APPLICATION OF INTERACTIVE CHARTS IN THE EVALUATION OF SOCIO-ECONOMIC DEVELOPMENT OF REGIONS; THE CASE OF POLAND

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ABSTRACT

The paper presents multidimensional interactive data charts as a tool to support presentation and characteristics of spatial phenomena. The phenomenon of socio-economic development of provinces has been analysed, as defined in multidimensional space of variables. Classification of objects was performed using the method of zero unitarization. Statistical data have been obtained from public sources, compiled in the form of a matrix, and then subjected to normalization in order to bring the tested objects to direct mutual comparability. The studies allowed us to observe great diversity in socio-economic development of regions. The analysis of line distribution of development meta-variables (indices) revealed that their biggest values concerned the group of social factors, and the smallest concerned the natural (environmental) ones. In the conclusion, it was pointed out that interactive visualizations of data complement the tabular form of their presentation, and they facilitate an analysis of phenomena in spatial terms, while showing their internal structure and also the correlations between individual objects.

Keywords: data visualization, typology, spatial taxonomy, classification of objects, multidimensional charts

INTRODUCTION

In developed countries, socio-economic development is associated with sustainable development, respecting the principles of environmental protection (Kauffman and Martin 2017) and the principles of spatial order (Hełdak and Raszka 2013). In 2002, the World Summit on Sustainable Development adopted an extended definition of sustainable development, as such development that strikes a balance between three aspects: social, economic and environmental (Bolis et al. 2017). Sustainable development refers to the balance between three elements: the environment, the economy and the society (Kasprzak and Raszka 2017). In addition, in Agenda 2030, cultural considerations were also taken into account in sustainable development (Agenda...).

Socio-economic development is defined as a process of integrating political, economic and social activities, preserving the natural balance of the environment, as well as sustainability of natural processes, in order to guarantee the possibility of satisfying the basic needs of the community – both the contemporary, and the future generations (Chmielewski and Głogowska 2015).

The control over the compliance with the basic principles of sustainable development within the area of specific local government units is possible, among others, through the use of legal instruments.

Local government authorities undertake strategic activities aimed at minimizing disparities between regions, as well as supporting problem areas and less developed areas (Feltynowski et al. 2015). Undertaking such activities requires previous multidimensional

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analyses (Prus and Król 2017). Socio-economic development is associated with an increase in investment, employment, and production value, as well as the development of technical and social infrastructure. In addition, it depends on human capital and is conditioned by geographical location.

Numerous analyses of socio-economic conditions are carried out in a spatial context, where objects located in space are described with extensive sets of metadata (Büchi et al. 2016). These data come from direct measurements in the field, and they are analysed using GIS techniques and tools (Salata and Król 2012). Sometimes, they are also obtained from generally available public statistical databases. Analyses of data thus collected are often carried out using the classification procedure, which enables multidimensional, spatial analysis of phenomena (Prus and Król 2017). One of the methods of object classification is the taxonomy, which facilitates grouping of homogeneous objects into smaller, more homogeneous sets, and their assessment from the point of view of the factors adopted for the analysis. Taxonomic methods make the creation of multidimensional structures possible (Dunn and Everitt 2004), whereas they have a wide range of applications and allow for better characterization of a given phenomenon (Gawroński et al. 2014). Interpretation of such analyses can support multidimensional, interactive data visualizations.

RATIONALE AND PURPOSE OF THE RESEARCH

The aim of the present study was to assess the socio-economic development of the regions (called "województwo" or voivodship) in Poland, by means of using interactive visualizations as tools to support the interpretation of statistical survey results. Analysis of socio-economic development of voivodships enables a synthetic look at the level of development of individual regions of Poland. It indicates the areas – of stagnation and growth – that require remedial or supporting measures (for instance, in terms of spatial planning or economics) or activities in the scope of environmental protection. A systematic analysis of the conditions of socio-economic development is of particular importance in a dynamic approach, in which this development is analysed as a phenomenon subject to constant changes. A comparison of the existing

development conditions between different administrative units of territorial division of the country may facilitate making decisions to support problem areas, and aimed at alleviating the disproportions in the development of individual regions.

