Application Tools of Geographic Information Systems in Demogeography

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Abstract
The goal of the article is to elucidate relationships between demogeography and geographic information systems (GIS) referring to the relevant terms, concepts and applications with the impact on the identification of fitting tools and GIS methods in the field of spatial analyses and visualisation of demogeographical data.
Keywords: *geographic information systems, (demo)geographical information and databases, demogeography, spatial analysis, cartography, visualisation.*

Introduction

What is the outgrowth that provides tools united under the name of geographic informational systems (GIS) for demography or demogeography? The answer is not immediately obvious, despite the fact that demographical data are quite frequently processed and represented with the help of GIS. Our goal is to look at this issue through the prism of geographer or demogeographer with the reference to earlier works on this topic (Kusendová 1999[1], Kusendová 2003[2]).

Demogeography, Demography and Demogeographics

To refer to the processing, analysis and visualisation of demographical data in the GIS environment, some relevant terminology related to population and inhabitants should be addressed.

The Slovak geographer J. Mládek (1992, p. 15[3]) determines **geography of population** as „ a scientific discipline of human geography which deals with basic characteristics and patterns of development, size, distribution, structure and dynamics spatial structures of population in their interactions (mutual relationships) with other geographical elements of these structures“. According to him, **demography** is a social science, which studies the size, structure, development and development patterns of the population structure with that difference that population processes and phenomena are being studied in the aspect of the population reproduction. He defines the term of **demogeography** in the study (Mládek 1998[4]), where it was used to define ***geography of population***. Hence, demogeography is equal to geography of population.

According to B. Goodall (1987, p. 365[5]), ***demography*** is a scientific and statistical study of population, and, in particular, the size of population, their

[1] KUSENDOVÁ, D. (1999). Geoinformatika v demogeografii. In *Teoreticko-metodologické problémy geografie, príbuzných disciplín a ich aplikácie*. Zborník referátov. Bratislava, pp. 33-40 (Prírodovedecká fakulta Univerzity Komenského).

[2] KUSENDOVÁ, D. (2003). Geografické informačné systémy a humánna geografia – vybrané teoreticko–metodologické a aplikačné aspekty. *Acta Facultatis Rerum Naturalium Universitatis Comenianae*, Geographica Nr. 44, pp. 89-140.

[3] MLÁDEK, J. (1992). *Základy geografie obyvateľstva*. Bratislava (Slovenské pedagogické nakladateľstvo).

[4] MLÁDEK, J. (1998). *Demogeografia Slovenska*. Bratislava (Univerzita Komenského).

[5] GOODALL, B. (1987) The Penguin Dictionary of Human Geography. Harmondsworth (Penguin).

development and structure, and ***population geography*** is a study of the relationship between spatial variations in the distribution, composition, migration and growth of population and the geographic character of places.
Demographer of the Czech demographical school Z. Pavlík (Pavlík et al. 1986[6]) considers human population to be an object of demographical study and regards demographic or population reproduction as its subject. He comprehends ***geography of population*** to be an important part of **human geography** which studies regularities in spatial organisation of human activities, where demographic reproduction and its patterns traditionally remain beyond scientific concern. The boundaries between geography of population and demogeography are considered to be as vague as both disciplines use the same methodology (statistical methods of population survey), though the core of their interest sets them apart.
According to him, demography may incorporate the studies on migration. However, the studies on the population distribution, e.g. urbanization processes, are addressed less often. Such extension of demography into the sphere of population geography according to Z. Pavlík may be defined as **geodemography**. The differences in definitions and approaches basically originate from relevant national traditions and scientific schools. Even though clear mutual relationships between human geography and demography are broadly acknowledged, changing definitions of both scientific disciplines along the different approach to the subject of their study should be taken into consideration.
Vaňo et al. 2003[7], regard ***geodemography*** as a kind of applied demography, what corresponds with the contemporary comprehension and use of the term **geodemographics**, especially in relation to the application of extensive geographical databases of demographical data (geodemographical databases) in the environment of geoinformatic technologies.
According to J. Goss (Goss 2001[8]) ***geodemographics*** describes a rapidly growing segment of the marketing industry that collects massive amounts of data on consumer characteristics and behaviour, constructs spatial statistical models of consumer identity and maps, and analyses distribution of market-related activity.
In geospatial, respectively in geoinformation terminology (Smith et al. 2007, p. 17[9]), the term ***geodemographics*** is explained as „the analysis of people by where they live, in particular by type of neighbourhood. Such localised classifications have been shown to be powerful discriminators of consumer behaviour and related social and behavioural patterns“. Thus, we recommend

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[6] PAVLÍK, Z., RYCHTAŘÍKOVÁ, J., ŠUBRTOVÁ, A. (1986). *Základy demografie*. Praha (Academia).
[7] VAŇO, B., JURČOVÁ, D., MÉSZÁROS, J. (2003). *Základy demografie.* Bratislava (Občianske združenie Sociálna práca).
[8] GOSS J. (2001). Geodemographics. *Internationl Encyclopedia of the Social & Behavioral Sciences*, pp. 6166-6169 (Elsevier Sciences Ltd.).
[9] SMITH, M.J., GOODCHILD, M.F., LONGLEY, P.A. (2007). *Geospatial Analysis - The comprehensive independent guide to principles, techniques & software tools a comprehensive guide.* 2nd Edition. Leicester (Matador). http://www.spatialanalysisonline.com/output (Accessed 29 January 2009).

using the term **geodemography or geodemographics** only in this context, i.e. referring to the application of spatial statistical methods and cartographical visualisations with the help of geoinformatic technologies and GIS. Spatial aspects of population applicable to geoinformation technologies and GIS are also extensively studied by other boundary disciplines such as **spatial epidemiology** (Elliont and Wartenberg 2004[10]), or **medical geography** (Sui 2007[11]).

