For office use only	Team Control Number	For office use only
T1 ________________	**55280**	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**A**	F4 ________________

2021
MCM/ICM
Summary Sheet

ti

Summary

This is the **Abstract Part**

Keywords: keywords1,keywords2,keywords3

ti

February 8, 2021

Contents

1 Example For Section

1.1 Example For SubSection

1.1.1 Example For SubSubSection

Example for Fig. 1.

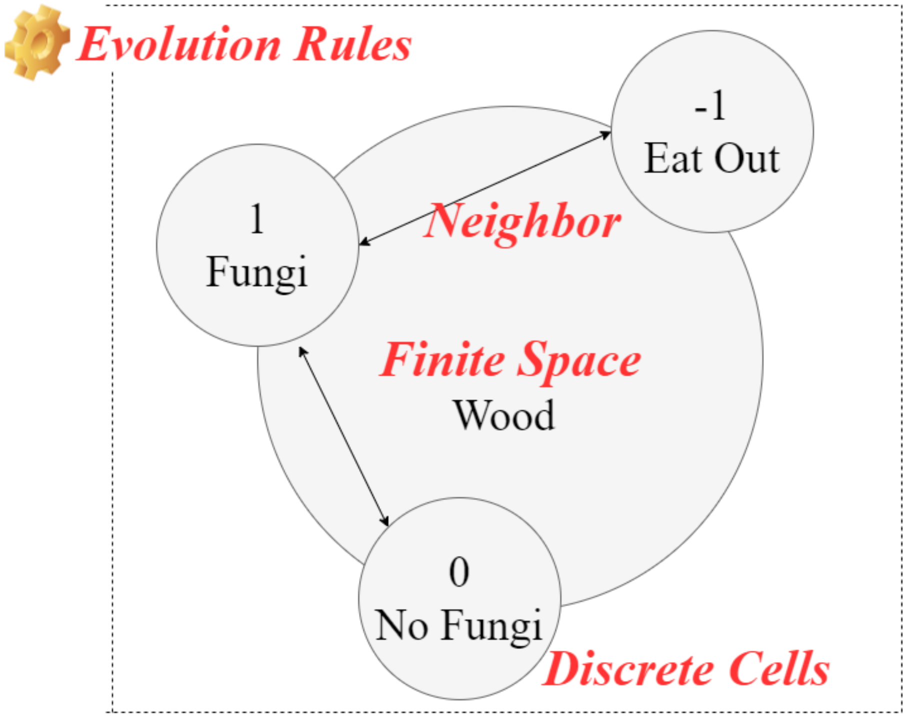


Figure 1: e.g.

Example for Tab. 1.

Table 1: e.g

	Symbol	Definition
1	2	3
1	2	3
1	2	3
1	2	3
1	2	3

Algorithm 1: Cellular Automata Simulation of F

Input: λ_0, λ_{max}, ω, $x_{0,ini}$, δ, n_{max},
Result: ΣP, f_{t1}, f_{t2}, *score*
while *there are other combinations of* (λ, n, x_0) **do**
  the distribution of the force $f(x)$
  the position of the rod $g(i, n, L, \lambda)$
  get the force on each rod $f_i(i, n, F, X, x0)$
  calculate tention $[f_{i,1}, f_{i,2}] = T_i([x0, y0], [x1, y1], [x2, y2], f_i)$
  next (λ, n, x_0)
end
Data normalization for $(f_{i,1}, f_{i,2}, (\Sigma P)_i)$
Score $= \frac{\omega}{2}(f_{i,1} + f_{i,2}) + (1 - \omega)(\Sigma P)_i$

Cellular automata is a model that defines **a finite space** and a series of **discrete cells**. These cells will automatically evolve according to the different states of their eight **neighbors** and follow certain **evolution rules**. It is a dynamic and discrete system which can simulate the growth, decomposition and competition of various fungi on the wood very well. Fig.(2) shows a brief sketch of cellular automata model.

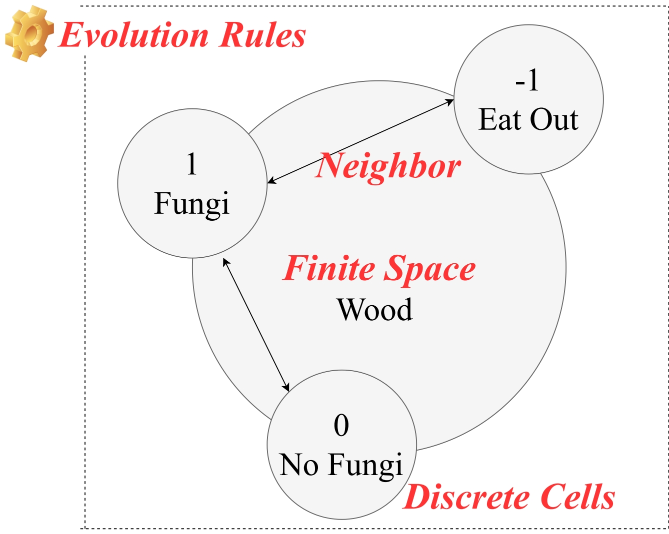


Figure 2: Cellular automata model

Fig.(6) is the **evolution rules** for the fungi cell. In the whole process, the growth speed of the cell follows the modified extension rate which is shown on Eqn.(**??**), the winning probability is defined by Elo rating system which is shown on Eqn.(**??**) and the decomposition rate is calculated by Eqn.(**??**).

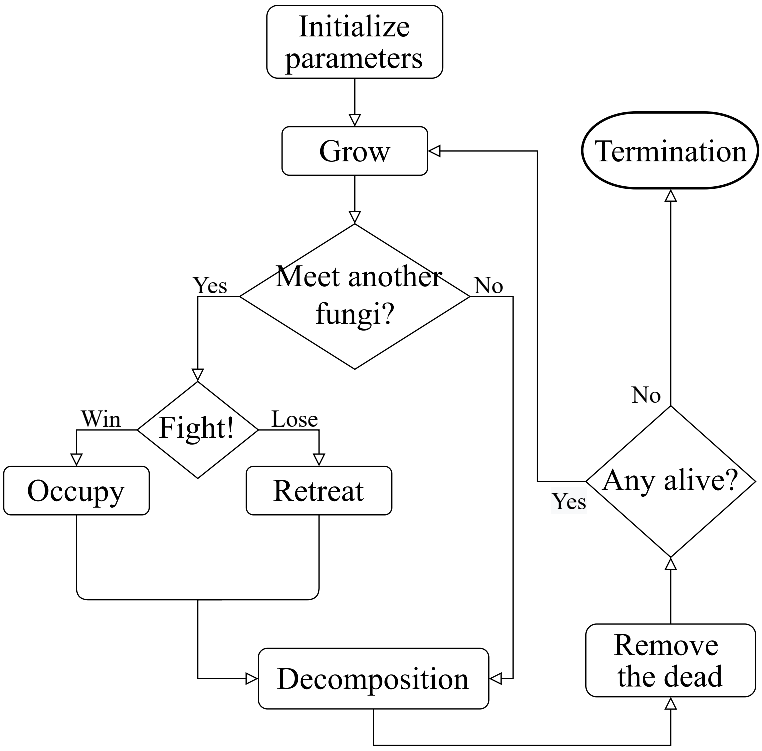


Figure 3: Algorithm schematic

Table 2: Notations

Symbol	Definition
L	Beam Length
E	Modulus of Elasticity of the Beam
I_B	Second Moment of Inertia for the cross section of the beam
h_0	The hight difference between the beam and the top
λ	Quadratic equation constant
λ	Quadratic equation constant
W	Weight of the trailer
n	Number of the rod
P_b	Unit price of the beam(1m)
P_r	Unit price of the rod(1m)
P_c	Unit price of the cable(1m)

