Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 145 (2016) 267 – 273

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Sustainable Design, Engineering and Construction

Application of Clonal Selection Algorithm in Construction Site Utilization Planning Optimization

Xi Wang [a,*], Abhijeet S. Deshpande [b,*], Gabriel B. Dadi [a], and Baris Salman [c]

[a] *Department of Civil Engineering, 382 Raymond Building, University of Kentucky, Lexington, KY 40506-0281, US*
[b] *Department of Civil & Architectural Engineering and Construction Management, 795 Rhodes Hall, University of Cincinnati, Cincinnati, OH, US*
[c] *Department of Civil and Environmental Engineering, 151H Link Hall, Syracuse University, Syracuse, NY,US*

Abstract

Various algorithms inspired by evolutionary and physical processes have been extensively applied in solving complex construction engineering optimization problems. In this paper, Artificial Immune Systems (AIS), a computational approach inspired by the processes of human immune system, is introduced in terms of its basic mechanisms and its applications in construction engineering. Specifically, Clonal Selection Algorithm (CSA), one of main algorithms that form AIS, is based on clonal selection process of the immune system which includes the selection, hypermutation, and receptor editing processes. We discuss the CSA in detail and present its application in the classic construction optimization problem, construction site utilization planning (CSUP), which is the decision making process for identifying the most optimal layout of temporary facilities designed to support the construction process. When applied to a test case published in research literature, we found that CSA shows a robust capacity to search the solution space effectively and efficiently.

Peer-review under responsibility of the organizing committee of ICSDEC 2016

Keywords: Optimization, Artificial Immune Systems, Clonal Selection Algorithm, CLONALG

1. Introduction

Algorithms inspired by various natural and physical phenomena are being extensively used to develop intelligent systems and to provide solutions to complicated problems in civil engineering. For example, Genetic Algorithm (GA), an algorithm inspired by natural evolutionary processes, has been applied to various problems such as optimization of construction site layouts [1, 2], project scheduling [3-5], structural optimization [6, 7]. In this paper, we present a novel computation strategy, Artificial Immune System (AIS), which has been inspired by the biological process of human immune systems. The Clonal Section Algorithm, Negative Selection Algorithm and Immune

Peer-review under responsibility of the organizing committee of ICSDEC 2016
doi:10.1016/j.proeng.2016.04.073

Network Algorithm are the three main algorithms developed from the principles of Artificial Immune Systems. Since the foundational principle of immunology is the clonal selection theory, the Clonal Selection Algorithm is the most representative algorithm inspired by the AIS theory. In this paper, we discuss the biological processes underlying the AIS algorithms, and specifically illustrate the Clonal Selection Algorithm with an example.

2. Biological Immune Process

The immune system is a natural, fast and effective defense mechanism for a host body against infection brought by invaders from outside. The immune system is composed of two subsystems, the innate system and the adaptive system. The innate system is the first line of defense against a wide variety of invaders such as bacteria. Once the innate system fails to recognize the invaders, then the adaptive immune system is activated to do the further protection of the host [8, 9]. It is known as the specific immune system that has highly specialized cells (B-cells and T-cells) and processes that eliminate or prevent antigen's growth. At the same time, it creates immunological memory after an initial response to a specific pathogen, leading to a strengthened response to the same kinds of antigens in the future so the system is described as "adaptive". The adaptability is because of the somatic hypermutation process. It is a process of genetic recombination of gene segments on receptors. This mechanism allows a small number of genes to generate a large number of different antigen receptors, which are then uniquely expressed on each individual lymphocyte. All of the offspring of that cell then inherit the specificity of their parents. It indicates the important capacities of the adaptive immune system are memory and learning [10]. To be more specific, the T-cells are activated once they are stimulated by antigens. T-cells divide and secrete chemical signals to stimulate the B-cells. After that, the B-cell will proliferate and differentiate into plasma cells that secrete antibodies to destroy the antigens. At the same time, some activated B-cells will also differentiate into memory cells that are used for future protection against same antigens [10, 11].

3. Clonal Selection Algorithm (CLONALG) and Application

The theoretical model of the clonal selection process proposed by Burnett provided the inspiration for the Clonal Selection Algorithm (CSA) [12, 13]. During selection, only the cells that recognize the antigens are selected to proliferate. During the proliferation (cloning), the ability of reaction with antigen is strengthened by a hypermutation process called affinity maturation which is the result of random genetic recombination. After reproduction and affinity maturation, the cells can be further selected through receptor editing. This process eliminates parts of individuals with worse affinities and introduces new ones to replace them. Both processes increase the diversity of the population of cells so that at least one cell creates an antibody with the receptor capable of recognizing and binding with antigens. For the next proliferation, cells are selected and optimized through mutation from the cells of the previous generation rather than generating random ones. This scheme presents learning and memory capability of immune system. It increases the selection reaction speed and mutation accuracy so that the organism is able to adapt to the environment fast. The CLONALG uses the clonal selection, clonal expansion, hypermutation and the receptor editing mechanisms, consisting of 7 steps: Population initialization, Affinity Evaluation, Clonal Selection, Cloning (proliferation), Hypermutation, Affinity Evaluation and Receptor Editing, Convergence and Termination. The detail of each step will be discussed in the next section.

This paper presents the implementation of Clonal Selection Algorithm in construction site utilization planning (CSUP). CSUP is the decision making process for determining the locations of temporary facilities within the boundary of a construction site by identifying spatial, functional relationships between the temporary facilities. Its objective is to identify an optimal layout from a large number of alternative solutions so that a set of predetermined facilities are appropriately located while satisfying site specific constraints [1, 14]. In this paper, the application of the Clonal Selection Algorithm in construction site layout optimization is presented with a data set from a published study. In an early, pioneering study, Li and Love [1] used Genetic Algorithm for solving site layout optimization problem. One of effective and direct ways to analyze and evaluate Clonal Selection Algorithm is to compare the results obtained from the two algorithms, so data sets from the published study have been used for the objectivity and comparability of the research. Representation (Encoding) Scheme