The relation of all the mentioned fields to GIS is quite special because the number of theoretical and methodological aspects implemented and developed in the GIS environment depends on development trends, research methods and applications that call for a new synergy between them in future research and educational efforts.

Geographical Information and Geographic Information Systems

Demographical information or data in geographical/spatial context are significant for different solutions related to geographical space. Today, information technologies provide new options for the collection, administration and visualisation of spatial or **geographical information** (**GI**) and this mainly owing to the development of specialised **GeoInformation Technologies (GIT)** and their subset – **Geographical Information Systems (GIS)** or *Geographic Information Science*. In the broadest sense, GIS is a system-based information technology (in a narrower scope – program systems) for the creation, maintenance, administration, integration, presentation and supply of GI. **GI** implies the data on the location, shape and relations between geographic events stored usually over a coordinate system and topology. According ISO 19101 (TeSlo 2008[12]) GI is about "the data concerning phenomena implicitly or explicitly associated with a location relative to the Earth". **Geographic Information Science** (GIScience) or geomatics may be distinguished as new scientific discipline dealing with theoretical and methodical aspects of geoinformation processing through GIS (Goodchild 2001[13]). GIScience is the basic research field that facilitates the redefining of geographic concepts and their use in the context of GIS, examines the impacts of GIS on individuals and society, and the impacts of society on GIS. GIScience re-examines some of the most fundamental themes in traditional spatially oriented fields such as geography, cartography, and geodesy incorporating recent developments in cognitive and information science. When defining the subject domains, it is important to recognise the suite of tools, which most professionals accept as

[10] ELLIOTT, P., WARTENBERG, D. (2004). Spatial Epidemiology: Current Approaches and Future Challenges. Environmental Health Perspectives, *Annual Review Issue*, vol. 112, 9, pp. 998-1006. http://www.ehponline.org/docs/2004/6735/abstract.html (Accessed 29 January 2009).

[11] SUI, D., Z. (2007). Geographic Information Systems and Medical Geography: Toward a New Synergy. *Geography Compass*, vol. 1, 3, pp. 556-582 (Blackwell Publishing Ltd). http://geog.tamu.edu/~sui/publication/pub2007/SuiCompassPaper.pdf (Accessed 29 January 2009).

[12] *TeSlo* (2006). http://gis.fns.uniba.sk/wiki/index.php/Hlavn%C3%A1_str%C3%A1nka (Accessed 29 January 2009).

[13] GOODCHILD, M. F. (2001). Geographic Information Systems. *International Encyclopedia of the Social & Behavioral Sciences*, pp. 2001, 6175-6182 (Elsevier Science B.V.).

directly applicable to GI. These tools include GIS, Remote Sensing, Global Navigation Satellite Systems and others, all of which belong to information and communication technologies.

The aim of each GIS shapes its ***structure***, which embodies three main elements: ***technical, dataset*** and ***organisational***, where the data are of key importance, whereas the organisational element refers to the human aspect represented by the management/administration, service and users. All GIS components should be interconnected in a single unit functionally conditioned by the use of the appropriate hardware and software in all the system's levels, then the thorough analysis of the data quality in relation to the system's objects and functions should be observed, and the specification of the data integration in individual system's levels, along the system's organisational supply.

First GIS have been developed as the helping tools for technical and geography-related disciplines (geodesy, cartography, mathematics). Gradually, they have transformed to systems that interlink **spatial** or **geographical** *research methods* with *information technologies*. Later, their design has targeted general commercial GIS (meeting various customer's requirements and integrating plenty of functions from other application fields) and national markets, with specific demands upon each application. The development of monolithic multifunctional GIS launched by individual companies reached the peak in the 1990s. Today, GIS represent a mature information technology being sold or implemented by specialised companies, such as ESRI and Intergraph, in the form of multifunctional module computer systems.

However, the contemporary trend of GIS development is mostly aimed at meeting requirements for **OpenGIS**[14], i.e. open system environment – a comprehensive set of interfaces, services and supporting formats, plus user aspect for interoperability and/or portability of applications, data, or people, as specified by information technology standards and profiles. Despite the limited program options, they are thoroughly designed. But the data configuration, operations and the computer visualisation of the results (geographical information) have been still left on complex GIS.

Current trend is shifting towards GIS, which along other tools, can be integrated into the data processing, where GIS is merely a device that processes and exports GI to other subsystems or processes, or communicate over the open computer interface with other expert or cognitive systems. In line with the recent trends of contemporary information technologies development, open GIS program platforms that are significant integrators of geographically referenced statistical data and geostatistic methods and techniques are applied. The new paradigm of GIS technologies and their application says: from proprietary to interoperable (based on standards of the Open Geospatial Consortium - OGC), from stand alone to networked, from desktop to mobile, from owned geodata and software to geoweb (provides an open, global, and scalable infrastructure

[14] According to the Open Geospatial Consortium: http://www.opengeospatial.org/ – a non-profit, international, voluntary consensus standards organization leading the development of standards for geospatial and location-based services.

for rapidly discovering information on the Internet) based on the spatial data infrastructure (SDI)[15].

