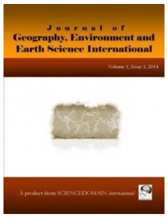

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Spatial Interaction of Socio-Geographical Objects: New Approaches and Methods of Investigation

Konstantin Niemets[1], Katerina Segida[2], Taras Pogrebskyi[1*] and YevgeniaTelebeneva[1]

[1]*Department of Socio-Economical Geography, V. N. Karazin Kharkiv National University, Ukraine.*
[2]*Department of Social and Economic Geography, V. N. Karazin Kharkiv National University, Ukraine.*

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

This article describes a new methodological approach of modeling the field parameters of socio-geographical objects by cumulative influence. This method involves determining the radius of the zone of influence of each object and determines the influence function, which interpreted as the opportunity to meet certain social needs. Integral function of the impact is determined by adding the influence functions of interacting objects and displayed on the background component, which depends only on the location of objects on the territory, and the attribute reflecting their interaction depending on the value of the parameter. The method makes it possible to explore a variety of structural sections of the field by changing the base radius of influence.

Keywords: Socio-geographical object; interaction; zone of influence; the radius of influence; the influence function; integral function of influence; background component; attribute component; spatial optimization; anomaly.

**Corresponding author: Email: tarastimo04@mail.ru;*

1. INTRODUCTION

1.1 Relevance of the Work

The problem of researching the interaction of socio-geographical objects is becoming increasingly important due to the growing influence of society on all processes in the society. Heterogeneity of settlement, due to the nature of the spatial organization of production, migration processes with periodic character, urbanization and other social processes lead to a complication of the organization of social infrastructure, unequal access to social services and exacerbate other social problems. For their solution and optimization of social infrastructure there were a need in the research of the spatial organization of society in relevant aspects and new methods which were created in the second half of the twentieth century, for example [1].

The modern concept of geographical (socio-geographical) space explains the interaction of socio-geographic features through the superposition and interference of the fields of their properties, which is a significant difference of the modern methodology of the research of spatial organization of society. In the basis of the development of new methods of spatial analysis in human geography laid achieve of synergy, for example, [2,3] ideas about the development of the Universe [4] and the spatial organization of geosystems [5]. The development of new approaches and methods of spatial analysis to identify the background and anomalous components of fields of socio-geographical features, fully accelerated, thanks to flexibility and creativity tools of GIS technology. In particular, the selection of positive or negative anomaly fields properties is an important prerequisite for the optimization of the social infrastructure. Therefore, the introduction of new methods of spatial analysis in the social and economic geography is very important and has great importance in terms of improving the effectiveness of socio-geographical research.

1.2 Formulation of the Problem

Geographical space, as a fundamental concept of modern geography, has a dual character. On the one hand, its elements are discrete geographic objects (GO), which form a spatial structure and interact within it. On the other hand, the reaction in GO is carried out by means of continual fields of different nature which are presented, in particular, by mathematical models. Thus, depending on the representation of GO quantitative characteristics, two types of tasks are solved. In the first case, if the parameters of GO are treated as deterministic values and do not contain random errors, the task of their fields modeling is reduced to interpolation - minimizing errors analogy. In the second case, when the value of the field at the reference points is presented as random variables, approximation methods are used with varying degrees of model approximation to the true values of the field. Thus, the epistemological problem of the geographical space study is that between the epistemological representation of the spatial structure of GO fields parameter and its ontological essence there is a conflict due to the methodological limitations of science. Therefore, in geographical study it is important to find in existing episteme the approximation method that is most appropriate for the research purpose and the most clearly spatial structure reflects the studied fields [6].

Typically, the spatial structure of GO fields parameter is interpreted as a reflection and the result in stationary or dynamic interaction of multiple GOs. If in physical-geographical studies, this interaction is defined and explained by the general principles of development in material world (conservation of mass, energy, momentum, movement, low power dissipation, etc.), in sociogeosystem studies we should take into account a significant complication in actions of mentioned principles and laws due to subjective (human) influence. Taking this into account, the parameter fields simulation of socio-geographic objects (SGO) is more difficult task due to the increased unpredictability of social sociogeosystem impact.

