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Foam Morphology as a Higher Order Structure Model of a Layer System

Toshio Ishii, Eiji Hatta* and Koichi Mukasa*
Tsurumi University, School of Dental Medicine, 2-1-3 Tsurumi, Tsurumi-ku Yokohama, 230-8501, Japan
Fax:81-45-585-3216, e-mail:ishii-t@tsurumi-u.ac.jp
*Nanoelectronics Laboratory, Graduate School of Engineering, Hokkaido University, Kita13, Nishi8, Kita-ku, Sapporo, 060-0813, Japan
Fax:81-11-706-6537, e-mail:mukasa@nano.eng.hokudai.ac.jp

Interfacial tension plays an important role in a small system such as a molecular assembly system. For an example of such a system, we studied 2-dimensional soap film system which was constructed by several glass rods between two sheets of glass plates. It has shown that the calculation using Hopfield neural network is a good method to estimate the film patterns which were observed in the experiments.
Key words: Hopfield neural network, soap film, 2-dimension, interfacial force, foam

1. INTRODUCTION

Nowadays, devices in computer are constructed by a large number of molecules, which are governed by a statistical mechanics. In the near future, one or several molecular devices could be used in computors. To find a rule in such a system, we tried to find how to make a self assembly system by spontaneous rearrangement of several components.

2. EXPERIMENTAL AND SIMULATION SYSTEMS

An experimental system was made of several number of glass rods between two flat glass plates as introduced by Almgren Jr. and Taylor[1]. The system was immersed in aqueous soap solution and was lifted up. By this operation, 2-dimensional patterns were made in the glass rod system (Fig.1). When one sees the membrane assembly from the top of the system, one can see 2-dimensional shape connected by straight lines.

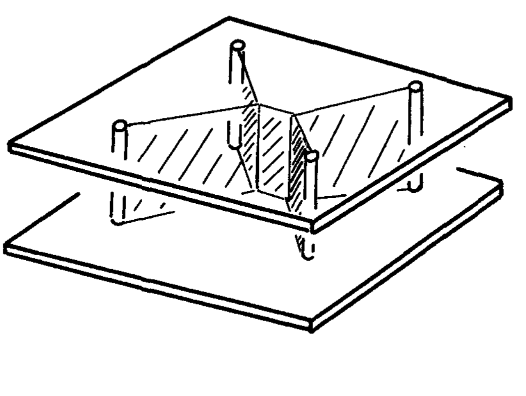


Fig.1 2-dimensional bubble system with four glass rods between two flat glass plates. The system was immersed in a soap solution and lifted up.

Calculations using Hopfield neural network were made on simulated systems in a computer (DEC·station 3100) where the initial conditions were the same as those in the correspondent experiments.

In the calculation, we proposed three conditions to modify Hopfield neural network, for calculating the soap film assembly.

1. Membranes are connected with one another by flat plane .
2. There are two types of points in these 2-dimensional connection.
   a. glass rods (fixed points)
   b. turning points where three straight lines are connected with one another (there are no glass rods). At one turning point, three straight lines are connected by angle of 120° between each two lines.
3. A triangle is made by three fixed points. If all of the angles of the triangle are smaller than 120° degree, there occurs one turning point. If one of the angles is larger than 120°, there occurs no turning point. However, for convenience of the calculation, we imaged a turning point in a triangle on the point with the largest angle of the triangle (Fig.2).

At time, t, one of a unit, U_i receives signs from (N-1) points (fixed points and turning points).

$$U_i(t) = \sum_{j}^{N} W_{ij} X_j(t) + h_i \quad (1)$$

W_{ij} : strength of combination between unit i and unit j.

$X_j(t)$: the signal sent from j to i.

$h_i(t)$: the threshold value of unit i.

At the next time, $(t+1)$, the sign of unit i to send is as follows.

$$X_i(t+1) = \begin{cases} 1 : U_i(t) \geq 0 \\ 0 : U_i(t) < 0 \end{cases} \quad (2)$$

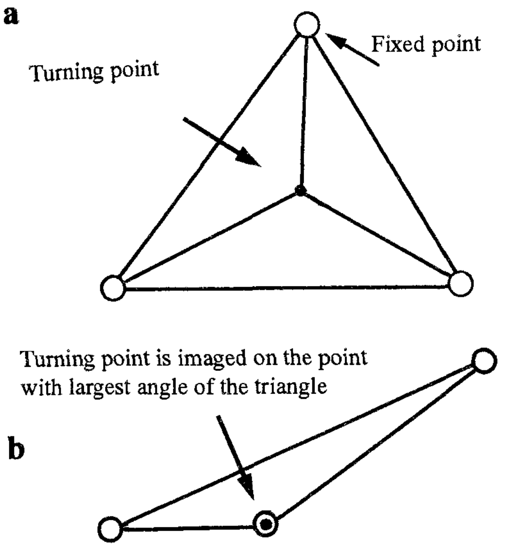


Fig.2 Relationship between fixed points and turning points.
a All of angles in a triangle are smaller than 120°.
b One of angles in a triangle is larger than 120°.

