Immune algorithm with immune network and Major Histocompatibility Complex

Naruaki Toma
tnal@eva.ie.u-ryukyu.ac.jp
Graduate School of Science and Engineering
University of the Ryukyus
1 senbaru, Nishihara,Okinawa 903-0213
Japan

Satoshi Endo , Koji Yamada
{endo,koji}@ie.u-ryukyu.ac.jp
Faculty of Engineering
University of the Ryukyus
1 senbaru, Nishihara,Okinawa 903-0213
Japan

Abstract

Adaptive problem solving techniques such as neural networks and genetic algorithms become so popular in the AI field. The biological immune system is one of the adaptive biological systems whose functions are to identify and to eliminate foreign material. In this paper, we propose an adaptation algorithm based on immune model with immune network and Major Histocompatibility Complex. Immune network is a leaning technique as an adaptive problem solving. MHC expresses a characteristic that an agent can act some behaviors. To investigate an adaptation ability of the proposed algorithm, we apply to n-th agent's travelling salesman problem called n-TSP. This algorithm performs adaptive behaviors for distributed cooperation.

1 Introduction

Such as neural networks and genetic algorithms, adaptive problem solving techniques become so popular. These techniques are based on information processing in biological organisms and are applied many kinds of optimization problems[1]. On the other hand, the biological immune system is widely recognized as one of the adaptive biological system whose functions are to identify and to eliminate foreign material. In order to perform such functions, Major Histocompatibility Complex (MHC) is used to identify foreign material by difference of MHC. Immune network is used to control making antibodies to eliminate antigens by activation among immune cells.

In this paper, we propose a model of immune functions and an immune algorithm as an adaptive problem solving on multi-agent system. Immune network is defined as controlling mechanism of immune response to eliminate effectively. MHC expresses a characteristic that an agent can act some behaviors and uses to cooperation among the agents. By using their characteristics, this algorithm will perform effective adaptation in dynamically changing environments by the distributed cooperative among some agents. Then, we apply the proposed algorithm to n-th agent's travelling salesman problem (called n-TSP) which is one kind of multi-agent systems. Some computer simulations are designed to investigate the performance of the proposed immune algorithm.

2 Biological immune system and proposed algorithm

2.1 Immune network

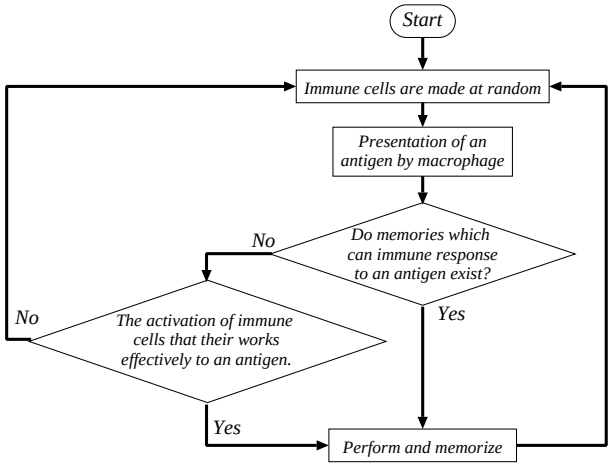

Figure 1: Memory mechanism with immune network

Immune network is defined as controlling mechanism of immune response, primary and secondary immune response, by activation on the network that is composed of immune cells and their connection. The immune cells are composed of following three cells. First one is macrophage whose function defined as primitive response (random recognition, presentation

and elimination against foreign materials). Second one is T cell that recognizes infected cells (activation of development of antibodies, recognition and elimination by matching between T cell antigen receptor(TcR) and foreign material). Third is B cell that recognizes uninfected cells (presentation and development of antibodies by matching between its antibody and foreign material). By mutual cooperation among their cells, especially essential functions are 1) widely recognition ability by 3 kinds of recognition, 2) strongly adaptation ability to unknown vast antigens by production of random solutions controlling of immune response, 3) memory mechanism is used to eliminate antigens that eliminated once.

In the multi-agent system, there is environments as dynamically changed by autonomic behavior of agents. The exhaustive search for the environments is difficult problem because the problem space is too large. The biological immune system will have the advantages of learning and adaptive technique on the environments because the system is possible to make solutions against unknown vast problems (i.e., the problems which immune systems deal with are too large like dynamically changing environments).

2.2 MHC

In the biological immune system, a characteristic of an individual is defined as MHC[2]. If the infected MHC on the cells which is composed an individual is different from original(uninfected) MHC, the individual can recognize antigens by matching with TcR. In other words, MHC is used to distinguish a "self" from other "not self".