Geographic Information Systems and Demogeographic Databases

GIS have entered demogeography in a form of two basic components of geoinformatic technologies and methods, applicable in creation, storage and distribution of (demo)geographical databases. Actually, they are about the creation and distribution of standardised geoinformatical or geographical data in the international and national levels, together with the creation of respective serving programs with selected types of program functions like **desktop mapping GIS** (*MapInfo Professional*, *ArcGIS, GeoMedia* ect.) which allow users to get and present the cartographically relevant GI in a simple way.

GIS provide great prospects for geographers penetrating areas of statistical data collection, processing, management analysis and distribution. GIS development has substantially influenced census demographic statistical databases and their applications. As early as in the 1970s, the results of the USA census were implemented into the data structure suitable for the GIS environment known under the acronym *TIGER* (Topologically Integrated Geographic Encoding and Referencing). This geographically referenced encoding system of the Federal Statistical Office under the USA Ministry of Defence – *United States Bureau of the Census* has become a prototype, frequently used for census statistical geographical database applicable in the GIS environment (Mark et al. 1996)[16].

Similar census databases have often been offered commercially, including the *desktop mapping GIS* or **webmap services** (as "sample" data files suitable for the processing and analyses within the given program). However, if they do not have sufficiently generalised content the actualisation is a weak side of these files. Unfortunately, this way of actualisation cannot really guarantee correct and actual data. The exception is distributors who are either administrators, or cooperate with the state guarantors of demogeographical or socio-economic statistical data.

Different statistical organisations (authorised to collect, to process and distribute demogeographical data) use GIS to promote their activities. The data are collected, maintained and actualised centrally and then being distributed to different users within and beyond these authorities. Practice has shown that the local administrating means multiple maintenance of highly resemble data for high costs. This may be reduced by just using GIS technologies, providing the essential organisational procedures had been applied.

The developed **GIS interoperability** has recently reached a distinct share in the market with digital demogeographical data. The new procedures of network services, data access and sharing, new program application interfaces and metadata structures have been elaborated. The interoperability and standardisation and normalisation of geographical data structures closely

[15] SDI - a set of elements that provide the functionality for interoperability of geographical information sources.

[16] MARK, M. D., CHRISMAN, N., FRANK, A. U., MCHAFFIE, P. H., PICKLES, J. (1996). *The GIS History Project.* http://www.ncgia.buffalo.edu/gishist/bar_harbor.html (Accessed 29 January 2009).

connected with it are the long-term goal for all geoinformatic community (the database distributors, national mapping and statistical services, etc.). Created Global, Regional and National **Spatial Data Infrastructure** comprise of the following elements: metadata, spatial data and data services, network services and technologies, the rules of sharing, accessing and exploitation of the data and services, coordinating and monitoring mechanisms, processes and procedures.

Generally, the geographic information market in Europe demonstrates different dynamics than in the USA, where e.g. *United States Geological Survey* and *United States Bureau of the Census* have a mandate to collect and distribute primary geographic (topographic) and referenced statistical data of socio- and demo-character. These data cover all the state in small to large scales and are accessible free on the Internet only for the price of their reproduction. In Europe, for instance, these data are collected by numerous national agencies, which have different authorisation. The data they provide are mostly payable. Still unresolved copyrights create barriers for the wider use of data. Further problems (Meixner and Frank in Frank et al. 2000[17]) encounter:

- low awareness of the GIS users,
- lack of availability of geographical information and data,
- compartmentalisation of the GIS market.

The best prospects to penetrate the European market of applicable demogeographical data for spatial or geospatial analyses and map presentations have paradoxically the American GIS producers, e.g. ESRI (The Environmental Systems Research Institute, in Redlands, California) and Pitney Bowes MapInfo Corporation.

Many digital geographical databases, gained via the *Remote Sensing*, are mostly used for the administration and maintenance of natural (environmental) resources. Human resource management and geoinformatisation of socio-economical sciences have its own, relatively separated path of development, which is the natural consequence of the different character, comprehension and thus different modelling of objects and phenomena of their research. The efforts are made to interlink these two paths of development by the identification of spatial interactions of human and environmental activities, which can solve the problem of actual and locally more accurate GI collection when analysing the population distribution based on the interpretation of the ERSI data (Martin, Bracken 1993[18]). The lack of suitable datasets describing socio-economic variables consistently and with suitable detail for large areas is needed to be resolved too. From this point of view *The Global Demography Project* (Tobler et al. 1995[19]) is very interesting, launched to assemble the world's

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[17] FRANK, A. U., RAUBAL, M., VAN DER VLUGT, M. eds. (2000). Panel–GI Compendium A guide to GI and GIS. Vienna, *GeoInfo Series Nr. 21 (*Institute for Geoinformation Technical University of Vienna, 2000, pp. 9-42.

[18] MARTIN, D., BRACKEN, I. (1993). The interpretation of socioeconomic and physical resource data for applied land management information system. *Applied Geography*, Vol. 13, No. 1, 1993, pp. 45-53.

