PalArch's Journal of Archaeology of Egypt / Egyptology

VISUALIZATION AND COGNITIVE GRAPHICS IN SCIENTIFIC RESEARCH

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Olga G. Berestneva, Ivan A. Lyzin, Konstantin A. Sharopin, Elena V. Berestneva, Alena I. Polisadova, Lyudmila A. Petrova, Nina P. Stepanenko. Visualization And Cognitive Graphics In Scientific Research-- Palarch's Journal Of Archaeology Of Egypt/Egyptology 17(10), 1606-1618. ISSN 1567-214x

Keywords:
Visualization Methods, Cognitive Graphics, Cluster Analysis, Spectral Representations.

ABSTRACT

The aim of the research is to apply methods of structural analysis of multidimensional data using different approaches to visualizing the results of experimental studies. To solve applied

problems, the authors used NovoSparkVisualizer (demo) system, as well as the R scripting language.

The leading approach to the study of this problem is the mapping of multidimensional experimental data in the form of generalized graphic images on the basis of original methods and approaches developed by the authors.

The paper presents the results of solving two applied problems illustrating the effectiveness of the method for visualization of multidimensional experimental data:

1) analysis of the dynamics of the physiological state of pregnant women;
2) study of breathing parameters in patients with bronchial asthma.

In the first case, the use of cognitive graphics tools made it possible to propose an effective way of displaying the dynamics of the state of the bio-object (for example, comparing the patient's condition before and after treatment). In the second case, it helped to reveal some previously unknown patterns of physiological response of the bronchial-pulmonary system to psycho-physiological exposure.

The results of the research allow the authors to state that the methods and approaches presented in the paper can be regarded as promising directions in the analysis and presentation of multidimensional experimental data.

INTRODUCTION

The man's desire to express a thought, to convey an idea in the form of a graphic image, goes back to the earliest times. Application of graphics in research works not only increases the speed of information transfer and raises the level of its understanding, but also contributes to the development of such important for a specialist of any industry qualities as intuition and visual thinking.

Data visualization is the presentation of data in a form that guarantees their most effective study. [1] Data visualization is widely used in scientific and statistical research (in particular, in forecasting, intellectual analysis of data, business analysis). Data visualization is related to visualization of information and scientific data, exploratory data analysis and statistical graphics.

In the first half of the XIX century, there was a significant increase in the number of fields, which used graphic data display. By the middle of the century, all the main types of data representation were invented: columnar and circular diagrams, bar charts, linear graphs, time series graphs, contour diagrams, etc. [2]

The growth trend began to decline in the early XX century, giving way to mathematics. Nevertheless, it was during this period that textbooks and courses on graphical methods of data presentation began to appear, and researchers started to use graphs not only for presenting results, but also for researching information and putting forward hypotheses in astronomy, physics, biology, and other sciences. [3]

A new stage of visualization started in the third quarter of the 20th century. This development was caused by three events [4]: the appearance of John Tuke's work [5] devoted to exploratory data analysis; the appearance of Jacques Bertin's "Graphic semiology" (Fr. Sémiologiegraphique) [6].

At this stage there appeared an ability to visualize data using computers: the emergence of effective output tools (pen plotters, graphic terminals), as well as ergonomic means of data entry (encoding tablet, mouse). The impact of interactive computer graphics (ICG) led to the emergence of a new issue in the problem of artificial intelligence, called cognitive (i.e.aimed at accumulating knowledge) computer graphics. This term was introduced in the Russian science in the 1990's by A.A. Zenkin. Cognitive graphics is a set of tools and methods of visual representation of the conditions of the problem, which allows either to immediately see the solution, or to get a hint for finding it. Cognitive graphics allow the user to see a new way or approach to solving a problem that was not visible when using traditional data visualization tools. D. A. Pospelov formulated three main tasks of cognitive computer graphics [7]:

- the creation of models of information representation in which it would be possible to represent with same means both objects that are characteristic of logical thinking and images / pictures with which figurative thinking operates,
- visualization of the human knowledge for which it is not yet possible to find textual descriptions,
- the search for ways of transition from the image-pictures to the formulation of a hypothesis concerning those mechanisms and processes that lie behind the dynamics of the observed patterns.

