SIMULATION OF THE FLUCTUATIONS AND SEGMENTATION OF URBAN SYSTEMS BY DIFFUSION METHODS

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Abstract: *Segmentation method for forecasting of social-economic processes in accordance with methodology of applique fractal crystals growth methods in fuzzy attraction potential field was proposed. Impact of model empirical parameters on appearance of fractal structure fluctuations in the form of creating additional aggregation centers was investigated. Computer experiment give a possibility to simulate structures which are well correlated wit experimental data received.*
Key words: *potential of attractiveness, fractal, fuzzy logic, molecular dynamics.*

1. INTRODUCTION

Stormy development of all tourism activities at the end of XX century influence on the concentrating of big capital in tourist industry – hotel chains appear, building of tourist centers begins, transport infrastructure and restaurant services grow up.

Investing considerable funds in tourism development, a large capital requires a maximal income as soon as possible. Natural landscape and local population are perceived only as labors for goal achievement. No wonder that mass growth of non regulation visits of the prominent natural complexes has the negative influence on them and also on a local social and cultural environment: the rare plants are destroyed, trees are cut down, reservoirs are contaminated, populations of many types of animals disappeared or considerably decreased. Such kind of tourism which got the name of "cruel tourism" took place in the last decades in many countries.

Information stated above testifies that the tourism development planning and prognostication are very important nowadays. To solve this problem various mathematical methods and models should be used. The usage of mathematical methods in economic researches gives us the possibility to solve specific tasks with the construction of forecasting scenarios and a possibility to foresee forming and development of the complex socio-economic processes.

Development of GPS technologies and various international programs of the space sounding and Earth photographing, digital cards creations allowed everyone to be freely oriented on locality, get topographical data and information about the location, plan the route, to get the locality images from space and other [1]. These data open up large possibilities for scientists to conduct researches in the sphere of GIS technologies, architecture, sociology, economies and other science industries. The imprints of most settlements which are done from space remind the aggregated crystal growth on the definite centers (entertaining, recreation, industrial and others centers) and deformed by the definite potential field. In this paper the methodology of crystals fractal growth appliqué methods in the fuzzy potential attraction field for forecasting of poorly controlled social processes on the example of

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settlements geometrical form forecasting is proposed. Advantages and lacks of the modified theory of diffuse-limited aggregation (DLA) and «Accidental rain» (AR) are discovered and the combination algorithm of this theories to remove basic failings and to perform maximal use of advantages of the lasts are offered.

The purpose of this research is the creation and the approbation of the methodology of crystals fractal growth appliqué methods in the fuzzy potential attraction field for social processes forecasting on the example of settlements geometrical form forecasting.

Research actuality consists in conception development of the poorly controlled social processes prognostication such as the cities and settlements growth, related to active development of green tourism, creation of concomitant infrastructure, people division on segments after general interests, work, rest, and others based on crystals fractal growth methods well known in solid physics in combination with fuzzy logic theory.

Forming of structures with growing surfaces are present in the wide range of the phenomena which are actively studied by science, in particular crystals growth under various conditions, snowflake evolution in an atmosphere, the directed solidification in some processes that act important part in metallurgy [2].

Settlements growth is characterized by the set of features which are present in the physical processes of crystals growth, in particular:

Physical crystal growth begins on a definite center. Such centers could be production enterprises, historical and cultural legacy, tourist-recreation systems (TRS), mountain-skier centers, entertaining centers, beaches and others;

Clusters deformation in physical crystals is conditioned by diffusion in the potential field. The role of the potential field in social processes play the attractiveness field, that depends on distance, infrastructure, innovative-investment climate, relief, legal and other aspects. The field can be built by the fuzzy logic theory.

In the movements process the free particle which creates the accidental mooving joins either to the center of cluster or to the before aggregated particles. In obedience to marketing researches [3] new recreation objects or new buildings appear in a direct closeness from neighbors, forming quarters, analogue of clusters.

From stated above becomes clear that basic processes of settlements alteration similar to the processes that are observed at crystals growth. It enables to use the approved theories DLA and the «Accidental rain» [4] for the design of socio-economic processes.

Forecasting of settlements growth geometry will allow creating proper infrastructure and communications with a maximal economic value and possibility to foresee the structure of a new building near accrued tourist-recreation systems. In its turn this will allow optimizing strategy of building new TRS's, defining specialization of separate settlement segments and foresee the money streams of the system [5].

