



Method for numerical description of coordinated objects spatial structure

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Introduction

ia whereby bacterial community formation and signal information exchange take place.

nt and immune system influence.

leared. Also the issue of relation between spacial organization features and pathogenicity degree of



Aim and tasks of the research

The aim of the research is elaboration of methods for cellular structures spatial organization analysis.

Tasks:

- complex of characteristics elaboration for cellular structures spatial coordination description;
- investigation of the elaborated complex using model images;
- working out image segmentation method for bacterial preparations;
- investigation of the relationship between spatial organization features and bacteria type.

Topological indexes

- Topological index is mathematical invariant (in relation to graph nodes numeration) representing graph topological features numerically.

- Topological indexes are calculated from the following matrixes:

- Adjacency graph matrix:

$$A_{ij} = \begin{cases} 1, & \text{if an edge between nodes } i \text{ and } j \text{ exists,} \\ 0, & \text{otherwise} \end{cases}$$

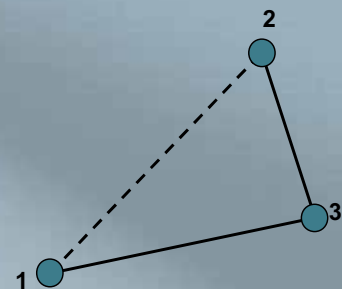
- Distance matrixes:

$$g_{12}^{(1)} = 2;$$

$$g_{12}^{(2)} = \exp\left(\frac{l_{13}}{L}\right) + \exp\left(\frac{l_{32}}{L}\right);$$

$$g_{12}^{(3)} = \frac{l_{13}}{L} + \frac{l_{32}}{L};$$

$$g_{12}^{(4)} = \frac{l_{12}}{L};$$



Topological indexes

- Wiener index:

$$W = \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n d_{ij},$$

where d_{ij} is an element of Distance matrix D

- Platt index:

$$F = \sum_{f=1}^{f_{tot}} \deg(e_f),$$

where $\deg(e_f)$ is the number of edges adjacent to edge f ;

f_{tot} - total number of graph G edges;

- Comparability index

$$M3 = \prod_{i=1}^n v_i,$$

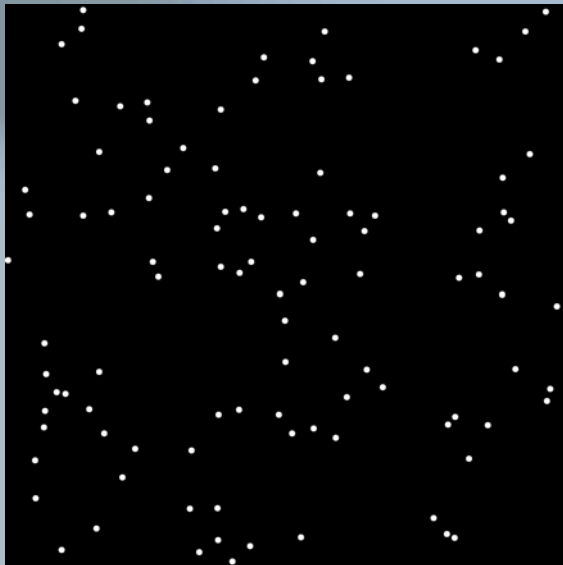
where v_i is the degree of i -th node in graph G

