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Crystal's fractal growth patterns in the fuzzy potential field for prognostication of socio-economic processes

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Summary: Methodology of crystals fractal growth appliqué methods in the fuzzy potential attraction field for forecasting of socio-economic processes is offered. Methodology of the fuzzy potential attractiveness field construction is shown. Modification and integration methodology of classical fractal growth methods is offered: diffusely limited aggregation and «accidental rain» methods with the molecular dynamics theory. The offered methodology was approved at forecasting of settlements geometrical structure. Geometrical structures which were received during calculations well correlated with experimental data received using modern GIS technologies.

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 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:

1. 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;
2. 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.
3. 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:

$$U = F(a_1, a_2, ..., a_n) \tag{1}$$

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).

Algorithm Sougeno:

Let knowledge base contain only two fuzzy rules like:

Rule1: if x is A1 and y is B1, then $z_1 = a_1 x + b_1 y$,

Rule2: if x is A2 and y is B2, then $z_2 = a_2 x + b_2 y$,

1. Fuzziness: the true degrees of every pre-condition for each rule are found.

$$\mu_{A1}(x0),\ \ \mu_{A2}(x0),\ \ \mu_{B1}(y0),\ \ \mu_{B2}(y0). \tag{2}$$

2. Fuzzy conclusion: the even "cutoffs" for pre-conditions of each rule are found (with the use of ***min*** operation)

$$\alpha 1 = \mu_{A1}(x0) \wedge \mu_{B1}(y0) \tag{3}$$

$$\alpha 2 = \mu_{A2}(x0) \wedge \mu_{B2}(y0). \tag{4}$$

Then “cutoff” membership function are found

$$z^*{}_1 = a_1 x0 + b_1 y0 \tag{5}$$

$$z^*{}_2 = a_2 x0 + b_2 y0 \tag{6}$$

3. The sharp variable value of conclusion is found:

$$z0 = \frac{\alpha_1 z^*_1 + \alpha_2 z^*_2}{\alpha_1 + \alpha_2} \quad (7)$$

For the calculation of potential attractiveness field form the method of recreational potentials maps construction could be used [11]. For this purpose the map of the territory *T* is covered by a rectangle $R = [a,b] \times [c,d]$. Obviously, that a rectangle R contains the set (territory) *T* ($T \subset \Pi$). Rectangle R is broken up by a net $\Delta = \Delta_x \times \Delta_y$, where:

$$\Delta_x = \bigcup_{k=0}^{N} \{x_k\} \quad (8);$$

$$\Delta_y = \bigcup_{l=0}^{M} \{y_l\} \quad (9);$$

$$x_k = x_o + kh_x, \ \ k = \overline{0, N} \quad (10);$$

$$y_l = y_0 + lh_y, \ \ l = \overline{0, M} \quad (11);$$

$$h_x = \frac{b-a}{N} \quad (12);$$

$$h_y = \frac{d-c}{M} \quad (13).$$

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.

Let the transport networks of the explored territory be set by an array:

$$w_f\left(x_{f1}, y_{f1}, x_{f2}, y_{f2}\right), \quad f=\overline{1,n}; \tag{14}$$

where n – quantity of roads vectors on the explored territory $x_{f1}, y_{f1}, x_{f2}, y_{f2}$ – co-ordinates of road vector.

Then distance h of point with co-ordinates x, y to the nearest road is determined in obedience to the following reasoning: we will consider a triangle with tops $A(x,y), B(x_{f1}, y_{f1}), C(x_{f2}, y_{f2})$ (Fig. 1.). The sides length is determined as:

$$a=\sqrt{\left(x_{f1}-x_{f2}\right)^2-\left(y_{f1}-y_{f2}\right)^2}; \tag{15}$$

$$b=\sqrt{\left(x_{f1}-x\right)^2-\left(y_{f1}-y\right)^2}; \tag{16}$$

$$c=\sqrt{\left(x-x_{f2}\right)^2-\left(y-y_{f2}\right)^2}. \tag{17}$$

The triangle attitude to side *a* (segment of road):