1.3 The Purpose of the Work

The purpose of the work is to describe a new approach of modeling the field parameters of socio-geographical features, based on the concept of the influence function of the object.

2. BASIC MATERIALS

In the structure of geospatial data vector there usually are present three components: X and Y coordinates on the horizontal plane and the value of the field Z – “height” point. However, in the practice of socio-geographical research, there are occasions when the value of Z is determined semi-quantitatively, on an ordinal or nominal scale or does not have a quantitative assessment. An example of such situation could be an analysis of the social structure (commercial, cultural, religious, educational institutions, etc.) for which the coordinates are set, but there are no exact data of the number of visitors or users. In this case, the traditional methods of spatial analysis are ineffective or does not apply, so we need new approaches, one of which is covered in this paper.

Consider at first the situation where the vector of initial data is full. Usually in such cases, the procedure of trend analysis is used. Traditional model - the gravitational - reflect the spatial structure either too rough (as the potential parameter Z) or too detailed, making it difficult to analyze. Therefore, the method of statistical averaging in the sliding window is used which allows us to consider different levels of generalization in the field structures changed by the size of the sliding window. However, in our opinion, to use the same radius for all SGO windows is not quite correct. The fact is that even the same type of SGO in social infrastructure have different demand of the population, that is, figuratively speaking, have different "power". For example, the library on district, city and regional level has qualitatively and quantitatively different fund and, therefore, satisfy the needs of the population in different ways. Obviously, that the level of the regional library has the ability to meet the needs of readers more fully, so it is visited by more users and the radius of its service is bigger. Similarly, it can be argued that the clinic which has a regional value has much greater influence than the district hospital or infirmary. We generalize this to the theory of central places, where it is stated that the service centers of different levels have different radius of services. Thus we come to the conclusion that the SGO key feature that determines its interaction with other objects, is the radius of influence zone, by which we mean the distance from the SGO, on which it ceases to interest the consumer, as a source to meet a specific need. More generally, the influence radius of SGO can be definedas the radius of the zone in which the SGO affects any component of sociogeoprocess [4].

In determining the radius of GSO influence zone it is logical to assume that it is proportional to the capacity of the facility - the value Z. Therefore, SGO which has the smallest value Z, will have the smallest radius of influence R_0, which can be defined as a base. We offer to use the following relationship: [4].

$$R_i = R_0 + k * \ln(Z_i / Z_{\min}) \tag{1}$$

where Ri – a radius of influence of ith SGO; R_0– base radius of influence; Z_i and Z_{min} – respectively, the value of the parameter of ith and basic facilities; k –a scaling factor. From this formula follows that changing the influence radius of SGO (and correspondingly the generalization degree of the model fields) can be performed systematically by R_0 or scale factor k [4].

Obviously, the intensity of SGO influence within its area of influence regularly decreases from the center to the periphery, which can be described, for example, by nonlinear dependence of invariant features (Δ):

$$\text{If } L \geq R\ \Delta = 0;\ \text{If } L < R\ \ \Delta = (1 - L/R)^n \tag{2}$$

Where L – current distance to the center of SGO influence zone; R – radius of SGO influence; n – an exponent which is defined arbitrarily. Then the SGO influence parameter in zone of influence is defined as following:

$$p = Z^* \Delta \tag{3}$$

where Z –quantitative parameter (the power) of SGO in the center of influence zone.