- Total amount of indexes: 36

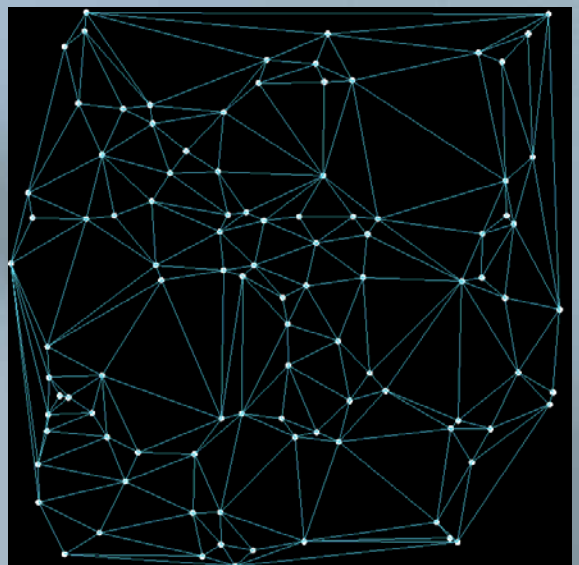
Model images

- Uniform distribution (N=100):

a) original image

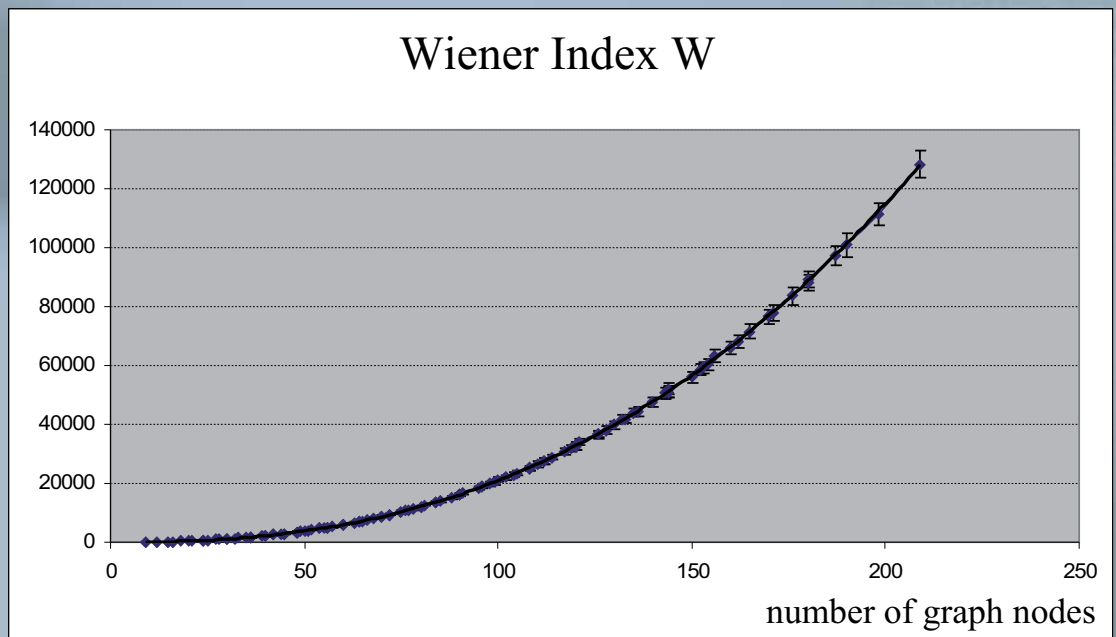


b) after triangulation



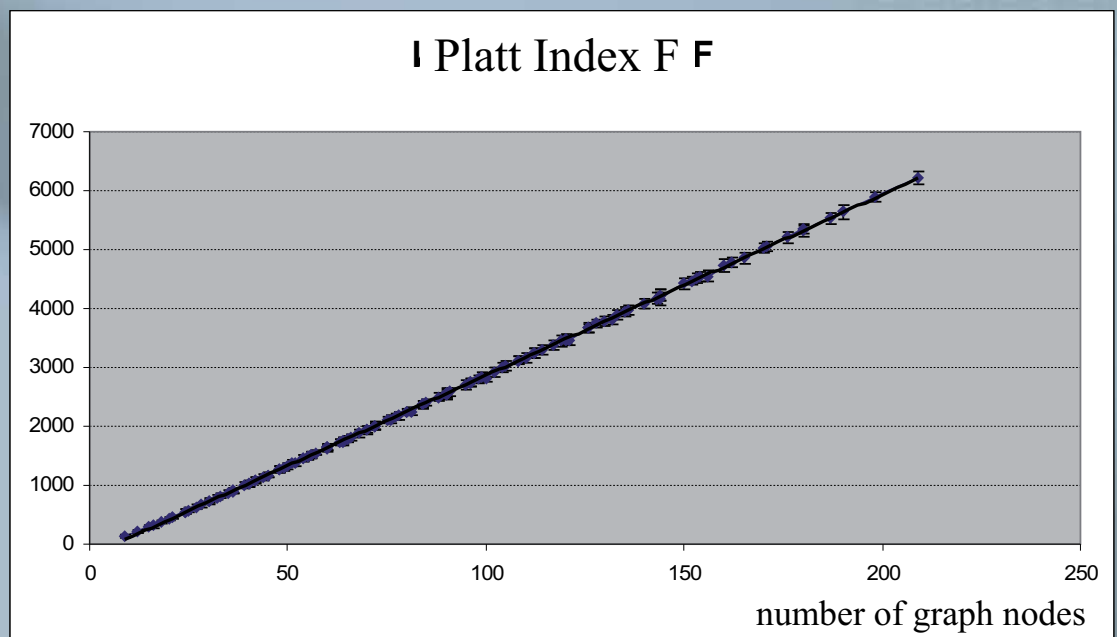
