https://doi.org/10.37658/procgeo19145j

UDC: 912.43

SUBLIMATION OF GRAPHICATION AND GEOVISUALIZATION USING THE CARTOGRAPHIC METHOD

Jasmina M. JOVANOVIĆ, Dragica ŽIVKOVIĆ, Vladan GRBOVIĆ

University of Belgrade - Faculty of Geography, Belgrade, Studentski trg 3/III, Serbia
jasmina@gef.bg.ac.rs

Abstract

The map is the basic tool of interactive, dynamic geospatial research. The complex structure of geo-data is necessary to be graphically interpreted with the help of cartographical presentation (locational and attributional). The synergy of cartographic visualization, generalization and cartographic methods enables efficient implementation of geosystem analysis. Geovisualization includes a range of activities according to research, systematization, classification and typification, analysis and synthesis, comparison, presentation to the interpretation of occurrences and processes in geospace. The cartographic translation is a complex process of visualization of geo-data, based on the scientific procedures of generalizing the content of the map using the cartographic method. The gnoseological sense of the cartographic method is also the primary goal of geovisualization: - spatial definition of the phenomenon, - time correlation of the phenomenon and processes of actual reality and their evolution, and - essential definition of the phenomenon and processes of actual reality. The cognitive sense of cartographic visualization is primarily achieved through the procedures of cartographic generalizations. Digital technology provides great opportunities for modern cartographic visualization. Besides realistic, virtual maps are of great importance too. Visual dynamic representations of geo-data (interactive visualization of spatial databases) and the creation of detailed 3D and 4D models are continually increasing. Digital data processing enables new dimensions of data analysis, and the process implies generalizing data from the source database while respecting different geo-data attributes, as well as adequate graphical solutions in displaying a generalizable data set.

Keywords. Map, cartographic method, cartographic generalization, geovisualization, geo-data translation

Introduction

Digital, information society implies a visual presentation of systematic geo-data, in order to obtain complex information, which enables the acquisition and exchange of knowledge about geospace in a fast and clear way. The map enables the materialization of real-world knowledge and a graphic-visual interpretation of that knowledge. Grelot (1994) points out that “the task of cartography is to transform geospatial information into a visual form.” The efficiency of the cartographic visualization form of a large set of geo-data, of heterogeneous nature (in quantitative and qualitative terms), is conditioned by the degree of their generalization (taxonomic, spatial, attribute and graphic). The complexity of research and presentation of components of a geospatial content, in order to obtain the necessary information (location, properties, specificities, structures, degree of correlation, intensity, territorial-temporal pattern of distribution, development and dynamics of phenomena and processes), requires a high degree of correlation of procedures for generalizing the map content and the applied cartographic method.

Cartographic visualization and geospatial analysis

Geovisualization as a term covers a wide range of activities ranging from research, systematization, classification and typification, analysis and synthesis, comparison, presentation, to the interpretation of phenomena and processes of geospace. In a narrow sense, the term refers to the visual presentation and way geospatial data are used (Jovanović, 2017). Cartographic visualization involves the visualization of data that provide spatial, temporal, and attributive information. In this context, the cartographic translation of geo-data is a complex visualization process, which is unambiguously based on scientific procedures for generalizing the map content and applying the adequate map method. The gnoseological meaning of the cartographic method is at the same time the basic aim of geovisualization, which achieves: - the spatial definition of phenomena and processes (spatial localization and reciprocal relations), - the temporal correlation of phenomena and processes of true reality and their evolution, and - the essential definition of phenomena and processes of true reality (determination and research of quantitative and qualitative characteristics of phenomena and processes) (Salishchev, 1982).

Estimates indicate that of all digital data, 80% include geospatial reference (geographical coordinates, address, etc.). Georeferencing integrates a large number of heterogeneous data simultaneously through their shared geospatial connection. In this way, from originally derived data by visual presentation and interpretation, the derived systematized and classified heterogeneous data are obtained. That is, through visual research and analysis, the interpretation of geo-data provides integrated information that acquires knowledge (MacEachren & Kraak, 2001).

For centuries, maps have visually presented knowledge and enabled people to understand system-related real and abstract phenomena and processes of geospace. In the past, analog maps were designed to represent databases that only presented reality. With the development of digital technology and GIS, the role of maps is changing. “The map is not only a graphical representation of geographical space, but is a dynamic portal for interconnection and distribution of geospatial data resources, and is moving towards supporting information research and knowledge creation” (Jovanović, 2015). The map nowadays provides faster access to geospatial data and information derived from it. Geosystem analysis extends the traditional role of the map - from presentation to the complex process of organizing and exploring geospatial data, within knowledge-related activities (access, presentation and use of productive information). Cartographic space is expanding with the use of digital technology. Geospatial presentation graphics, using visualization tools, becomes more versatile, realistic, and oriented to user needs in a given time (interactivity, dynamics, analytics, etc.).