$$h'_f=\frac{2\sqrt{p(p-a)(p-b)(p-c)}}{a}; \tag{18}$$

$$p=\frac{a+b+c}{2}. \tag{19}$$

Segments a_1 and a_2, that determine distance between the attitude basis to the tops B and C accordingly and co-ordinates of attitude basis $\left(x'_h, y'_h\right)$ are determined as follows:

$$a_1=\sqrt{b^2-h_f'^2}; \tag{20}$$

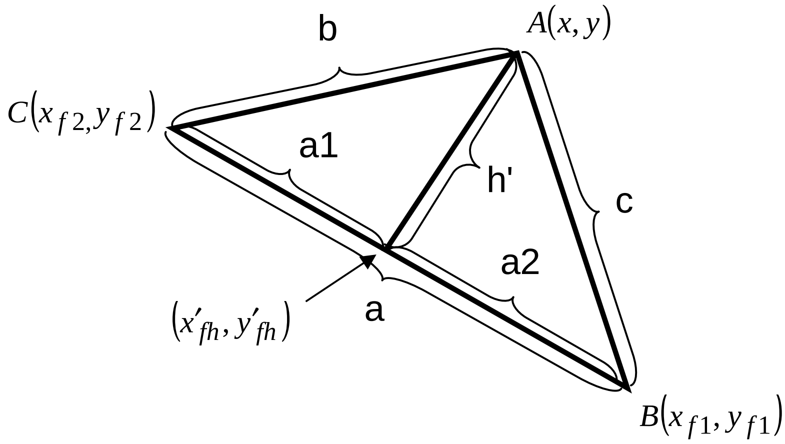

Fig.1. The triangle co-ordinates for determine the attitude to side a (h') and the attitude basis (x'_{fh}, y'_{fh}).

$$a_2 = \sqrt{c^2 - h'^2_f}\,; \qquad (21)$$

$$x'_{fh} = x_{f1} - (x_{f1} - x_{f2})\frac{a_1}{a}\,; \qquad (22)$$

$$y'_{fh} = y_{f1} - (y_{f1} - y_{f2})\frac{a_1}{a}\,. \qquad (23)$$

An attitude (12) is the shortest way to the road in the case if point (x'_{fh}, y'_{fh}) lies on the segment of road f. In other case the shortest distance to the road will be determined as:

$$h_f = \begin{cases} a_1 + a_2 = a, & h'_f \\ a_1 + a_2 > a \ \ and \ \ b < c, & b \\ a_1 + a_2 > a \ \ and \ \ b > c, & c \end{cases} \qquad (24)$$

Intersection co-ordinates accordingly:

$$(x_{fh}, y_{fh}) = \begin{cases} a_1 + a_2 = a, & (x'_{fh}, y'_{fh}) \\ a_1 + a_2 > a \ \ and \ \ b < c, & (x_1, y_1) \\ a_1 + a_2 > a \ \ and \ \ b > c, & (x_2, y_2) \end{cases} \qquad (25)$$

Then distance to the nearest road is determined as:

$$h = \min_{f=1,n}(h_f) \qquad (26)$$

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].

Let us suppose that in the moment of time t a particle is found in a point $(x(t), y(t))$ but moves with speed $(v_x(t), v_y(t))$. So in a projection on an axis the force which operates on a particle is:

$$F_x(t) = -\frac{\partial U}{\partial x(t)}; \tag{27}$$

$$F_y(t) = -\frac{\partial U}{\partial y(t)}. \tag{28}$$

Considering that during small period of time Δt force remains unchanging speeds of particle are calculated in the moment of time $t + \Delta t$:

$$a_x(t) = \frac{F_x(t)}{m}; \tag{29}$$

$$a_y(t) = \frac{F_y(t)}{m}; \tag{30}$$

$$v_x(t + \Delta t) = a_x(t)\Delta t + v_x(t); \tag{31}$$

$$v_y(t + \Delta t) = a_y(t)\Delta t + v_y(t); \tag{32}$$

$$x(t + \Delta t) = \frac{a_x(t)\Delta t^2}{2} + v_x(t)\Delta t + x(t); \tag{33}$$

$$y(t + \Delta t) = \frac{a_y(t)\Delta t^2}{2} + v_y(t)\Delta t + y(t). \tag{34}$$

where m – particle mass [15, 16].