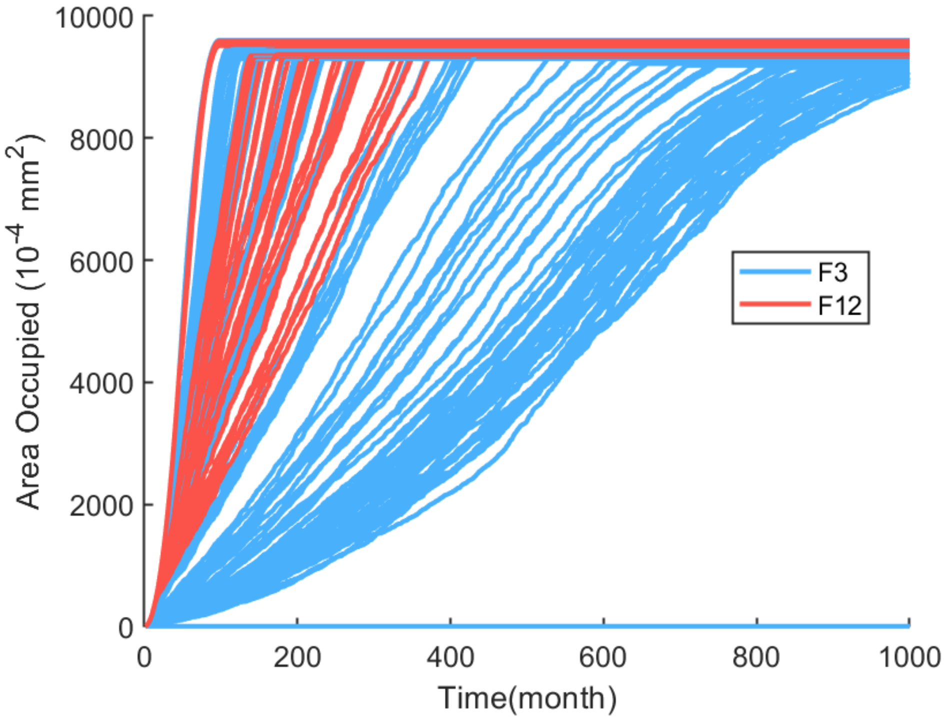


Figure 4: Algorithm schematic

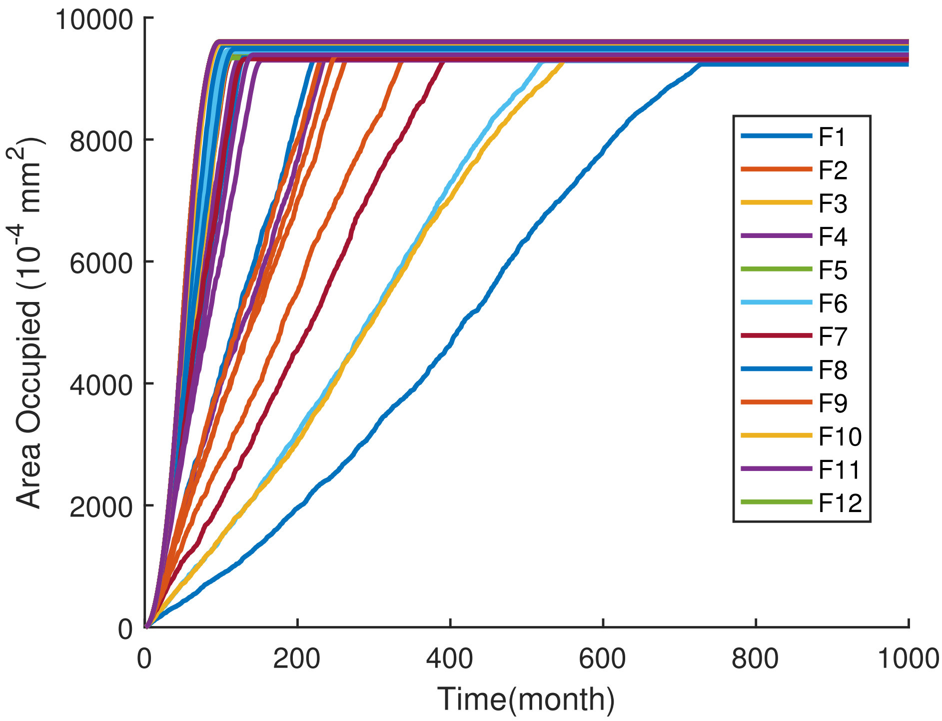


Figure 5: Algorithm schematic

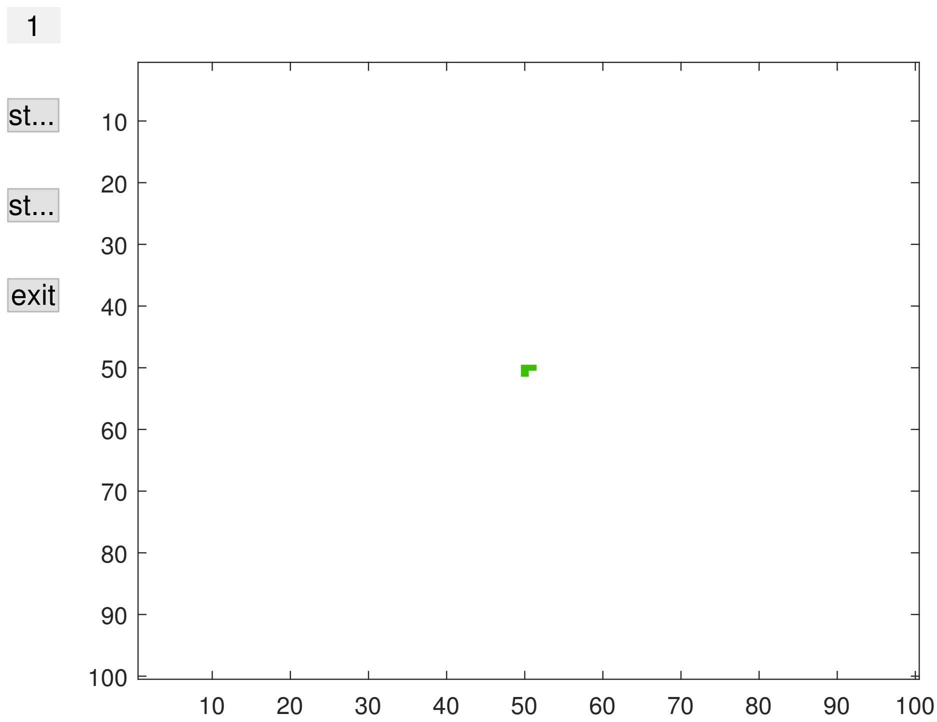


Figure 6: Algorithm schematic

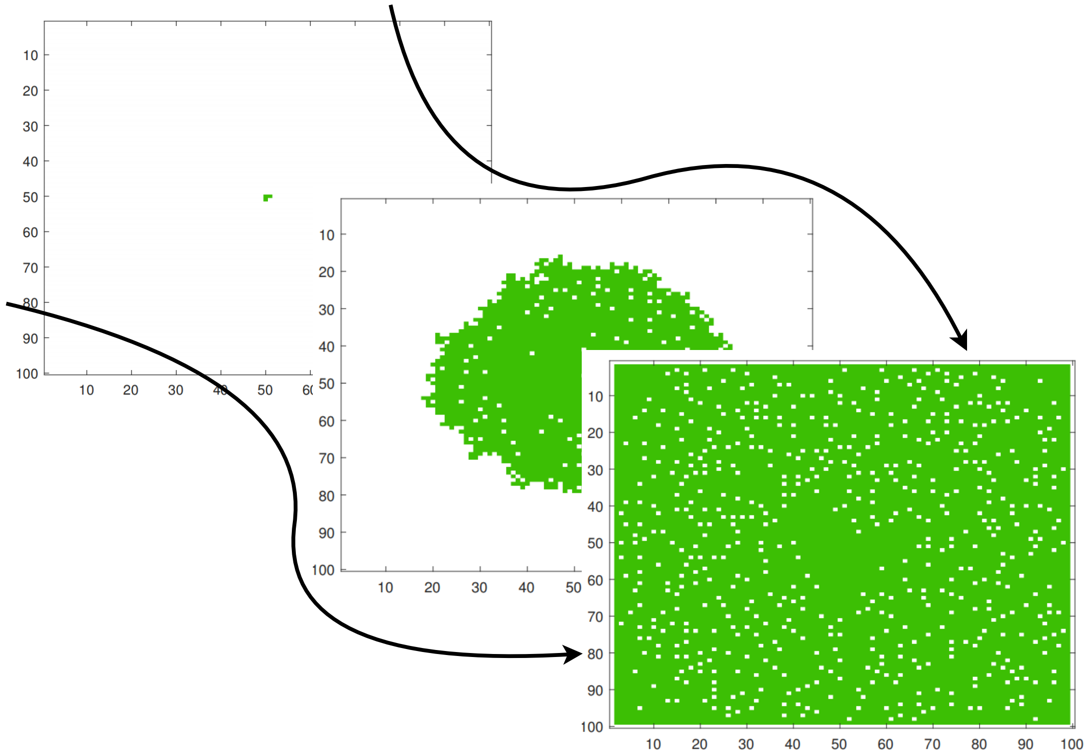


Figure 7: Algorithm schematic

Algorithm 2: Optimal Architecture

Input: λ_0, λ_{max}, ω, $x_{0,ini}$, δ, n_{max},
Result: ΣP, f_{t1}, f_{t2}, $score$
while *there are other combinations of* (λ, n, x_0) **do**
  the distribution of the force $f(x)$
  the position of the rod $g(i, n, L, \lambda)$
  get the force on each rod $f_i(i, n, F, X, x0)$
  calculate tention $[f_{i,1}, f_{i,2}] = T_i([x0, y0], [x1, y1], [x2, y2], f_i)$
  next (λ, n, x_0)
end
Data normalization for $(f_{i,1}, f_{i,2}, (\Sigma P)_i)$
Score $= \frac{\omega}{2}(f_{i,1} + f_{i,2}) + (1 - \omega)(\Sigma P)_i$

Then the celluar automata model will be used to simulate how a single fungus grow under random and rapid environmental changes. Article ??? claims that the hyphae of fungi that can better adapt to the environment are denser and expand more slowly, so will they have high adaptability in this random environment? We mainly measure the change of the surface area of a fungus on 100[mm] $\times$ 100 [mm] wood blocks. It will expand from the center until covering the whole block. Fig.(12) shows the process and area change curve for 12 different fungi under 5 different random conditions.

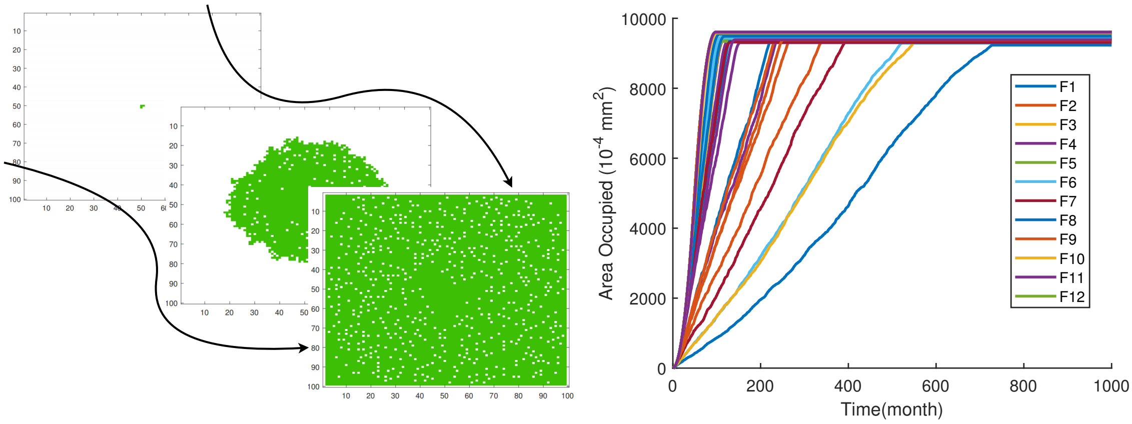


Figure 8: Tset process and results for rapid fluctuations in T and m.

From the Fig.(12), we can find that some color curve families, such as F3-orange curve family, do not deviate too much from each other and almost grow in the same trend, while some color curve families, such as blue-F8 curve family in, deviate much from each other. This is because fungi like F3 have a higher moisture niche width and temperature niche widt so when they face the fluctuation of the environment, their range of change is smaller which means that they are more **stable**.

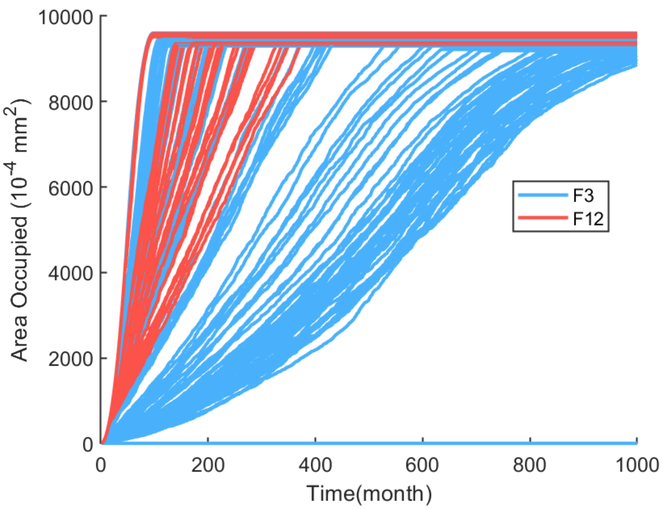


Figure 9: Area change curves of F3 and F12 (50 for each).