However the distinguishing feature of settlements growth is that crystallization (aggregation) takes place not in one center as is observed in the physical phenomena. In the real life there are several crystallization centers and regions within the limits of the explored object and they have almost all the time difficult geometry. The potential attraction field in turn also has a difficult form. In large towns and megalopolises strategy of alteration is formed in obedience to expert estimations and permissions of the proper establishments. Alteration of small settlements carries a probabilistic character and in a prominent measure relies on the attractiveness of definite territory. From foregoing becomes clear that the classic methods of crystal growth like imitation, dendrite and fractal growth should be substantially modified [2].

2. MODEL OF THE POTENTIAL FIELD

Unlike the physical fields it is difficult to formalize the potential attractiveness field of some territory for building using classic mathematic tools. Such behavior is the result of basing of potential territory attractiveness field on human logic and human senses. In addition, the size of the potential attractiveness field relies on the geographical location, locality relief, presence of the proper flora and fauna, temperature conditions, possibilities to form proper transport infrastructure etc. Taking into

account the transferred entry parameters the size of the potential field can be described by mathematical fuzzy logic tools.

In general the potential U could be presented as:

$$U = F(a_1, a_2, ..., a_n), \quad (1)$$

where a_i – entry parameters F – function which is determined be the type of potential.

The type of function and choice of algorithm of the fuzzy conclusion (Mamdani, Sougeno, Tsoucamoto and others [6]) relies on the mechanism of construction of fuzzy production rules, that are used in consulting and handling models and in its basis had the knowledge base formed by the specialists-experts of subject domain or got as a result of neural network teaching, educational great number of which, in turn is based on experimental data, as an aggregate of fuzzy predicate rules. Fuzzy logic tools show on advantage in the researches of economic and social processes, in particular at computations of the efficiency integrated indexes [7], decision of multicriterion tasks [8] and economy growing competition determination between regions in China [9]. In previous work [10] we showed the advantages of using algorithms Mamdani and Sougeno for determination of recreation potential. It was shown, that the results which were received after using these methods correlate well with experts estimations. Therefore in subsequent computations we have used Sougeno with the Gaussian membership functions [2]. This algorithm was chosen because the presence of experimental knowledge basis gives the possibility of using hybrid neuron networks ANFIS (Adaptive Neuro-Fuzzy Inference System). For the calculation of potential attractiveness field form the method of recreational potentials maps construction could be used [11

For every knot of the net the entry parameter's values are determined. Received matrices serve by the entry parameters for fuzzy function of the attractiveness potential field (1). A matrix is the result of calculation which determines the form of territory potential T.

Entry parameters are divided into two types. Their co-ordinates are exactly definite by GPS technologies and those which should be determined with one's own hand.

The entrance sizes of the first type can be divided into sub-groups. There are locally concentrated and definite by the vectors.

Locally concentrated objects (medical water, history-cultural centers, mountain-skier, parks etc.) act as part of crystallization centers. For determination of the objects attractiveness potential distance to them is used and not the co-ordinates of these objects.

Vectors help to determine transport networks. It is implicit circumstance that habitation alteration, especially in green tourism, move to the already existing motorways. It is confirmed by the numerous settlements pictures from space [1]. While the distance to the roads increases the territory attractiveness for building falls. We suggest using distance to the nearest road and distance by the road to the nearest crystallization center as entry parameters for fuzzy attractiveness potential.

3. MODEL OF THE MODIFIED DIFFUSE-LIMITED AGGREGATION THEORY (DLA)

Nowadays there are a lot of models which describe the irreversible particles unions in clusters. Aggregation process is described by the nonlinear differential equation in partial derivative. Solution of these equations come from on analytical and a number of methods and has large complication. One of possible methods studying such questions consists in the study of the model systems which are able to generate such structures. The most known method is DLA model [2].

A classic DLA model is very simple: particles with accidental moving in the aggregation process form a cluster. So the particle starts it motion from random point joins either to the point clustering center or to the before aggregated particles. Intensive computer researches showed that the difficult ramified fractals [2, 4] which have a spherical form appear as a result of such process.

In our case a particle must move in the potential field which has influence on fractal form. To design this motion we could use molecular dynamics methods [12 – 14].

Lack of such approach is that negative part is acted by the energy conservation law. During close to the crystallization center kinetic energy grows in particles and its speed accordingly. Due to discrete time in many cases a particle flies everywhere and is not aggregated on the crystallization center. The solution of this problem is to reduce discreteness time which influence on increasing

computation time. Another solution is normalization particle speed after each iteration step. However, as computer experiments showed, in many case a particle goes out on a stationary orbit round the aggregation centers.