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. As an example there could be the motion of bodies in air, resistance force of which at subsonic speeds is proportional to speed:

$$F_l = -\beta v; \tag{35}$$

where β – resistance coefficient.

Then:

$$a_x(t) = \frac{F_x(t) - \beta v_x(t)}{m}; \tag{36}$$

$$a_y(t) = \frac{F_y(t) - \beta v_y(t)}{m}. \tag{37}$$

As experiments showed, consideration of viscid friction allows evading the afore-mentioned failing.

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 (Fig.2.). 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 banal value $D = 2$ [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 a few clustering centers

Lets exist n clustering centers. For every center determines its weight w_i. In case if a settlement has a few attractiveness centers, gravimetric multipliers could be calculated, as the relative quantity of tourists who visited this centers for the definite period of time:

$$w_i = \frac{S_i}{\sum_{i=1,n} S_i} \tag{38}$$

where S_i – visitors quantity which visited i^{th} recreation object.

In obedience to an algorithm AR a particle moves on a random chord to one of clustering centers. The clustering center for every particle gets out random appearance depending on the size of the rationed weight w_i [17]. To avoid appearance of empty regions we suggested modifying the aggregation algorithm. On the whole algorithm of joining to the cluster is similar to AR, but after aggregation the copy of particle («transparent particle») is created that continues its motion to the center irresponsive on crystallizing particles. As soon as it gets in a region where there are no aggregated particles in a small radius R (that is a particle got in an empty region) «transparent particle» becomes «ordinary particle» and the accretion algorithm proceeds by a classic rule. How our researches showed the offered method allows to evade the first lack of model AR.

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. Then probability of aggregation of particle is determined as:

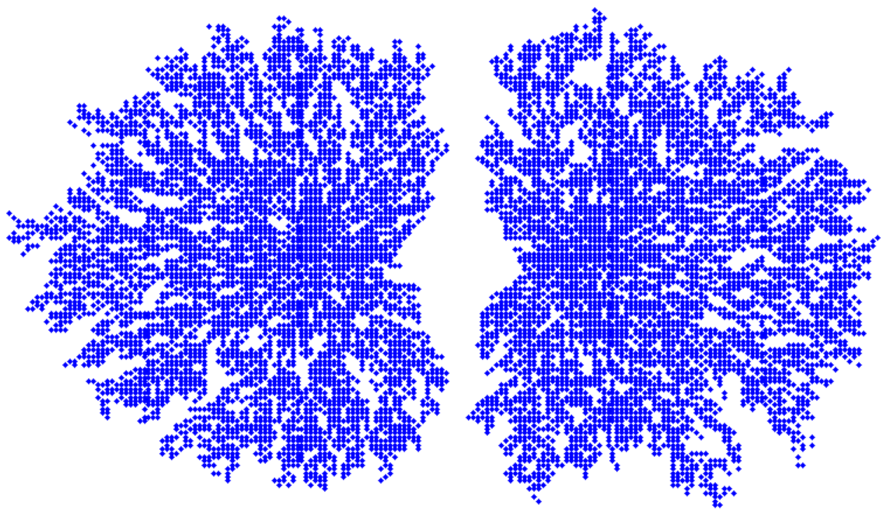

Fig. 2. Growth cluster in DLA model in the case with 2 crystallization centers

$$P(x,y) = U(x,y) \cdot P_a(x,y) \quad (39)$$

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. Computation algorithm

Computation of fractal structure of settlements consists of the following steps:

Step 1: *Determination of entry parameters and limitations.* Using the modern GIS systems (in our computations Google Earth was used) it is necessary to import the image and “kml”-cod of explored region. From downloaded “kml”-cod the geographical co-ordinates of clustering centers and roads vectors are determined. According (14-26) the matrices of fuzzy model entry parameters of the potential field are determined. Limitations and additional entry parameters are built in the analysis of image and imported in the proper matrices (8-13).