Number of graph nodes index dependencies

- 1. Power law dependence: $y = a \cdot n^b$



Number of graph nodes index dependencies

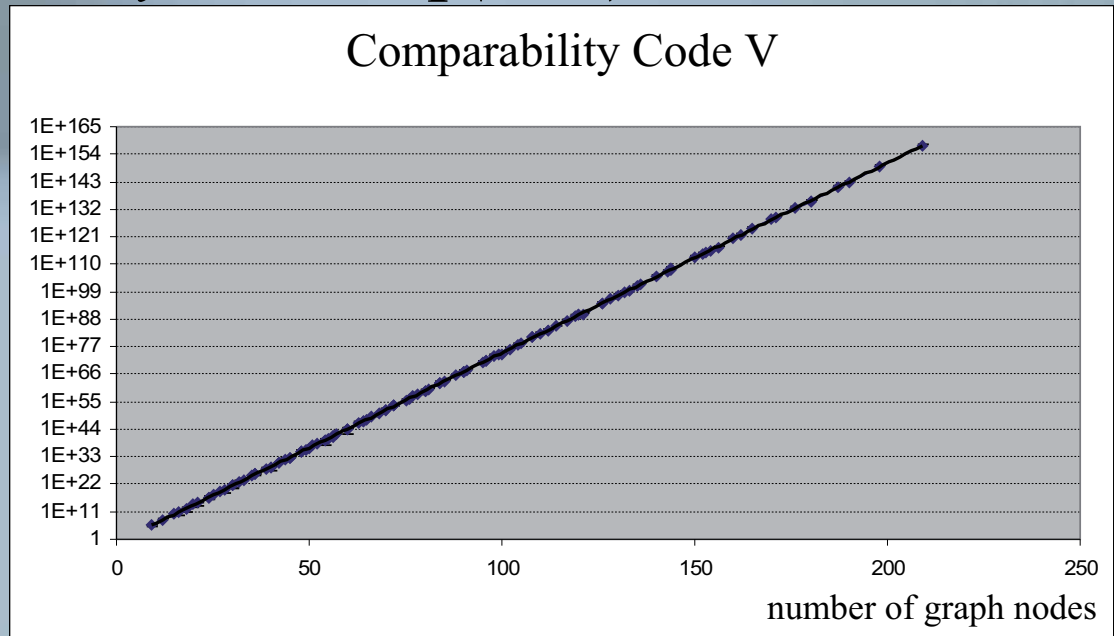
- 2. Linear dependence: $y = a \cdot n + b$