Information on position is included in $X_j(t)$. The value of X_j determines the strength of combination between i and j.. The positions of turning points are decided by X_j.

With the above parameters, the energy of the system, E is defined as follows.

$$E = -\frac{1}{2}\cdot\sum_{i}^{N} W_{ij} X_i(t) X_j(t) - \sum_{i}^{N} h_i X_i(t) \qquad (3)$$

3. RESULTS AND DISCUSSION

When the number of glass rods was small, the same patterns were observed between the experiments and simulated calculations, as shown in Fig.1. Different patterns were observed when number of glass rods was increased in the experiment. In such a case, there were needed a lot of time to simulate it and there occurred various patterns in the process to obtain a final result, and there were lots of difficulties to obtain the final result.

A process of a simulation were shown in the previous paper[2].The final patterns given the initial conditons and the energy change of the systems expressed in the equation (3) were shown in Fig.3 and Fig.4. When the number of glass rods is increased, a final shape depend on how to lift up the glass rods system, in an experiment.. Similar tendency was observed in a calculation. Especially, if N is larger than 8, final shapes often depend on the initial conditions. In such a case, energy of the system of a final shape means a local minimum. Hopfield neural network should be a good simulation to obtain a local minimum rather than real minimum.

Hopfield neural network is useful to know the final assembly, in which only a few molecules will be used in electronic devices, where spontaneous rearrangements of molecules would be needed. In such a case Hopfield

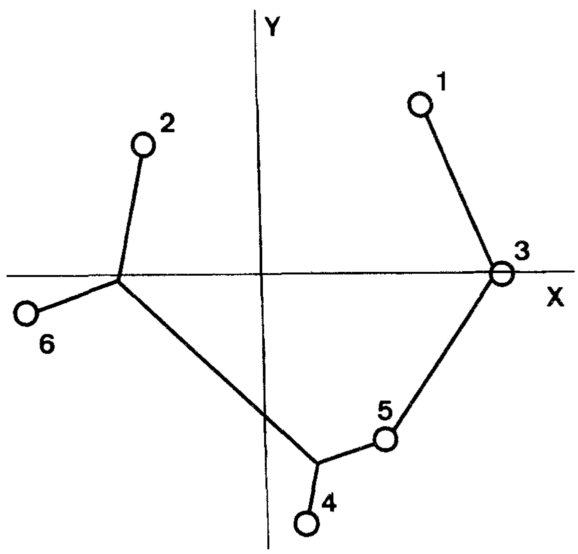
a. Initial conditions

fixed point (X, Y)

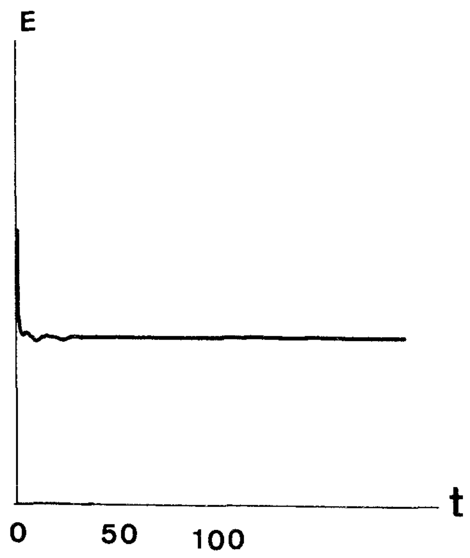
point 1	(4.0,	4.0)
point 2	(-3.0,	3.0)
point 3	(6.0,	0.0)
point 4	(1.0,	-6.0)
point 5	(3.0,	-4.0)
point 6	(-6.0,	-1.0)

turning point (X, Y)

point 1	(-3.0,	3.0)
point 2	(6.0,	0.0)
point 3	(1.0,	-6.0)
point 4	(3.0,	-4.0)



b. The final pattern



c. Energy change in the system.

Fig.3 The final pattern(b) given by the initial conditions(a) and the energy change(c) of the system.