Step 2. *Potential field computation.* Using the method of construction of the aggregated attractiveness indexes [7-9], that will be based on the algorithm of fuzzy conclusions [6] the map of the potential attractiveness field (2-7) is determined. Entry parameters of model are the matrices received on the first step (8-13).

Step 3. *Initialization of clustering centers.* A zero matrix FT is initialized with dimension $n \times m$, that covers the explored region (($FT(0,0)$ – is the overhead left corner of received image $FT(n-1, m-1)$ – right is lower). The geographical co-ordinates of clustering centers, received in step 1 are translated in the co-ordinates of matrix FT. To the proper knots of FT the value «1» is appropriated. The single value of the matrix element determines the aggregated particle.

Step 4. *Design of fractal growth by a AR method.* In obedience to gravimetric coefficient w_i the center of accretion (38) gets out random number. In the random zero barn of matrix FT on large distance R from the center of accretion a moving particle will be initialized. The curvature of trajectory is determined randomly. In accordance with chosen trajectory a particle moves to the accretion center abandoning the aggregated own copies of the accordant modified method AR (39). A step 4 repeats oneself define amount times N .

Step 5. *Withdrawal of aggregation center.* Particles, that have less than two neighbors are considered free and carried in a separate matrix FP. The got matrix FT describes the aggregated cluster (settlement center).

Step 6. *Design of fractal growth by a DLA method.* Randomly chosen particle from matrix FP will be initialized in the matrix FT . In accordance with (27-37) acceleration, co-ordinate and speed of point in a next moment of time is determined. Iterations proceed while a particle does not aggregate at the observance of limitations, or the quantity of iterations will not exceed a definite large number M . A step 6 repeats oneself while matrix FP does not becomes zero.

Step 7. *Presentation of results.* Calculated matrix FT on step 6 is designed as the point graph. Co-ordinates of nonzero barns of matrix FT are translated into geographical co-ordinates of the explored region. Using the GIS maps editors (for example Google Map) co-ordinates are imported in «kml»-cod which is connected as an additional layer in Google Earth.

6. Computer experiment

As approbations of model we chose the known resort small town of Ukrainian Carpathians Vorohta, French city Albertville and resort seashore small town of south-east Crimea Sudak. The choice of these settlements is explained by their different

Fig.3. Vorohta (figure of the locality from space)

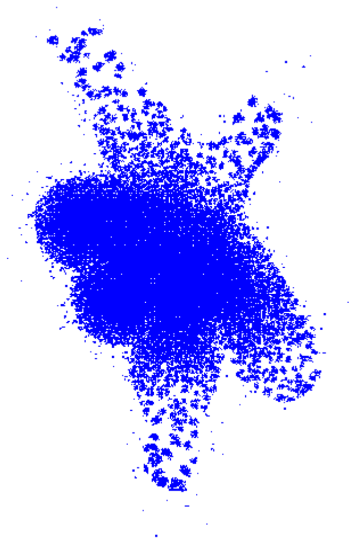

Fig.4. Prognosticated fractal structure of Vorohta built in the fuzzy potential attraction field according to the offered methodology (Step 6)

recreational directions, and also other mentality and legislation of Ukraine and France. Approbation of methodology will allow confirming its adequacy and possibility of the use of it for subsequent scientific researches.

The Vorohta settlement is located on height of 850 meters above a sea level on the river Prut (Fig. 3.). A resort Vorohta is the center of preparation of the Ukrainian sportsmen’ jumps from a springboard, biathlon and ski races. From the end of the XIX century Vorohta develops as a sporting-tourist center. Today Vorohta is one of basic centers of tourism of the Ivano-Francivsk region, both in summer and winter. For the admirers of ski sport here are a few lifts. Near a base « Avangard» there are bows: a 300-meters high and a 2-kilometre. Makivka is 250-meters bow lift. During a winter season two additional l00-meters lifts are set. Not far away from a settlement there is sporting-tourist base "Zaroslyac", from where the route on the greatest top of Ukraine Goverla begins.