[19] TOBLER, W., DEICHMANN U., GOTTSEGEN, J., MALOY, K. (1995). *The Global Demography Project*. Technical Report TR-95-6 (National Center for Geographic Information and Analysis). http://www.ncgia.ucsb.edu/Publications/Tech_Reports/95/95-6.pdf (Accessed 29 January 2009).

demographical data in geographical grids – latitude/longitude quadrilaterals – a data format providing considerable advantage for comparative environmental analytical studies. Gridded Population of the World, and the Global Rural-Urban Mapping Project[20], produced by the Centre for International Earth Science Information Network of the Earth Institute at Columbia University, are the latest developments in the rendering of human populations in a common geo-referenced framework.

GIS Visualisation and Demogeography

In practice, GIS and presentation of GI are mostly associated with maps. Traditional analogue (paper) maps have gradually been superseded by automated digitally designed maps developed using GIS technologies. They offer a suitable platform for the creation and processing of extensive digital databases and for their computer cartographic/map visualisation. Current database and visualisation GIS tools applied within the public demographic databases allow to produce required GI and to generate own thematic maps.

Traditional cartographic methods have been applied there, what was confirmed by our study of the census atlas production (Kusendova 2002[21]). In systematic survey of demographic atlases that contained the data from population censuses in the territory of Slovakia the **classification scheme of map representation methods** by J. Pravda (2006[22] – Tab. 1 and Fig.1) has been used.

Tab. 1. Classification scheme of the map methods (Pravda 2006)

Formal name*	Method name	
	Full name	Abbreviation name
S_F (Q)	Method of quality figural signs	Quality figural signs
S_F(Q-M,Dens)	Method of quality-quantity figural signs	Density figural signs
S_L(Q)	Method of quality-quantity line signs	Quality line signs
S_L(Q-M,Course)	Method of quality-quantity course line signs	Course signs
S_{AD}(Q)	Method of quality discrete area signs	Quality areas
S_{AD}(M,Int)	Method of quantity (intensity) discrete area signs	Quantity areas
S(M,Diagr)	Method of diagram signs	Diagram methods
S_{AC}(M,Isogr)	Method of continuous quantity isogradation surfaces	Isogradation method
S(Georelief)	Method of visualisation of georelief	Georelief visualisation
S(Anam)	Method of ananamorphous visualisation	Anamorphous cartograms
S(Sat-RS)	Method of the satellite used (Remote Sensing)	Satellite scene used
S(3D/2D)	3D in 2D visualisation methods	Methods 3D in 2D
S(Dyn)	Dynamic and animation methods	Dynamic methods

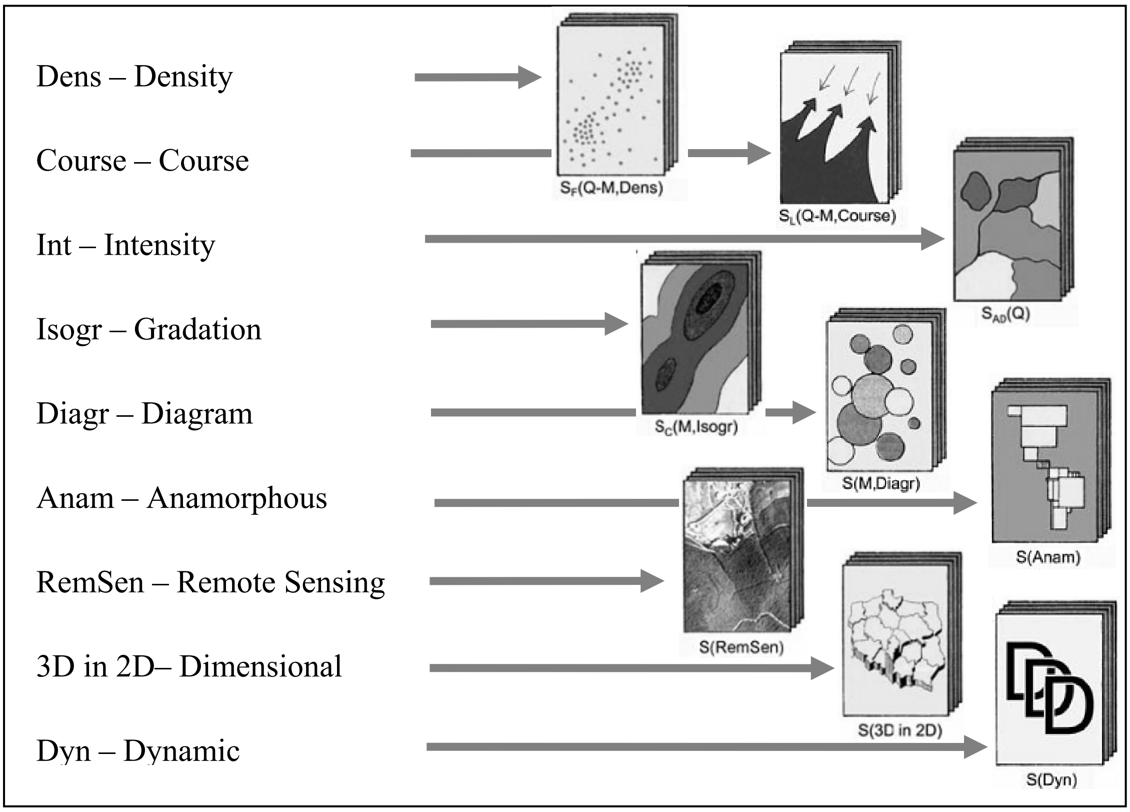
**S – sing, S_F – figural sign, S_L – line sign, S_{AD} – area discrete, S_{AC} – area continuous, Q – quality, M – multitude, Dnes – density, Diagr – diagram, Course – course, Int – intensity, Isogr – gradation, Anam – anamorphous, Sat – satellite, D – dimension, Dyn – dynamic*

[20] http://sedac.ciesin.columbia.edu/gpw/

[21] KUSENDOVÁ, D. (2002). Kartografická prezentácia demogeografických dát. *Aktivity v kartografii 2002*. Bratislava, pp. 79-87 (Kartografická spoločnosť Slovenskej republiky a Geografický ústav SAV).