In a molecular dynamics temperature is considered as a measure of kinetic energy and come forward as a lever of particles middle speed change. So it is possible to decrease particles' speed if temperature will be decreased too [16]. In our research it is necessary to develop and prove mechanism of temperature gradual reduction and particle speed growth. It's clear, that it is outside influencing which has not analogues in nature.

For the correct influencing of the potential field and prevention of sharp speed growth we suggest considering particles motion in an environment that owns viscid friction.

Particle aggregation takes place during motion if it runs into the center of cluster or the before aggregated particles. In the case if entry parameters of fuzzy potential which carry maintenance of local limitations aggregation (coast, bog and reservoir) hinder a particle is withdrawn from computation.

Our researches showed that the offered method describes very well the front geometry of settlement growth. However the given method has the substantial lack: crystals growth process in most cases takes place either on one center or on a plate or wire. The same situation is observed at the design of settlement located along a definite curve (sea coast, road). In this case there is a good concordance with present experimental data. However most settlements have the ramified infrastructure network and set of the territorial distributed attractiveness centers, round which settlement is growing. As our computations showed presence even two distributed accretion centers lead to appearance of empty regions in which particles can not get from outside regardless of its trajectory form. It leads to situation when city center has empty regions without buildings, that is not observed in real world. The indicated lack could be easily removed using the model of the «Accidental rain».

4. THE MODIFIED MODEL OF «ACCIDENTAL RAIN»

The model of «accidental rain» (AR) was offered by Mardgori Vold and Sazerland [2]. In the model of the AR particles move on to the definite accidental trajectories. In paper [2] was shown, that the best concordance with the experiment shows a model in which the clustering center is disposed in the center of the explored region, and particles (candidates on aggregation) begin to move from large distance inward circles. Every particle started from a random point and moved on a random chord, uniting at the collision either with the line of basis, or with a growing cluster. A model AR generates the ramified structures look like ones received by the DLA model.

Less time of computation is basic advantage of AR model against DLA substantially. And Hausdorff-Besicovitch cluster dimension D has the value $D \approx 1.72$ [2].

As our researches showed a classic model AR has the substantial lack, namely: presence of empty regions, in the case of presence of a few clustering centers; a model does not foresee the presence of the potential field which deforms spherical structures. It was offered to remove these lack as follows.

Consideration of the potential field

The potential field deforms the bodies' trajectories [12-16]. However, in obedience to the theory of the AR particles trajectory remain unchanging during all motion. Therefore we suggested interpreting the potential attractiveness field as the particle aggregation probability potential field. Therefore the potential field of the explored region must be rationed for this purpose. The aggregation probability is determined as the probability of offensive of two independent events, namely the presence of the alongside aggregated particle and the «possibility» of aggregation in the given point from one side of potential field $U(x, y)$. In our computations the authenticity $P_a(x, y)$ found alongside with the moving particle of the aggregated cluster was accepted as 1 if aggregated atom is found in the cell neighboring on a verge with a particle, 0,5 if the aggregated atom is found alongside bias, and 0,01 in other case.

The offered method of modification AR indeed allows empty regions being deprived and taking into account influence of the potential field at the design of settlement growth. However calculated fractal front is characterized by the fuzzy structure and presence of a plenty of the isolated aggregation points, which are not experimentally observed.

For the removal of lacks of each considered methods we offer to combine AR and DLA in obedience to the following reasoning: calculate the fractal structure of settlement in obedience to a model AR; select the center of settlement; consider received cluster as only one aggregation center; particles which did not get to the cluster are considered free and continued motion in the potential field in obedience to DLA, aggregated on one cluster. This method gives a possibility to evade the problem of empty regions and calculate correctly front of fractal growth.

5. COMPUTER EXPERIMENT

For model approbation we have conducted experiment in which fractal structure of settlements Sudak-Noviy Svit, Novoselitsya, Kitsman' was simulated.

The settlements were chosen because of a presence in them brightly expressed summer residence buildings (fig.1 – fig.3). The geographical features of these settlements are:

- Sudak-Noviy Svit – located by the sea, has a considerable historical-cultural legacy and only one approach road (fig.1);
- Novoselitsya is a district center; there is two motor-car roads located under an acute angle to each other; a summer residence settlement appeared only on one of approach road (fig.2).
- Kitsman' is a district center; basic attractiveness centers are located in a city center; the road of state value hasn't many turns and crosses the center of city (Fig.3).