Albertville is a popular winter resort. In 1992 the Winter Olympic Games passed in the town. Although Albertville is founded in XIX sentury, Conflan is apart of the city – settlement with well-kept building of XIV century.

To the prominent places of Sudak it is possible to deliver the well-kept fortress of the XI—XIV item, resort architecture of XIX century, charming natural landscapes, vine making state farm-factory Sudak, that lets out fine wines, aqua park. In a few kilometers from Sudak a small town Novyi Svit is located. In Novyi Svit the ex-manor of Leo Golitsin is situated, one of founders of the Russian vine making and factory of champagne. Around a small town the botanical preserve with unique plants, picturesque bays with grottoes is located.

As the first approaching at computation of the potential field by the entry parameters of fuzzy model, based on the algorithm of fuzzy conclusion Sougeno, distances to the afore-mentioned objects, distance to the roads, way by a road to the nearest object and the geometry of seashore (Sudak) were chosen. Relief features were not taken into account.

On stated below figures stepped results of the offered methodology are presented on an example of Vorohta city.

The received map of attractiveness potential, shown on fig. 5, evidently represents attractive places for building in districts Vorohta. However it does not give an answer about the real geometry and density of city quarters.

Computations by the method of modified AR were conducted in approaching of higher described. During the experiments the motion of 10 000 particles was explored. On fig. 6, forecast fractal structure of Vorohta is represented. From figures it is visible, that center of city, which is attractive for building indeed has greater density than «sleeve» which is located along roads. However, a plenty of the single houses located on large distances from a center and communications does not meet present data (fig. 3).

In accordance with offered methodology the aggregated cluster and «free particles» are selected (fig. 7,8).

Computations by the method of modified DLA were conducted in the next approaching. Initial velocity of particle got out accidental appearance. Mirror maximum terms were used [16]. So abandoning the explored region on one verge, a particle appeared from an opposite side saving of all other dynamic indexes. Most correlation of the reseived results with data of satellite survey was attained at mass of particle $m = 0.05$ but coefficient of viscid friction $\beta = 10^{-4}$. At the increase of acceleration mass falls (36, 37) and accordingly diminishes influence of the potential field. Reduction of mass results on the loss of fractal structure and the aggregated cluster fully repeats geometry of the potential field.

On figure 4 forecast of fractal structure of Vorohta is presented in accordance with offered methodology, that is folded with about 21 000 aggregated particles, on comparison with figure of this locality from space (fig.3.). Due to modification of AR model quantity of the aggregated particles exceeds the quantity of initiated.

From figures you can see that the received fractal structure repeats well the basic features of the explored region. The center of city and area is most densely populated, that adjoins to mountain-skier self-controls. Building is disposed along the elements of infrastructure and gravitates to the center of city. Moving away from a center the density of settlements falls and they form group in quarters, or tourist centers, that occupy a considerable area. From figure 4 you can see that combination of AR and DLA methods allows taking advantages and depriving lacks of the given methods.

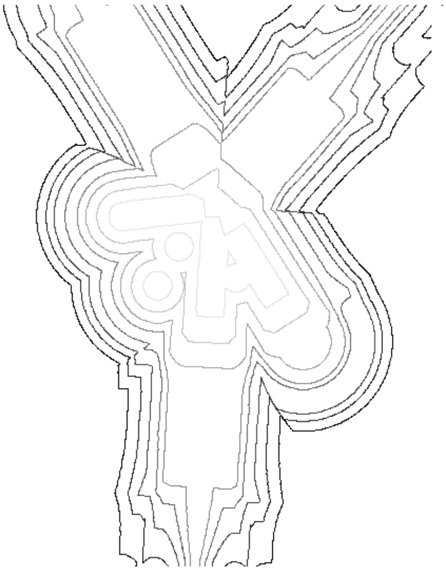

Fig.5. Potential attraction field of Vorohta which is based on the Sougeno fuzzy algorithm

