Aitso: an artificial immune systems tool for spatial optimization

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1. Introduction

The process during which a spatial entity achieves the optimal status under certain constraints is referred to as spatial optimization (Xiao 2008). It has recently become one of the critical issues in environmental research since it is key to the environmental management and planning processes. Most practical environmental problems can be regarded as a typical spatial optimization process, such as spatial sampling optimization (Di Zio, Fontanella et al. 2004, Romary, de Fouquet et al. 2011), environmental monitoring network design (Martinez, Merwade et al. 2010, Do, Lo et al. 2012), land-use optimization (Holzkaemper and Seppelt 2007, Cao, Huang et al. 2012), etc. Spatial optimization in environmental modeling generally involves various high-dimensional, non-linear, and complex relationships. The majority of the traditional spatial or geostatistical models provided by geographical information systems (GIS), however, are limited in their ability to address such problems. Under such circumstances, artificial immune system (AIS) has been advocated and has proven to be promising in spatial optimization.

AIS can be defined as intelligent and adaptive computational systems inspired by theoretical immunology principles and mechanisms in order to solve real-world problems (Dasgupta 1998, de Castro and Timmis 2003). Although the previous studies have greatly contributed to AIS development, they have failed to advance the applicability to spatial optimization research, given that performing AIS requires knowledge of computing. Besides, the algorithms described before were too problem-specific, and a user-friendly professional software is still unavailable, which is a great impediment to the popularity of artificial immune systems.

Hence,This paper describes free, accessible software, named Aitso, which is capable of solving various optimization problems. Aitso has been developed based on "plugin-host" architecture by the use of C# language and the open-source GIS components called DotSpatial. Since the clonal selection algorithm (CSA) proposed by de Castro (de Castro and Von Zuben 2002) is the most outstanding and most commonly used immune algorithm in spatial optimization studies; therefore, the immune algorithm integrated into the platform in this study is the clonal selection algorithm, and the other immune algorithms will be integrated in our future studies.

2. Framework of the clonal selection algorithm for spatial optimization

A unified algorithm framework is a prerequisite for the establishment of a universal platform. Such an algorithm framework must meet two basic requirements. For one thing, the framework must be extensible as, in practice, algorithms are usually revised and improved to solve specific problems. For another, the algorithms or operators that are integrated into the framework must be reusable. When a new algorithm or operator is developed, it should be able to be used in other cases.

We referred to the principle proposed by M. Keijzer (Keijzer, Guerv\ et al. 2002). Here, the immune algorithms are decomposed into two parts; one includes the common immune mechanism, and the other is problem-specific. Two steps are included, as follows:

1. The process of an immune algorithm involves several basic steps based on the classical clonal selection algorithm proposed by (de Castro and Von Zuben 2002). As shown in Fig. 1, all the clonal selection based algorithms can be decomposed into eight steps: initialization, evaluation, selection, cloning, mutation, re-selection, replacement, and decoding.
2. All the immune operators mentioned above can be divided into two categories, according to whether or not the operator has to operate the genes of an antibody. Since the data structure of genes is usually problem-specific, the operators which need to change the genes have to know the data structure of the genes.

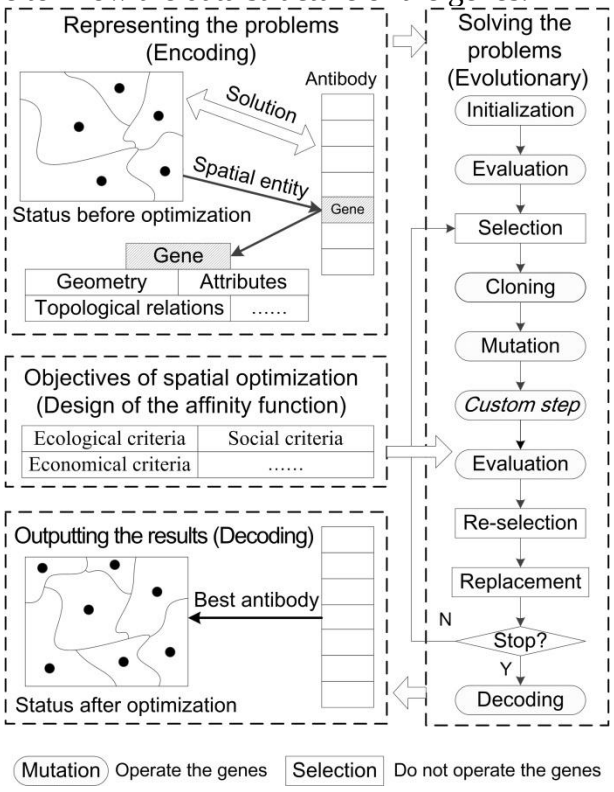

Figure 1. The framework of the clonal selection algorithm for spatial optimization.

3. Features of Aitso

Aitso was developed based on the open-source DotSpatial GIS components (http://dotspatial.codeplex.com). The C# 4.0 programming language was chosen to develop Aitso, as with DotSpatial. The technology of assembly reflection provided by the .NET Framework is a very powerful and convenient tool for building operators or application plugins. Furthermore, parallel programming technology has been introduced to the .NET Framework 4.0, which is a very useful tool for promoting the performance of computation. The main graphical user interface (GUI) of Aitso is shown in Figure. 2.