[22] PRAVDA, J. (2006). Metódy mapového vyjadrovania – klasifikácia a ukážky. *Geographia Slovaca*, 21, Bratislava (Geografický ústav SAV).

Fig. 1. Graphic representation of the basic map methods (Pravda 2006).



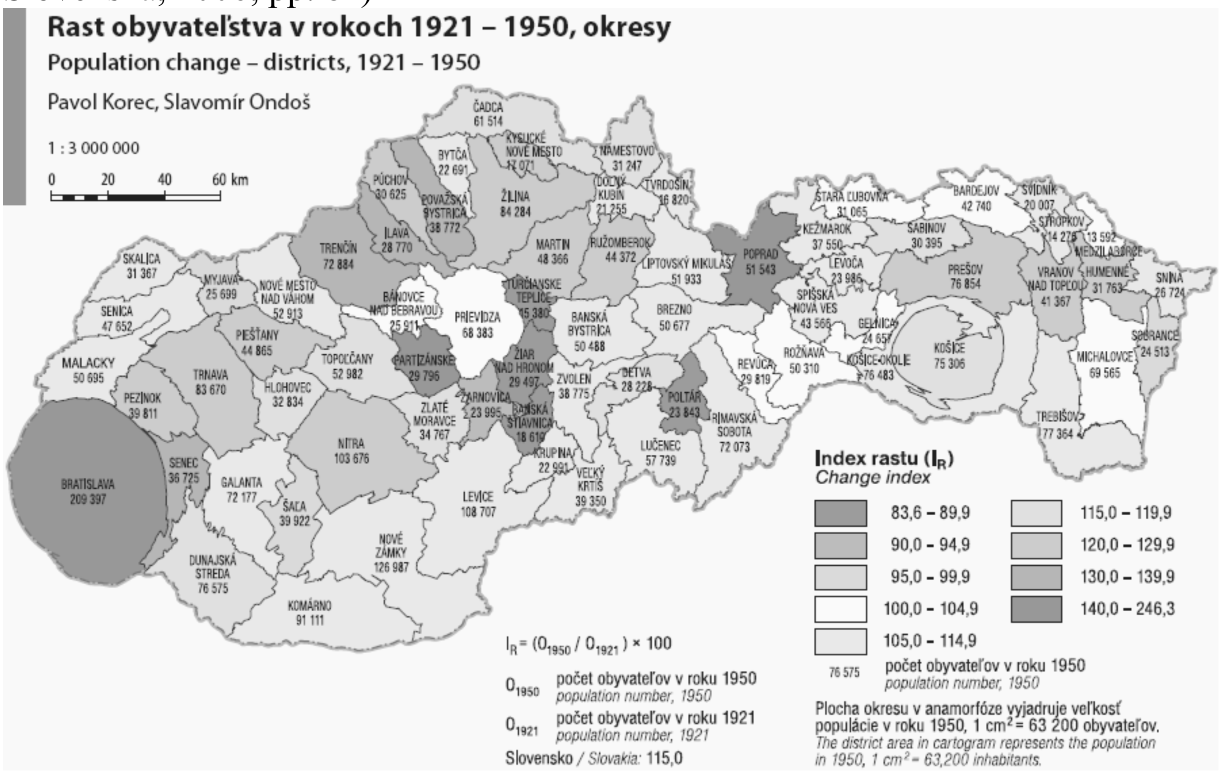
The classification scheme was based on the three criteria: the way of data statistic processing, the character of map representation and used map signs. The new classification of map presentation methods unifies their terminology, introduced a symbiosis of terms *choropleth map* (frequent in the USA) and *cartograms* (frequently used in eastern and central Europe) and established the new methods: of the *quantitative areas*, *remote sensing*, *3D in 2D space* and *dynamic*.

From the analyses of atlases based on this classification scheme it can be said that the figural and area methods of map representation were most frequent. Among area methods, the following prevailed in descending order: quantitative/intensive (that is traditional cartogram), quantitative/diagram (cartodiagram), and quantitative with mainly simple (less composed) colour and structural (pattern or raster) signs. Figural methods used the most were as follows: quantitative and quantitative-density, diagram and comparative/intensive with the attempt of topographic localisation of points, lines, areas and some other geometric and associable (motivated) sings.

The course line method was used only in one atlas and the anamorphous method had not been applied at all. All map methods in surveyed atlases had represented and still represent the traditional ways of cartographic visualisation of aggregated demographical data (in traditional statistic territorial units – state, region, district, community) in the form of statistic two-dimensional (2D) maps of medium and small scale.