Potential field was calculated using entry parameters of fuzzy model with Sugeno fuzzy inference algorithm. As entry parameters we use distances to the historical-cultural centers, administrative objects, roads and distance by a road to the nearest object and geometry of seashore (Sudak-Noviy Svit). Relief features were not taken into account.

Calculations were carried out by the modified DLA method with such approaching: initial velocity of particle selected randomly; mirror border terms were used [15]. I.e. crossing the verge of probed area a particle appeared from an opposite side keeping all other run-time indexes.

In the process of Sudak-Noviy Svit region research obtained fractal consisted close to 74 000 aggregate particles. General structure of obtained fractal displays all features of the simulated region (fig.7, fig.10). Fractal growth at this region simulation reminds the projection of physical crystal growth on a plane. The basic objects of attractiveness are located coast-wise and near a road. As evidently from fig.10, the limitations account hinders fractal growth in the sea area.

Fig. 1 Picture from space: Sudak-Noviy Svit

Fig. 2 Picture from space: Novoselitsya

Fig. 3 Picture from space: Kitsman'

Figure 4 shows infrastructure segmentation of the probed region. From figure evidently that the more expensive infrastructure aggregates from particles $m = 1$ located along a coastline and surrounds the basic historical-cultural centers of Sudak-Noviy Svit. I.e. overtakes an area which more attractive. The middle class infrastructure is located very close to the expensive elements and makes a small layer compared to the expensive elements of infrastructure despite the initial amount of aggregate particles

with mass $m = 0.1$ exceeds twice aggregate particles with $m = 1$. Evidently absorption of middle business by the large business. Penetration of middle class elements in the area with expensive infrastructure is insignificant despite small business. The elements of small business with masses $m = 0.01$ are located on considerable distance from the basic attractiveness centers and gravitate to the road. From fig.4.c evidently, that this segment overtake both the surrounding villages outskirts for the probed region and «leaks» between the expensive elements of infrastructure. An alike picture is indeed observed, especially on resorts, where small shops and booths are located on the most prestige and expensive areas near-by a sea or centers of attractiveness.

As was said it is possible to reach the coast by approach road. From fig.4.c evidently that aggregating center formed by lightweight particles on an entrance to the probed region. As evidently

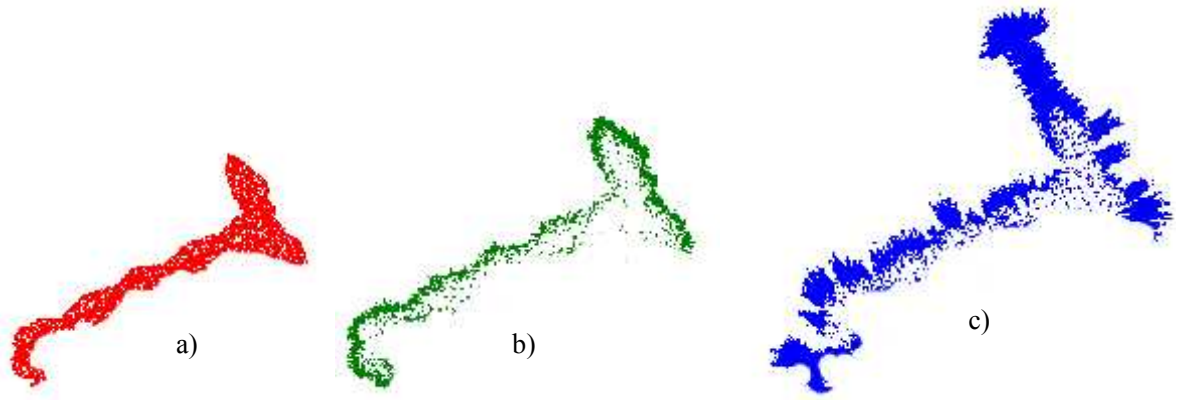

Fig. 4. Fractal structure segments of Sudak and Noviy Svit: a) $m = 1$, **b)** $m = 0.1$, **c)** $m = 0.01$