Taking into account that zones of SGO influence are often overlapped with each other, that actually reflects their spatial interaction, it is useful to analyze the situation from the standpoint of capacity to meet the needs of the user [7]. If it is in the one SGO influence zone, it hasn't any alternative choices, that is, the user has access only to this SGO. The situation is different when the user is in several SGO influence zones, then he has a choice, which increases the possibility of an optimal satisfaction of his needs. Obviously, this option is proportional to the sum of SGO influence functions at this point, that we can express by the integral function of impact (IFI) [4]:

$$F = \sum_{i=1}^{m} (1 - L_i / R_i)^n \tag{4}$$

Where F– integralfunction of influence at given point of territory; m – the number of SGOs which have impact at this point, the rest of the notation is the same. The field models based on the described procedure reflect different levels of field generalization, allowing to explore its spatial characteristics in a wide range of reflection - from the most subtle spatial structure, up to the roughest approaching to the gravity model.

In case of estimating the power of SGO on nominal or ordinal scales, in formula (1) code (threshold) values of Z may use expert estimates. In the absence of parameter estimation Z (case of incomplete vector of geospatial data) the differentiation of the investigated SGOs by power becomes impossible, but the use of influence function (2) and IFI (4) allow us to perform an analysis of the spatial structure of the field with certain approximation.

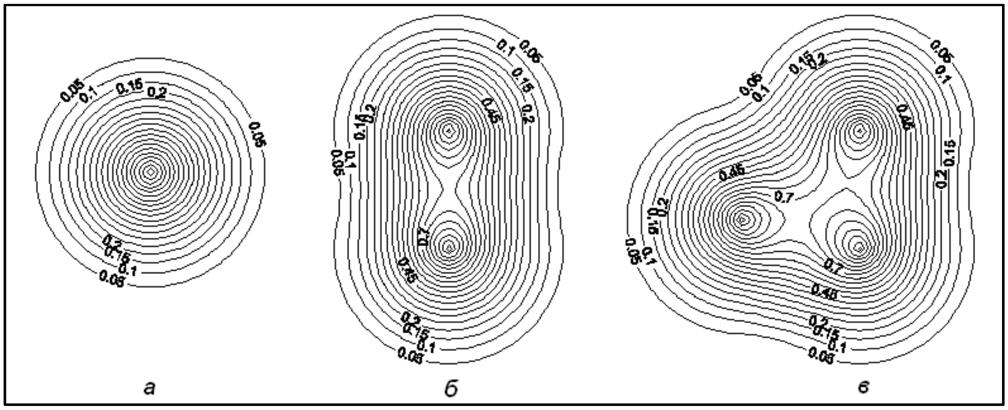

Fig. 1. Examples of display zones of influence of social and geographic features: a) one object; b) two interacting objects; c) three interacting objects; contours reflect the level of integrated functions influence

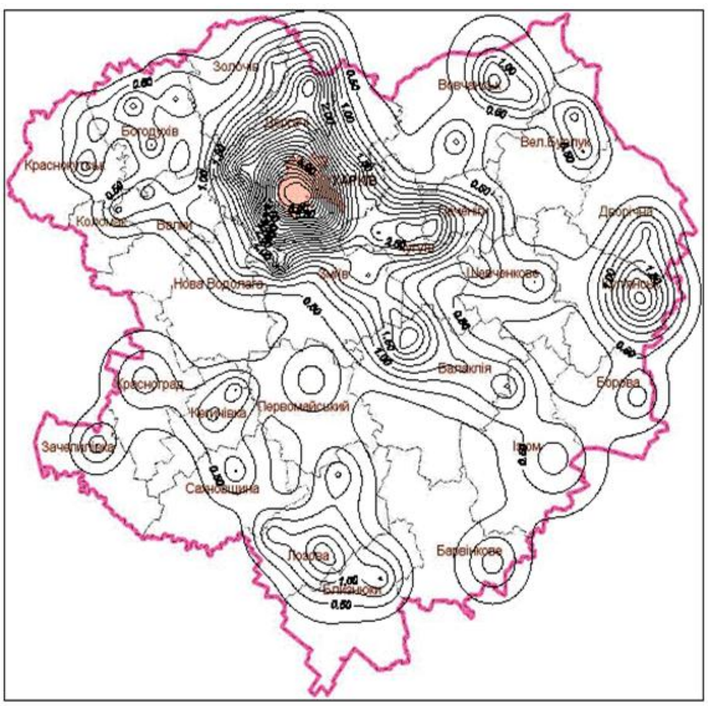

Fig. 2. The model of population of the cities of Kharkiv region with a base radius of influence R_0= 5 km

