Published in the USA
European Journal of Technology and Design
Issued since 2013.
E-ISSN: 2310-3450
2023. 11(1): 27-32

DOI: 10.13187/ejtd.2023.1.27
https://ejtd.cherkasgu.press

Informational Granular Analysis

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Abstract

The article offers a new type of analysis of complex heterogeneous situations. The article introduces a new information model, called a granular information model. The model has two categories of parameters. The first category of parameters defines the boundaries of the model and defines the commonality. The second category of models describes the specific properties of the model. On the basis of the information model, a new type of analysis is proposed – granular information analysis. The difference between this analysis and the methods of granular information processing is shown. For the granular information model, a set-theoretic description is proposed. Granules are considered as homogeneous sets in a heterogeneous field. Granules have homogeneous and heterogeneous parameters. When describing granules, there is an analogy with the description of geodata. Homogeneous coordinates define the boundaries of the granules. Granules are objects of real and parametric space. Inhomogeneous coordinates describe the quality and relationships in granules. The article introduces the concept of contextual structure. The contextual structure does not have a visual form of representation and can only be analyzed with the help of computer technologies and construction rules. The new model expands the range of solvable tasks of analysis and applied problems.

Keywords: modeling, analysis, information models, normative sets, granular model, information field.

1. Introduction

Information granular analysis is a new direction in the theory of analysis and the theory of information modeling. Granular computing is widely known (Yao et al., 2013; Bargiela, Pedrycz, 2022). Informational granular analysis is an analytical direction in analysis. Information granular analysis (IGA) is based on combination with other types of analysis. Among these types of analysis, the following should be distinguished: set-theoretic analysis, cluster analysis, qualitative analysis, comparative analysis, system analysis, and spatial analysis. IGA methods are (Rogov, 2020): composition, overlay, conceptual mixing (Savinykh, 2017), stratification, clustering, and others. Granular analysis is not limited to a single method or algorithm. IGA should be seen as an approach to finding patterns that exist in the real world. IGA is related to the information granular model and methods for its construction. The Information Nullified Model (IGM) is a complex model that is found in cluster analysis and is rarely found in set theory. The difference between

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IGM and other models can be shown using topologies. Most areal and cluster models can be described by a planar graph. In general, a nulled model is not described by a planar graph, but is a hypergraph in parameter space.

The aim of the IGA is to develop additional methods of analysis and reasoning methods. IGA can be referred to as gentle methods of information analysis (Zhang et al., 2020). Information analysis using granulation is closeto fuzzy calculations. Fuzzy information granulation and, in fact, the basics of granular analysis were first proposed by JI. Zadeh. The theory of analysis is based on fuzzy information granularity (TFIG) (Zadeh, 1979).

The basic idea of IGA is to isolate in space some homogeneous sets called granules. Granules are combined and their influence in the information field or in the real field on ongoing processes or on a situation is evaluated. In this way, IGA makes it possible to find cause-and-effect relationships, explain complex situations or processes, and predict further developments.

2. Discussion and results

A granule as a local set.

To describe information granules, let's introduce the concept of local set (LS). A local set has boundaries and two categories of elements: homogeneous P and inhomogeneous U (Figure 1).

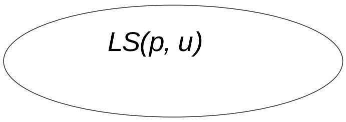

Fig. 1. Granule as a Homogeneous Set

Homogeneous elements of the granule differ, but have the same quality, describe the same indicator.The most striking example of homogeneous elements is coordinates. For example, homogeneous elements can be three-dimensional coordinates $p_1 = X$, $p_2 = Y$, $p_3 = Z$, or distance L. An example of a set of homogeneous elements would be a map or plan that has areal or line features. Map granules are areal features. When describing granules, there is an analogy with the description of geodata (Savinykh, Tsvetkov, 2014; Zuo, 2020). Homogeneous coordinates are analogous to coordinates that describe space. Inhomogeneous e coordinates are analogous to attributive coordinates.

