Topological Optimization of Random Distributed Points

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***Abstract*—Modern structural design achieves a lighter and more efficient structure by mimicking the natural structure of insects, plants and microorganisms. There are many masters in nature, such as nests, spiders, dragonflies, ants, etc. In this paper, the topology optimized by mimicking spiders and bacteria, the load point or structural coordinate point are simulated into scattered random points, then search these points like bacteria looking for food and connect the points together as spiders build nets in the space, and control the topological structures based on parameter control. This bionic topology method can achieve synchronization of structural design and structural optimization.**

Keywords-Structural Design; Topology; Random Points; Optimization

I. INTRODUCTION

Atsushi Tero of Hokkaido University in Japan and colleagues placed oatmeal on a damp surface, which placed various points equivalent to the cities around Tokyo and allowed the velvet bacteria to grow outward from the center. They saw the slime bacteria self-organizing, spreading out and forming a network that is comparable in terms of efficacy, reliability, and cost to the real-world Tokyo Rail network infrastructure (Figure1). [1]

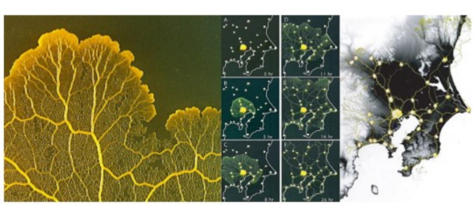

Figure 1. Network formation in bacteria and Comparison with the Tokyo rail network (Nakagaki, 2000)

Spiders can create a variety of spatial structures by weaving spider silk, which provides inspiration for our spatial structure design (Figure2). Velvet bacteria can find irregularly distributed food sources in the shortest path in a maze, or connect different food arrays in an efficient way, without the fault tolerance. Since slime molds have been subject to countless evolutionary choices, their diet has made them more efficient in forming communication network systems.[2-5] Therefore, the efficiency and accuracy of searching for load points and structural control points can be improved by simulating the search method of the velvet bacteria and create new structure as a spider[5] .

The path of searching for food by velvet bacteria is complicated, and there is no need to connect such lots of redundant points in a structure. [6-9] Therefore, need to simplify the point regions, and then connect the simplified points searched by the velvet bacteria to form a new topology network.

This paper provides a new method to optimize the connection of random points. First, locate the points, second, to classify and simplify the point regions into new location points, finally connect these new location points to create a new form.

Figure 2. Spider silk

II. METHOD

A. Step1

Release the 'multi-headed velvet bacteria' in a field of random points to search load point (structural point) in figure3, and merge the points with distances less than the parameter value limit, new points read in equation 1. The bacteria search angles show as figure4, each bacteria can search at least 4 different angles, and all these angles add up to 2π. The angle of each individual search is calculated by the equationequation2-4.

$$p = (p_1, p_2, \cdots\cdots, p_n)^T \tag{1}$$

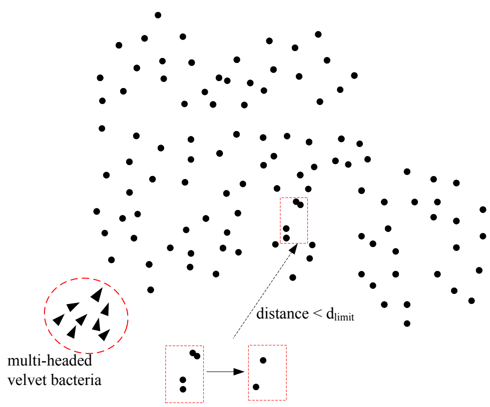

Figure 3. Search and merge structure points

$$\vec{V}(\theta) = [\vec{V_1}(\theta_i), \vec{V_2}(\theta_i), \cdots, \vec{V_m}(\theta_i)] \tag{2}$$

$$\sum_i^n \theta_i = 2\pi \tag{3}$$

$$\theta_1 + \theta_2 + \theta_3 + \theta_4 = 2\pi \tag{4}$$

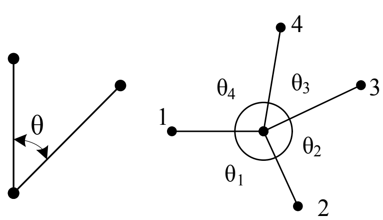

Figure 4. Search direction

B. *Step2*

According to the point weight value, the scattered points are divided into different regions, and the central value of these regions is calculated as a new structural point to screen out the redundant points and simplify the structure point distribution, as figure5 shows.