The variety of cartographic visualization is constantly increasing, and as a result, its field of application is increasingly evolving. The use of information and communication technologies (ICT) in cartography expands and redefines its importance. Geospatial analysis has become a standard data processing operation. Key elements in this process are cartography and geographic information system (GIS). Essentially, GIS enables the integration of different geospatial data, and cartography to direct the GIS-derived mapping results to a good mapping design to perform geospatial analysis (Kessler & Slocum, 2011, Hennig, 2016). Methodological solutions, through adequate forms of geovisualization, should enable the performance of new productive information. Geovisualization is an integral part of cartographic research and plays a key role in understanding and analyzing data.

Guerin (2004), Poore (2003) and Schuurman (2003) point out that GIS is not a magic box that makes significant results of geospatial analysis and produces stunning images. It is the user who influences these processes. Therefore, cartographic and computer knowledge is required. Geospatial data visualization is in the domain of cartographic science and practice. In doing so, a map design represents one of the vital components of cartographic and computer science education. The importance of a cartographic design is to present the contents of the map to the user in a concise and sophisticated manner. Digital technology is a part of this process, and in a technical sense, it should facilitate the creation of quality maps, facilitate the practice of mapping, actively promote it and enable the efficient performance of complex geospatial analyzes (Hennig, 2016). Geovisualization, as a process of interactive visualization of geographic information, is present in any step of spatial analysis. MacEachren, (1994) and MacEachren, et. al. (2004) state that visual thinking using maps is an integral part of the scientific process and hypothesis generation, and that the role of maps has grown beyond the communication of only the results of the analysis process or the final documentation of numerous studies.

Within the scope of geospatial analysis, the map may not have a subordinate, but a primary role. Hennig (2016) states that in addition to technological advances, standardization of rules for digital cartographic practice that goes beyond merely translating existing traditional principles is required. The mapping principles need to be adapted to new design concepts when creating digital maps. The concept of applicability of the principles should be oriented towards technical capabilities, not be subordinated to them. The principles must be formulated outside of specific, individual technical ways of implementation, conditioned by different software. They should be independently applicable. It can be said that digital technology has made the process of map-making and geographical visualization both easier and more complex.

Method and form of a cartographic presentation

A wide range of graphical map-making capabilities using computer tools makes them very popular and attractive. However, the correct map-making requires the application of the necessary, verified knowledge of the methods of the map presentation. Database formation (including corrections and updates), correct mapping, and graphical presentation (dynamic and multimedia) are complex mapping processes. The applied cartographic methodology (from the selection and application of methods to the form of presentation of geo-data) is in the context of accurate and clear perception of the map and the effectiveness of the visual transmission of mapped geo-data (Korycka-Skorupa & Nowacki, 2019). Geovisual analytics is focused on the dynamic representation and interaction of spatial data related to support operations (cross-filtering, highlighting, selection, etc.). The cartographic design must be customer-oriented in order to facilitate analytical reasoning when processing geospatial information.

As part of the research on the evaluation of cartographic presentation methods, Korycka-Skorupa (2002a, b) and Korycka-Skorupa & Nowacki, 2019 highlight the difference between the terms: method and form. They define the method as a process of transition from data to the presentation form. They define the form as the outcome of this process - a graphic image (map). The form of graphical presentation of the components of the geospatial content as a result of visualization is complex. It includes all methodological procedures from data collection and processing, mapping, cartometrics to geospatial analysis.

The choice of methods and contents of the cartographic presentation form depends on the following: - geographical characteristics (topographical and attributive), - spatial distribution of geographical phenomena (point, line, surface), - methods of classification of data (types, classes, kinds), - types (quantitative, qualitative) and - character of the data (absolute, relative) to be represented on the map. It is necessary to define, depending on the purpose and size, the degree of generalization of the map content and to perform an optimal scaling of signs (line, surface, volume) according to the type and size of the indicator being mapped. Scaling is adapted to the map content and presentation method (method and form). It is necessary to adjust scaling algorithms, especially in the procedures of symbol-scale mapping and semi-metering, concerning the requirements of methods of presentation of the map content, possible needs for updating, the transformation of data, etc.