Also, this kind of stability will also affect the speed of expension. For example, the expension speed of F12 fungi is 0.77 mm/day while the expension speed of F3 is greater than F12 which is 1.09 mm/day. However on Fig.(9), we repeat the simulation 50 times for F3 and F12 and can conclude that the average expantion speed of F12 is far more than F3 which means that those kind of fungi that are more stable will also have **advantage on expansion speed** when facing great change on emvironment.

References

2 Importance of Biodiversity

As introduced in Section 1, the breakdown of ground litter is an important process in ecological cycles. Therefore, the efficiency of decomposition is one of the determinants of the efficiency of ecosystems. In order to study the importance of species diversity of fungi, we are going to test whether the diversity of species will improve the efficiency of decomposition and adaptation to variable environments.

2.1 Fungi Combination Selection

First of all, according to the results of the previous models, we can get the following rules on the selection of fungi.

- According to the analysis of XXXXXX(task 1 name) and xxxxx(task Boston name), we need to choose species that can coexist peacefully on long-term trends to ensure the **stability of biodiversity**.
- From xxxxx(fluctuation model name), we can know that the decomposition rate of bacteria is sensitive to environmental changes, so the **adaptability and viability** of fungi are considered prior to the expansion rate of bacteria. Moreover, when different fungi are combined, the temperature and moisture niche width that the whole system have should be maximized.
- When the above two conditions are satisfied as much as possible, we should choose the combination of fungi that expand as fast as possible, because they show great advantages when we do not consider the environmental impact in our initial model.

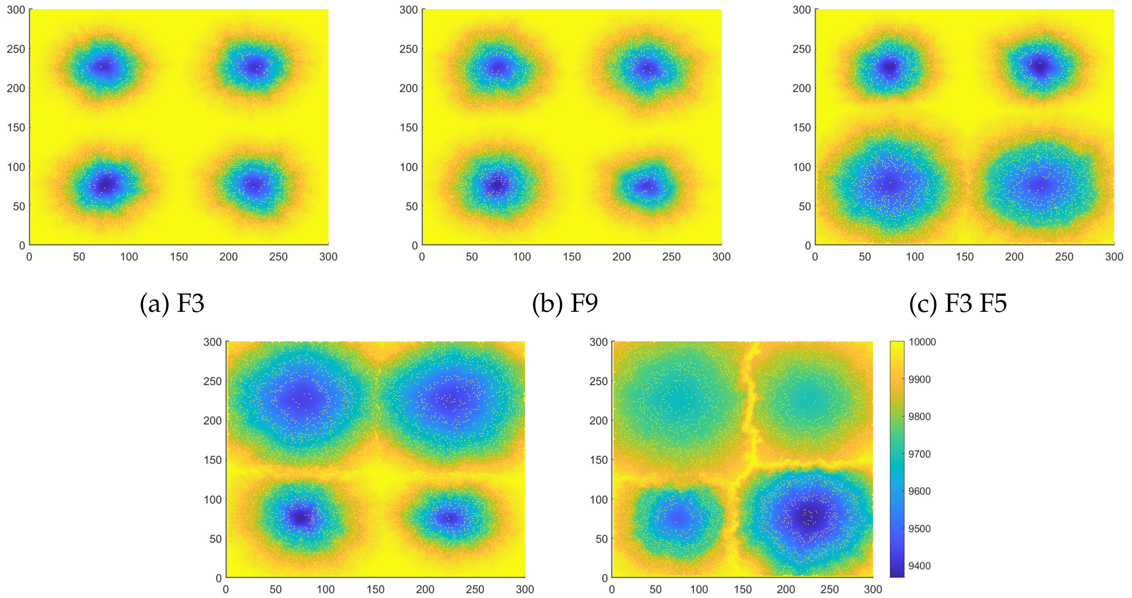
So that according to the previous rules, we can set 5 groups with the same initial numbers of fungi and the same initial positions.

