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Improving Thermal Comfort in Smart Buildings by an Artificial Immune System

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1 Extended Abstract

1.1 Introduction

Nowadays most HVAC (Heating, Ventilation and Air Conditioning) systems for residential buildings employ a single-zone, two-position control system which is simplistic. According to statistical studies, people spend 80% of their lives in buildings. Corresponding to the increasing demands for environment, comfort, energy, and productivity, advanced methods are applied for improving thermal conditions in residential buildings thanks to the dramatically rapid development of information and artificial intelligence technologies. Certainly, this kind of control system is a classic example of Cyber-Physical Systems (CPS), which are integrations of computation with physical processes, where embedded computers and networks monitor, control and affect the physical processes and vice versa [4].

In this work, based on the artificial immune system (AIS) theory [1, 2] and its advantageous properties, we try to build an intelligent system to keep the inside air temperature comfortable while reducing energy consumption [5]. The contribution of this work is threefold :

- An AIS architecture for intelligent thermal control of residential buildings is proposed, based on which it is more appropriate to build a CPS.
- An adaptive reward function to update the affinities between antibodies and antigens is designed.
- The AIS approach is compared with the traditional baseline control method, namely two-position control, and their experimental results are analysed.

1.2 Methodology

The human immune system has been proved to possess three capabilities : recognition, adaptation and memory. When the human body is invaded by a specific pathogen or antigen, it will be recognized and bound by specific antibodies to be tagged for attack or neutralised to death. The regions of the antibodies that match the antigens are called paratopes, while the counterpart regions of the antigens are called epitopes. Recent studies on immunology have clarified that each antibody has also its antigen determinant part called idiotope, which means that an antibody can not only recognize antigens, but also other antibodies. This self-organizing property enables the immune system to maintain an effective dynamic set of antibodies in order to deal with antigens. Based on this fact, N. K. Jerne proposed a model called Jerne's Idiotypic Network [3]. The network is defined by stimulation/suppression links between antibodies and the degrees of correlation are measured by affinities.

Our immune-system-based architecture is an interpretation of Jerne's theory. The main principle of this architecture is that each antibody represents a possible action of the system, its paratopes mean the preconditions under which the action is stimulated, and its idiotopes interlink other antibodies as a network to memorize some knowledge (the degree of the linkage is expressed by affinity). In other words, it is an arbitration mechanism that allows the choice of an action according to antigens, knowledge learnt and the continuous computation of affinities among these antibodies.

The interface of the system is shown in Figure 1. In this figure, building thermal model is simulated in Simulink, the heating system is built as an control agent in a java multi-agent framework named JADE and a middleware called

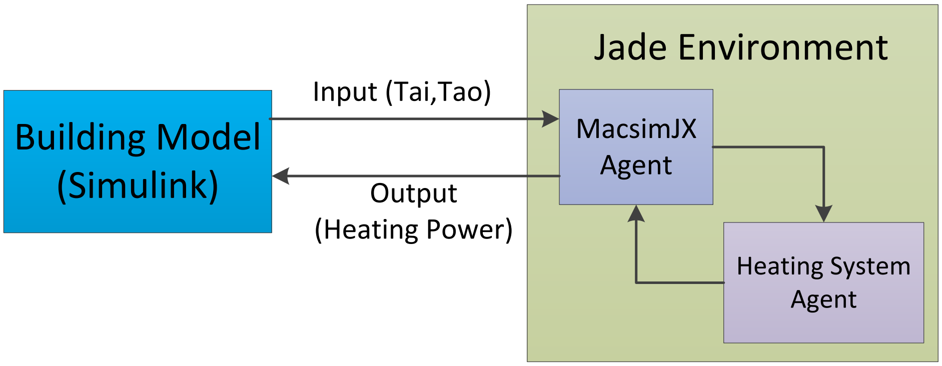
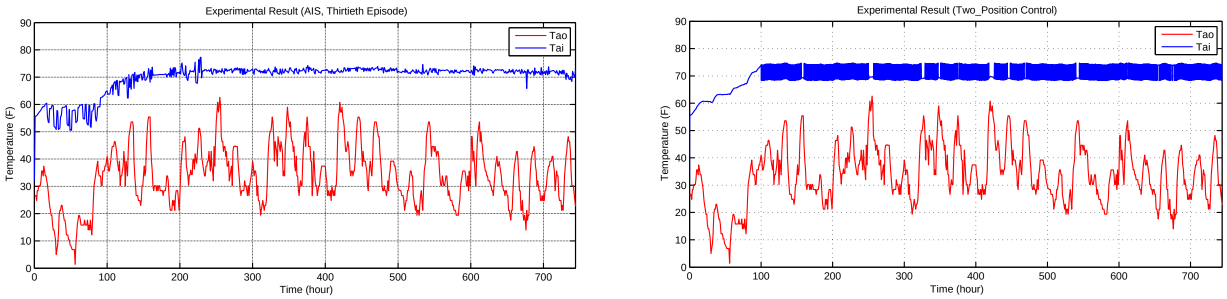