Recent development of computer and geoinformatics technologies creates suitable conditions for the creation of new methods of demographical data presentation. As clearly readable anamorphous maps were used very rarely in the past, e.g. in the form of demovalent maps (Kusendová 2004[23], Majo 2006[24]), mainly due to the extreme laboriousness of their creation, today, when the tools for their creation in the GIS environment have become accessible, they represent a significant part of interactive cartographic presentations. New – satellite, 3D and dynamic cartographic methods – only recently unimaginable forms of cartographic presentation, are becoming to be used frequently.
During the creation of the Population Atlas of Slovakia (2006), this led to the application of non-traditional (i.e. scarcely used in demographic practice) methods as the anamorphous (Fig. 2), line course, isoline or isogradational (Fig. 3), and tree-dimensional – 3D in 2D methods. For the population density map remote sensing data were used (Fig. 4).

Fig. 2. Anamorphous method (continuous demovalent cartogram) has been used for the population change index in the districts of Slovakia, where the district area represents the number of inhabitants in the actual year (Atlas obyvateľstva Slovenska, 2006, pp. 8[25])



[23] KUSENDOVÁ, D. (2004). Kartografická vizualizácia rozmiestnenia obyvateľstva Slovenska. In *Geografie a proměny poznání geografické reality*. Ostrava, 2.svazek, pp. 488-497 (Ostravská univerzita).
[24] MAJO, J. (2006). Etnická štruktúra obyvateľstva a demovalentné kartogramy. *Kartografické listy*, 14, Bratislava, s. 121-126 (Kartografická spoločnosť Slovenskej republiky a Geografický ústav SAV).
[25] *ATLAS OBYVATEĽSTVA SLOVENSKA. (2006).* Eds. Mládek, J. et al. Bratislava (Univerzita Komenského).

Fig. 3. The non-traditional application of the isogradational (isoline) method for the visualisation of time-spatial changes of the natural population decrease in the districts of Slovakia (Population Atlas of Slovakia 2006, pp. 56)

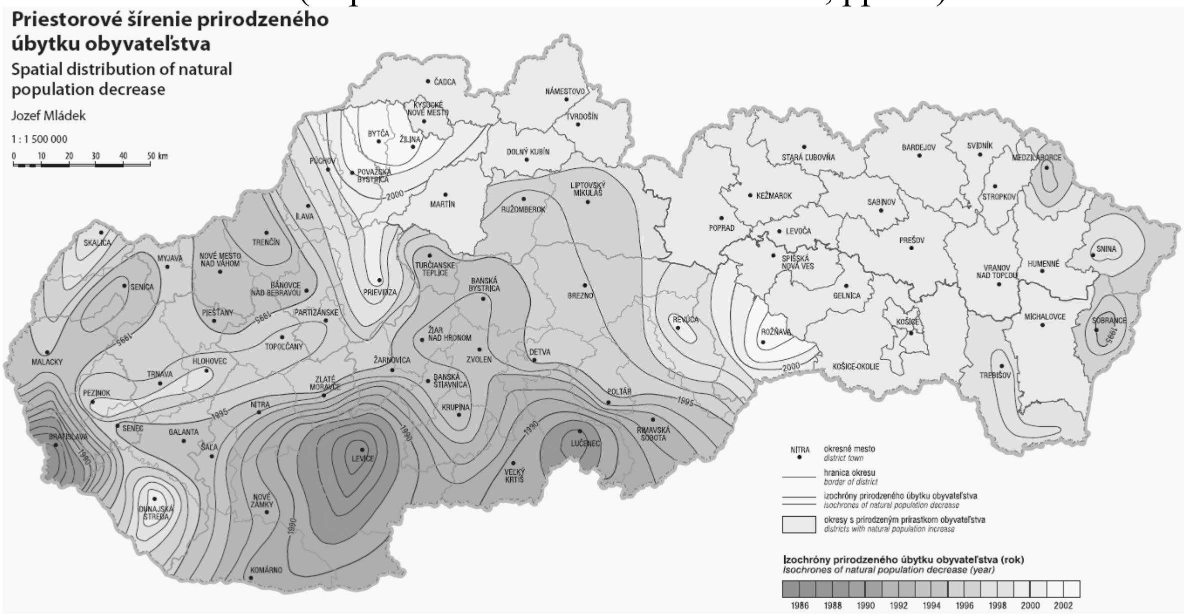
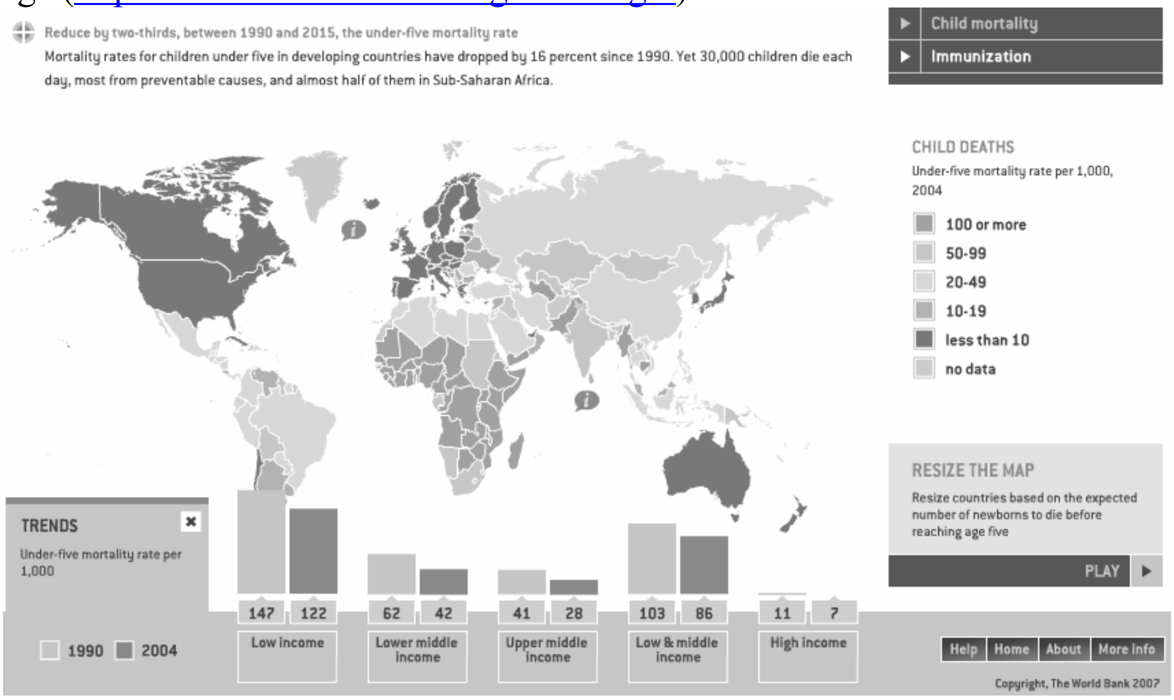


