

Artificial Immune System for Multi-Objective Land-use Allocation (AIS-MOLA) User Manual

1. Introduction to AIS-MOLA

Thank you for using the software of Artificial Immune System for Multi-Objective Land-use Allocation (AIS-MOLA). AIS-MOLA was proposed and developed by Mr. Kangning Huang, under the guide of Prof. Xiaoping Liu and Prof. Xia Li, and assisted by Ms. Jiayong Liang, all of whom are with School of Geography and Planning, Sun Yat-Sen University.

AIS-MOLA aims to solve multi-objective land-use allocation problem by using an improved artificial immune system (AIS). By seeking the Pareto front of multiple land-use planning objectives, this software is able to reveal the possible trade-offs between these objectives. The revealed trade-offs can inform land-use planners about how much deterioration on other objectives will be caused by improving one certain objective, and will provide potentially useful supports for land-use planning activity.

In AIS-MOLA, the land-use allocation is represented by a two-dimensional grid with R rows and C columns and there are K different kinds of land uses that can be allocated to each cell (i, j) . Thus, the spatial pattern of the allocation solution can be formulated mathematically as a binary decision variable x_{ijk} , with 1 if the k -th land use is allocated to cell (i, j) , and 0 if otherwise. In such way, the solution is represented as an $R \times C$ dimension binary decision vector $\mathbf{X} = \{x_{ijk}\}$.

In this first version of AIS-MOLA, only the spatial suitability and spatial compactness are taken into account:

- (1) Maximizing the suitability of land use

Set $suit_{ijk}$ as the suitability of cell (i, j) for the k -th land use, and the total suitability of the study region is:

$$suit_{total} = \sum_{i=1}^R \sum_{j=1}^C \sum_{k=1}^K (suit_{ijk} \square x_{ijk}) \quad (1)$$

To define a dimensionless objective, we normalize the suitability by:

$$f_{suit} = \frac{suit_{total} - suit_{min}}{suit_{max} - suit_{min}} \quad (2)$$

where $suit_{max}$ is the total suitability when each cell is allocated by a land use with maximum suitability, and $suit_{min}$ is that allocated by those with minimum suitability. The value of f_{suit} is within the range of $[0,1]$.

(2) Maximizing the spatial compactness of land use

Set L_{total} as the total perimeter of all land use patches. The shorter the total perimeter, the more compact is the allocation solution. The compactness objective is defined as follow:

$$f_{comp} = \frac{L_{total} - L_{min}}{L_{max} - L_{min}} \quad (3)$$

where L_{max} and L_{min} can be calculated as:

$$L_{max} = \sum_{k=1}^K (4Q_k) \quad (4)$$

$$L_{min} = \sum_{k=1}^K \left(2\pi \sqrt{\frac{Q_k}{\pi}} \right) \quad (5)$$

If every selected site is separated from each other, the possible maximum perimeter L_{max} can be obtained by Equation (4). As the amount of each land use Q_k is known, the possible minimum perimeter can be formulated as the perimeter of a circle with the same area by Equation(5).

In the future version of AIS-MOLA, there will be more pragmatic planning objectives available. Moreover, the users may customize their own objectives.

2. Description of the optimization procedure

The optimization algorithm behind this software is designed based on the conceptual framework of AIS, equipped with three modified immunological operators, namely, 1) a heuristic hyper mutation based on compromise programming is developed to improve efficiency; 2) the non-dominated neighbour-based selection and proportional cloning method is introduced to make the immune system pay more attention to less-explored regions; and 3) a novel crossover operator that preserves connected land-use patches is designed to generate better solutions. The main procedure of AIS-MOLA is as follow (also illustrated in Figure 1):

Step1: Initialization. Initialize the antibody population \mathbf{B}_t as a set of randomly generated decision vectors with size n_B . Create the initial extended Pareto set as $\mathbf{P}_t = \emptyset$. Set $t = 0$.

Step2: Hyper mutation. Apply hyper mutation operator $\mathbf{T}^H(*)$ to \mathbf{B}_t , and get the resulting population \mathbf{B}_t^* .