Data visualizations are most often made available as the final result of the research. They usually present inferences from the observations made, as well as conclusions and summaries. They often perform the task of disseminating research results, making the presentations thereof more attractive, and facilitating their understanding (Król 2016). Data visualizations – in particular those taking the form of interactive charts and diagrams presented in a web browser window – are less frequently used as a tool to support statistical data analysis. To a large extent, this is due to the very nature of the visualizations, which primarily perform the function of presentation, and often in a limited, predefined range. However, there exist technologies that make it possible to create dynamic, animated and interactive presentations. They are not widely used, but they allow you to experiment with the form of data presentation, for instance by creating multidimensional visualizations, which can also be modified in real time – as in changing the angle of observation, adding or removing variables. Three-dimensional (panoramic) perspective and gradients (appropriate colours) often allow for observing dependencies or correlations that are invisible in tabular formats. Therefore, interactive data visualizations can be used, for example, in the presentation of statistical data, also in the assessment of socio-economic development.

INTERACTIVE DATA VISUALISATIONS

In recent years, one can observe a clear transition from the literary culture (culture of word) to the culture of images (pictorial culture). The age of visual media is a response to changes in the conceptualization of reality. Recipients learn more and remember more effectively when the presentation of information is an attractive combination of words and images (Krauss 2012). The specificity of the Internet, focused on visual communication and on functionality, forces some content creators to use not only text but to use multimedia instead (Doshi et al. 2014). The recipients are

focused on quick information retrieval, while expecting an attractive and concise form of conveying the message. On the other hand, due to ubiquitous digitization, there is a growing body of various kinds of data that requires collection, processing and presentation (Król 2015, Nair et al. 2016).

The basic form of presenting statistical data is in tabular format (i.e. tables). However, this is not the only way to present them. The increased interest in data storage, processing and visualization observed in recent years (including statistical, economic, and spatial data) becomes an inspiration for the creators of various techniques and tools that facilitate and support this. The availability of these tools and techniques, coupled with the growing processing power of computers, resulted in the dynamic development of graphical methods of data analysis (Andrienko et al. 2016, Król et al. 2016). The latter enable the presentation of research results in the form of various maps, charts and infographics (Bryant and Wildfire 2016, Król and Zuśka 2017).

Interactive data visualizations presented in the web browser window can be helpful in conveying complex statistical issues, whereas the graphic presentation can be an attractive way of providing information, while being accessible at the same time. Maps, charts, diagrams and infographics improve the forecasting of complex phenomena (Kończak 2014). Furthermore, they simplify the presentation of statistical data, show hidden relationships in the numbers, and facilitate their interpretation (Bowie et al. 2014, Pieniążek et al. 2014).

SOURCES OF DATA AND RESEARCH METHODS

In the first stage of analysing the socio-economic development of voivodship regions, the initial set of variables was selected (see: Table 1). The study was based on the data obtained from public statistical sources (Local Data Bank) for the NUTS-5 level municipalities, from 2014 (GUS Statistical Authority 2017). The selection of variables was conditioned by the availability of data, and it resulted from the subjective assessment that decided on accepting or rejecting a given feature. The acquired data was compiled in the form of a matrix, and then subjected to normalization in order to ensure their comparability.

Table 1. A set of output variables, on the basis of which the level of socio-economic development of the regions (voivodships) was determined

Evaluation attributes	Name of feature	Unit of measure
Social	x_1 – population density	number of persons /km²
	x_2 – population in non-working age per 100 people in working age	number of persons
	x_3 – working people per 1,000 people	number of persons
	x_4 – registered unemployment rate	%
	x_5 – flats put into service	pc.
Economic	x_6 – general income of the region's budget per 1 inhabitant	zł (PLN)
	x_7 – general expenses from the region's budget per 1 inhabitant	zł (PLN)
	x_8 – expenditures on research and development activity	thou. of PLN
	x_9 – business entities in the REGON statistical register per 1,000 people	pc.
	x_{10} – index of poverty risk	–
Environmental	x_{11} – afforestation	%
	x_{12} – expenditures on fixed assets that serve municipal economy and environment protection	thou. of PLN
	x_{13} – sorted urban waste collected during the year	tons
	x_{14} – area of lands under legal protection	ha

The method of zero unitarization was chosen to normalize the variables. In the unitarization process, the formula (1) was used for the stimulant variables, and the formula (2) was applied for deterrent variables (Kukuła and Bogocz 2014):

$$x'_{ij} = \frac{x_{ij} - \min_i \{x_{ij}\}}{\max_i \{x_{ij}\} - \min_i \{x_{ij}\}} \tag{1}$$

$$x'_{ij} = \frac{\max_i \{x_{ij}\} - x_{ij}}{\max_i \{x_{ij}\} - \min_i \{x_{ij}\}} \tag{2}$$