In his work [8], he points out that "the cognitive function of images was used in science before the advent of computers. Visual representations associated with the concepts of graph, tree, net, etc. helped to prove many new theorems, the Euler circles allowed us to visualize the abstract relation of Aristotle's syllogism, the Venn diagrams made visual analysis of the functions of the algebra of logic. "

The technology of cognitive modeling, designed for analysis and decision-making in unclear situations, was proposed by the American researcher R Axelrod. The main direction of his activity was the evolution of cooperation in living systems [9]. In the course of research of this issue he came to the concept of cognitive perception [10]. These studies gave an impulse to the development of cognitive modeling. As a result, there emerged a modern viewpoint on the use of cognitive modeling with the help of cognitive maps. SeeFig. [11].

Later it became clear that graphic images can activate the associative logic of the subconscious processes of thinking in the human brain, which allows us to quickly find original and often unexpected solutions with the help of cognitive graphics [12].

Using cognitive graphics enables the user to draw conclusions without analyzing a large amount of information. Information can be presented in a cognitive way: by a sector, a bar chart, a cross, a circle, etc., parts of which have different colorseach havinga certain meaning [13]. A separate field of cognitive graphics are the poorly structured problem areas, such as socio-psychological and medical field. Visualization of the current state and characteristics allows to ensure continuous control over the condition of groups of individuals or an individual.

The purpose of the research was to visualize the images represented by numerical data and to show the possibility of revealing the relationships between them on the basis of observations of the set of images obtained.

MATERIALS AND METHODS

The most complete description of the approaches used here, accompanied by detailed references to key papers, is presented in “Computer data analysis” by O.G.Berestneva et al. [14]. “Information technologies in biomedical research” byV.Duke and V.Emanuel [15] gives a classification of the main methods for analyzing the structure of multidimensional data:

1) data visualization: linear methods of diminishing dimensionality, non-linear mappings, multidimensional scaling, space-filling curves;
2) automatic grouping: factor and cluster analysis of objects and attributes, hierarchical grouping, definition of "condensation points".

Thebasis of the classification above is a criterion reflecting the degree of participation of the experimenter in distinguishing the features of the relationship between the objects and the characteristics under investigation. The application of data visualization methods aimsat finding the most expressive images of all the objects under investigation for the subsequent maximum utilization of the potential of the experimenter's visual analyzer.

Computer data processing involves mathematical transformation of data using certain software tools. For this, it is necessary to have an idea of both the mathematical methods of data processing and the corresponding software tools [16].

The methods of visualization allow the researcher to visually detect features, reveal regularities and anomalies in large amounts of information. The main task of data visualization is the task of obtaining a visual image that totally corresponds to the data set [17]. The basis of the visualization approach [18, 19] is the linear transformation of the values of the multidimensional observation *A* into a two-dimensional curve $f_A(t)$, i.e. $A \leftrightarrow f_A(t)$. It is guaranteed that visually close images / curves$f_A(t)$ and $f_B(t)$ will correspond to observations *A* and *B* that are close in values, while for images that differ greatly in the values of their observations, the curves will be markedly different.

In the case under consideration, the most general form of data representation is the vector of the finite-dimensional space R_n

$$A = (a_0, a_1, a_2, ..., a_{n-1}) \in R_n. \qquad (1)$$

To move from this vector to the visual image, the authors use a basis of orthonormal functions $\{\varphi_i(\tau)\}_{i=0}^{\infty}$. As a basis, known functions can be used, in particular, orthonormal Legendre polynomials on the interval [0,1], the set of which is denoted by $\{l_i(\tau)\}_{i=0}^{\infty}$.

Legendre polynomials $l_n(x)$ are orthogonal polynomials on the interval [-1,1], which are found by the formula:

$$l_n(x) = \frac{1}{2^n \cdot n!} \cdot \frac{d^n}{dx^n} \cdot (x^2 - 1)^n. \tag{2}$$

Fig. 1. Legendre polynomials

In this case, a point with coordinates $A = (a_0, a_1, a_2, ..., a_{n-1})$ can be associated with a function:

$$F_A(\tau) = \sum_{i=0}^{n-1} a_i l_i(\tau). \tag{3}$$

The formation of vector *A*is connected with the transformation of the data. The values of a multidimensional object's coordinates play an important role in its characterization. In most cases, each indicator has its own unit of measure, and its value will affect the function $F_A(\tau)$. In order to exclude the effect of a difference in the indexes on the form of the function $F_A(\tau)$, it is necessary to move to dimensionless units using one of the known ways.