Evaluation of the cartographic method - from data to a cartographic presentation

The complexity of the cartographic presentation is influenced by the topic and purpose of the map, the characteristics of the mapping territory, the scale and degree of generalization, the applied cartographic method and the graphic means of expression, volume, type, and quality of data. The aim is to enable the analytical and synthetic approach of studying and evaluating the quantitative and qualitative characteristics of the presented indicators, their functional and substantially interconnected and conditioned relationships, in order to highlight the typical, specific and essential, using the appropriate cartographic method. According to Salishchev (1982), the cartographic method enables the following: - the increase in the informative extent of the map, that is, the extent of concluding and reporting the spatial information from the map; and - improving the legibility of the map, i.e. easy and quick visual observation and adoption of its contents.

The results of research and knowledge about the components of the geospatial content are achieved through the process of applying one or more methods. The graphic solution requires the adaptation of cartographic expressive means to the applied cartographic method, in order to achieve a cognitive interpretation of the map. The quantity and quality of the information provided by the map are defined by the applied cartographic method and graphic means of expression, through the following properties: metric, expressive, transparent and obvious. Sign and colour are the primary means of transmitting information about the phenomena and processes represented on the maps.

The colour as a means of expression, in the compositional sense of design, provides the possibility of spatial and contextual generalization, extraction, grouping, and classification of map content elements. The legend defines this diversity and typification. The use of colour on the map has: - conditional (reflecting the characteristics of the mapping phenomenon), - symbolic (expression of the analogy with the mapping phenomenon), and - metric sense (comparing the number and intensity of change, the ratio of parts and the whole of the mapped phenomena) (Jovanović, 2017).

The sign as a means of expression is used to represent the quantitative and qualitative characteristics of the phenomena and processes on the map. When composing the map content, it is necessary to optimally characterize the signs, in order to correctly highlight the characteristics of the mapped phenomena and their relations and to avoid the graphical loading of the map. A series of signs can indicate the dynamics and intensity, direction and tendencies of the development of the presented features of the phenomenon, and the colour of the signs should highlight and distinguish the main characteristics of the phenomena (type, kind, structure, relationships, classification, etc.).

The metric intensity of the phenomenon on the map is achieved by the following:

1- systematic layout of signs (number and distance of signs concerning the intensity of the phenomenon);

2- continuous or stepwise sign size determination (proportional or arbitrary) and

3- symbol-scale determination of values (Salishchev, 1982) and (Sretenović, 1982/83). According to Sretenović (1982/83), symbol-scale sign construction enables optimal dimensioning and alignment of individual sign metrics according to the corresponding numerical values of a series of indicators. In this way, it is possible to express, in quantitative terms, the different spatio-temporal determination, structure, and comparability of the mapped phenomenon.

Through the examples given in this paper related to the demographic indicators of the municipalities of the Bor and Zaječar districts, an analysis and comparison of the selected applied cartographic methods were performed in relation to: - presentation properties (metric, expressive, transparent and obvious), - selection of the type of indicators (absolute, relative) and - selection of the scale.

On the following maps: Comparison of the population change of the municipalities of the Bor and Zaječar districts, 1971-2011 in comparison to 1961 (Fig. 1), Population changes of the municipalities of the Bor and Zaječar districts, 1961-2011 (Fig. 2 and Fig. 3) and Population of the municipalities of the Bor and Zaječar districts, 2011 (Fig. 4 and Fig. 5) - the same indicator is presented - population. The map diagram method (Fig. 1, Fig. 2 and Fig. 3), the colour method (Fig. 4) and the point method (Fig. 5) were applied. Although the first three maps were made using the same method, using the same type and shape of the sign as a scale indicator, due to the difference in the method applied to achieve the metric of the intensity of the phenomenon and the type of indicators (absolute or relative), the mismatch of the presentation is obvious. This raises the question of the existence of reasons for the inconsistency and the fidelity of the presentation. When comparing the presentation methodology, the purpose of the presentation, which responds to different modes of presentation, should be also taken into consideration. Map 1 presents symbol-scale mapping of a series of numerical values of the indicators with a series of signs (Fig. 1). In their metric representation, the relative indicators (rise/fall index) were taken. The assignment was to present the deviation of the population by selected census years relative to the population of the selected base year. Therefore, it was necessary to calculate the deviation of the indices obtained from the base (100) and to obtain the intensity of variation, which represents the value of the indicator being mapped. The selected base year and the base value of the indicator (minimum value) from the series of numerical values of the indicators were taken conditionally. It could have been the maximum, the average, or some other chosen value relative to the purpose of the research. According to the theoretical and methodological settings of the symbol-scale mapping defined by Sretenović (1982/83), the following were determined: base scalar, scalar indicator, sign scalars, scalar denominator of a symbol-scale mapping, and the symbol-scale mapping was constructed. On Map 2, the symbol-scale mapping procedure is the same (Fig. 2), but the choice of the phenomenon indicator values is different. The assignment was to present the population changes for the selected period based on the absolute phenomenon indicator. The map diagram method was applied to both maps; a symbol-scale constructed sign through its differentiated aspect. Both maps are characterized by metrics and obviousness of presentation. The difference in the presentation is conditioned by the type of mapped indicator concerning the presentation purpose. Map 1 (Fig. 1) used only the method of the map diagram, while Map 2 (Fig. 2) applied the colour method too. In this case, the method of the map diagram is dominant, because it represents changes in the number of inhabitants during the defined period, as a basic space-time indicator, in absolute amounts. This provided the basis for the presentation and analysis of the second, complementary component in relative amounts - the population growth/decline index for the observed period, the colour method and the application of a conditional, arbitrary step scale.