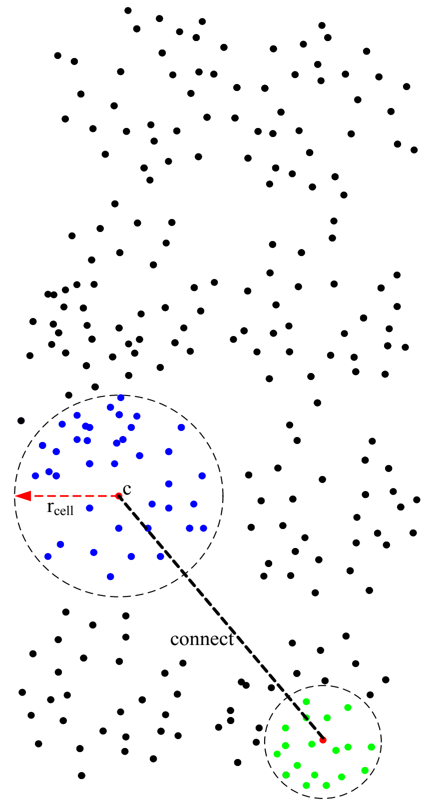

Figure 5. Classify the random points.

C. *Step3*

Connect new structural points and adjust number of connections to adjacent points, as in figure7, point a connects 3 adjacent points and point b connects 4 adjacent points. After connect all the new points can create a new form and can make the length is the shortest, as shows in figure 6. The length calculated in the equation 5. The L should be kept to a minimum when connecting points.

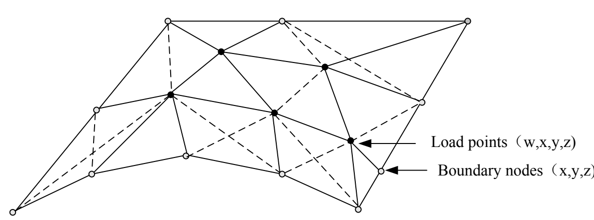

Figure 6. New topology network

$$L_i = \sqrt[2]{\Delta^2(x_i - x_{i-1}) - \Delta^2(y_i - y_{i-1}) - \Delta^2(z_i - z_{i-1})} \tag{5}$$

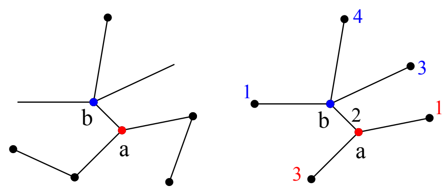

Figure 7. Each point connections, n_a=3, n_b=4

III. CASE STUDIES

185 random points set distributed in the field in figure 8 a and then released amount of searchers to search these points in figure 8 b and figure 9 show, they firstly found the points region1, region3 and region 5, then they found region0 and region 6, finally they found the last region2.

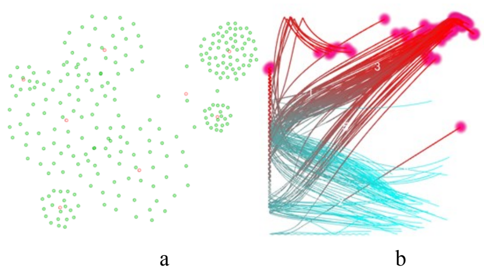

Figure 8. Points distribution (a), searched points region 1, 3, 5 (b)

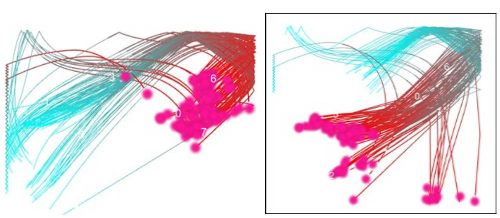

Figure 9. Searched points region 1,3,0,6 and points region 6,0,5,2

Connected the trial of the searchers can make connections between searchers and points as show in figure10, the more searchers found the points the more complicated the connection became.

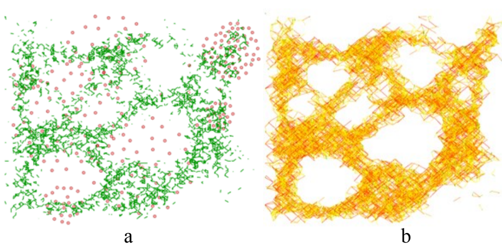

Figure 10. searchers number 4950(a), searchers number 22779(b)

If connect points directly without classify and simplify the point regions, the form will be very complicated and need to simplify these connections through massive calculation as shows in the figure11a. In figure11 b the point regions simplified into 7 points when finished searching and optimized path topology in figure11 c to make sure the path to the 7 regions is the shortest.

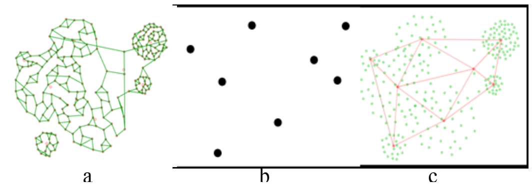

Figure 11. Simplified point distribution and optimal path topology

IV. DISCUSSION

In this paper, the randomly structural points are divided into multiple regions as searching for the food of the velvet bacteria. The number of structural points are simplified before connect them. Compare the method of connecting and then deleting the redundant connecting lines, this method can pick out most useful points to be connected, such a topology connection is more efficient and simple. This method is more suitable for densely distributed structure points topology optimization.

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