Artificial Immune Algorithm Based Obstacle Avoiding Path Planning of Mobile Robots

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Abstract. This investigation studies the applicability of using mobile robots with artificial immune algorithm (AIA) based obstacle-avoiding path planning inside a specified environment in real time. Path planning is an important problem in robotics. AIA is applied to determine the position and the angle between a mobile robot, an obstacle and the goal in a limited field. The method seeks to find the optimal path. The objectives are to minimize the length of the path and the number of turns. The results of the real-time experiments present the effectiveness of the proposed method.

1 Introduction

Over recent years, artificially intelligent systems have been developed for robots. Every class of robot is applied in industry and society. Neural networks, genetic algorithms [1] [2], fuzzy control [3], and robust control are important to AI. These methods have been developed and some have exhibited excellent planning performance.

The modern industry applies an effective method to optimize the performance. In fact, it is an optimization planning problem. This artificial immune algorithm was developed based on a biological immune system. The biological immune system incorporates three functions - the defense of the body, the maintenance of the homeostasis of the body and surveillance. The biological immune system exhibits a high degree of specificity and the remarkable characteristic of remarkable memory. The biological immune system incorporates various cells, such as T-cytotoxic cells, T-helper cells, B cells and others. Fig. 1 shows that the main cellular agents of the artificial immune algorithm including the B cells, the antibody, the antigen, the idiotope and the paratope, according to N. K. Jerne, who created the idiotypic network hypothesis [4] [5]. The relationship between the antigen and the antibody is like that between a key and a lock.

The investigation proposes an AIA method to be applied to mobile robot behaviors. This investigation compares Dongbing Gu's method [6] with the proposed method. Section II introduces the artificial immune algorithm. III describes the mobile robot's sensor and the learning and settings for this method. Section Ⅳ compares results.

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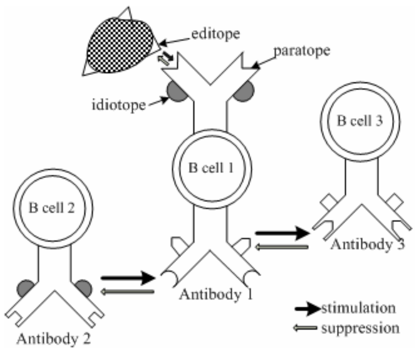

Fig. 1. Jerne's idiotypic network hypothesis

c_1	c_2	c_3	……	c_k

Fig. 2. One antibody

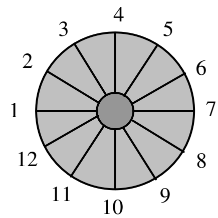

Fig. 3. Construction of Mobile Robot

2 Introduction of Artificial Immune Algorithm（AIA）

In this investigation, a behavior is viewed as an artificial immune algorithm. The running of the robot using AIA is evaluated. The artificial immune algorithm specifies rules. Therefore, fig. 2 defines one antibody again.
The operations of the AIA include the following:

1. Initialization: The first antibody is initialized randomly. Each antibody is uniformly selected from the AIA singletons.
2. Detect antigen: The first antigen is recognized simply because every B cell can recognize a particular antigen.
3. Individual immune network: The antigen combines with the antibody. In the adaptive mechanism, the lymph hormone simulates and activates the division of the B cell, or antibodies suppress the B-cell.
4. Antibody concentration: The antibody concentration closely relates to the relationships among crossover, mutation and artificial immune network function.
5. Eliminate antigen: When the antigen enters a human body, the B-cell triggers the antibody production until the antigen is eliminated.

3 Mobile Robots That Use the Artificial Immune Algorithm (AIA)

The mobile robot is used 12 sensors to detect the distance and angle between the robot and the obstacles or the goal. Every included angle of the robot is 30°. Fig. 2 shows the construction of the mobile robot. The environment of the mobile robots is a playing field with an area of $90cm^2$. In this simulation, the mobile robot must move across numerous obstacles and arrive at a goal, which is a limited area. Then, the mobile robot associates with several selected angles when the obstacles are detected behind the mobile robot.

The immune networks are divided into two groups. One part is between the mobile robot and the obstacle in the immune network a_i^o. The other is between the mobile robot and the goal of the immune network a_i^g. The antibody α_i is defined as follows:

$$a_i = (1-\gamma_i)\cdot a_i^o + \gamma_i \cdot a_i^g \quad (1)$$

where γ_i is the ratio between antibody a_i^o and antibody a_i^g. The antibody with the highest α_i is selected. γ_i is:

$d_o > d_g$	$d_o < d_g$	$only \quad d_g$	
$\frac{d_o}{d_o + d_g}$	$\frac{d_g}{d_o + d_g}$	1	(2)

where d_o and d_g are the distance the obstacles to the mobile robot and the goal to the mobile robot. When d_o exceeds d_g, the numerator is d_o. Otherwise, the numerator is d_g. If the robot is detected only at the goal, then γ_i equals 1. The obstacle antibody a_i^o and the goal antibody a_i^g in an immune network are calculated as:

Obstacle	Goal	
$a_i^o = \left\{ \frac{\sum_{j=1}^{n} m_{ji}^o \cdot a_i^o}{n} - \frac{\sum_{i=1}^{n} m_{ji}^o \cdot a_i^o}{n} + m_i^o - k_i^o \right\} \cdot a_i^o$	$a_i^g = \left\{ \frac{\sum_{j=1}^{n} m_{ji}^g \cdot a_i^g}{n} - \frac{\sum_{i=1}^{n} m_{ji}^g \cdot a_i^g}{n} + m_i^g - k_i^g \right\} \cdot a_i^g$	(3)

where n is the number of antibodies in the first term and second term. The first term on the right hand represents the degree of stimulation by other antibodies. The second term represents the degree of suppression by other antibodies. The third term represents the external input from the antigens. The fourth term is the natural death ratio. a_i^o and a_i^g can be calculated using similarly method. m_{ji}^o and m_{ji}^g are the obstacle matching ratio and the goal matching ratio between the antibody and the antibody. m_i^o and m_i^g are antibody and antigen matching ratios.

Obstacle ($\alpha_o = \frac{D-d_o}{D}$)	Goal($\alpha_g = \frac{D-d_g}{D}$)	
$m_{ji}^o = \frac{m_{ji}^o}{1-\alpha_o} \quad d_o > d_{set}$ $m_{ji}^o = \frac{m_{ji}^o}{\alpha_o} \quad d_o < d_{set}$	$m_{ji}^g = \frac{m_{ji}^g}{1-\alpha_o} \quad d_g > d_o$ $m_{ji}^g = \frac{m_{ji}^g}{\alpha_o} \quad d_g < d_o$	(4)

The matching ratio of the obstacle was calculated before α_o. D was the maximum size of the limited area. d_o is the distance between the robot and the obstacle. d_{set} is the radius of the robot required to avoid the obstacle. When d_o exceeds d_{set}, the denominator is $1-\alpha_o$. When d_o is less than d_{set}, the denominator is α_o. d_g is the distance between the robot and the goal. When d_g less than d_o, the denominator is $1-\alpha_g$. The other way round, d_g exceeds d_o, the denominator is α_o.

4 Experimental Results

This section presents simulation results that validate the proposed method. This investigation compares two methods. Fig. 4 shows the simulation results when the artificial immune algorithm and Dongbing Gu's genetic algorithm are used.

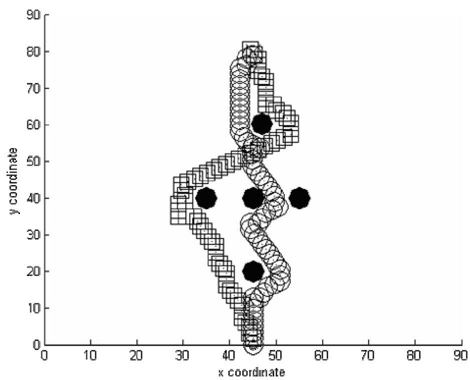

Fig. 4. Obstacle avoiding path planning of mobile robot. ("○" :the proposed method, "□" : Dongbing Gu's method.)

The solid circles refer to the obstacle. The other circles refer to the proposed method. The squares refer to Dongbing Gu's method. The fork represents the position of the goal. The total step is 59 in the artificial immune algorithm and 66 in Dongbing Gu's genetic algorithm. Fig.4 shows that the proposed method resulting in the selection of more actions. The proposed method is clearer when compared with the other method because the robot moves among obstacles toward the goal.

5 Conclusion

In this investigation, the presented method is the artificial immune algorithm controlling the mobile robot for decreasing the distance to prevent the obstacle from arriving the goal position. The robot was controlled by calculating only a few parameters. This focuses on the external environment for robot's sensors and learning methods in different conditions. Experiments were performed to elucidate the artificial immune algorithm control rules as the length of the antibody in the immune network were adjusted using this method.

References

1. Shuhua Liu, Yantao Tian, Jinfang Liu: Multi mobile robot path planning based on genetic algorithm. IEEE Trans. on Intelligent Control and Automation, Vol. 5. (2004) 4706-4709
2. Ying Zhang, Cheng-Dong Wu, Meng-Xin Li: Rough set and genetic algorithm in path planning of robot. IEEE Trans. on Machine Learning and Cybernetics, Vol. 2, (2003)698-701
3. Kawanaka H., Yoshikawa, T., Tsuruoka S.: Acquisition of Fuzzy Control Rules for a Mobile Robot Using Genetic Algorithm. IEEE Trans on Advanced Motion Control, (2000)507-512
4. N.K.Jerne: The immune system. Scientific American, Vol. 229, No. 1, (1973)52-60
5. N.K.Jerne: Idiotypic networks and other preconceived ideas. Immunological Rev., Vol.79, (1984)5-24
6. Dongbing Gu, Huosheng Hu, Jeff Reynolds, Edward Tsang: GA-based Learning in Behaviour Based Robotics. IEEE Trans. on Computational Intelligence in Robotics and Automation, Vol. 3, (2003)1521–1526