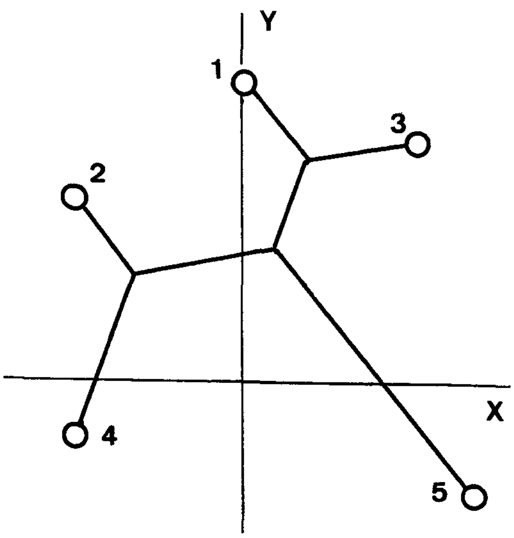
a. Initial conditions

fixed point (X, Y)

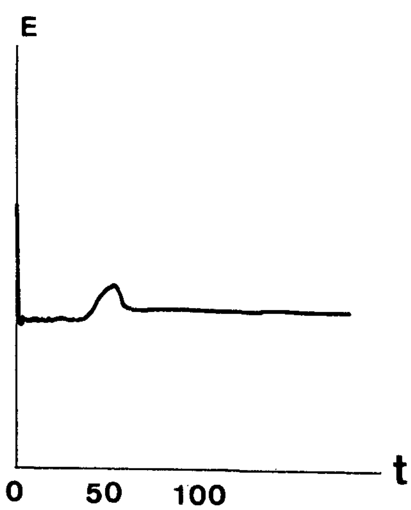
point 1	(0.0,	5.0)
point 2	(-3.0,	3.0)
point 3	(3.0,	4.0)
point 4	(-3.0,	-1.0)
point 5	(4.0,	-2.0)

turning point (X, Y)

point 1	(0.0,	5.0)
point 2	(-3.0,	3.0)
point 3	(-3.0,	4.0)



b. The final pattern



c. Energy change in the system.

Fig.4 The final pattern(b) given by the initial conditions(a) and the energy change(c) of the system.

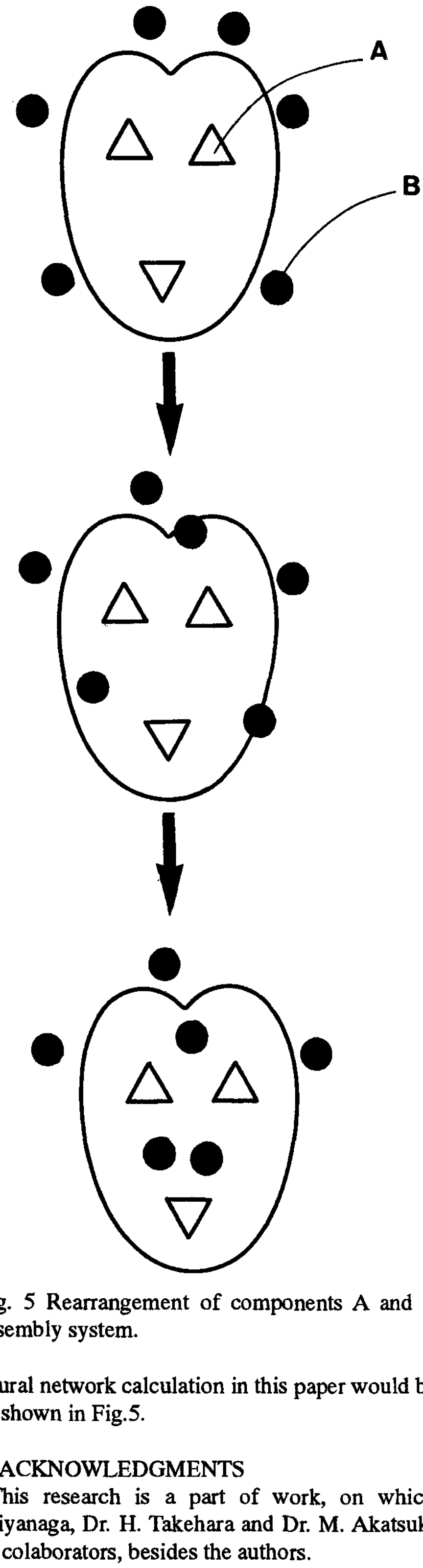


Fig. 5 Rearrangement of components A and B in self assembly system.

neural network calculation in this paper would be useful, as shown in Fig.5.

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