Step3: Update extended Pareto set. Set the dominant population \mathbf{D}_t as the dominant antibodies in \mathbf{B}_t . Copy \mathbf{D}_t to the extended Pareto set, and remove all dominated antibodies in \mathbf{P}_t .

Step4: Clonal selection. Calculate the crowding distance of each antibody in \mathbf{D}_t , then get the clone population \mathbf{C}_t by performing proportional cloning $\mathbf{T}^C(*)$ on \mathbf{D}_t .

Step5: Recombination. Perform recombination $\mathbf{T}^R(*)$ on \mathbf{C}_t with randomly selected antibodies from \mathbf{D}_t , then get the next generation of antibody population \mathbf{B}_{t+1} by combining the resulting population and \mathbf{D}_t .

Step6: Termination. Set $t = t + 1$. If $t < t_{max}$, go to Step2; otherwise, terminate the procedure.

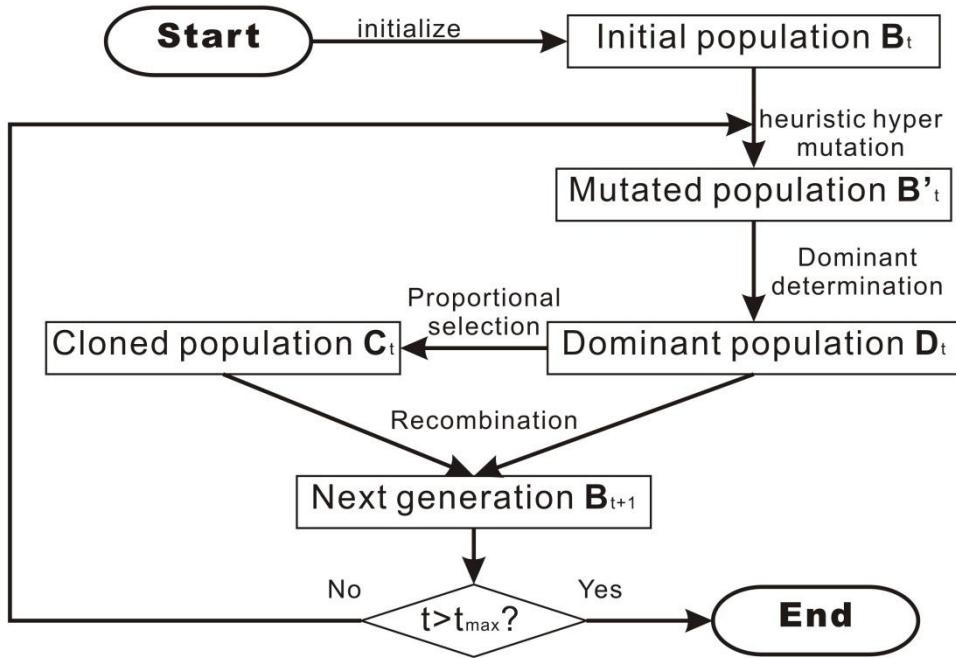


Figure 1

More details about this procedure and the three modified operators are presented in a forthcoming article. The link to the corresponding article will be provided as soon as it is published.

3. How to use AIS-MOLA

3.1 Download and Setup

AIS-MOLA can be downloaded from <http://www.geosimulation.cn/AIS-MOLA/index.html>. It has been packed into a compressed file called “AIS-MOLA.zip”. Unpack the file, execute “AIS-MOLA.exe”, then the main form (Figure 2) will show up.