Fig. 4. Elevation zones represented by the raster – the product of processed Remote Sensing data (Population Atlas of Slovakia 2006, pp. 10-11)

Analogue maps have become less used in favour of digital ones, which became a part of the computer and computer-network GIS applications (*geovisualisations*) defining the new face of GIS cartography. The Internet has stimulated the production of not only passive, but also active (interactive) forms of cartographic visualisation of demographical data (Fig. 5). This technological development induces the acute need for new theoretical and methodological conceptions and solutions in map communication, cartographic design, geographical visualisation, **GIS cartography**, etc. Cartographers have to transform these new theories to new cartographical models, such as digital maps, map-based hypermedia, web maps and atlases with advanced map languages and symbolism with the help of interdisciplinary cooperating teams (Voženílek 2005[26]).

Fig. 5. The atlas web-program application of demographical data through the anamorphous map method (cartogram) animation from the World Bank Internet page (http://devdata.worldbank.org/atlas-mgd/)



Spatial analysis and GIS

Geographic technologies play one of the key roles in the study of geographical systems. The concept of the digital processing of geographical data caused in many scientific disciplines, including demogeography, fundamental changes in analysing procedures of studied geographical systems. Spatial analyses of geographical data belong to the most fascinating GIS field. They come up after the sophisticated collection, processing and integration of the data into spatial databases.

Many of spatial analyses and associated modelling techniques are provided within currently available and widely used GIS and associated software. Collectively, such techniques and tools are described as **geospatial analysis** or in more common term as **spatial analysis**.

The complex of the GIS analytical techniques and tools is aimed at the following aspects of spatial systems (Hlásny 2007)[27]:

- the description and quantification of systems' structure (morphology, arrangement of elements),

[26] VOŽENÍLEK, V. (2005). Cartography for GIS Geovisualization and Map Communication. Olomouc (Univerzita Palackého).

[27] HLÁSNY T. (2007). *Geografické informačné systémy - Priestorové analýzy*. Zvolen (Zephytos & Národné lesnícke centrum – Lesnícky výskumný ústav).

- the description of systems' functions (of their functional characteristics – autocorrelation),
- the time-spatial description of systems (of their behaviour),
- the systems' modelling and simulation,
- the research of spatial ranges (scales and dimensions), where systems are analysed to determine so-called scale-dependent system, where the system spatial structure and behaviour have been changing.

From structural characteristics (connectivity, heterogeneity, fragmentation and others), the genesis, functions of studied phenomena or processes can be derived, and spatial continuity (autocorrelation) can be evaluated along some other characteristics. This assumes simply programmable techniques, which are the standard part of the GIS programs or specialised spatial geostatistical modules (FRAGSTATS, CRIMESTAT, and others).

Recently, GIS have entered initially pure statistical programs, e.g. the SAS System[28] , by mean of SAS/GIS specialised modules, providing simple and effective merge of geoinformatical and statistical procedures and methods in a single program system. This eliminates the problem with the data import/export and visualisation that decrease their quality.

Time GIS

From the viewpoint of historical development of time-spatial analyses and the GIS program applications, 1964 may be regarded as the breakthrough year when BERRY (1964[29]) suggested using two-dimensional matrix/layer for the description of geographical data. Later, this concept was extended to the third dimension by the incorporation of time layers. Today, this signify a dominant method of the data organisation in geography paradigm – the discreteness of geospace and geoobjects, that relate to **Time GIS** (Langran 1993[30]) or **Time Integrative GIS** (Ott, Swiaczny 2001[31]) and to specific methods, as e.g. time-spatial geostatistics, which formulate the theoretical, technical and philosophical frameworks of time and space integration into the GIS platform.