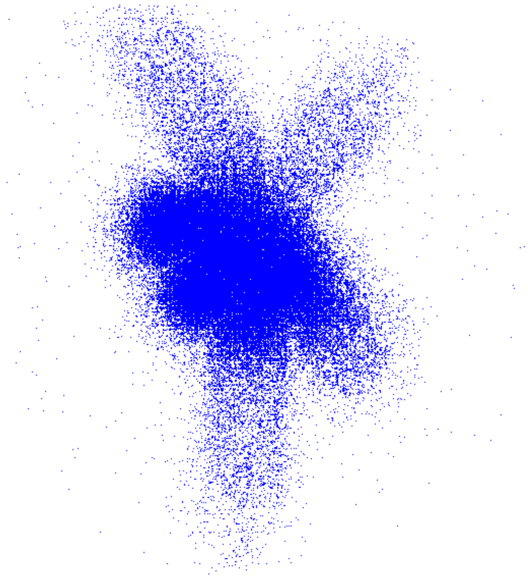

Fig.6. Prognosticated fractal structure of Vorohta built in the fuzzy potential attraction field according to the method of modified AR (Step 4)

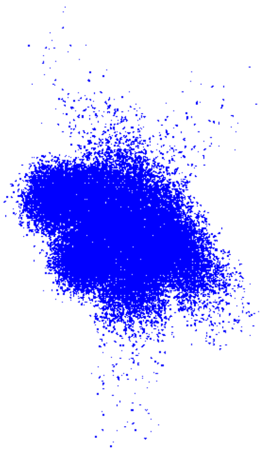

Fig.7. The received center of aggregation (Step 5)

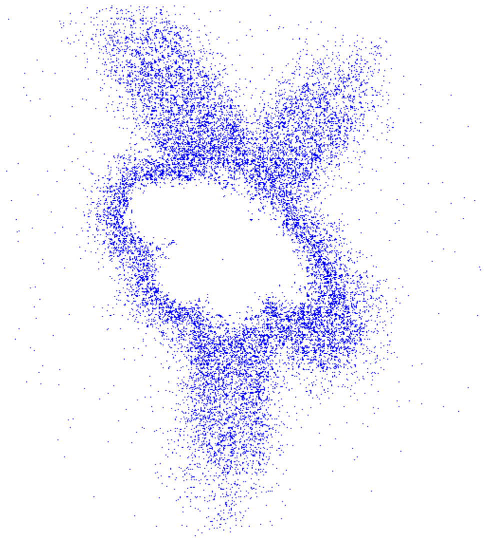

Fig.8. “Free particles” (Step 5)

Good correlation of the received results with experimental allows to use these methods for fractal structures prognostication of afore-mentioned settlements.

On fig. 9, 10 forecast of Albertville fractal structure is presented that is folded with about 28000 aggregated particles. As the clustering centers in Vorohta are located more compact than in Albertville, so during growth of fractal last one the greater quantity of empty regions appears (fig.2). Due to this the quantity of the aggregated particles fractal in Albertville almost in 1,5 times exceeds their quantity in Vorohta. The received results also show good correlation with the present structure of the explored region and repeat similar conclusions on Vorohta.

At research of region Sudak-Novyi Svit received fractal structure was folded close with 24000 aggregated particles. Calculated results also show good correlation with the present structure of region (fig. 11, 12). Fractal growth during modeling of the region reminds the projection of physical crystal growth on a plane. The basic objects of attractiveness are located along a coast and near a road. As you can see on the figure the consideration of limitations stuns fractal in the sea area.