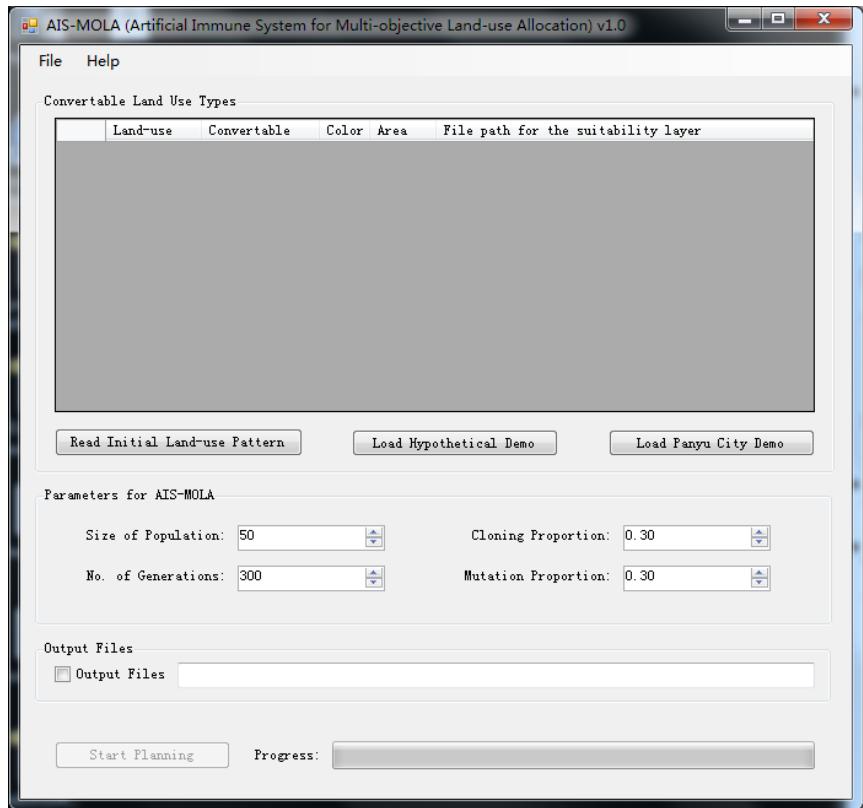


Figure 2

3.2 Data Preparation

Before running the software, an land-use allocation dataset is required, including the initial land-use pattern, the areas for convertible land-use types and the spatial suitability layer for each type. All of these two-dimensional grid layers must be in format of ASCII, converted by the “Raster to ASCII” function in ArcGIS. More importantly, remember to align these layers and clip them into same size.

First of all, click the button **Read Initial Land-use Pattern**, or “File -> Read Initial Land-use Pattern” to open a file dialog (Figure 3):