Zero unitarization is one of the methods of standardizing the diagnostic features, based on the formula of the quotient transformation. It is characterized by a fixed point of reference, which is the range of a normalized variable. Standardization is an activity aimed at adopting diagnostic variables so that they may serve as partial criteria in the process of assessing a complex phenomenon. Usually the diagnostic features are expressed in different units of measure, and they correspond to different numerical ranges. Taking into account the need to get rid of the units of measure, and to standardize the ranges of numerical diagnostic variables, normative methods are used to transform absolute values into relative values (Kukuła 2014). In this sense, the methods of standardization constitute a certain ratio transformation, which in the final result produces a transformed diagnostic variable. This variable is dimensionless and unified as to the range of values it can take. Standardization of features allows us, therefore, to make comparative studies of objects (complex phenomena) described with the help of many variables (Balcerzak 2015, Len et al. 2016).

The transformation of variables facilitated replacing their varied range of variability with a fixed range, and this has brought them to mutual comparability. Thus, the sequence of variables x_i of any given value (positive or negative) has been converted into a sequence with values ranging from 0 to 1.

The general measure of socio-economic development was calculated as an arithmetic mean based on measures acquired for individual evaluation attributes. This facilitated a line ordering of voivodship regions in terms of the degree of their development.

The analysis of the spatial distribution of synthetic indicators in individual voivodeship regions was carried out based on the division into four classes, applying the natural breaks classification method (the Jenks Method), using the QGIS program. Then, the acquired measures were presented in the form of interactive charts created using selected JavaScript tools (see: Table 2). The graphs thus created were analysed to find correlations between particular objects.

Table 2. Basic functionalities of the tested design tools

Plugin tool	Form of data presentation, licence	Design techniques
vis.js	A dynamic, browser based visualization library. Graph 3D cloud with coloured dots. Licence: dual licensed under both Apache 2.0 and MIT.	HTML, JavaScript
Google Scatter Chart	Dual –Y charts. Scatter charts plot points on a graph. When the user hovers over the points, tooltips are displayed with more information. Licence: Google APIs Terms of Service.	Visualization API, HTML, JavaScript, SVG or VML
Google Bubble Chart	A bubble chart is used to visualize a data set with two to four dimensions. The first two dimensions are visualized as coordinates, the third as colour and the fourth as size. Licence: Google APIs Terms of Service.	Visualization API, HTML, JavaScript, SVG or VML

Characteristics of the tested designing tools

The vis.js library allows the user to create dynamic, interactive, animated, and 3D charts, including the spread of points, as well as enabling a smooth presentation of a large amount of data that can be analysed from various perspectives. The tool allows you to capture the graph with the mouse cursor, rotate it and change the zoom level of the data view. In turn, these data are collected in a matrix composed of rows and columns, although the library also allows you to import data from an external source (DataSet JSON objects). Analogous solutions are commonly used in other programming libraries (Król and Prus 2016). In the case described herein, the presentation covered 16 points (according to the number of the analysed spatial units – regions i.e. voivodships), each described with 3 attributes: a normalized indicator of development in the social, economic and environmental aspects.

The Google Scatter Chart and Google Bubble Chart, implemented in the structure of the hypertext document using the Google Visualization API, were also used to visualize the results. Google Charts is an extensive service that allows you to create graphically diverse, interactive charts, diagrams and other data presentations. Graphs created in this way are generated in the browser window in SVG or VML format (Gesmann and Castillo 2011).

RESULTS AND CONCLUSIONS

As a result of the classification, groups of voivodship regions were obtained, homogeneous in terms of the degree of their socio-economic development. Spatial distribution of synthetic meta-variables (indices) illustrating particular aspects of the phenomenon of socio-economic development, as well as the general indicator in particular voivodship regions, produced some idea of, for instance, the impact of the examined aspects on the result of the classification. While assessing the socio-economic development of individual voivodship regions, their large diversity was observed. The highest values of all indicators were recorded in the Mazowieckie Voivodship (see: Figure 1, Figure 2). Furthermore, by analysing the line chart of the distribution of meta-variables, it was noted that the highest values correspond to the social factors, while the lowest values are noted for the environmental ones (see: Figure 3).