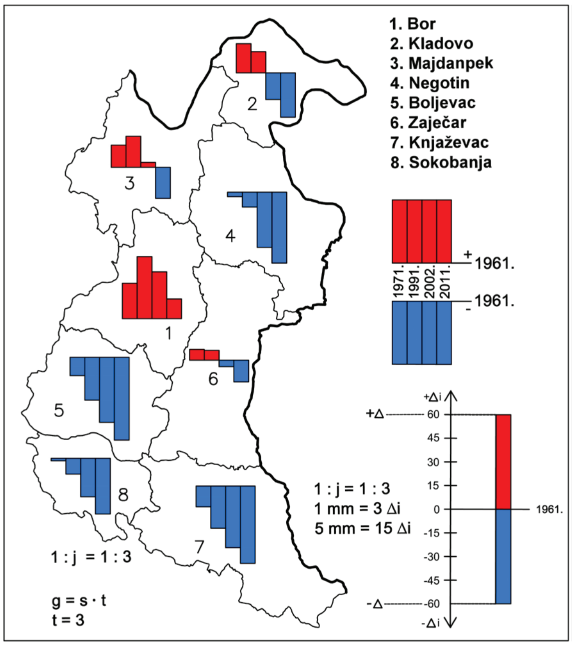

Figure 1: Comparison of the population change of the municipalities of the Bor and Zaječar districts, 1971-2011 compared to 1961

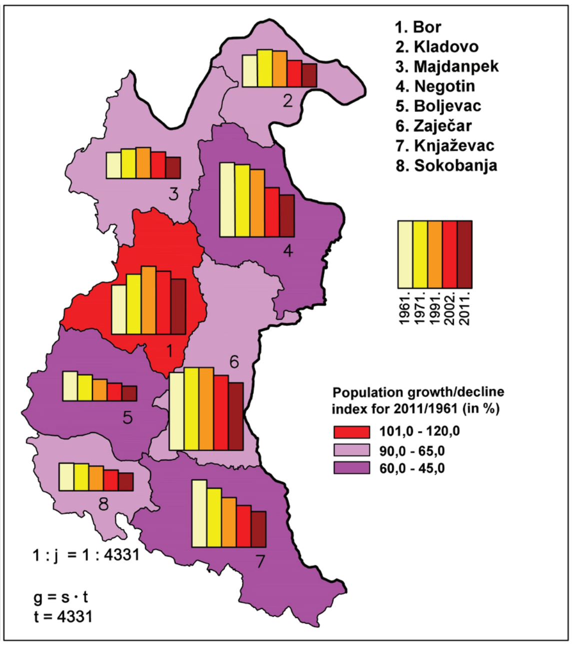

Figure 2: Change of the population of the municipalities of the Bor and Zaječar districts, 1961-2011

By applying a differentiated form of the symbol-scale mapping of demographic indicators on both maps, the changes in the spatial and temporal series of numerical values of the indicators are presented simply and proportionately. The application of the method of the map diagram enabled the mapping of both absolute and relative values of the indicators in the optimal symbol-scale mapping. In this way, the differences in the numerical expression of the specificity of the treated issues, depending on the purpose of the research, were highlighted: - modeling of similar demographic indicators in relation to the one selected, baseline indicator (change of population by census years compared to the selected, base year), and - modeling of the similar demographic indicators in different time sections (change in population per census) (Jovanović & Živković, 2008). The symbol-scale sign construction enables direct semiometry on both maps - reading and calculating the mapped numerical values of the indicators. Metric consistency and comparability of a series of numerical values of the indicators, with a series of the same signs, is made possible by a common scalar indicator (t). The same denominator of the symbol-scale mapping (1: j) enables comparability of the change in the population of the municipalities of the Bor and Zaječar districts, 1961-2011 (spatial and temporal).