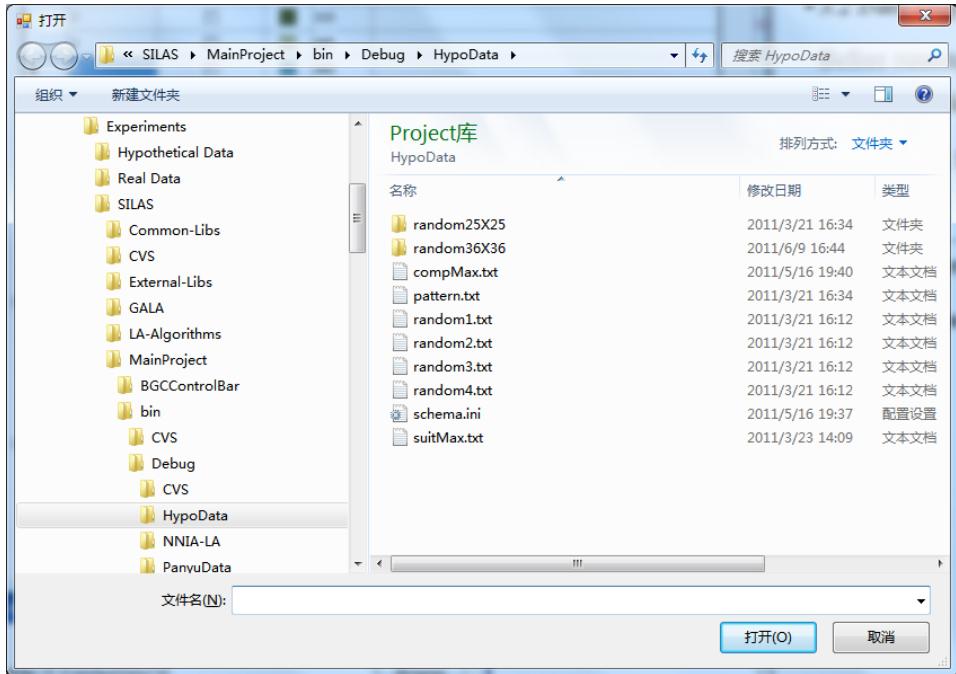


Figure 3

Browse and select the ASCII file of initial land-use pattern. The initial land-use pattern is a layer with integer numbers, representing different land-use types. For instance, the ASCII file of the initial land-use pattern in the hypothetical demo is shown in Figure 4.

```
pattern.txt - 记事本
文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)
hcols      36
nrows      36
xllcorner  0
yllcorner  0
cellsize    1
NODATA_value -9999
4 1 4 2 1 2 4 1 2 2 4 4 1 3 4 2 4 3 2 1 3 3 1 1 4 2 2 2 2 3 4 2 3 1 1 4
2 4 3 2 1 2 3 4 2 4 4 4 1 4 4 1 2 1 2 2 4 3 1 1 1 2 1 2 2 2 1 2 3 4 1 1
1 1 3 3 2 2 3 1 3 3 2 1 3 4 1 1 1 2 1 3 3 4 2 4 1 1 3 1 3 3 4 2 4 2 3 3 1
1 2 2 2 3 3 3 4 2 4 2 1 1 1 4 4 3 1 4 3 1 3 1 4 3 2 2 3 1 4 4 2 1 1 4 1
3 1 2 4 2 3 1 3 2 3 3 3 2 4 3 4 2 2 3 2 4 3 2 3 4 2 1 3 1 4 2 3 4 3 3 4
4 2 1 1 4 2 3 4 4 2 1 1 1 2 2 2 4 4 2 3 3 3 3 1 3 2 3 2 4 3 4 1 4 1 1 1
4 3 2 3 1 1 2 1 1 4 2 2 2 1 2 3 4 3 2 2 1 2 1 3 3 4 1 4 4 1 2 1 4 4 1 2 2
2 1 3 4 3 4 2 2 4 4 2 3 1 3 1 4 4 1 2 2 2 3 1 4 3 2 1 2 2 3 1 4 1 4 2 3
4 4 2 4 3 4 4 2 1 4 3 4 1 2 1 1 1 4 3 4 4 2 2 3 3 4 4 1 3 1 1 2 4 4 4 1
1 1 2 2 3 4 4 3 4 4 3 1 4 3 3 3 3 2 3 4 2 3 2 1 1 3 2 3 4 4 1 3 2 1 3 1
3 2 2 3 4 2 4 4 4 1 3 4 3 2 3 1 2 1 4 4 1 3 3 4 3 3 4 3 3 4 3 3 4 4 2 3
3 4 1 4 2 3 1 2 4 3 4 1 2 4 2 4 2 4 1 1 4 1 1 1 2 2 2 1 4 4 3 4 4 3 2 3
1 3 2 3 2 2 3 3 3 2 2 2 3 3 2 4 1 1 2 2 1 3 2 4 1 3 3 2 3 2 1 1 4 4 1 2
4 1 1 3 1 1 2 3 2 2 2 2 1 2 2 3 4 4 1 1 1 2 2 4 4 4 3 2 4 4 2 3 1 1 4 3
4 4 2 2 4 2 2 4 2 3 2 2 2 4 3 3 1 1 3 1 3 2 2 2 4 2 3 3 2 1 3 2 4 4 3 3
2 1 3 4 4 4 1 1 3 4 4 3 2 2 1 2 3 2 1 2 1 3 4 1 4 1 1 1 1 1 1 2 3 3 1
1 3 1 1 2 4 3 2 2 4 4 3 4 3 2 4 1 2 1 4 1 2 3 2 3 3 2 4 3 2 2 2 1 4 2 3
2 2 3 2 3 4 2 4 1 2 2 2 1 4 1 3 1 2 3 4 3 4 3 2 1 4 3 4 3 2 1 1 1 2 1 4 3
3 3 2 2 3 4 1 2 3 3 4 4 2 1 2 1 4 2 2 4 3 4 1 1 4 4 2 4 2 2 2 3 2 2 4 4 4
3 3 1 2 2 2 1 3 1 4 4 1 4 1 2 1 3 4 1 1 1 4 2 4 2 1 4 2 2 2 3 2 1 2 2 2
4 4 3 1 1 1 4 4 3 1 2 3 3 3 1 3 2 4 1 4 3 2 2 3 4 3 4 1 4 2 2 4 4 4 2 1
2 2 4 1 1 2 2 4 3 3 3 4 2 3 4 3 4 1 2 2 2 4 3 4 1 4 1 1 1 2 3 2 1 1 1 1
1 2 2 3 4 3 4 3 1 3 1 1 4 1 2 4 1 4 2 4 1 1 3 2 1 4 3 3 1 4 2 2 1
1 4 4 1 3 3 3 1 2 4 3 3 4 4 4 1 4 4 3 4 4 1 4 3 2 4 2 2 1 3 1 1 4 2 3 4
4 4 1 4 2 2 1 3 4 1 1 1 3 2 4 2 2 4 3 4 4 4 2 2 4 3 3 4 4 1 2 1 3 4 4 4
```