Table 3: Groups Setting

	Group 1	Group 2	Group 3	Group4	Group5
Fungi choose	F3 $\times$ 4	F9 $\times$ 4	F3 $\times$ 2 & F5 $\times$ 2	F11 $\times$ 2 & F12 $\times$ 2	F7, F8, F11, F12
Moisture width	1.32	1.57	1.35	5.17	5.17
Temperature width	15.8	18.6	25.0	28.5	29.1

2.2 Results

In the simulation of this section, we fixed the trend of temperature and moisture to be similar to that of semi-arid area and use cellular automata model to run for 1000 days. The following Fig.(10) shows theremaining wood thickness for the five different groups of fungi.



(a) F3 (b) F9 (c) F3 F5

(d) F11 F12 (e) F7 F8 F11 F12

Figure 10: Remaining wood thickness.

In order to analyze the process better, we draw the change relationship of the remaining proportion of trees during the process. We set the overall thickness of the wood very large in order to maintain the stability of the system.

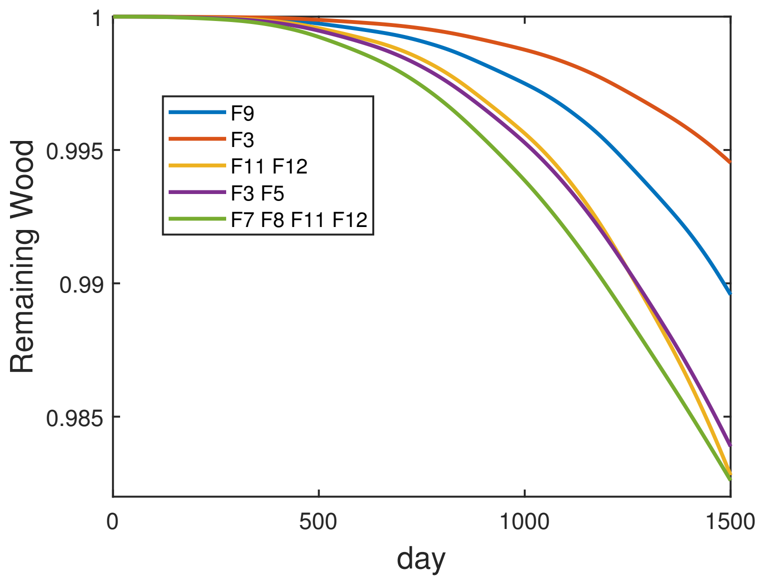


Figure 11: Changes in mass of wood.

From Fig.(11), we can conclude that when environmental factors are taken into account, biodiversity affects the decomposition rate of fungi. When the total number of fungi and the changing trend of the environment remained unchanged, the decomposition efficiency of the system with four different kind of fungi can reach **twice** as high as that of a single kind and **1.25 times** as high as that of two kinds.

However, there are preconditions for the conclusion in the previous paragraph, which are **stability of biodiversity** and **adaptability and viability** of fungi. Only when these conditions are fully met can we say that the system has **real biodiversity**.

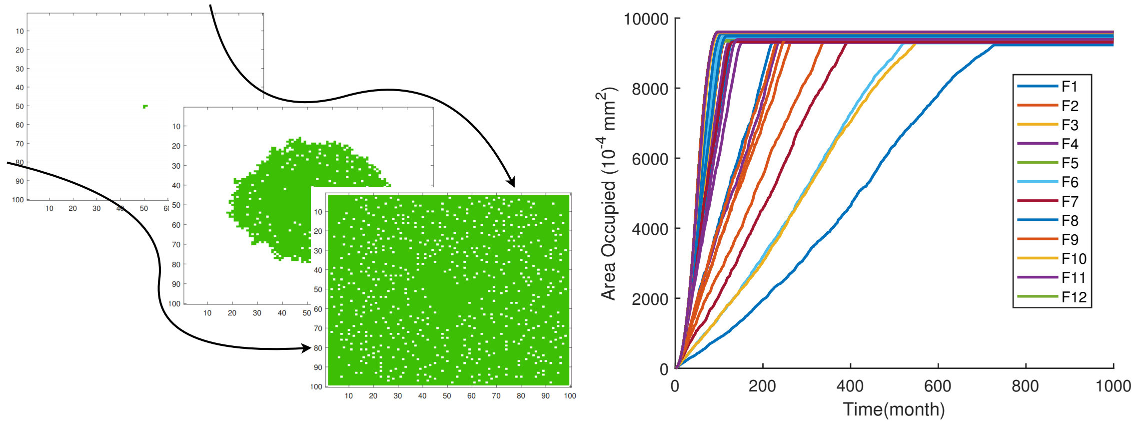


Figure 12: Tset process and results for rapid fluctuations in T and m.