Taking into account the analysed aspects, as many as 4 regions (Mazowieckie, Małopolskie, Śląskie and Wielkopolskie voivodships) were classified in the group of social conditions as the most developed regions, and only two as the least developed regions (Warmian-Masurian and West Pomeranian voivodships). In terms of economic development, only two of the regions (Wielkopolskie and Dolnośląskie voivodeships) were characterized by the highest level of development. In turn, 4 regions: Wielkopolskie, Świętokrzyskie, Kujawsko-Pomorskie and Łódzkie voivodships, located in the central part of Poland, exhibited the lowest level of economic development.

Analysis of the spatial distribution of development conditions in particular aspects allows to conclude that the general development index is determined mainly by the value of the index in the environmental aspect, as the one that assumed the lowest values. The cumulative synthetic index adopted the highest value in this aspect only in the Mazowieckie voivodship, while the lowest values were recorded in five regions: Podlaskie, Kujawsko-Pomorskie, Łódzkie, Świętokrzyskie and Opolskie voivodships.
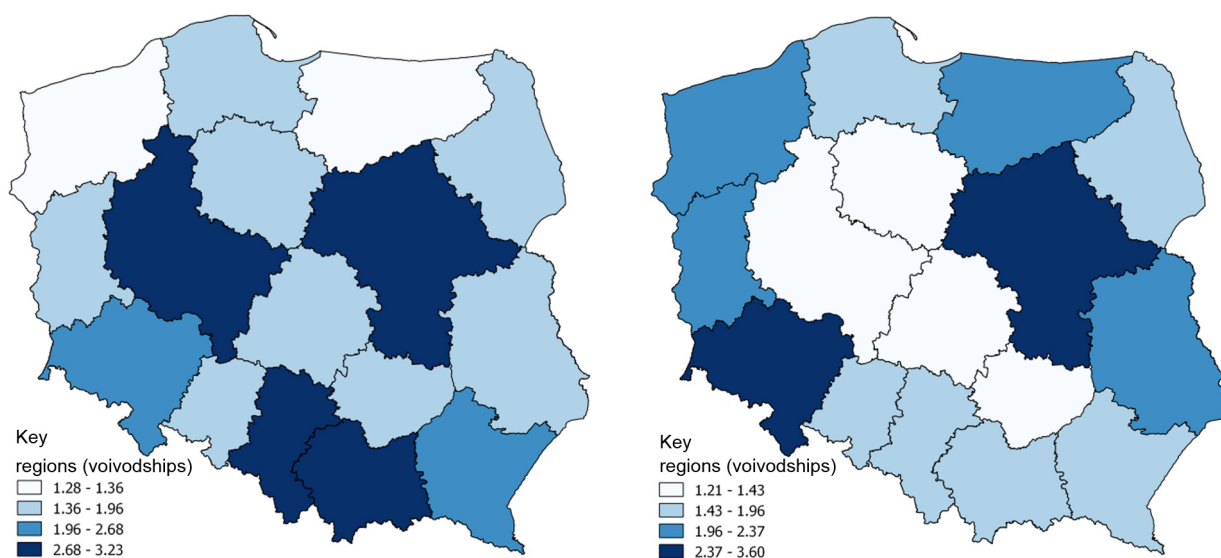