Figure 4

After loading the initial land-use pattern, different land-use types will be identified and their corresponding areas will be counted and listed in the table (Figure 5). Edit the attributes of each type, namely, whether it is convertible, the colour to be rendered and the occupied areas.

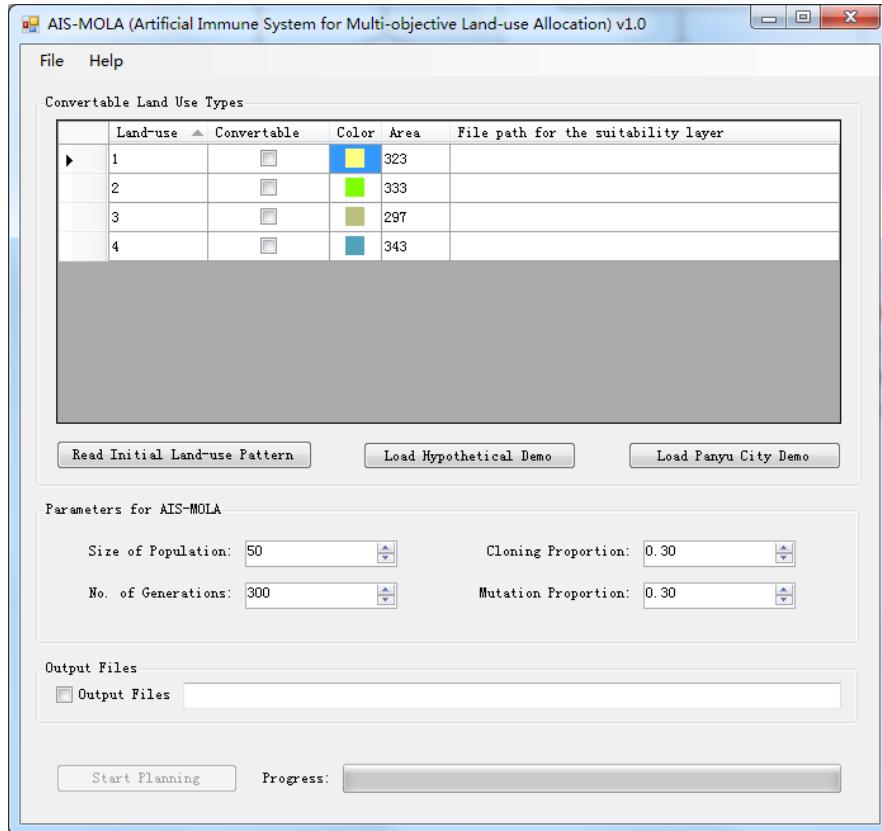


Figure 5

For each convertible land-use type, there must be a corresponding spatial suitability layer. Therefore, once click on the “convertible” attribute, a file dialog will pop up for choosing one.