Number of graph nodes index dependencies

3. Exponential dependence:

$$y = a \cdot \exp(b \cdot n)$$



Informativity of modified indexes

Informativity coefficient:

$$t = \frac{|x_{i1} - x_{i2}|}{\sqrt{S_{x_1}^2 + S_{x_2}^2}}$$

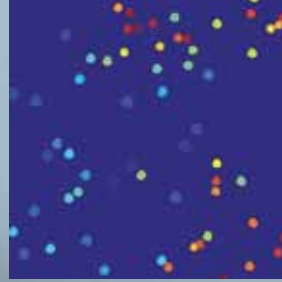
Uniform - Gaussian	t	Regular - Gaussian	t
Averaged Distance Sum Connectivity JJ_1, JJ_n	1.38	Distance polynome Zz_g	71.53
Wiener index W_1, W_n, W_g	1.37	Comparability code V	5.45
Root mean-square distance index D2_n, D2_g	1.36	Platt index	3,49
Distance polynomial Zz_n, Zz_g	1.05	Averaged Distance Sum Connectivity JJ	3,25

Image processing

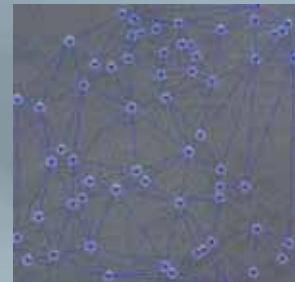
original image



result of segmentation using watershed method

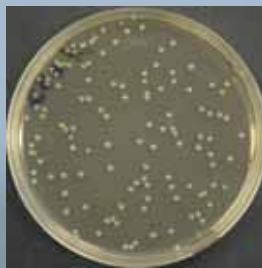


distance transform



result of triangulation

Results of the research



Salmonella enterica ser. Typhimurium C53



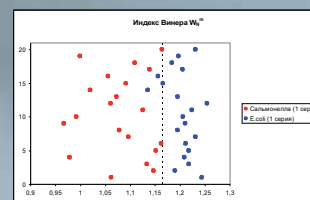
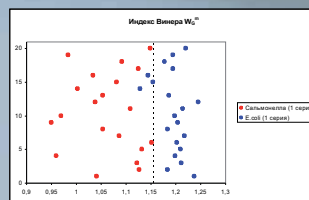
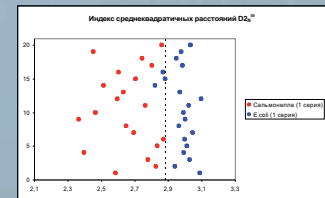
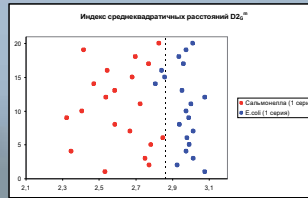
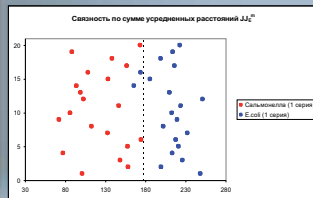
Escherichia coli J62

Most informative modified topological indexes for microbiological preparations

N ^o	Name	Designation	Formula	K _{inf}
1	Averaged Distance Sum Connectivity	JJ_{E^m}	$JJ_{E^m} = JJ_E - 2,38 * n$	2,30
2	Root mean-square distance index	$D2_{G^m}$	$D2_{G^m} = \frac{D2_G}{n^{(-0.19)}}$	1.99
3	Root mean-square distance index	$D2_{N^m}$	$D2_{N^m} = \frac{D2_N}{n^{(-0.18)}}$	1.91
4	Wiener index	W_{G^m}	$W_{G^m} = \frac{W_G}{n^{1.83}}$	1.87
5	Wiener index	W_{N^m}	$W_{N^m} = \frac{W_N}{n^{1.84}}$	1.78

Results of the research

Characteristics complex for cellular structures spatial coordination



mental research demonstrated existence of spatial bacteria organization which depends