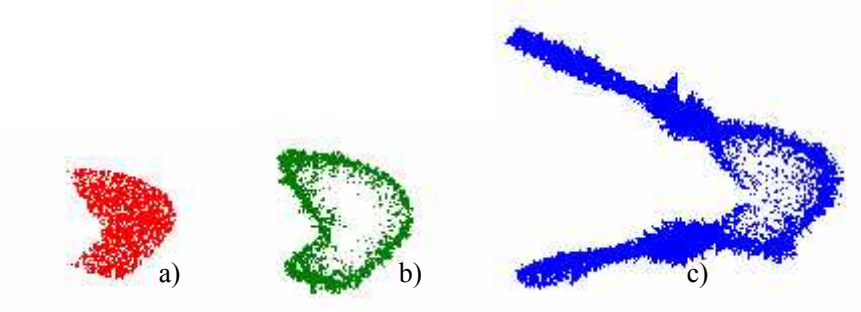

Fig. 5. Fractal structure segments of Novoselitsya: a) $m = 1$, **b)** $m = 0.1$, **c)** $m = 0.01$

from fig.1 and fig.4.c theoretically obtained aggregation center well correlates with this summer residence settlement with respect to distance to the coast and size. The differences in form can be explained by the territorial limitations accounting.

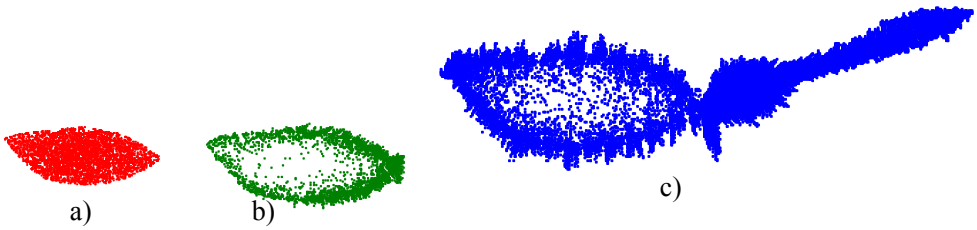

Fig. 6. Segments of fractal structure of Kitsman': a) $m = 1$, **b)** $m = 0.1$, **c)** $m = 0.01$

The obtain fractal structures of Novoselitsya (41 000 aggregate particles) (fig.5) and Kitsman' (30 000 aggregate particles) (fig.6) are repeated basic features of internal structure, which was observed for a region Sudak-Noviy Svit. I.e. the elements of large business take most investment attractive territories, ousting middle business. The elements of small business and private houses from one side gravitate to the roads and removed from a center, forming summer residence settlements and actively penetrate through the elements of large business.

From fig 5.c evidently that obtained fractal structures forecast formation of the two new aggregation centers in a direct closeness from the settlement center. When compared to fig.4 evidently, that the overhead center of aggregation in size and form repeats this summer residence settlement. However a lower center doesn't have the real analogues. It can testify to the potential attractiveness of this territory for development. And it is scientific soil for planning and development strategy of this region.

Fig.5.c represents clearly expressed summer residence settlement formation on the edge of the city with the clearly expressed peak in the place of road turn. As evidently from figure 3 such features of settlement geometrical structure is indeed observed on snapshots from space. Fig.3 testifies that on certain distance from a district center exists another settlement. On figure 6.c in this area indeed there is a bulge of fractal structure. Consequently this territory has a potential attractiveness for development. It resulted in an origin of new settlement in mentioned neighborhood. And now for this region real structure simulation it is needed to take into account this new settlement centers of attractiveness.

Similarity of theoretical structures and obtained segments with experimental structures confirms correctness of the offered prognostication and segmentation method and is foundation for subsequent theoretical and practical researches.

7. CONCLUSIONS

Method for the construction fuzzy potential field of attractiveness is presented. The algorithm of entry parameters calculation for fuzzy model is offered.

The algorithm of fractal growth calculation is presented in the fuzzy potential field by the «casual rain» and DLA methods. It is showed that accounting elements of molecular dynamics instruments, force of viscid friction and limitations in the DLA model allows adequately describe motion of particle in the fuzzy potential field.

Influence of the model empiric parameters on the form of cluster which grows is investigated. Empiric parameters values at which fluctuations in growth of cluster have place were defined. That results in appearance of the new aggregation centers. This mechanism was explained and proved.

During computer calculations we received fractal structures which well conform to experimental information. It confirms supposition that a crucial role in formation of settlements is played by a present infrastructure, namely: roads and present attractiveness centers.

Received segments are confirmed basic economic features of present infrastructure.

It is showed that the aggregation centers formed due to fluctuations repeat basic characteristics of the real summer residence settlements with respect to form and location.

Good correlation of experimental and computational data leads to adequacy of the offered methodology and allows to use it for subsequent prognostication both geometrical form and internal

structures of settlements. Research and analysis of new aggregation centers emerging is scientific soil for planning the strategy of region development.

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