In the information or geoinformation field, a granule is an information model. It can be called an information granule. An information granule is an information model that can be described as a local set.

The part of the granule that is defined by homogeneous coordinates is called homogeneous. A homogeneous part of a granule can be a volumetric object, an area, or a linear feature. For example, a section of railroad or a set of connected railways is an example of a linear granule. For homogeneous elements, $p_1 \cap p_2 \cap p_3 = \varnothing$. Homogeneous variables provide a coordinating basis or basis for analysis. They can be not coordinates, but any selected coordination parameters against which heterogeneous parameters are analyzed. Homogeneous elements or variables create a coordination system for heterogeneous elements.

Heterogeneous elements have different qualities. They can describe different metrics. Heterogeneous elements can be compared to the "load" parameter in geostatistics (Diggle et al., 1998; Emery, Maleki, 2019). For example, the density of rock in the volume of the soil, indicators of pollution of the reservoir with various chemicals, the concentration of harmful substances in the air, population density, transport provision of the region, the level of education in the For an urbanarea, the U elements can be:

Transport accessibility u1;
Air pollution u2;
Development of the social sphere u3;
Noise level u4;
Soil contamination u5;
Traffic intensity on the road network u6;
Degree of medical care u7;

Provision of educational institutions u8
Number of recreation areas u8;
The density of industrial enterprises is 9;
Problem areas in traffic u10;
The presence of problem areas in the movement of pedestrians u11;
The presence of traffic junctions u12;
Availability of safe crossings u13;
Building density u14;
Population density u15;
District status u16 and so on.

Heterogeneous elements or characteristics create a stratified system. There is ananalogy with stratified information in GIS. Heterogeneous elements lie in different layers, but together they can amplify the impact andcause a negative or positive effect. For them, you can enter an influence function (IF) measure. The "influence function" is a complete analogue of the field function in the theory of the information field (Kudge, 2017). Therefore, the theory of the information field can be fully applied in information granular analysis.

Information granule.

An information granule is an information granular model (IGM). The IGM reflects a set of related elements. The elements of a set can generally be independently related. IGM has boundaries and two categories of elements: homogeneous and heterogeneous. Homogeneous elements define boundaries. Heterogeneous elements define commonality. IGM is physical in nature or parametric in nature. In the physical nature, an information granular model reflects a physical object, such as a cloud in the sky or a physical container. In the parametric nature, the granular information model reflects an object in parameter space, such as an information container. The IGA is a situational model and describes the situation. The more parameters there are in a situation, the more complex its visual representation and the more difficult it is for a person to analyze it. Detailed granular analysis requires the use of additional functions that describe the situation.

A distinctive feature of the granular model from other information models is its contextual structure. The contextual structure has no visual or topological representation. It is based on multiple parametric relationships. A physical granule can be an area object, a three-dimensional object, and a linear complex object. An information granule always has content.

Logical constructions in IGA.

Building a granular model or a granular situation should be based on logic. Any cause-and-effect relationship or logical chain is based on logical constructions. In the information field, logical constructions are associated with information construction (Tang et al., 2019). In logical constructions, it is necessary to distinguish between direct descriptions and contextual descriptions. Granules that use context are called "contextual" granules. Granules that use a straight, logical linear description are called "straight" granules. For straight granules, logical constructions in the language of formal logic are possible. For contextual granules, logical constructions are possible using argumentation, modal logic, natural language logic, and fuzzy set theory. Methods of logical construction have led to the concept of "logical space" (Pinkal, 1989).

In order to combine granules and connect them into a system in logical constructions, it is necessary to introduce the concept of "logical structure". In logic, the basic relation is the equivalence relation. It allows you to transform one Boolean expression into another while maintaining truth. In granular analysis, a broader and sometimes contextual relationship is used – the "correspondence relationship".