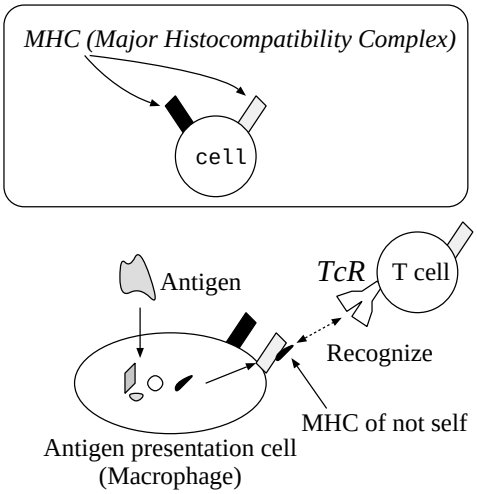

Figure 2: MHC and recognition of not self

In the design of effective multi-agent system, distributed operation with efficiency by mutual cooperation among agents is one of the most important aspects. It is thought as a such subject that the operations which don't include repeat operation among agents design. In other words, we aim to construct the system whose operations of every agent compose exclusive ones. To consider the construction with biological immune system, agents own operations that are necessary information for establishment of "self" is defined as MHC, at first. By such definition, it is thought one aspect that MHC between agent A and agent B is difference, but a part of MHC both of agents is equal. In such a case, if both of agents recognize other agent as a "not self" and try to eliminate an opponent, the system that is composed such agents will hope to be the purposed construction.

2.3 Adaptations in biological immune system

It is thought of as two types of adaptation mechanism as a view, pre-adaptation and post-adaptation, in biology. It considers one case that the individuals change self-inertia to exist against selection pressure from dynamically changing environments. The pre-adaptation is defined as changing self-inertia in an aspect before selection pressure occurs (i.e., adapt independently of selection pressure). The post-adaptation is defined as changing self-inertia in an aspect after selection pressure occurs (i.e., adapt in consideration of selection pressure). When adaptation system to the environments is composed, is important how to implement their two types of adaptation mechanisms. In the biological immune system, immune network takes charge of them. Making of random solutions means the pre-adaptation and adaptation using memory means the post-adaptation. It will be possible to construct that an adaptation model keeps being effective adapted (i.e., without the condition that falls into the local optimum).

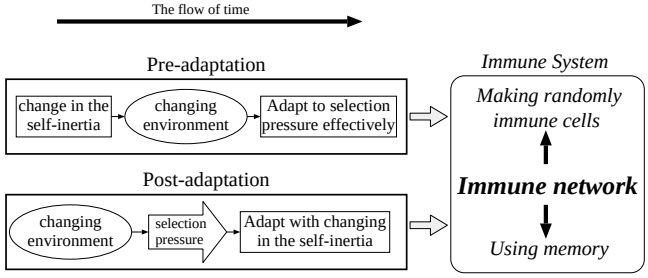

Figure 3: Pre-adaptation and post-adaptation in the immune system

2.4 Proposed immune algorithm

The proposed IA to adaptive solving for multi-agent model illustrated on figure 4. Each step of the proposed IA is explained in the following. At this point, antigens are solving problems of not self agents and environments, and one individual composed of immune cells is one agent.

Step1. Definition of an antigen
Information which agents can recognize is defined.

Step2. Own establishment
MHC of agents as each an individual's characteristics are defined, and initial agents composed of immune cells (here, macrophages, T cells, and B cells) make. The immune cells make with random or memory.

Step3. Swapping the immune cells
The immune cells that their energies as a life-time was lost, become extinct. Make new cells with random and swap lost cells for new cells.

Step4. Acquisition of the environment information and presentation to the agent
Agents can acquire information of not self by using macrophages. The macrophages that have information about not-self change own MHC itself.

Step5. Energy transmission for activation
Agents recognize not self by T cells and B cells that are matching MHC about not self. When T cells and B cells that recognized it, they get energy from macrophages. The energy that each cell can get is in proportion to their affinity, match degree of between information of macrophages and T cells (or B cells).

Step6. Memory and production of an antibody by division and differentiation
T cells and B cells that energy exceeded their threshold divide to memory cells and (only B cells) antibody producing cells. Memory cells continue to exist as a memory of recognized antigens. When agents meet with the same antigen memory cells, can recognize it, produce antibodies quickly than first encounter.

Four steps, from step 3 to step 6 are one time step. In addition, this algorithm is adapted by repeating from step 3 to step 6 until terminal condition.