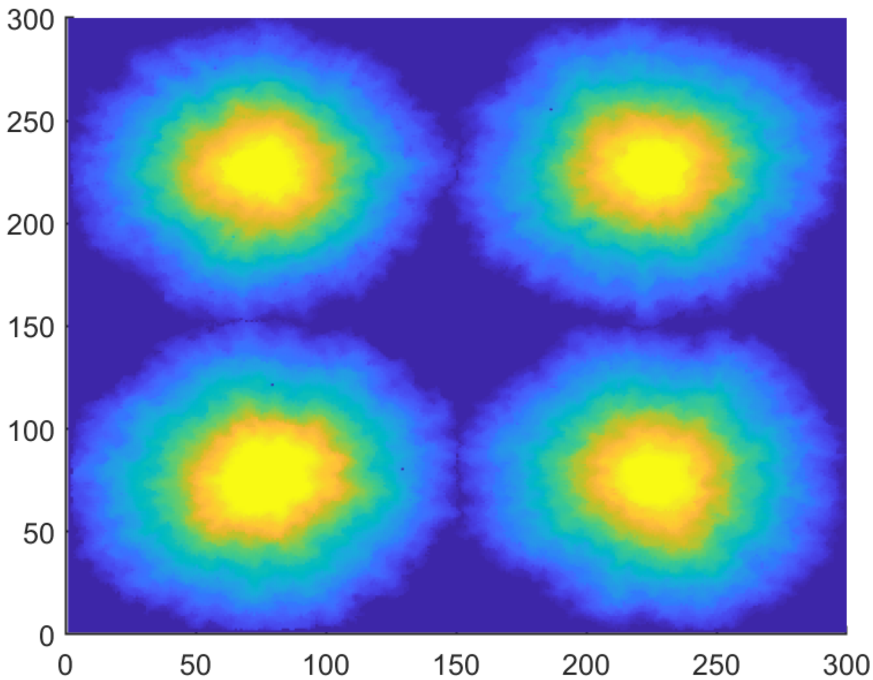


Figure 13: Algorithm schematic

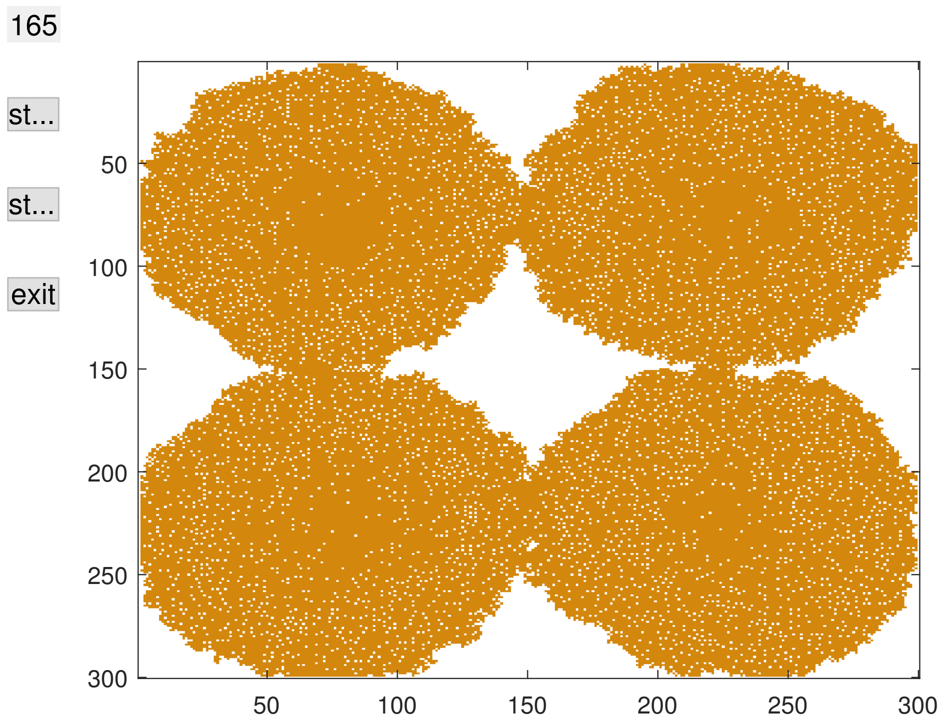


Figure 14: Algorithm schematic

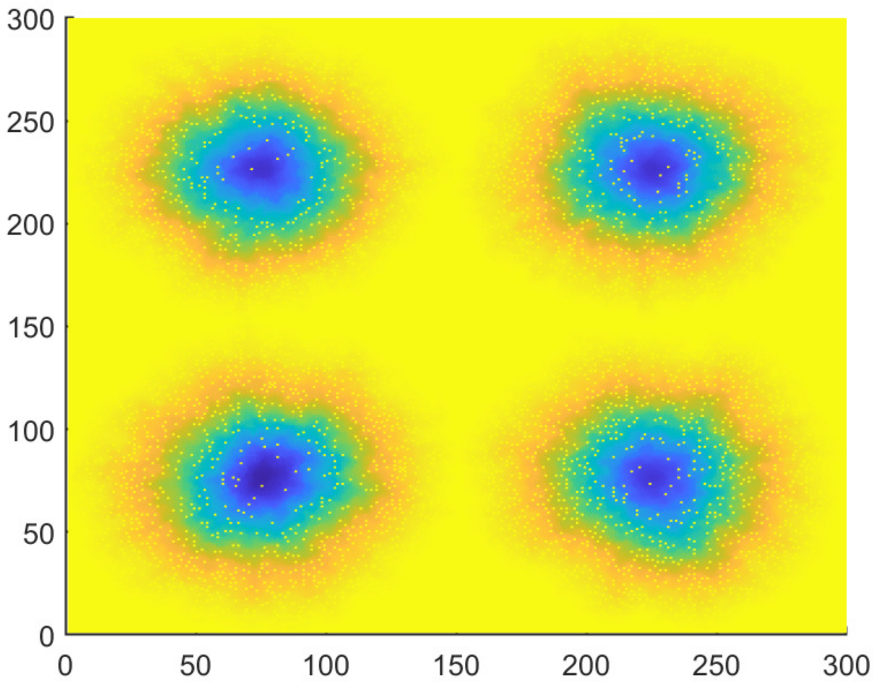


Figure 15: Algorithm schematic

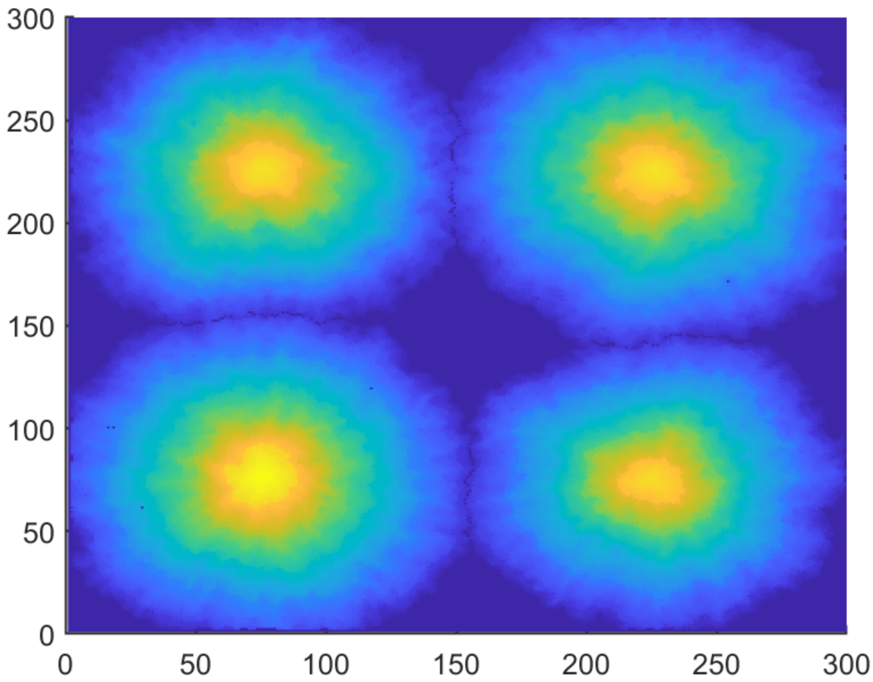


Figure 16: Algorithm schematic

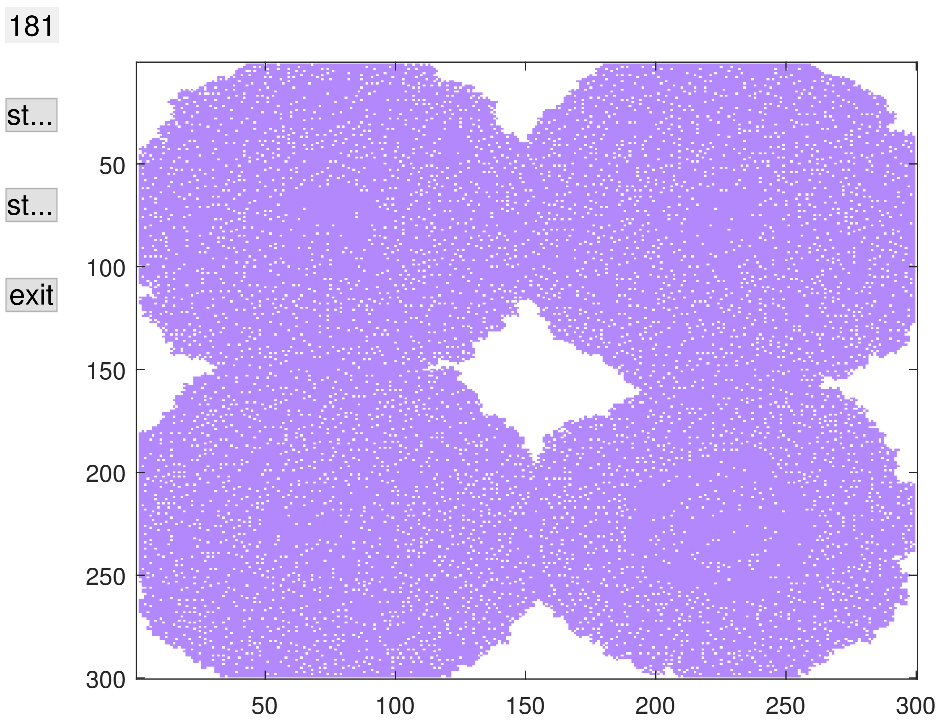


Figure 17: Algorithm schematic

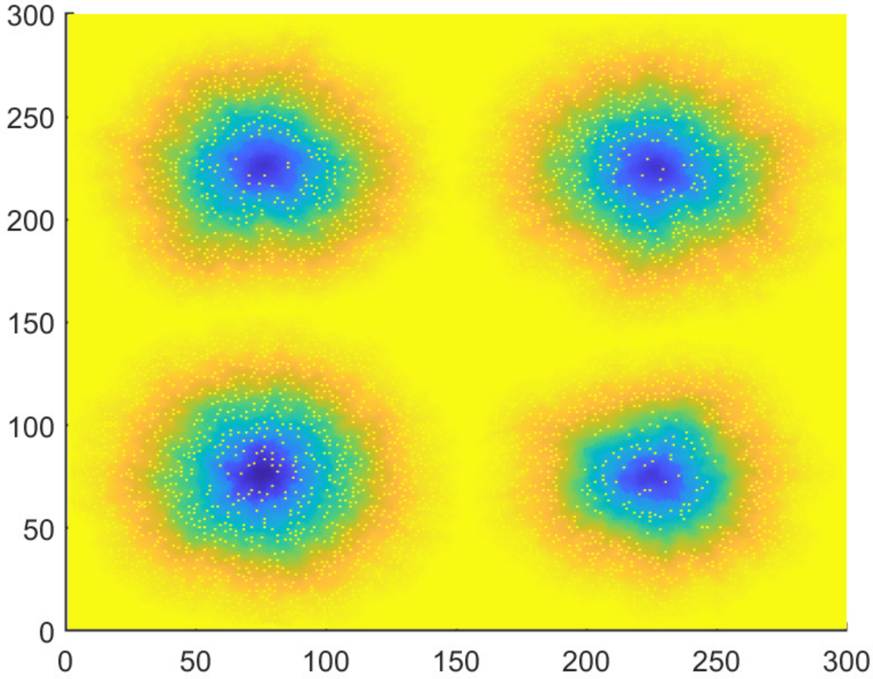


Figure 18: Algorithm schematic

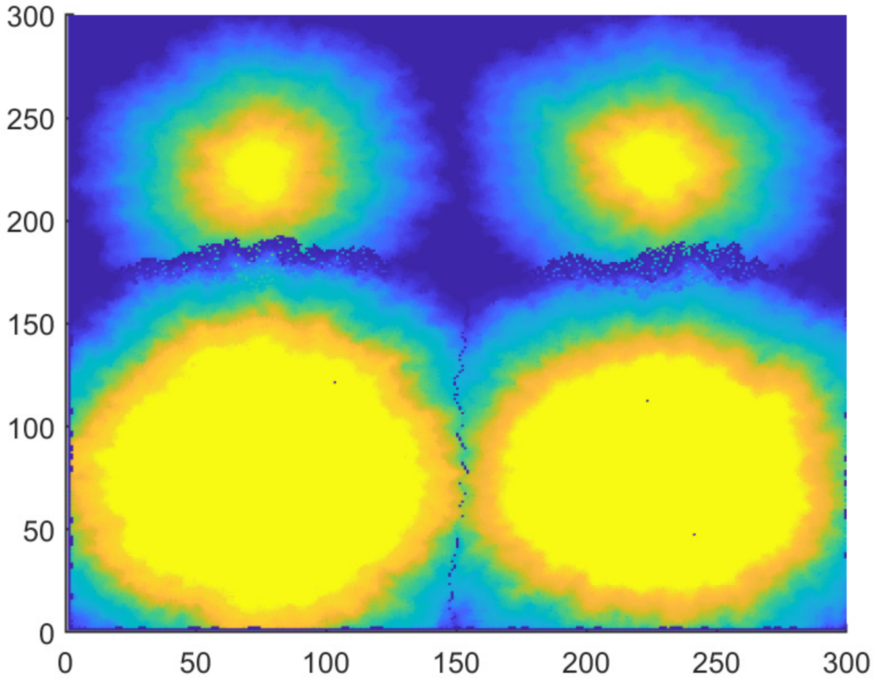


Figure 19: Algorithm schematic

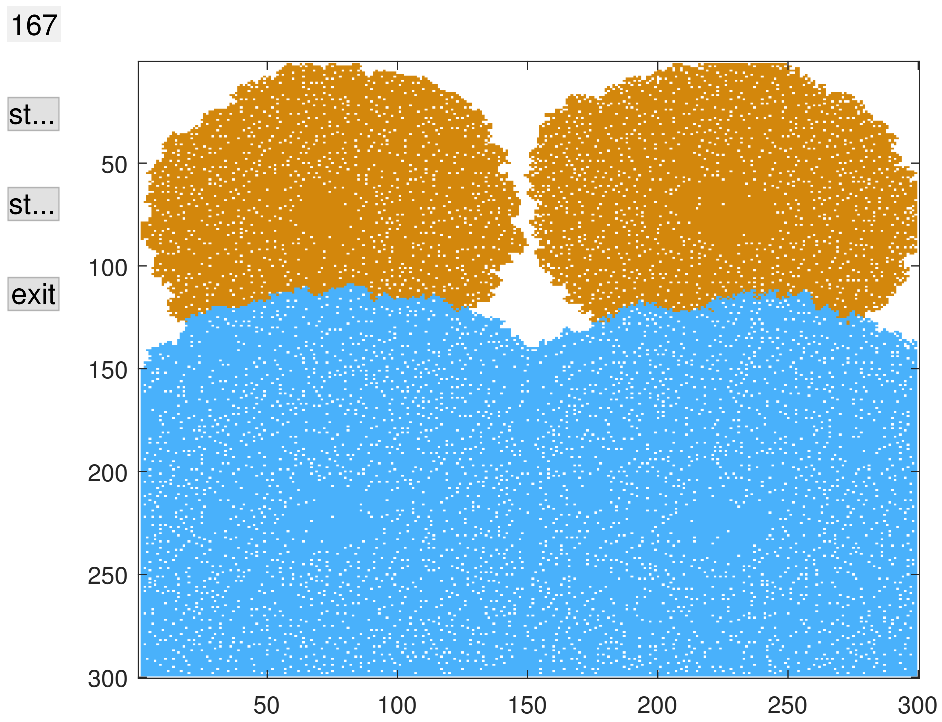


Figure 20: Algorithm schematic

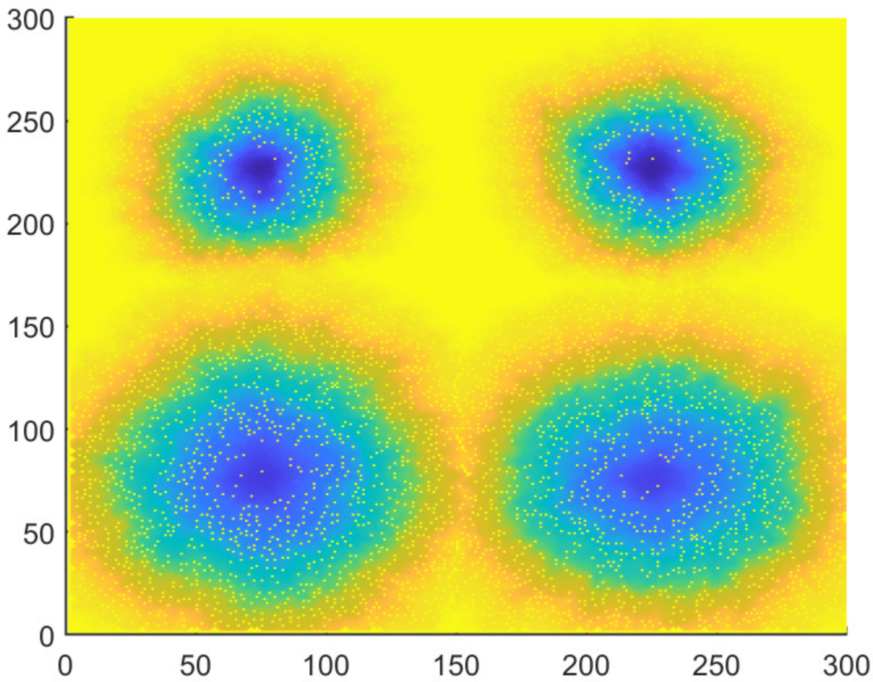


Figure 21: Algorithm schematic

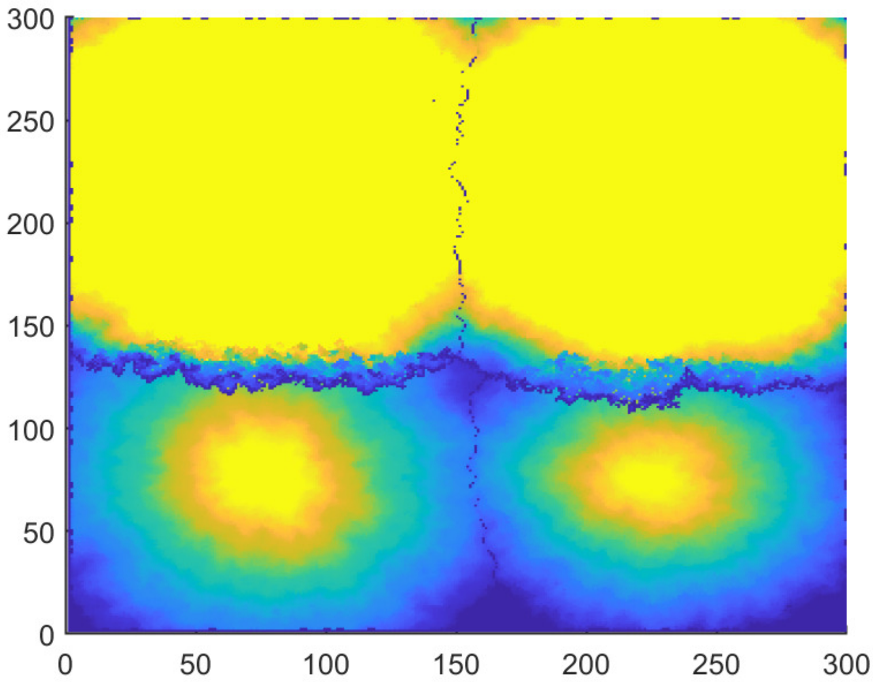


Figure 22: Algorithm schematic

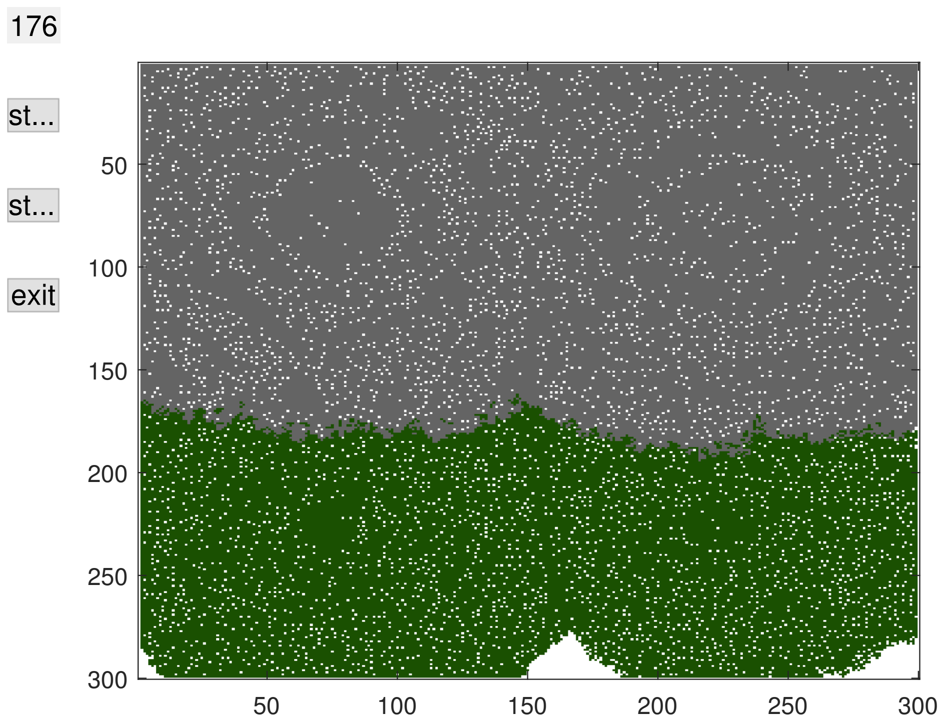


Figure 23: Algorithm schematic

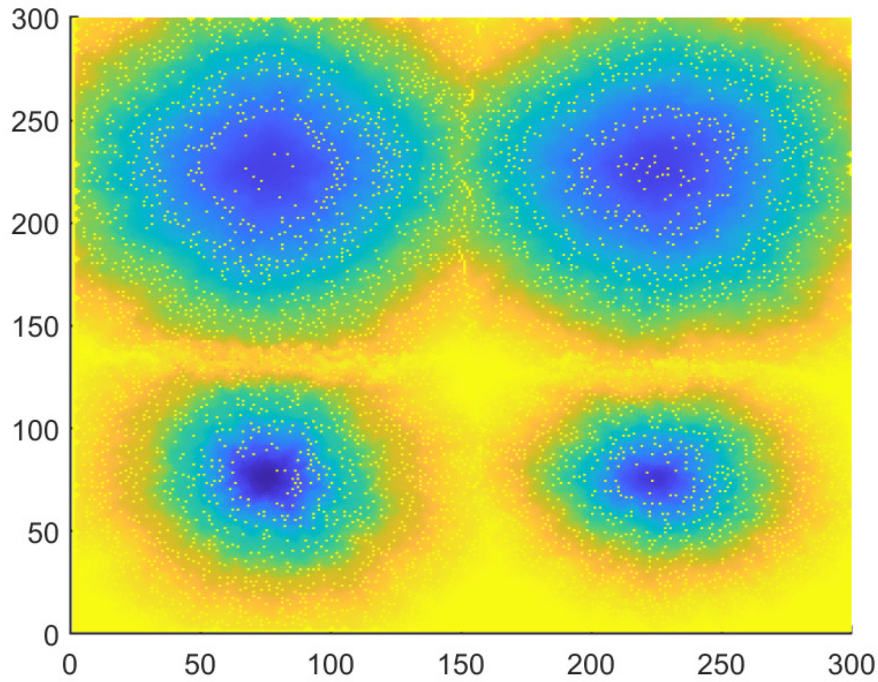


Figure 24: Algorithm schematic

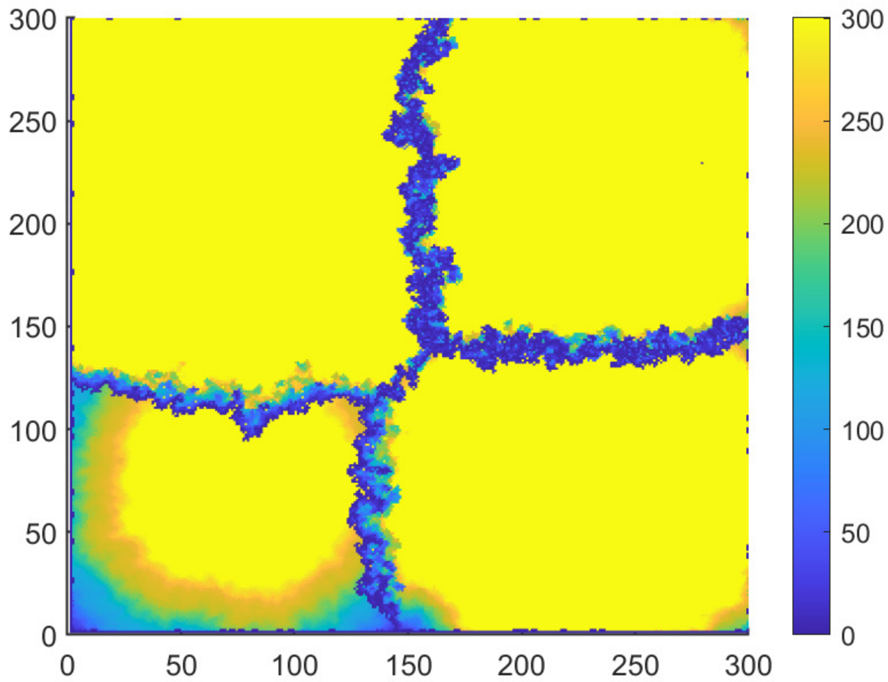


Figure 25: Algorithm schematic

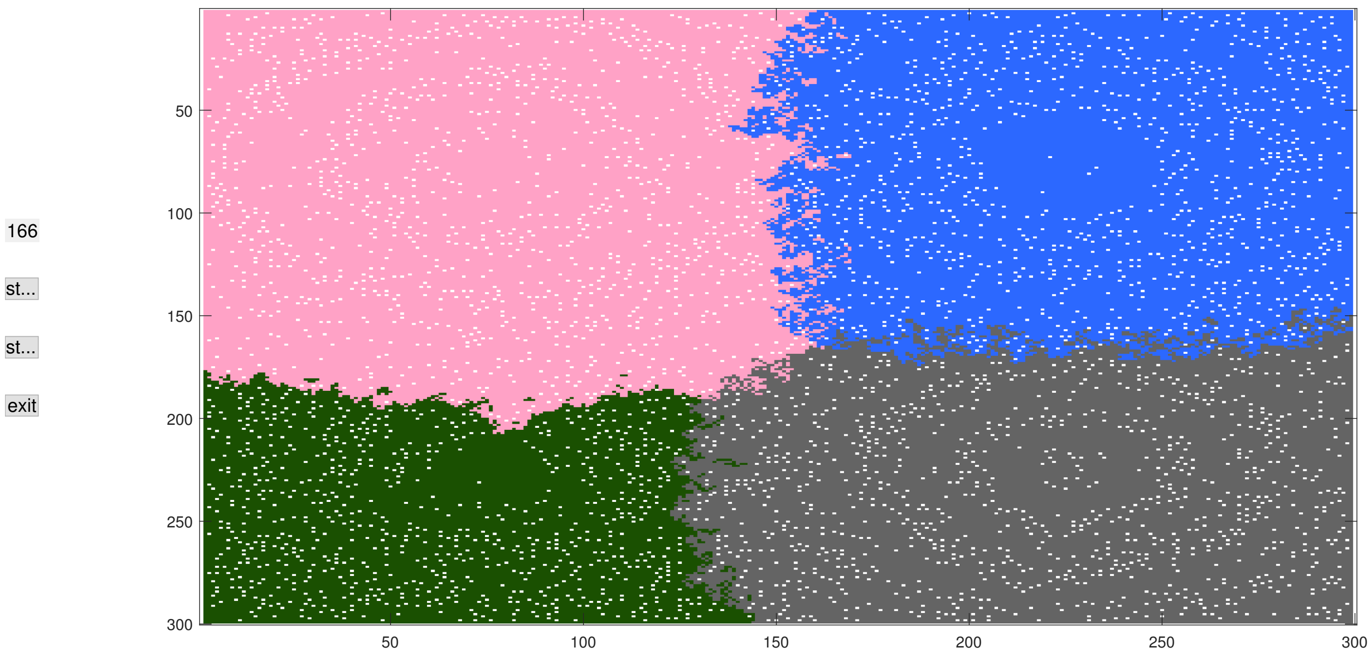


Figure 26: Algorithm schematic

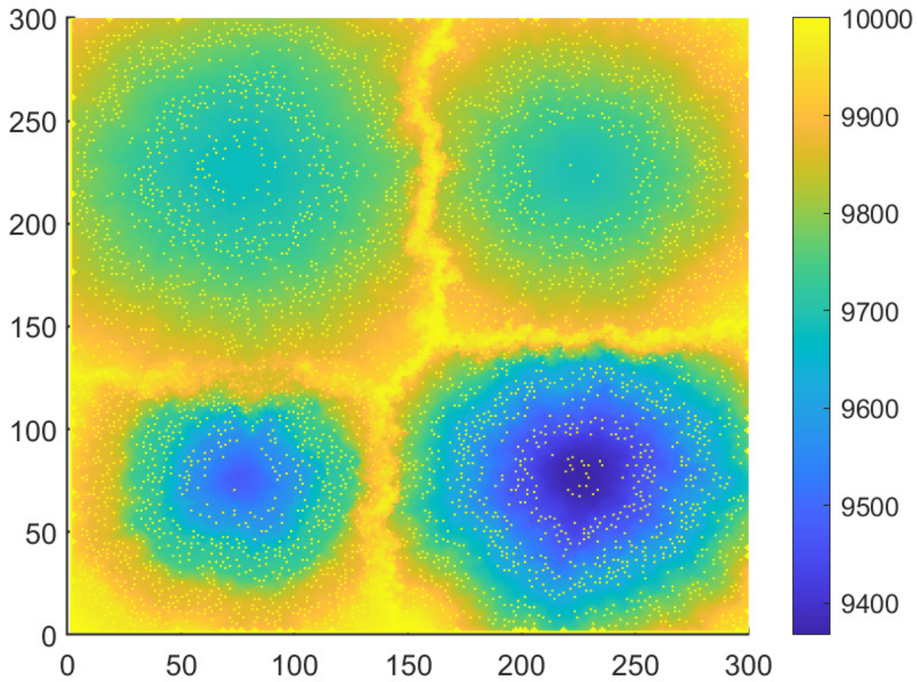