It should be noted that the order of inclusion of indicators in vector *A*, will also affect the form of the function $F_A(\tau)$. The difference between formulas (1) and (3) is that for vector A from formula (1) only an analytical representation is possible, while for the function $F_A(\tau)$ a representation in the form of a graph is possible. Between formulas (1) and (3) there is a one-to-one relationship in both directions, that is, a one-to-one mutual relationship. If we introduce the second vector $B = (b_0, b_1, b_2, ..., b_{n-1}) \in R_n$ into consideration, it will be associated withthe function

$$F_B(\tau) = \sum_{i=0}^{n-1} b_i l_i(\tau).$$

By way of illustration, the present paper uses several examples from "Visual interpretation of quantitative characteristics of biosystems" by V.A.Volovodenko et al.[18]. Suppose there are two 10-dimensional observations named A and B with the following values:

A: {53.78,1,17.56,2.54,6.36,0.16,4.63,8.1,3.28,1.9},
B: {50.53,1.4,19.05,2.34,5.95,1.53,3.63,7.82,2.98,2.48}.

The following curves are visual representations of observations A and B.

Fig. 2. Images / curvesof observations A and B

Below is the combination of these two images. Curves A and B are very similar to each other. This means that the initial observations are also very close to each other.

Fig. 3. Curves A and B combined

The more the curves are indistinguishable from each other, the more identical the observations they represent, i.e. the method establishes a one-to-one correspondence between the rows in the data set and their curves.

Many interesting propertiescan be revealed if the observation curves are displayed in three-dimensional space using a third dimension ("Z-dimension") as a distance in a multidimensional space or the time interval between two observations. The Z axis is the axis of the imagemovement. In the simplest case, the values of Z coincide with the image number, but this coordinate can be given the value of the distance in the feature space from the origin to the image (object).

Fig.4. Curves A and B in three-dimensional space

*NovoSpark Visualizer*package implements the presented approach [19]. On its basis, the authors have successfully solved a number of applied problems of analysis and interpretation of multidimensional data in the social sphere [20] and medicine [21].
The results of solving two applied problems that illustrate the effectiveness of the presented method of visualization of multidimensional experimental dataare presented below.

RESULTS

Analysis of the dynamics of the physiological state of pregnant women

As initial information of the first problem, we have selective information about pregnant women and the corresponding results of laboratory and clinical studies (a detailed description of the experimental data is presented in [21]). The experiment includes three groups of pregnant women (30 people) aged 18 to 44 years.

The first (control) group consisted of 10 virtually healthy pregnant women aged 20 to 42 years who had not received any treatment. The second (comparison group) consisted of 10 pregnant women aged 18 to 40 years who had somatic diseases had not received any treatment. The third (the main group) consisted of 10 pregnant women aged 19 to 43 years who had somatic diseasesand had received a complex of treatment.

The authors assessed the change in their condition in the first and third trimesters of pregnancy according to a set of biomedical indicators. As a reference set, a control group was selected. Below are observations from each group:

1 - control group,
2 - comparison group,
3 - main group.

Fig. 5. Observations in the first trimester

Figure 5 shows that the observations of the main group and the comparison group are very similar and significantly differ from the control group's observation, which indicates that the initial set of pregnancy condition variables is "suitable" for assessing the dynamics of their state during a complex of treatment.

Figure 6 shows the curves of observations in the III trimester.

Fig. 6. Observations in III trimester

Fig. 7. Reference group observations

Figures 6 and 7 show that the observation of the main group strongly approached the control group, and the observation of the comparison group remained practically unchanged.

This means that by the third trimester, when receiving a set of health-improving measures, the indicators of pregnant women with somatic diseases are much closer to those of virtually healthy pregnant women.

Investigation of respiratory parameters in patients with bronchial asthma

During the last dozens of years, the fields that studythe complex mechanisms of bronchial asthma have been rapidly developing. In recent years, many different both medical and psychological works have been written and published. Basically, theyconcern the study of the role of psychosocial and emotional factors affecting the course of the disease and the patient's condition. Although at the moment, psychosomatic disorders have not been sufficiently studied, it can be reasonably assumed that the psychological factor participates both in the pathogenesis of the disease and changes the entire social situation in general.