Fig. 1. Spatial distribution of development conditions in the social aspect (a) and in the economic aspect (b)
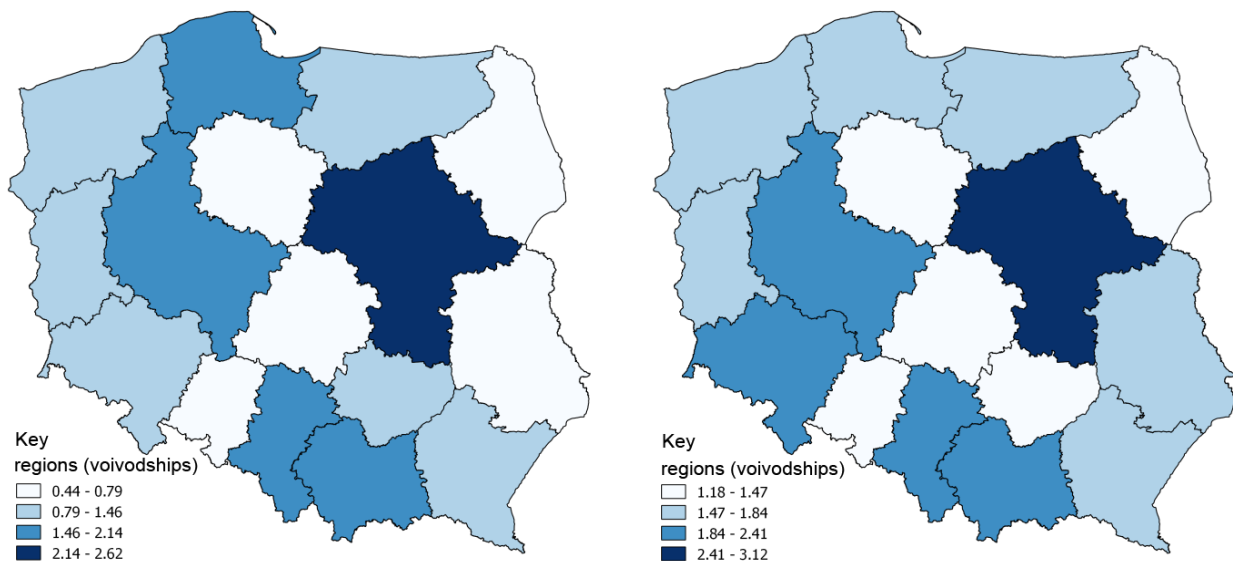
Fig. 2. Spatial distribution of development conditions in the natural (environmental) aspect (a) and spatial distribution of coefficient representing the synthetic indicator of socio-economic development (b)
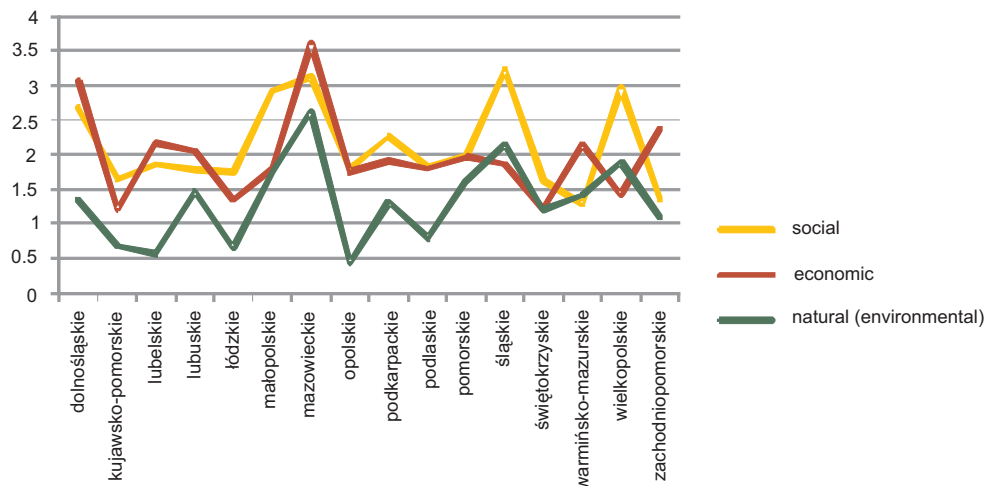

Fig. 3. Classic presentation of meta-variables (indices) representing aspects of socio-economic development in individual regions, using a two-dimensional line chart

Interactive presentation and interpretation of statistical analyses

On the multidimensional chart made with the use of Visualization: Scatter Chart (see: Figure 4), which presents the share of social and environmental factors in the socio-economic development, we note a greater diversification of the value of the meta-variable illustrating the environmental factor. The analysis of this form of presentation demonstrates that the environmental factor was characterized by lower values (i.e. it has a lower average value), while when analysing the economic factor, we note that over 60% of the analysed objects were characterized by its low value (11 objects – both marked in red for environmental, and blue for the social factor, remain in the range of between 1.0 and 2.5 units). Also, few objects noted high
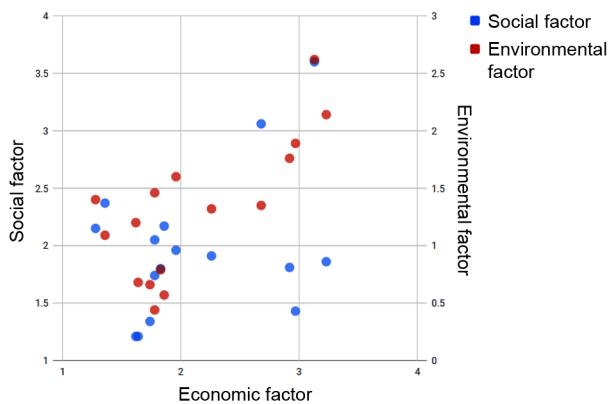
Fig. 4. Presentation of the rate of socio-economic development in regions, subdivided into social, economic and environmental aspects by means of Google Scatter Chart

Source: own study, using the Visualization: Scatter Chart

Fig. 5. Multidimensional presentation of socio-economic development of regions, subdivided into social, economic and environmental aspects

Source: own study, using the vis.js programming library

values of coefficients depicting economic and social aspects, with high values of the environmental factor at the same time.