The likeness of theoretical and experimental structures confirms justice of the assertion, that the basic part in forming of settlement geometry is acted by the existent

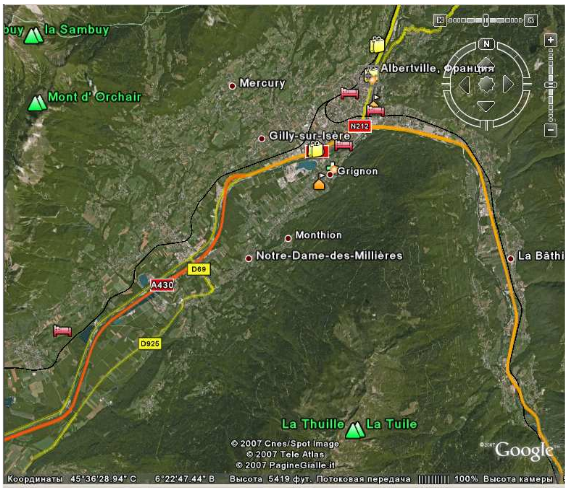

Fig.9. Albertville (figure of the locality from space)

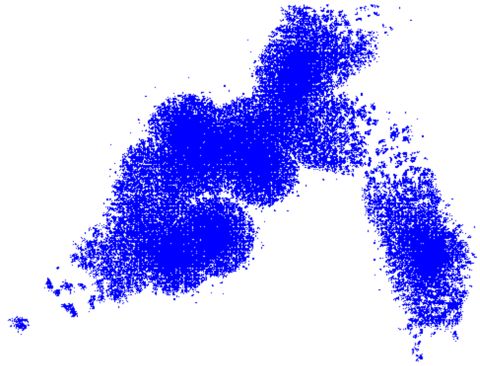

Fig.10. Prognosticated fractal structure of Albertville according to the offered methodology

Fig.11. Sudak, Novyi Svit (figure of the locality from space)

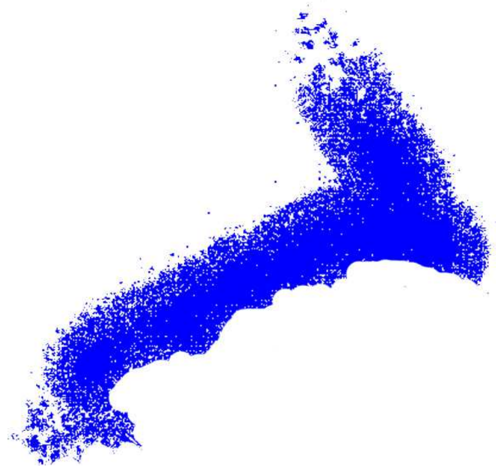

Fig.12. Prognosticated fractal structure of Sudak and Novyi Svit according to the offered methodology

ways of report and present centers of crystallization. And also is the authenticity index of the offered methodology.

Conclusions

The possibility of using the tool of crystals fractal growth for the modeling poorly controlled social processes on the example of settlements geometrical form forecasting in tourism industry has been observed and proved.

The construction methodology of the fuzzy potential attractiveness field was observed. Entry parameters types and limitations were defined and structured. Computation algorithm of fuzzy model entry parameters was offered.

Modified model of diffuse-limited aggregation offered by an author was observed and proved. It was shown that consideration of molecular dynamic tools elements' force of viscid friction and limitations in a model DLA allows to describe adequately motion of accretion particle in the fuzzy potential field.

Modified model of fractal growth «accidental rain» offered by an author was observed and proved. It was shown, the consideration of a few clustering centers and the determinations of particle aggregation probability allow describing adequately the motion of accretion particle in the fuzzy potential field.

The algorithm of AR and DLA methods combination is offered with the purpose of lacks removal and the receipt of the maximal adequacy of the model.

The algorithm of computer experiment is structurally presented.

During the conducted computer calculations fractal structures which conform well to present experimental data are received. It confirms our supposition that main part in forming of settlements is acted by present infrastructure, namely ways of report and present centers of attractiveness. From the other side, well correlated experimental data and data received during computation lead to adequacy of the offered methodology and allows to use it for subsequent prognostication of settlements geometrical form. It will give possibility at forming of the tourism development programs in a region, city, settlement to plan the centers of tourist attractiveness and create proper infrastructure.

The offered methodology will allow to conduct segmentation of settlements in the future with the purpose of determination of high-quality and quantitative composition and volume of segment in such a way that the given services must depend on the wishes of tourist. Integration on a volume will allow defining the middle quantity of tourists and accordingly foreseeing the money streams of the designed system.

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