There is a great variety of classifications of the disease: depending on the origin, severity of the disease, etc. Currently, many causes of bronchial asthma have been identified, but the question of rational and generally accepted classification is still open [22, 23].

In the course of a long-term follow-up of patients, analysis of life events, an anamnesis of life, K.G.Yazykov and E.V.Nemerov [23] identified a group of patients with high sensitivity to psycho-traumatic life situations. In 2009-2012, they obtained and published results confirming this hypothesis. They hypothesized that among people suffering from bronchial asthma, there are patients with special psychobiological reactivity. Psychosocial stress effects trigger the development of the disease and further aggravation of its symptoms [23]. Scientists noted that it is possible to single out a special group of patients, with whom emotional factors play a great role in the pathogenesis. These observations allowedK.G.Yazikov and E.V.Nemerovtopropose a new classification of bronchial asthma [23]:

PIBA – psychogenicallyinducedbronchial asthma;
SPBA – somato-psychogenic bronchial asthma;
NPBA – non-psychogenicbronchial asthma;
PD –psychogenic dyspnea.

Classification is one of the fundamental processes in science. Application of multidimensional data analysis in solving problems associated with the classification of bronchial asthma will enhance the effectiveness of medical care and create more comfortable conditions for diagnosis and treatment of patients. The introduction of a new classification of bronchial asthma can lead to a more complete, accurate, in-depth and timely understanding of the problems associated with the treatment of patients.

The implementation of the approach proposed in “Visualization and analysis of multidimensional data using the NovoSparkVisualizer package” byV.A.Volovodenko, D.V. Eidzon [19] allows to display multidimensional objects in the form of "spectra". "Spectral representations" in this method emphasize the distinctive features of each curve and help to examine in more detail their visual properties. The color palette accentuates the levels of change in the values of the curves. Locating the curves along the axis, and looking at the result of this operation from above, one can obtain colored strips representing the spectrum of each observation [19]. The color scheme is definedin the map, where the reddish tones correspond to the highest values of the function, and the coldest, blue shades correspond to the smallest values.

The screenshots below represent a comparison of the sample data for four forms of bronchial asthma according to the visual proximity of the observation spectra (Fig. 8).

Fig. 8. Spectralrepresentationsofdataforpatientswithdifferentdiagnoses
a)PIBA; b)SPBA;c)NPBA;d)PD

Each color strip in the spectral form corresponds to the indicators of one patient. In Fig. 8, each screenshot presents five color strips, corresponding to five patients with different forms of bronchial asthma. The color "spectra" of patients diagnosed with *PIBA* and *PD* are similar. The same concernspatients diagnosed with *SPBA* and *NPBA*.

According to Figure 8, patients with *SPBA* and *PD* have the closest indicators. The most pronounced differences can be observed in patients with *PIBA*.

Thus, the use of cognitive graphics enabled us to identify some of the previously unknown patterns of physiological reactions of the broncho-pulmonary system to psycho-physiological effects.

Classification of forms of bronchial asthma

Cluster analysis reflects the features of multivariate analysis in the classification most clearly. A cluster is the union of several homogeneous elements, which can be considered as an independent unit with certain properties. The main purpose of cluster analysis is the partitioning of the set of objects and attributes under investigation into homogeneous groups or clusters. This means that the problem of classifying data and identifying their structure is being solved. Cluster analysis methods can be used in a variety of cases, even when it is a simple grouping, in which everything comes down to the formation of groups of quantitative similarity [14]. The main advantage of cluster analysis is that it allows you to split objects not by one parameter, but by a whole set of characteristics. Using various methods of cluster analysis, we can obtain various solutions for the same data.

The present paper uses the most common algorithm of k-means. The algorithm splits objects into k groups, where each group represents one cluster. The main difference between this method and the hierarchical cluster analysis is the need to initially determine the number of clusters to which the studied data set is to be divided. Therefore, it is desirable to have a hypothesis about the structure of the investigated set before the beginning of the analysis. Using this method, the authors investigated the structure of medical data,as well ascases of clustering for k = 4.