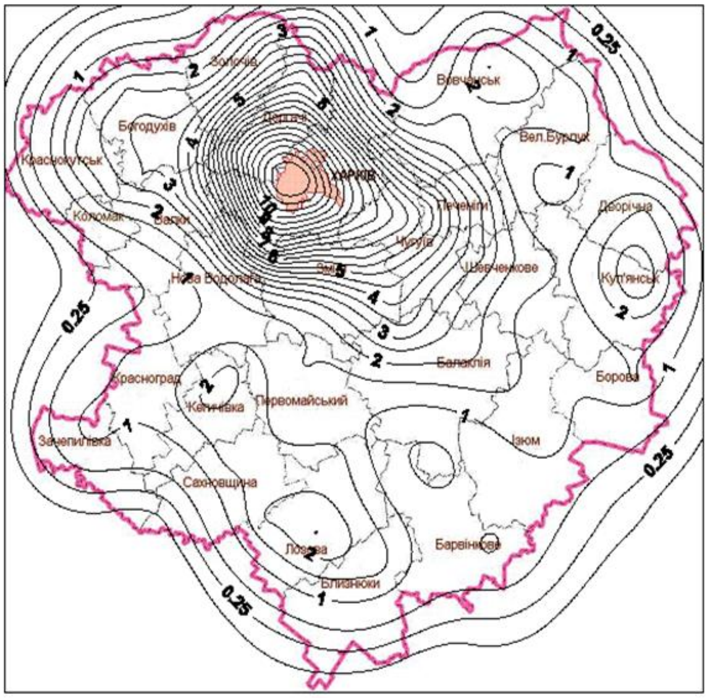

Fig. 3. The model of population of the cities of Kharkiv region with a base radius of influence R_0= 25 km

This models are an effective and versatile tool for investigating the spatial structure of the interaction of social and geographical features. Thus, the basic version with a small radius of influence (Fig. 2) in some detail reflects the microstructure field interaction of social and geographical features.

Increasing of the base radius of influence leads to generalization of the surface and gradual transition to display macrostructure field (Fig. 3).

The general model of field parameters can be decomposed into two components [4]. The first of them (background) reflects only the features of the spatial distribution of the SGO and is built with a permanent base for all objects influence radius R_0. It is obvious that this component is invariant with respect to the parameters of SGO. It should be considered in spatial optimization of social infrastructure. The second (attribute) component represents the distribution in space, depending on the parameters of SGO and strictly individual for each test parameter. It is obtained by subtracting from the total model background component and reflects the interaction of SGO for each parameter in the "pure" form. Anomalies of the field reflected on the second component should be considered when solving applied problems (optimization, network development, the definition of loads, etc.).

Using the described technique of spatial analysis of SGO interaction in the analysis of various aspects of the sociogeosystems on different levels proven to be effective and, in some cases – has no alternative in the socio-geographical studies.

3. CONCLUSIONS

The above can be summarized as follows.

1. In solving of many applied problems of socio-economic geography must perform spatial analysis based on the achievements of synergy, cybernetics, information theory and general systems theory.
2. Great methodological and applied significance have the spatial structure model of field parameters of socio-geographical features that allow to mark the background and anomalous components.

3. The proposed methods of modeling allow to explore the various structural sections parameter of fields of socio-geographical objects – from subtle to the most coarse structure that is necessary for the fundamental description of the spatial object interaction.In particular, the division of the total model on the background and attribute components useful for each section to optimize the placement of objects and various applications, such as optimization, network development, determination of loads, etc.
4. Testing of the proposed approaches and methods for solving a variety of scientific and applied problems of social geography has proved its effectiveness, efficiency and promising.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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