Within the framework of the correspondence relationship, logical constructions are carried out in granular analysis. A correspondence relationship allows you to move from logical formalism to natural language logic. The logical construction can be thought of as a reduction. This is due to the fact that functional and attributive aspects, as well as comparative characteristics, are excluded in logical constructions. In granular analysis, multivalued logic is also applicable due to the fact that heterogeneous variables have different qualities. The key to granular logic is the "correspondence of meaning" between the initial conditions and the granular model.

Granular information structure.

A granular information construct is a derivative of the model of an information construct. A granular information construct is a type of information model built with the use of granules.

Figure 2 shows a granular information model. It can be considered as a structure due to the fact that it has a general and conceptual appearance. Fig.2. have the following designations*:* R 1, R 2, R 3, *R4* – regions (granules), Granules G 1, common area *G2* – comfort zone (dotted line). Granule *G3 is* a zone of high contamination. Territorial zones X, Y.

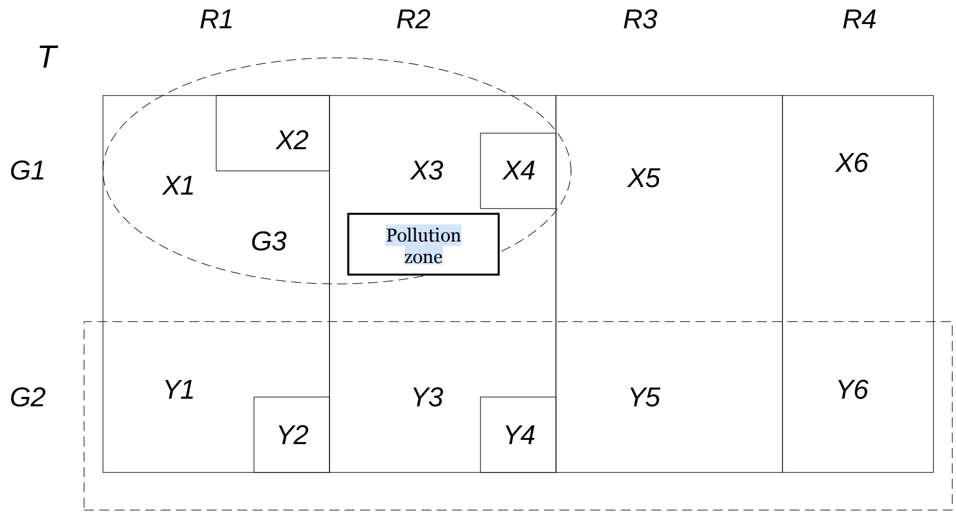

Fig. 2. Information granular structure

For the model in Figure 2, the following relationships apply.

$$R1 \cup R2 \cup R3 \cup R4 = T \quad (1)$$

In expression (1), T stands for the entire territory.

$$G1 \cup G2 = T \quad (2)$$

$$G3 \subset G1 \quad (3)$$

$$(X1, X2, X3, X4, X5, X6) \subset G1 \quad (4)$$

$$(X1, X2, X3, X4) \subset G3 \quad (5)$$

$$(Y1, Y2, Y3, Y4, Y5, Y6) \subset G2 \quad (6)$$

$$(X1, X2, Y1, Y2) \subset R1 \quad (7)$$

$$(X3, X4, Y3, Y4) \subset R2 \quad (8)$$

$$(X5, Y5) \subset R3 \quad (9)$$

$$(X6, Y6) \subset R4 \quad (10)$$

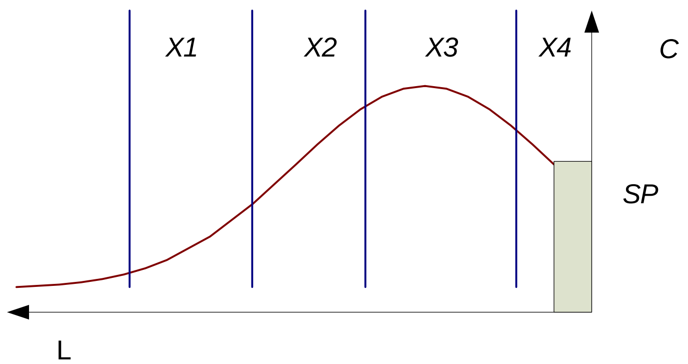

Fig. 3. Cross-section of granule *G3* according to the characteristic "ambient air pollution" (C).