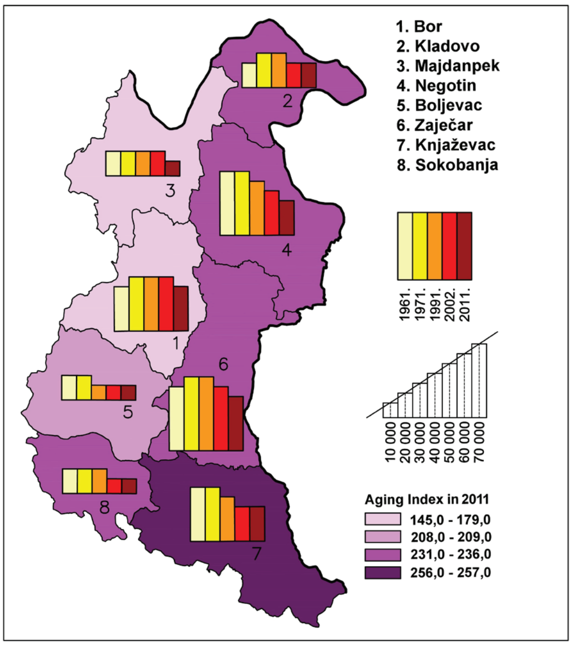

Figure 3: Change of the population of the municipalities of the Bor and Zaječar districts 1961-2011

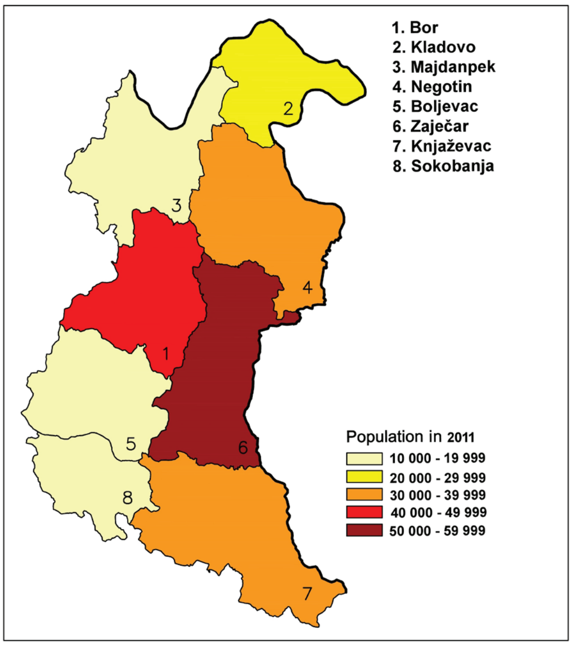

Figure 4: Population of the municipalities of the Bor and Zaječar districts, 2011

Map 3 (Fig. 3) represents the same, absolute values of change in the number of inhabitants of the municipalities of the Bor and Zaječar districts, for the same period as in Map 2 (Fig. 2) by the method of the map diagram. The difference is in the metric approach used. The ratio between the size of the sign and the size of the phenomenon represented by it is defined by the scale of the sign size. In this map, it is proportional, absolutely stepped. The sign sizes are proportional and determined based on the average value of the group to which they belong. The metrics of the sign is given a value consistent with the magnitude of the mapping phenomenon indicator. As with the previous map, the supplementary content (indicator - the value of the population aging index) is presented in a transparent and demarcated colour method, applying a conditional, arbitrary step scale. The Map: Population of the municipalities of the Bor and Zaječar districts, 2011. (Fig. 4) was done by the colour method, applying a continuous step scale. The method allowed for visibility, but not metrics and time comparability, because it presented one phenomenon characteristic for one particular year.