Three-dimensional visualization created with the aid of Visualization Scatter Chart makes it possible to observe that the largest number of objects noted low values in all three studied aspects of development (see: Figure 5). Only in the case of a few objects there were high values of indicators. In this case, interpretation of the data was facilitated by graph's interactivity. Visualization Scatter Chart makes it possible to capture the presentation with the mouse cursor, and rotate it around its own axis. This allows you to observe the correlations between objects from different perspectives.

An atypical visualization created using the vis. js library turned out to be difficult to interpret (see: Figure 6). Individual objects and correlations between them are in this case presented in the form of a prism grid. The height of the figures expresses the size of environmental development indicators. Their analysis led us to conclude that this factor assumes relatively low values. A considerable range of the figures may suggest that the phenomenon of sustainable development is represented by a wide range of factors, in the social and economic aspect.

Analysis of the visualization created using the vis.js library, taking the form of a three-dimensional plane, confirms the observations that we made earli-
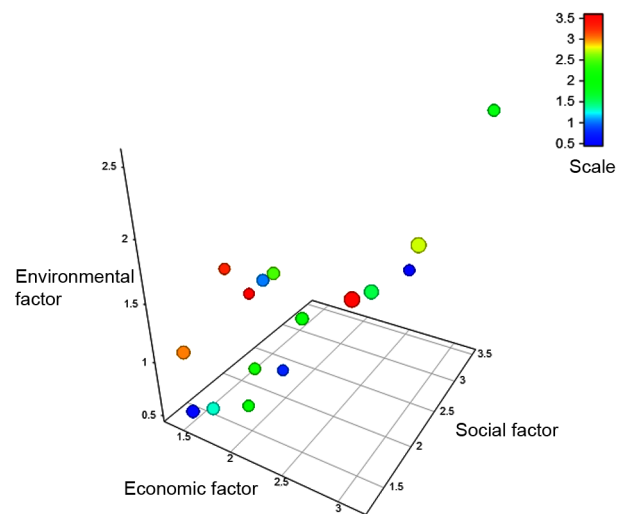
er (see: Figure 7). The predominance of cool colours may result from the relatively low values of the environmental meta-variables (indices). Such data presentation allows us to conclude that the phenomenon of development was characterized by high spatial variability. In addition, a larger spread of index values in economic and environmental aspects can be observed than in the case of the environmental aspect.

From the analysis of the visualization made with the aid of Google Bubble Chart, it can be concluded that the socio-economic development of the regions is only slightly affected by the environmental factor (see: Figure 8). The combined presentation on the vertical and horizontal axes of the social and economic factors, complemented by the colouring, whose intensity reflects the value of the environmental factor, indicates the smallest share in the overall result of the environmental aspect. From the presentation, it can be concluded that social and, to a lesser extent, economic factors have had the greatest impact on the socio-economic development.

Charts created with the help of the vis.js library largely supported the interpretation of the results of statistical surveys (see: Table 3). The visualizations of data created in this manner were characterized by,