Formulas (1-10) define the contextual structure of the granular model. In this example, you can see the difference between a topological structure in the form of a graph and a contextual structure in the form of relationships. The topological structure is observable by man and perceptible by man. The contextual structure is immeasurable by a human being and is perceived by a computer. The model in Figure 2 refers to the area of the information field. It is conceptual, as it describes the situation in a simplified way. Figure 3 illustrates this.

Figure 3 shows the source of SP contamination. It is usually the pipe of an industrial plant. The law of distribution of the concentration of a substance (C) is usually close to the logarithmic-normal distribution (Figure 3). Expression (5) does not distinguish between zones *(X1, X2, X3, X4)*. Figure 3 and the calculation of the function C(L) show such a difference. This example shows that the granular model does not provide comprehensive information about the situation. It allows for visual analysis. A more detailed analysis requires the use of functions that describe the situation. That is, the use of the field function of the information field.

Figure 3 shows that for this profile the place is a trend

$$C(X1) < C(X2) < C(X3) \quad (11).$$

For granules C(X2) C(X4) there is a proportionality ratio

$$C(X2) \approx C(X4) \quad (12)$$

Expressions (11) and (12) are used in decision support, for example, in solving the problem of placing a feature.

A granular information construct displays patterns and systems of relationships. A granular structure is a model Relationship systems are part of a granular model that reflects the situation of reality. A granular model is a situational model. Granular modeling can be thought of as an information field process. The purpose of granular modeling is to build a related set of parameters that describe a real situation. This combination allows for analysis and calculations.

3. Conclusion

The article introduces a new model, a granular information model. This model serves as the basis for granular information analysis. Granular information analysis is used when it is necessary to study complex heterogeneous models or sets. An example of granular analysis would be cluster analysis. An example of a granular information model would be a cognitive map. An information granule is a heterogeneous information model consisting of homogeneous models or clusters. There is a weak connection between the parts of the information granule. Physically, granules have a variable density. For example, clouds of smoke or the distribution of the concentration of harmful substances in the atmosphere. A granule has boundaries (often blurring) at qualitatively homogeneous coordinates and commonality at heterogeneous coordinates. On the example of granules Dissipation in the information or physical field can be observed.

A cloud is an example of a granule. A cloud has physical (fuzzy) boundaries and chemical composition (heterogeneous coordinates). A cloud is a three-dimensional physical granule in physical space. The information model of the cloud is the information model of the anula. A land plot is a physical areal two-dimensional granule. An information model of a land plot is an information granule. A section of railway with a right-of-way is a linear granule. An information model of a railway section is an information granule.

The information granule model is described using set theory and as an information model. An information granule has homogeneous and heterogeneous parts. An information granule can describe areal and linear objects. This increases its application in geoinformatics. In terms of content, an information granule is an information situation.

Granular analysis uses a contextual description of the structure. Such a structure has no visual form of representation. It excludes the possibility of human analysis of such a structure. The contextual structure is understood only by the computer, and this is a disadvantage of the granular approach. On the other hand, it is a method of analyzing complex structures.

A granular model is a situational model and describes a situation. The more parameters there are in a situation, the more complex its visual representation is and the more difficult it is for a person to analyze it. Detailed granular analysis requires the use of additional functions that describe the situation. These additional functions are field functions of the information field. It follows that information field theory is compatible with granular models. Information field theory helps to perform information granular analysis. The granular model makes it possible to describe complex aggregates that include different qualities. The proposed methods of granular analysis make it possible to analyze complex situations that cannot be analyzed by other methods.

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