Application of the point method (regular, mathematical form) in the making of the Map: Population of the municipalities of the Bor and Zaječar districts, 2011. (Fig. 5), allows for metrics, but not the exact location of the population distribution, which is a disadvantage as with the application of the colour method (Fig. 4). The advantage of the point method is that it provides an indirect, visual image of the population density (based on the number and distance between the points). Restrictions on the application of this method are the following: - it cannot be combined with another cartographic method (presentation of the phenomenon distribution, by the number of elementary signs, is within the entire territorial unit), - only one condition of the phenomenon can be presented on a single map, for one time section (number of inhabitants of one census year) and - presentation of the indicators in absolute values only. The population density is clearly and obviously presented by the map diagram method, as an indicator of the established spatial-demographic relations of the municipalities of the Bor and Zaječar districts, 2011 (Fig. 6). Quantitative characteristics are presented according to a mathematically defined scale. Integrated heterogeneous, but interconnected indicators are presented on the map in a transparent, obvious and metric way. The disadvantage of the cartographic method is that: - it cannot be combined with another cartographic method (the presentation of the phenomenon distribution is within the entire territorial unit), - only one condition of the phenomenon can be presented on one map, for one time section, and - the phenomenon indicator can be presented only in relative values.

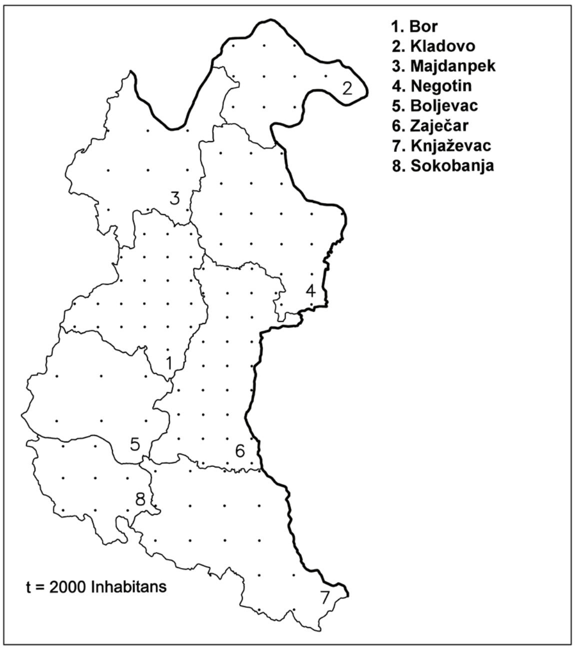

Figure 5: Population of the municipalities of the Bor and Zaječar districts, 2011

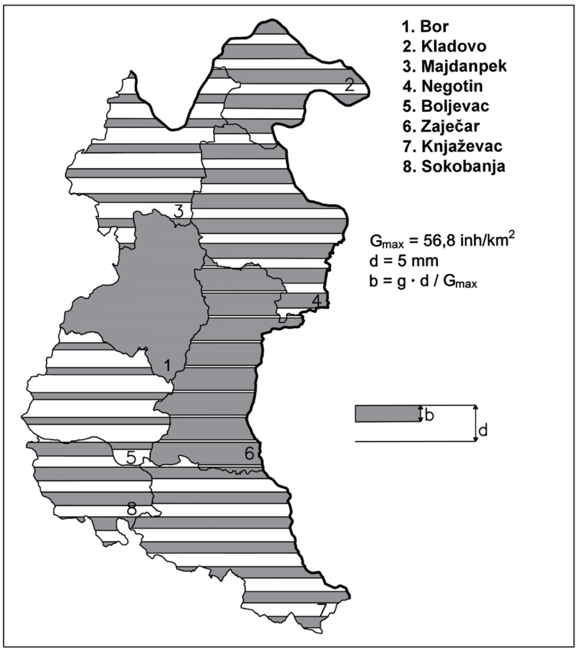

Figure 6: Density of population of the municipalities of the Bor and Zaječar districts, 2011

The demographic indicators on the maps were metrically, transparently and obviously presented by the method of the map diagram: Comparison of population, population density and area of the municipalities of the Bor and Zaječar districts, 2011 (Fig. 7) and Participation of age groups in the total population of the municipalities of the Bor and Zaječar districts, 2011 (Fig. 8). The application of the map diagram method to both maps enabled the mapping of heterogeneous indicators, presentation and metric comparison of absolute and relative values of the indicators. The signs were constructed in the symbol-scale mapping manner through comparative (Fig.7) and differentiated aspects (Fig.8). In this way, the specificities and differences of the numerical expression of the treated issues in relation to the research objective were highlighted as follows: - modeling of the different geospatial indicators (comparison of population, population density and areas for a given census year) in the same time section (Fig. 7), and - modeling of homogeneous indicators in relation to the total indicator (participation of age groups in the total population) (Fig. 8).