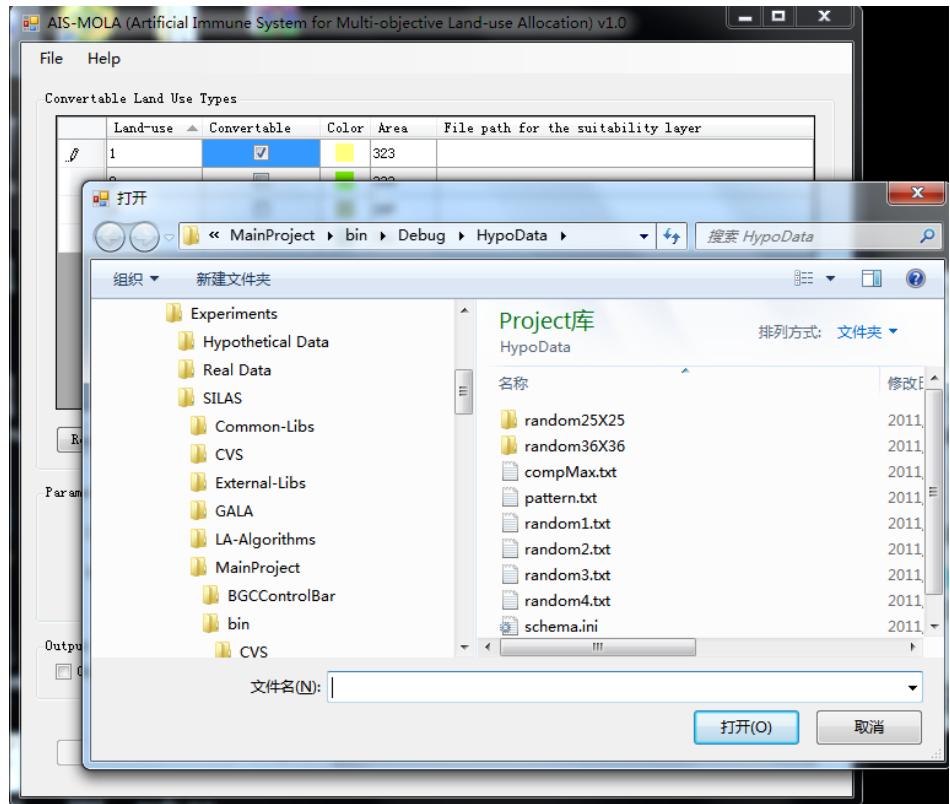


Figure 6

Finally, after setting up all the attributes for each land-use type, the table should look like Figure 7.

| Convertible Land Use Types | | | | | |
|----------------------------|----------|-------------------------------------|--------------------------------------|------|-------------------------------------|
| | Land-use | Convertable | Color | Area | File path for the suitability layer |
| ▶ | 1 | <input checked="" type="checkbox"/> | ■ | 324 | D:\项目\国家自然科学基金(刘小平)_土地利用规划... |
| | 2 | <input checked="" type="checkbox"/> | ■ | 324 | D:\项目\国家自然科学基金(刘小平)_土地利用规划... |
| | 3 | <input checked="" type="checkbox"/> | ■ | 324 | D:\项目\国家自然科学基金(刘小平)_土地利用规划... |
| | 4 | <input checked="" type="checkbox"/> | ■ | 324 | D:\项目\国家自然科学基金(刘小平)_土地利用规划... |

Figure 7

3.3 Parameters Setup

There are 4 key parameters can be set for AIS-MOLA (Figure 8), namely, the size of the antibody population, the number of generations, the cloning proportion and the mutation proportion. The size of population is the number of artificial antibodies that will be created in the immune system. The number of generations tells the software

how many iterations will be run before terminating the optimization algorithm. The cloning proportion determines the percentage of antibodies that will be cloned at each iteration, while the mutation proportion controls the percentage of land-use cells that will be mutated in the hyper mutation operation.



Figure 8

3.4 Start the optimization process and check out the results

Have all the data and parameters set up, start the optimization process by clicking the button **Start Planning**. During the optimization process, a chart will pop up and display the distribution of the current dominated solutions.

