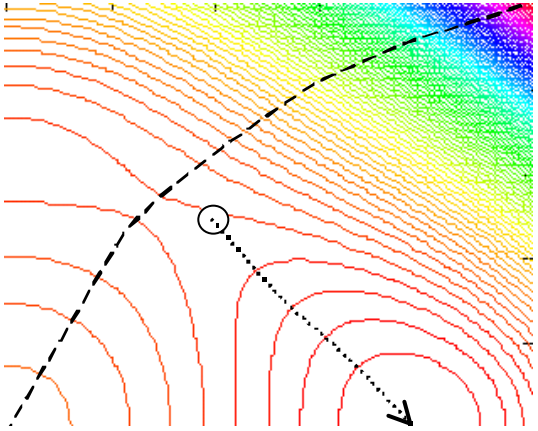
Depth of Attractors

	1.0 – 1.0	0.6 – 0.4	0.8 – 0.2
x_1			
x_2			

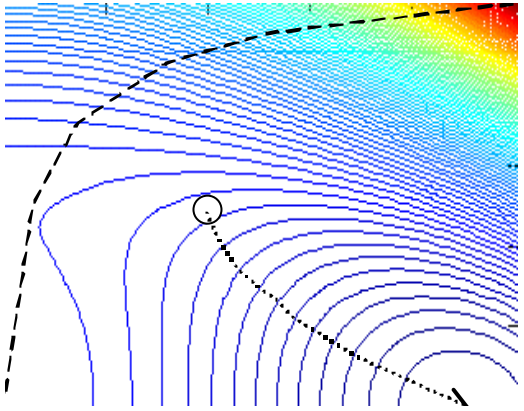
Attractive Domain



Balance
Attention
Parameter

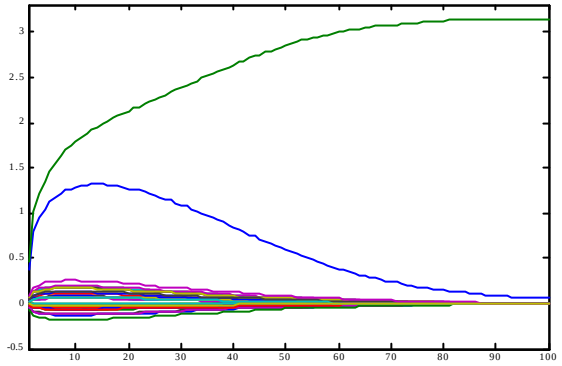


0.6-0.4



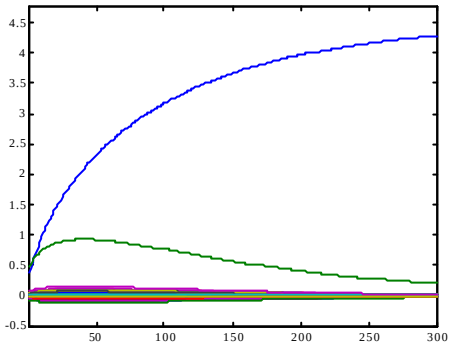
0.8-0.2

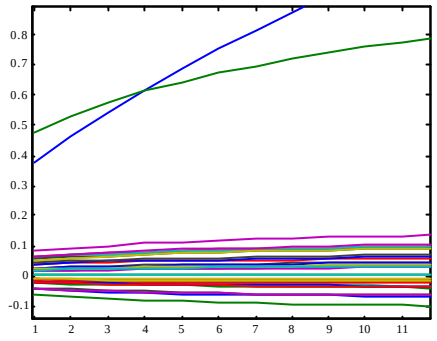
Experiment: Balanced Attention Parameters



	Time Cost	flops
Classic Algorithm	2.0420	40900
Quick Algorithm	<0.00005	34

Experiment: Unbalanced Attention Parameters





	Time Cost	flops
Classic Algorithm	7.2890	122700
Quick Algorithm	0.0667	143

Outlook for High dimensional competition

Basic principles for constructing V

$$V = \cos t + penalty$$

$$p\sum c_{\bullet}x_{\bullet} \qquad \sum r_{\bullet}f_{\bullet}(x)$$

Restriction should can be transformed into the summation of multiplication form of the square of order parameters. There will be same # of penalty term with the dimension of problem.

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.