Figure 27: Algorithm schematic

3 Strength and Weakness

3.1 Strength

- A scientific and accurate simulation model is established by using **cellular automata** in MATLAB. **Excellent visualization** of fungal growth process makes the output of the model more intuitive, and also adds a lot of fun when solving the model.
- **Continuous problem discretization**: It is easy to update the model and consider more influence factors. At the same time, it enhances the robustness of the model and makes the model more stable.
- We simulate the change and influence of temperature and moisture in a very **large range**, including long-term and short-term simulation under eight different conditions (Boston/completely random environment/fixed value/five climate types).

3.2 Possible Improvements

- In our model, we only consider the competition relationship between fungi, but there are **other relationships** between them, such as cooperation.
- As the model becomes larger and larger, the **time** required to run a simulation code will become correspondingly longer. So when all the factors were taken into account, the computer is not fast enough to support the interaction of more than ten fungi on too many cells.

4 Sensitivity Analysis

In section 5.4, we have proved that our model is **sensitive to the rapid and drastic changes of temperature and moisture**. This is because different fungi have different optimal temperature and moisture. In our model, although the behavior pattern of each cell is complex, the overall behavior pattern of fungi is predictable according to some existing rules and our simulation results is exactlky consistent with these rules.

Initial location is also an important factor affecting the final results, so in the process of solving all the previous models, the initial position of fungi is fixed. Here we want to test whether the initial position of fungi will have a great impact on the final area occupied by it when there are multiple fungi exists.