As a result of the comparative analysis, R scripting languagewas chosen for solving the problem. R is a programming language that is developed for application in such areas as exploration data analysis, classical statistical tests and high-level graphics. *Rstudio*was chosen as the development environment. *RStudio* is a free software development environment with open source for the Rprogramming language, which is designed for statistical processing of data and working with graphics. Cluster analysis is performed using the k-means method for 4 clusters using the *k-means* function:

>clus<-k-means (data, 4)

Figure 9 shows the result of clustering according to the physiological parameters of the bronchopulmonary system.

Fig. 9. Resultsofclusteranalysisaccordingtothe initial (“background”) physiological indicators

The first cluster includes, mainly, patients diagnosed with "psychogenic-induced bronchial asthma", the second - patients with non-psychogenic bronchial asthma and psychogenic dyspnea, in the third - patients with psychogenically induced and somato-psychogenic bronchial asthma. And, finally, in the fourth cluster there is practically the same number of representatives of each of the diseases. At the same time, the results show that clustering based only on the parameters of the bronchopulmonary system failed to single out clusters that uniquely match the diagnoses of PIBA,SPBA,NPBA and PD. Apparently, more research using socio-psychological indicators is necessary.

DISCUSSIONS

The representation of a multidimensional observation in the form of a two-dimensional image (curve) ensures that visually close images / curves correspond to objects close in their characteristics.For strongly differing objects, their images / curves will noticeably differ. It is now becoming possible to automatically classify observations, identify the most important variables in a model, cluster data, visually compare individual observations and whole sets of data, and perform many other tasks in working with multidimensional data.

The spectral representation of the visual image is a more "subtle" tool, emphasizing the differences or similarities of images, than the traditional methods characterizing these properties at the level of numerical parameters. This circumstance allows the researcher-operator to be more careful about the differences and to identify "similarities" in a wider range of properties. The operator can ignore common color differences by choosing a monochromatic view.

CONCLUSION

The results of the research allow the authorsto confidently state that the methods and approaches presented in the article are promising fields of study in the analysis and visual representation of multidimensional experimental data.

Methods, algorithms and software developed in the course of the research, are used in solving applied research problems by the authors of the article together with researchers in different subject areas (social sphere, medicine).

ACKNOWLEDGMENTS

The study was carried out with the partial financial support of the Russian Foundation for Basic Research (RFBR) within scientific projects Nos. 19-37-90005 and 18-07-00543

REFERENCES

1. N.B.Paklin andV.I.Oreshkov.Vizualizatsiyadannykh[Visualization of data] // Business Analytics. From data to knowledge. 2nd ed. St. Petersburg: Peter. P.p. 173-210(2013).
2. M.Friendly.Milestones in the history of thematic cartography, statistical graphics, and data visualization. http://www.math.yorku.ca/SCS/Gallery/milestone/milestone.pdf Accessed 21 July 2017(2009).
3. R.Krum. Cool infographics: effective communication with data visualization and design. - Indianapolis: Wiley. 348 p.(2014).
4. N.Iliinsky andJ.Steele. Designing Data Visualizations. Sebastopol, CA: O'Reilly.
5. J.W.Tukey. Exploratory Data Analysis. Reading, Mass: Pearson. 688 p.(1977).
6. J.Bertin andM.C.Barbut.SémiologieGraphique. Les diagrammes, les réseaux, les cartes. Paris: Gauthier-Villars. 431 p.(1967).
7. A.A.Zenkin and D.A.Pospelov.Kognitivnajakompjuternajagrafika. [Cognitive computer graphics]. M: Nauka. 192p.(1991).
8. D.A.Pospelov.Desyat «goryachikhtochek» v issledovaniyakhpoiskusstvennomuintellektu [Ten "hot spots" in research on artificial intelligence]. Intellectual systems (MSU). Volume 1, issue 1-4. P.p.47-56 (1996).
9. R.Axelrod, W.D.Hamilton. The evolution of cooperation // Science. Vol. 211. No. 4489. P.p. 1390-1396 (1981).
10. R.Axelrod.Schema theory: An information processing model of perception and cognition // American Political Science Review. Vol. 67. No. 04. P.p. 1248-1266 (1973).
11. R.Axelrod (ed).Structure of decision: The cognitive maps of political elites. Princeton university press (2015).
12. L.V.Massel, A.G.Massel, R.A.Ivanov.Kognitivnayagrafika I semanticheskoyemodelirovaniyedlyageoprostranstvennykhresheniy v energetike [Cognitive graphics and semantic modeling for geospatial solutions in the energy sector]. Materials of the International Conference InterCarto / InterGIS. 1 (21): 496-503. DOI: 10.24057 / 2414-9179-2015-1-21-496-503 (2015).
13. O.G.Berestneva, I.A.Osadchaya, E.V.Nemerov.Metodyissledovaniyastrukturymeditsinskikhdannykh [Methods for studying the structure of medical data] Bulletin of Siberian Science. No. 1 (2), pp. 333-338 (2012).
14. O.G.Berestneva, E.A.Muratova, A.M.Urazaev.Kompyuternyyanalizdannykh. [Computer data analysis]. Tomsk: Publishing house TPU. 204p.(2003).
15. V.Duke andV.Emanuel.Informatsionnyyetekhnologii v mediko-biologicheskikhissledovaniyakh [Information technologies in biomedical research]. St. Petersburg: Peter. 528 p.(2003).
16. K.A.Sharopin, O.G.Berestneva, G.I.Shkatova.Vizualizatsiyarezultatoveksperimentalnykhissledovaniy [Visualization of the results of experimental research]Izvestiya of Tomsk Polytechnic University. V. 316. № 5. P.p. 172-176 (2010).