inter alia: interactivity, dynamics of presentation, and expressive colours. In the case of visualizations created with the aid of the vis.js library, the observation of the correlations between the objects was facilitated primarily by their three-dimensional presentation, and the ability to rotate the chart around its own axis.
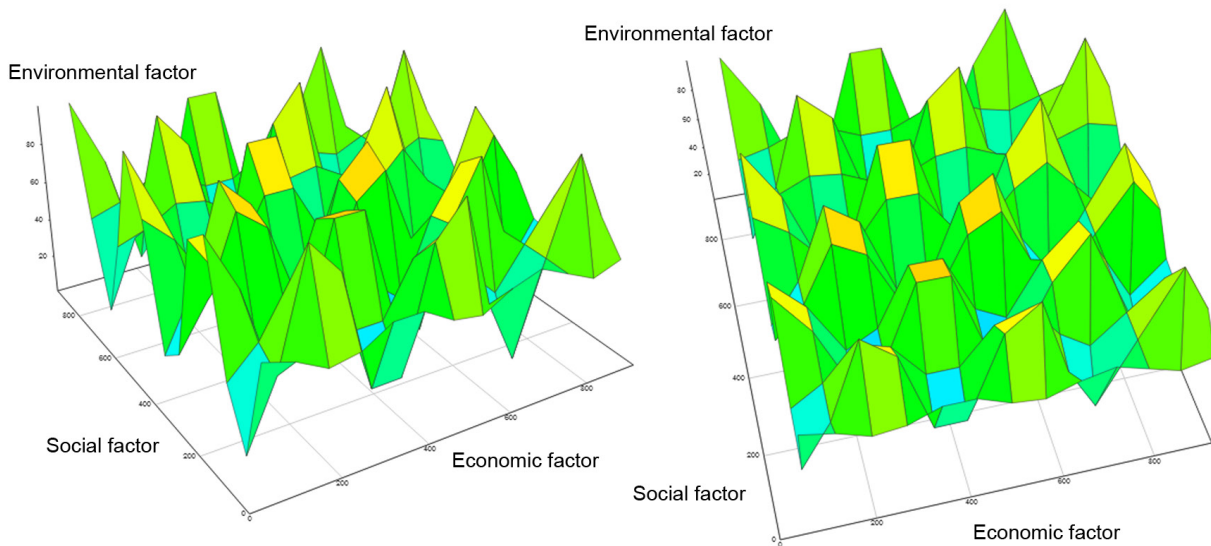

Fig. 6. Presentation of the rate of socio-economic development of regions, subdivided into social, economic and environmental aspects

Source: own study, using the vis.js programming library
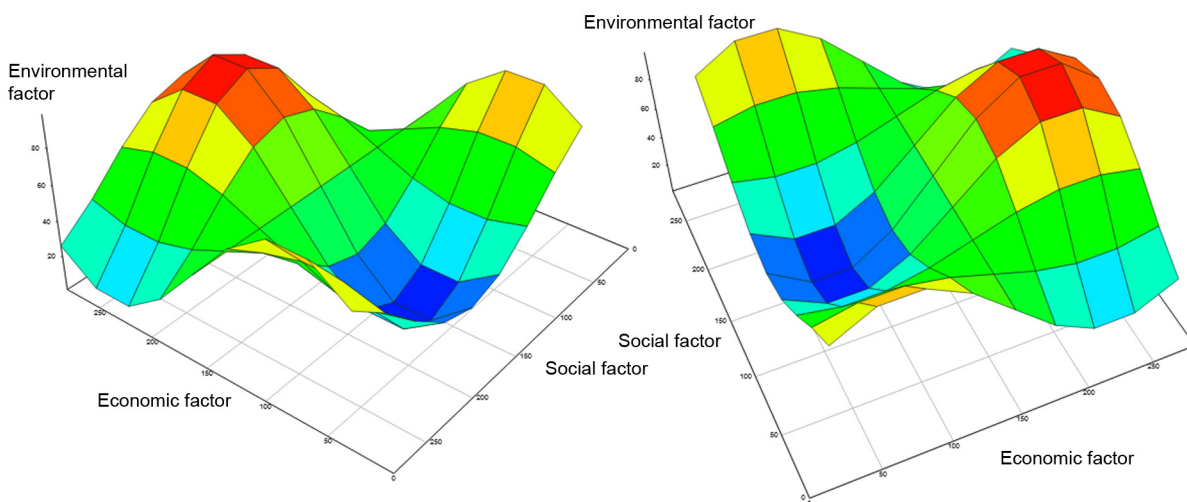

Fig. 7. Presentation (three-dimensional plane) of the rate of socio-economic development of the regions, subdivided into social, economic and environmental aspects

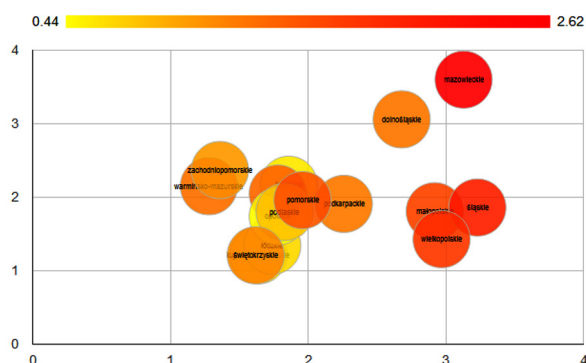Source: own study, using the vis.js programming library

Fig. 8. Presentation of the rate of socio-economic development of the regions, subdivided into social, economic and environmental aspects