On Map 7, the assignment was to present three heterogeneous indicators, of different units of measure, by the same series of signs (Fig. 7). By applying the symbol-scale mapping, different but related indicators (population, area and population density, certain spatial units, in a given census year) are integrated. Its implementation most adequately reflects the intensity and interdependence of the mapped phenomenon indicators. A good graphical-analytical presentation has been achieved through the symbol-scale mapping construction of signs, which represents the values of heterogeneous indicators. This enables a faster and better comparison of the values of three series of the heterogeneous indicators and the comparability of their deviation from the established average value. According to the methodologically established settings of the symbol-scale mapping, defined by Sretenović (1982/83), it was necessary to - determine the basic value of the indicator (the average value was calculated for each series of numerical values of the indicator), - make the choice of the base scalar, - calculate valerian indicators (separately for each series of numerical values of indicators), - determine the scalars of signs for individual series of numerical values of indicators and - calculate valer denominators of the symbol-scale mapping (separately for each series of numerical values indicators). In the process of interpreting the structure of the map content, this procedure enables adequate mapping and access to productive information.

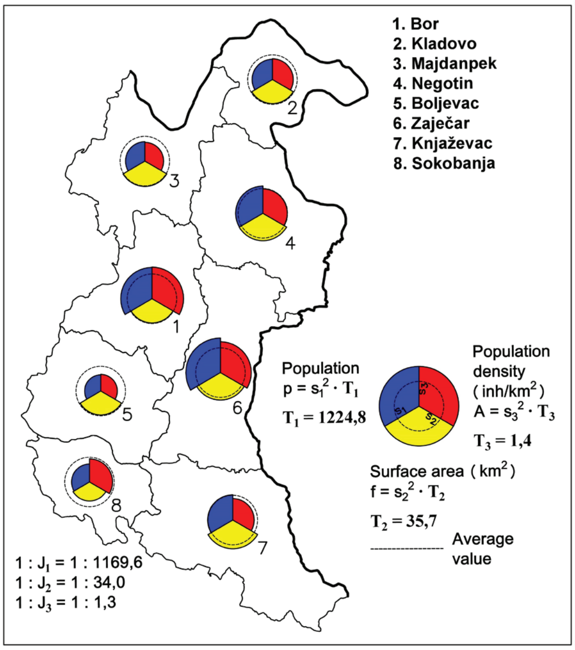

Figure 7: Comparison of population, population density, and area of the municipalities of the Bor and Zaječar districts, 2011

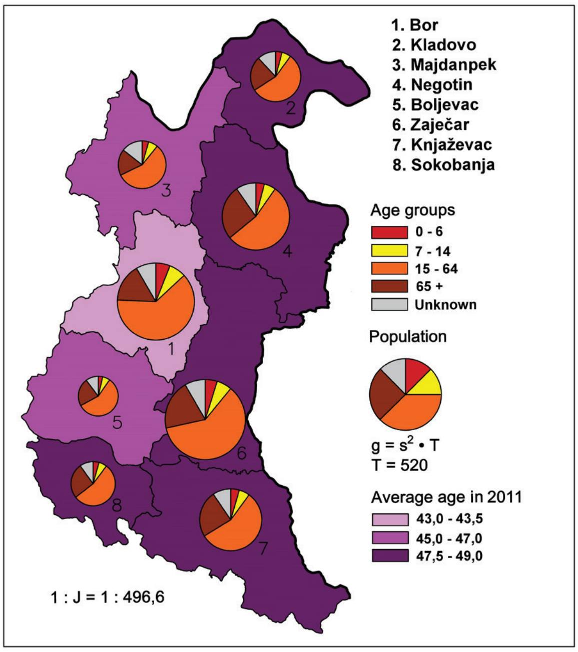

Figure 8: Participation of age groups in the total population of the municipalities of the Bor and Zaječar districts, 2011 (in %)

The cartographic presentation of the structural-demographic characteristics on Map 8 (Fig. 8) involves the application of two methods (the map diagram method and the colour method). By combining the two methods, compositional harmony is achieved, which, through a common graphic form, indicates the connection between the presented components. By applying these two methods, interconnected and conditioned characteristics of phenomena are presented, which allow the user to view and analyze the correlations between them, but also to interpret them individually. The primary, map diagram method is the symbol-scale mapping representation of the population of a given census year. A structural sign was used to show the participation of age groups in the total population. In order to obtain more information by the colour method, applying the conditional, arbitrary step scale, the average age of the population in the same census year is presented. By applying complementary methods on this map, good metric, legibility, and expressiveness of the overall visual-spatial representation of the complex structure of the presented data were achieved. This further influences the adequate, clear and professional way of processing visual-spatial information.