FIGURE 1 – Interface of the System

MacsimJX is engaged in supporting the communication between Simulink and JADE. At every certain time intervals, the thermal sensors of the building can record the present indoor and outdoor temperature and packaging them as an input send to MacsimJX Agent. This agent then repackages it as an antigen and sends it to Heating System Agent, which contains the idiotypic network and can operate the immune response mentioned above. After the arbitration process, the physical heating system in Simulink environment will be notified with a magnitude of power.

1.3 Experimental Results



(a) Experimental Result (AIS, Thirtieth Episode)

(b) Experimental Result (Two_Position Control)

FIGURE 2 – Experimental Results

By implementing AIS, through thirty episodes' training, a good experimental result can be obtained (see Figure 2a). This figure shows the variations of the outside air temperature (red line) and the inside air temperature (blue line) of Golden, CO in January 1999 (totally 744 hours). From the figure, after 5 days' very cold weather, the inside air temperature is maintained at $72^\circ F$ almost steadily. This is because the idiotypic network is organized with different antibodies and after being stimulated by the antigens a number of times, it can evolve into a good decision-making structure. The total energy consumed during this episode is 1,464,000 BTU.

Figure 2b reveals experimental results of two-position control. For two-position control, the output power is 3500 BTU/ hour when the heating system turns on, otherwise it equals 0. In order to keep a comfort temperature, the heating system has to turn on and off frequently, which may damage the physical system. The total energy consumed is 1,491,000 BTU.

1.4 Discussion

Based on the simulation results, the immune system has exhibited a more comfortable indoor circumstance and at the same time achieved the reduction of energy consumption (1.81% less than two-position control). Besides, as presented above, in order to maintain a set comfortable indoor temperature, the two-position control have to switch off and on frequently, while immune system does not so makes it be able to prolong equipments' service life. Last but not least, thanks to its innate properties, artificial immune system architecture is more suitable for distributed application and multi-agent paradigm.

Références

[1] Leandro Nunes de Castro and Fernando José Von Zuben. Artificial immune systems : Part i–basic theory and applications. *Universidade Estadual de Campinas, Dezembro de, Tech. Rep*, 1999.

[2] Leandro Nunes De Castro and Fernando José Von Zuben. Artificial immune systems : Part ii–a survey of applications. *FEEC/Univ. Campinas, Campinas, Brazil*, 2000.

[3] N. K. Jerne. Towards a network theory of the immune system. *Annals of Immunology*, 125(C) :373–389, 1973.

[4] Edward A Lee. Cyber-physical systems-are computing foundations adequate. In *Position Paper for NSF Workshop On Cyber-Physical Systems : Research Motivation, Techniques and Roadmap*, volume 2. Citeseer, 2006.

[5] Jiawei Zhu, F. Lauri, A. Koukam, V. Hilaire, and M.G. Simoes. Improving thermal comfort in residential buildings using artificial immune system. In *2013 IEEE 10th International Conference on Ubiquitous Intelligence and Computing*, pages 194–200, Dec 2013.