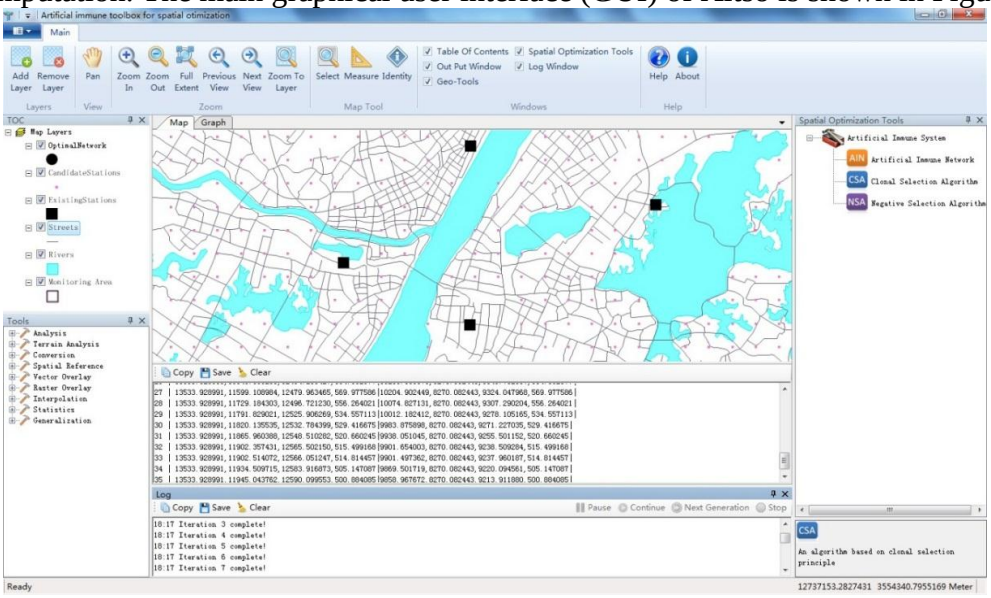

Figure. 2. Main GUI of Aitso.

To meet the different demands from these users, Aitso has adopted a very flexible architecture based on a "plugin host" structure to build the platform. As shown in Fig. 3, Aitso is composed of four key components: the foundation class library, the immune operator library, the application library, and the host program. The function and the relationships between the four components are described as follows.

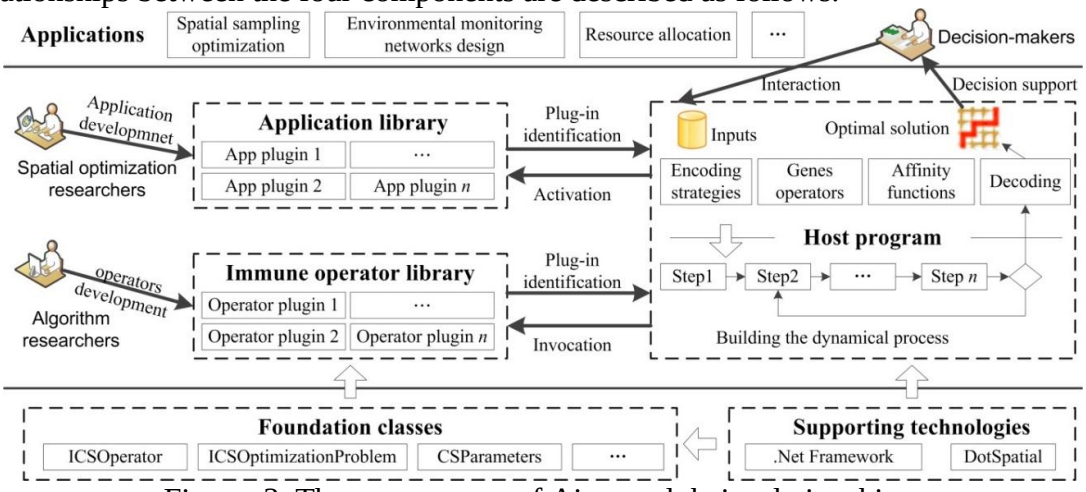

Figure. 3. The components of Aitso and their relationships.

The foundation class library comprises the definition of the fundamental abstract classes, interfaces, enumerations, and some ancillary classes.

All the immune operators are stored in a folder named “Operators”, in the form of dynamic link library (DLL) files. Algorithm researchers or anybody who wants to improve the performance of the algorithms can use the “ICSOperator” interface to develop a novel operator plugin.

Similar to the “immune operator library”, the “Application library” is a folder named “Problems”, which stores many application plugins. An application plugin is a DLL file which has packaged one or more spatial optimization problem classes inherited from “ICSOptimizationProblem”. Once an application class is activated, the host program can obtain the description, parameters from the instance of the class and show them to the final users.

4. Conclusions

This paper describes free, accessible software, named Aitso, which is capable of solving various optimization problems. Aitso has been developed based on “plugin-host” architecture by the use of C# language and the open-source GIS components called DotSpatial. It provides a series of standard application programming interfaces (APIs) which can: (1) assist researchers in the development of their own problem-specific application plugins to solve practical problems; and (2) allow the implementation of some advanced immune operators into the platform to improve the performance of an algorithm. The functionality, reusability and extensibility of Aitso is tested here using a simple spatial optimization model, which is used for solving an environmental monitoring network optimization problem, is also implemented as a case study to demonstrate how to solve such a typical environmental modeling problem in Aitso. As an integrated, flexible and convenient tool, Aitso contributes to knowledge sharing and practical problem solution. It is therefore believed that it will advance the development and popularity of spatial optimization in environmental modeling.

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