Conclusion

Sublimation of graphing and geovisualization by the cartographic method enables customized processing of geo-data concerning the requirements of cartographic presentation. By the use of graphing, the characteristics of the mapped phenomenon express – visualize the graphical variables through the applied method. The choice of methods and methodological procedures requires the data to be processed and adapted to the requirements of the mapping purpose and topic. By defining and implementing the necessary cartographic procedures, mathematical calculations and transformation of the data for the graphical expression of the chosen method or combination of the cartographic methods, a clear and accurate interpretation and analysis of the mapped content are enabled.

References

Grelot, J.-P. (1994). Cartography in the GIS age. *The Cartographic Journal, Vol.31, No.1*, 56-60.

Guerin, S. M. (2004). Peeking into the black box: some art and science to visualizing agent-based models. *In Proceedings of the 36th conference on Winter simulation* (Orlando, FL, 2004).

Hennig, D. B. (2016). Mapping Practices in a Digital World. *Advancing Geographic Information Science: The Past and Next Twenty Years. Chapter 11,* 153-168. Harlan Onsrud and Werner Kuhn (Editors). GSDI Association Press. USA.

Korycka-Skorupa, J. (2002a). 'Od danych do mapy'. (From data to a map). *Polish Cartographical Review*, *vol. 34. no. I*, 91-102.

Korycka-Skorupa, J. (2002b). 'Od danych do mapy'. (From data to a map). *Polish Cartographical Review*, *vol. 34. no. II*, 175-188.

Korycka-Skorupa, J., Nowacki, T. (2019). Cartographic presentation - from simple to complex map. *Miscellanea Geographica – Regional Studies on Development. Vol. 23. No. 1,* 16-22. DOI: 10.2478/mgrsd-2018-0023 (accessed on 11.05.2019)

Kessler, F. C., Slocum, T. A. (2011). Analysis of thematic maps published in two geographical journals in the twentieth century. *Annals of the Association of American Geographers, 101 2,* 292-317.

Jovanovic, J., Zivkovic, D. (2008). Cartographic Unification of Demographic Characters. *Demography, vol. V*, 35-42. Belgrade: Faculty of Geography University of Belgrade.

Jovanović, M. J. (2015). Cartography in a digital environment. (Картографија у дигиталном окружењу). *Proceedings of the 4th Serbian Congress of Geographers - Achievements, Current Affairs and Challenges of Geographical Science and Practice, marking the 150th anniversary of the birth of Jovan Cvijic*. Vol. 12, 19-22. Belgrade: University of Belgrade-Faculty of Geography & Serbian Geographical Society.

Jovanović, M. J. (2017). *Thematic chronography - practicum*. (*Тематска картографија-практикум*). Belgrade:

University of Belgrade-Faculty of Geography.

MacEachren, A. M. (1994). Visualization in Modern Cartography: Setting the Agenda. In A. M. MacEachren & D. R. F. Taylor (Eds.), Visualization in Modern Cartography, 1-12. Oxford: Pergamon.

MacEachren, A. M., Gahegan, M., Pike, W., Brewer, I., Cai, G., & Hardisty, F. (2004). Geovisualization for Knowledge Construction and Decision Support. IEEE Computer Graphics and Applications, 24*(1),* 13-17.

MacEachren, M.A., Kraak, M-J. (2001). Research Challenges in Geovisualization. *Cartography and Geographic Information Science. Volume 28, 2001 - Issue 1,* 3-12. https://doi.org/10.1559/152304001782173970 (accessed on 11.05.2019)

Poore, B. S. (2003). The open black box: the role of the end-user in GIS integration. *The Canadian Geographer, 47 1,* 62-74.

Salishchev, K.A. (1982). *Cartography.* (*Картография).* Moscow: High School.

Sretenovic, Lj. (1982/83). Types of semio-scale mapping. (Видови семиоразмерног картографисања). In: Proceedings of the Geographical Institute of the PMF. Vol. XXIX and XXX, 133-159. Belgrade: PMF, University of Belgrade - Geographical Institute of the Faculty of Science.

Schuurman, N. (2003). The ghost in the machine: spatial data, information and knowledge in GIS. *The Canadian Geographer, 47 1,* 1-4.