17. O.G.Berestneva andY.S.Pekker. Simulation and evaluation of biological systems, adaptive capabilities. Mechanical Engineering, Automation and Control Systems: Tomsk, October 16-18, 2014. Tomsk: TPU Publishing House (2014).
18. V.A.Volovodenko, O.G.Berestneva, K.A.Sharopin. The Visual Conception of Quantitative Characteristics of Biosystems. Fundamental medicine: from scalpel towards genome, proteome and lipidome. Proceedings of the Ist international conference, Kazan (2011).
19. V.A.Volovodenko andD.V.Eidzon.Vizualizatsiya I analizmnogomernykhdannykh s ispolzovaniyempaketa «NovoSparkVisualizer» [Visualization and analysis of multidimensional data using the "NovoSparkVisualizer" package] www.novospark.com. 2008. http://www.tsu.ru/storage/iro/k020410/s4/s4.docAccessed25 Nov2011, (2008).
20. O.G.Berestneva, V.A Volovodenko, O.M.Gerget, K.A.Sharopin, I.A.Osadchaya. Multidimensional Medical Data Visualization Methods Based on Generalized Graphic Images. World Applied Sciences Journal. No. 24. P.p. 18-23 (2013).
21. O.M.Gerget, O.V.Marukhina, Yu.A.Cherkashina. System for visualizing and analyzing multivariate data from medico-social research. Key Engineering Materials.Scientific Journal. Vol. 685 : High Technology: Research and Applications, p. 957-961 (2016).
22. S.I.Ovcharenko.Bronkhialnayaastma: diagnostika I lecheniye [Bronchial asthma: diagnosis and treatment].RMJ. V.10. № 17. P.p.766 – 767 (2002).
23. E.V.Nemerov andG.G.Kazakov.K voprosuizucheniyalichnostnykhsvoystv v psikhofiziologicheskoyreaktivnostibolnykhbronkhialnoyastmoynaaudiovizualnuyustimulyatsiyu [On the study of personal properties in the psychophysiological reactivity of patients with bronchial asthma on audiovisual stimulation].Bulletin of the Tomsk State Pedagogical University. Issue. 6 (108). P.p. 134-137 (2011).

Appendix A

Figure 1 – Legendre polynomials

Figure2 – Images / curves of observation A and B

Figure 3 – Curves A and B combined

Figure 4 – Curves A and B in three-dimensional space

Figure 5 – Observations in the first trimester

Figure 6 – Observations in III trimester

Figure 7 – Reference group observations

Figure 8 – Spectral representations of data for patients with different diagnoses
a)*PIBA*; b)*SPBA*;c)*NPBA*;d)*PD*

Figure 9 – Results of cluster analysis according to the initial (“background”) physiological indicators