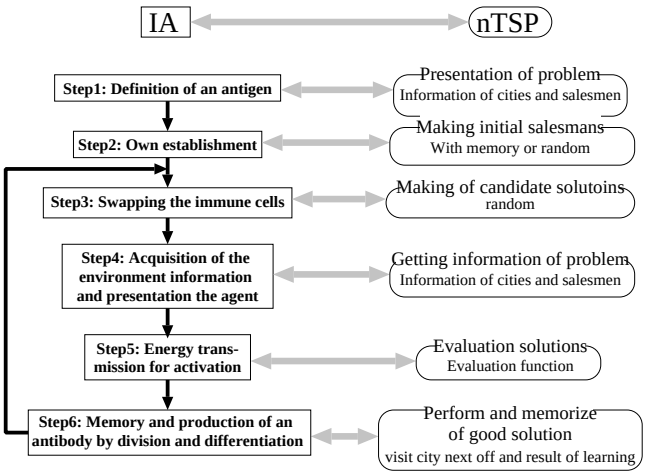

Figure 4: Proposed IA and n-TSP

3 Experiment

3.1 Design of IA for n-TSP

The design of antigens and immune cells are as the following.

[Antigen] : Information of "cities" and "salesman".

- cities;
  - m; a number of cities.
  - $Pos(m)$; position of cities.
  - $Dis(m_i, m_j)$; distance between m_i and m_j.
- salesmen;
  - n; a number of salesmen.
  - Now_Town; the city which it is in at this present.
  - $MHC[\ ] = Traveled_Town[1...m]$; set of visited city.
  - $Cost(Traveled_Town[\ ]) = \sum_i^m Dis(i, i+1)$; cost of traveled tour.
  - $Strength = 1/Cost()$; easiness to spread the tour.

where MHC is used as communication between agents. The evaluation value when an agent moves to the city m_{action}, as the following (i.e. an evaluation function in the step 5 of figure 4).

$$Eval(m_{action}) = Dis(Now_Town, m_{action}) * Strength \quad (1)$$

The value becomes lower as much as the cost of the tour is long. Therefore, the tour whose cost is smaller is supposed to be designed by the equation.

[Macrophage] : Acquisition from an antigen.
Composed of Traveled_Town[ ] , "Local_View[ ]" and "Energy".

- $Local_View[1...m]$; information of partial cities.
- $Energy$; life-time.

where $Local_View[\ ]$ which gets from an antigen presents to the agent.

[T cell] : Helping activation of B cell.
Composed of Local_View[ ] and Energy.
When the Local_View[ ] of Macrophage and T cell's one match only, T cell help activation of B cell (i.e. step 5 in the algorithm).

[B cell] : Making antibodies.
Composed of "m_{action}" , Local_View[ ] and Energy.

- m_{action}; visit city next off.

When one B cell that was helped by T cell makes an antibody as a behavior.

[Antibody] : Perform behavior of agent.
Composed of m_{action}.

3.2 Definition of experiment

The problem defined in the figure 5. The arrangement of the cities is a circle, which a start city was moved to the center, and the circumferential cities are being arranged uniformly. The performance is confirmed in this experiment with two standards. First is a visited all cities, and second is the cost proceed in the optimization direction.

(a) Parameters of nTSP	
number of cities	13
number of salesmen	3
time steps	1000

(b) Parameters of IA	
Macrophages	1
T cells	5
B cells	40
initial energy	1.0
threshold	2.0
decrease of energy	0.1

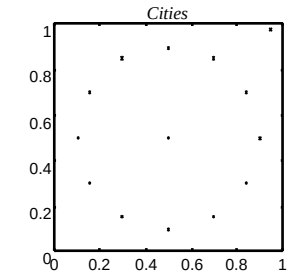

Figure 5: Definition of problem

3.3 Results and discussions

In the figure 6, *Cost* is the evaluation of the tour and *Complete* is the degree that satisfies the condition of the solution as n-TSP ($0 < value \leq 1$, if the value is 1, the tour composed all cities and no overlap). Though the production of solutions is made by random, the decrease of the cost by communication used MHC (equation 1). However, the algorithm could not find the optimum solution yet. As a reason, it is considered that the environment changes another one before better behavior is made, because importance is attached to the behavior which memories were used. Therefore, this algorithm may be necessary to shift of the search scope from local optimum because the decrease of the cost isn't seen after 500-time step.

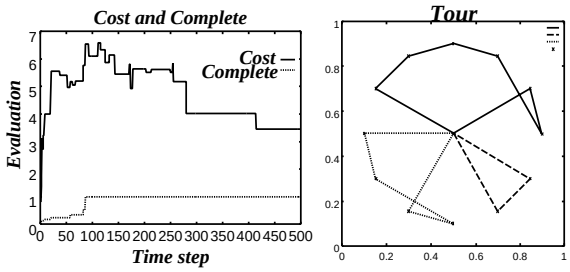

Figure 6: Cost and tour in the last step

4 Conclusion

In this paper, we proposed the immune algorithm for multi-agent system, composed immune network for pre-adaptation and post-adaptation, and MHC for mutual cooperation between agents. This algorithm was applied to simple n-TSP, and validity was examined. As future works, this algorithm becomes clear some points about its behaviors.

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