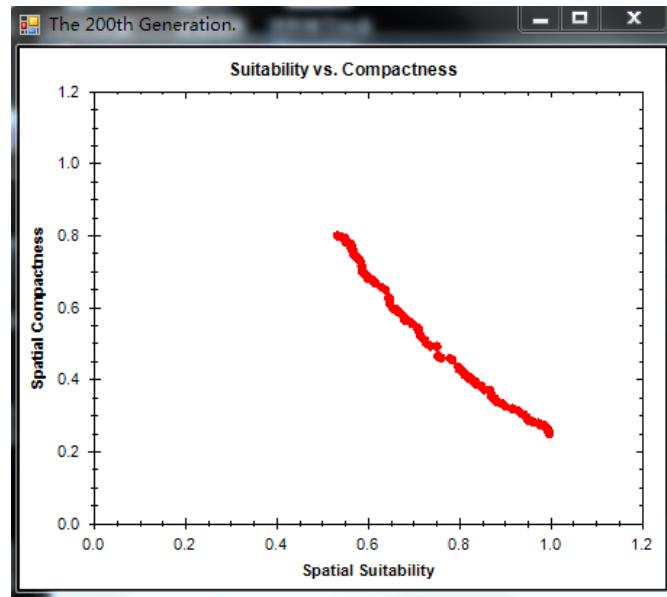


Figure 9

As soon as the optimization is finished, a dialog will be shown. Click “OK” to confirm the termination of the algorithm.

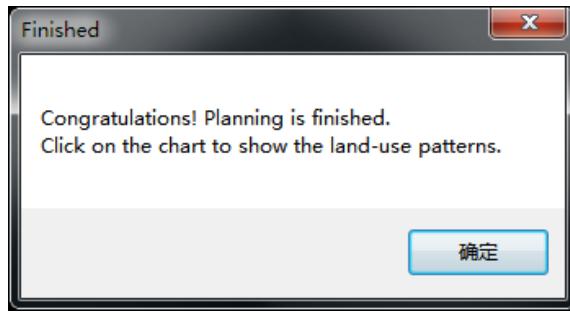


Figure 10

In this chart, every dot represents a image of one solution in objective space. To check the land-use pattern of a solution, click on the dots, then the corresponding patterns will be shown (Figure 11).

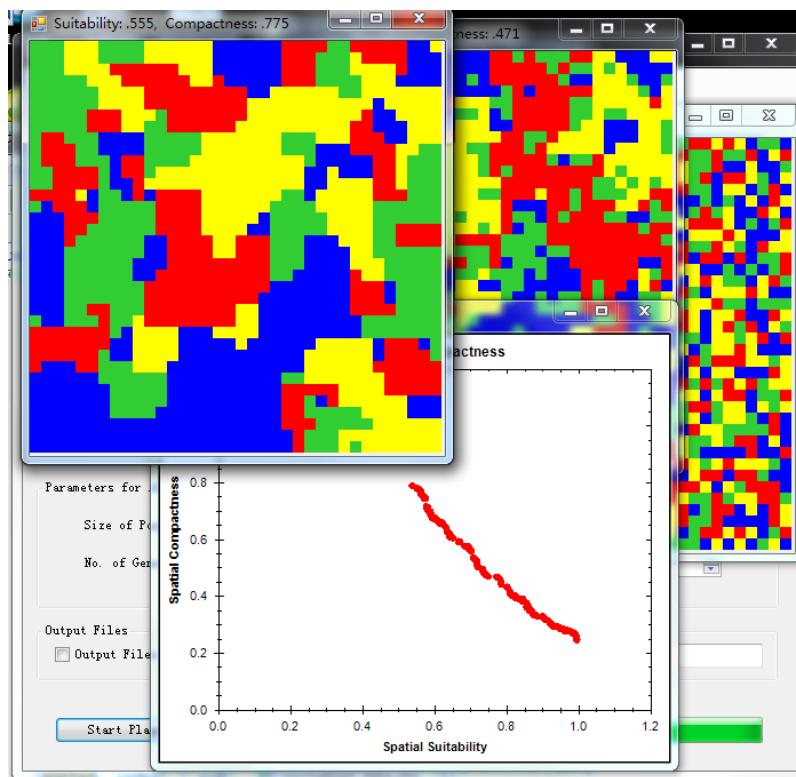


Figure 11

3.5 Run Demos of Hypothetical Dataset and Panyu City Dataset

For illustration, two AIS-MOLA demo dataset are prepared to run. Click the button

Load Hypothetical Demo

to run the hypothetical demo, or click the button

Load Panyu City Demo

to run the Panyu City demo. The results of these two demos are presented and analyzed in the aforementioned article about the algorithm AIS-MOLA.