The following Fig.(28) shows the results of the sensitivity analysis of the initial position. We fix the temperature and moisture and choose three different fungi (F5/F9/F12) for testing. Before each run of the cellular automata, we randomly generate initial positions for the three fungi and repeate the simulation for 50 times. Finally, we fit three curves for them using Matlab and because the slope of the three curves is close to 0, we can conclude that our model is **insensitive to the initial position of the fungus when the number of tests is large enough**.

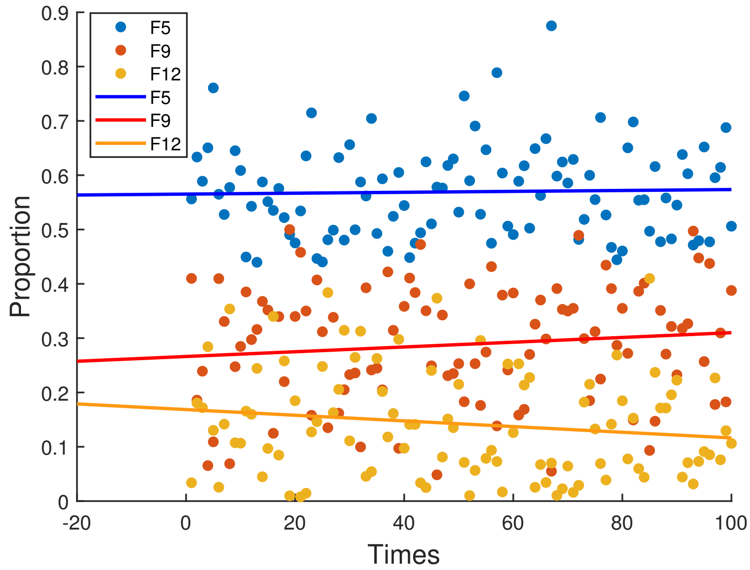


Figure 28: Algorithm schematic

Appendices

Appendix A Code Example

```
% This code is just an example. It can not run!!!!

absbs=13;% need adjust
B_su1=[zeros(n,1);0.00001];
%B_sb1 means the VLB of the Xi
B_b2=[ones(n,1)*2100;0.1];
%B_ub2 means the VUB of the Xi
B=[B_s,B_b2];
% consint of Xi
init=inliadaszega(n,B,'fitness');
[x enp,bp,tre]=ga(B,'fess',[],inop,[1e-6 1 1],
    'maxGTerm',100,'noomSelect',...
    [0.08],['arover'],[2],'nnUMutation',[2 10000 3]);
%3000 erations
xx=so(x(1:14));
% sis selection sorts as ascending order
x=[x,ad(15)];
% the last one is the on value
```