Source: own study, using the Visualization: Bubble Chart

Table 3. Comparison between selected functionalities of the tested design tools

Functionality	Design tools		
	vis.js	Google Scatter Chart	Google Bubble Chart
Animated 3d graphs	+	—	—
Interactive key	+	+	+
Zooming-in the view	+	—	—
Rotating the graph around its axis	+	—	—
Tooltips (pop-ups)	+	+	+
The possibility of selecting objects on the chart	—	+	+
The ability to change the form of visualization (interactive navigation menu)	+	—	—
Responsiveness (mobile)	+	—	—

CONCLUSIONS

The analysis we conducted made it possible to assess the level of socio-economic development of individual voivodship regions in Poland. Presentation of the interdependencies between three groups of factors – social, economic, and environmental (natural) – required the creation of relational graphs, showing the correlations between the three variables in separate reference systems. This was achieved with the aid of selected programming tools that enable the creation of interactive data visualizations. Each of the presentations highlighted different aspects of the studied phenomenon, and the degree of impact of particular elements of the assessment on the overall result of the classification. The use of multidimensional, interactive charts enabled a multi-aspect, in-depth analysis of socio-economic development. It also allowed us to estimate the degree of dependence of the studied phenomenon on its constituent factors.

Interactive charts, generated in the web browser window using scripting languages, can provide a helpful tool to support the assessment of multidimensional phenomena. The dynamic form of their presentation allows us to observe correlations in various planes, both between individual objects and between different levels of socio-economic development. Admittedly, an atypical axis distribution may make it impossible to determine the exact values of a given phenomenon, but nevertheless it facilitates the understanding of its internal structure.

From the analysis, it was concluded that the most important influence on the synthetic meta-variable (index) depicting the phenomenon of socio-economic development resulted from the social factor, while the lowest resulted from the environmental factor. It was also observed that the socio-economic development of individual voivodship regions in Poland is characterized by a large diversity in all of the examined aspects, with the highest development parameters recorded in the Mazowieckie voivodship (Mazowsze Region).

LIMITATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

In the described cases, interactive data visualizations take on various forms – of objects that are somehow "scattered" in a multidimensional space (outlined by the results of statistical analyses), and specific "jagged and undulating surfaces". The tools used in the research have their limitations. There is no possibility of their complete configuration or full adaptation to the requirements of the presentation. All this brings with it the danger of an "arbitrary" (uncontrolled) data visualization, and consequently also the "arbitrary interpretation" of the charts. Interactive visualizations that

are based on "adopted" software can therefore complement the research and the core presentations. This is because they facilitate presenting the phenomenon in an unconventional manner.

Interactive visualizations, although they facilitate presenting data (the objects) in an unusual way, are limited to the window of the web browser. Completely new possibilities of data visualization and data interpretation are provided by the technology of virtual, augmented reality (AR). The concept of the data presented in that latter manner assumes direct exploration of the visualization space, "staying with" or "interacting with data". This may potentially take the interpretation of data to a new, previously unknown level.

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ZASTOSOWANIE INTERAKTYWNYCH WYKRESÓW DO OCENY ROZWOJU SPOŁECZNO-GOSPODARCZEGO WOJEWÓDZTW: STUDIUM POLSKI

STRESZCZENIE

W artykule przedstawiono wielowymiarowe, interaktywne wykresy danych, jako narzędzie wspomagające prezentację i charakterystykę zjawisk przestrzennych. Analizie poddano zjawisko rozwoju społeczno-gospodarczego województw, definiowane w wielowymiarowej przestrzeni zmiennych. Klasyfikację obiektów przeprowadzono z wykorzystaniem metody typologii. Dane statystyczne pozyskano ze źródeł statystyki publicznej i zestawiono w formie macierzy, a następnie poddano normalizacji w celu doprowadzenia ich do bezpośredniej porównywalności. Badania pozwoliły zaobserwować duże zróżnicowanie rozwoju społeczno-gospodarczego województw w Polsce. Analiza liniowego rozkładu metawskaźników rozwoju wykazała, że ich najwyższe wartości przypadły w grupie czynników społecznych, zaś najniższe – przyrodniczych. W konkluzji zwrócono uwagę, że interaktywne wizualizacje danych uzupełniają tabelaryczną formę ich prezentacji, pozwalają analizować zjawiska w ujęciu przestrzennym ukazując ich wewnętrzną strukturę, a także relacje zachodzące pomiędzy poszczególnymi obiektami.

Słowa kluczowe: wizualizacja danych, typologia, taksonomia przestrzenna, klasyfikacja obiektów, wykresy wielowymiarowe