Conventional approaches towards the processing of the statistical data layers are implemented in GIS through the standard mathematic-statistical procedures. Time-spatial analyses are also based on such procedures of the time series analysis additionally enhanced by the time-space series methods of analyses (multidimensional spatially referenced matrixes) and by dynamic administration of so structured data.

From the time-spatial analytical methods, which can be easily implemented into GIS, the most important are those aimed at (Hlásny 2007):

- description characteristics of the time-space series,
- the determination of the trend component,

[28] http://www.sas.com/

[29] BERRY, B. (1964). Approaches to Regional Analysis: A Synthesis, *Annals of the Association of American Geographers*, 54, pp. 2-11

[30] LANGRAN, G. (1992). *Time in geographical information systems*. London (Taylor & Francis).

[31] OTT, T., SWIACZNY, F. (2001). *Time–Integrative GIS – Management and Analysis of Spatio-Temporal Data* (Springer-Verlag Berlin-Heidelberg).

- the evaluation of time changes,
- predicative modelling.

In spite of the fact that the depth of today's knowledge allows the complete time and space integration into the GIS, the demands of users are for now not challenging enough to turn the activities of commercial companies into this direction.

GIS and Related Software Tools and Products

Many GIS programs apply the term of (geo)spatial analysis in a quite narrow context. In **vector-based GIS,** commonly used in demogeography, this usually means procedures such as *map overlay* (combining two or more maps or map layers), *buffering* (defining regions of a map within a specified distance of one or more features, as e.g. settlements or roads), and similar spatial operations. This reflects the term *spatial analysis* within the Open Geospatial Consortium[32]. In **raster-based GIS**, commonly used in environmental sciences and remote sensing, this basically means a set of procedures with grid cells (matrixes) of one or more raster maps that often assumes filtering or algebraic operations (*map algebra*). Descriptive statistics of these cells, further measures and distance computations are often defined as spatial analysis. Subsequently, a large number of statistical techniques (descriptive, exploratory, explanatory and predictive) that were designed specifically for spatial and spatial-temporal data have to be added to these initial procedures. Such procedures are very important in social sciences, including demography.

However, the limitation of geospatial analysis to 2D mapping operations and spatial statistics is quite restrictive. There are other important areas which include further significant techniques of spatial analysis, such as **surface analysis (**particularly analysing basic characteristics as gradient, aspect and visibility); **network analysis** (analysing natural or man-made networks to understand the behaviour of flows in and around such networks) **locational analysis,** and **geovisualisation.** Geovisualisation is an important tool of geospatial analysis comprising the creation and processing of spatial models (maps, 3D views) and their tabular datasets. GIS packages provide tools for static and dynamic views, animations, and **spatial-temporal visualisations**. The latter are the least developed, reflecting limited range of suitable datasets and analytical methods, although this is changing rapidly. All mentioned geovisualisation techniques are important for the spatial analysis processes (e.g. data exploration, patterns and relationships identification, models construction, reliability of results and so on).

The guidance on GIS-related software tools and products for spatial analyses can be found in Smits et al. (2007). Their thoughts can be loosely interpreted as it follows below.

Most of spatial analysis techniques have been developed over the past half century in many areas, but they had not been implemented so far in mainstream GIS products. Rapidly changing field and increasingly used GIS packages

[32] http://www.opengeospatial.org/

include analytical tools as standard built-in facilities or as optional toolsets. In many instances such products are provided by the original software suppliers while in other cases these facilities are being developed and provided by third parties. The availability of analysing tools does not mean that one product is necessarily better than another — it is the selection of *appropriate* tools because they *fit for the purpose.* Only this is decisive.

Commercial GIS software is driven primarily by demand and applicability that reflects the willingness to pay for them. There are many characteristics in software packages that are supplied merely because of simplicity of their implementation by designers and programmers, especially of those concerned with the object-oriented programming and data models.

Commercial software products rarely provide access to source code or full details of the algorithms employed. Typically they provide references to books and articles on which the procedure is based, coupled with online help and "white papers" describing their parameters and applications. ***Non-commercial packages*** sometimes provide source code and test data for some or all of the analytical functions provided, although it is important to understand that "non-commercial" rarely means that users can download the full source code.

The list of software functions and applications for spatial analyses is long. There is a substantial difference between demands on research and practice. In many cases such programs fulfil specific operational needs, solving a well-defined subset of spatial problems and provide mapped output as an incidental but essential part of their operation. Many of the capabilities may be found in general GIS products. In other instances, a specialised package may use the GIS for the display, and in some cases for the processing of spatial data (directly, or indirectly through the interface or the file input/output). Numerous of these tools are free while others are for a small fee. Details of how to obtain these tools are provided on web links. In Tab. 2 and Tab. 3 some sample program tools (including GIS software) for spatial analyses and their specifications are given.

Tab. 2. Sample commercial software and tools for spatial analysis (modified according Smith et al. 2007)

Product	Product type, area of use and product authors
ArcGIS	General purpose, comprehensive, very extensive toolsets, vector focused with substantial raster support. Cross industry, Open Geospatial Consortium (OGC) compliant (ESRI)
CASE	Crime Analysis Spatial Extension (an ArcGIS extension, including the former Animal Movements Extension for ArcView developed by the United State Geological Survey)
CCMaps	Conditioned choropleth mapping. Interactive mapping/visualisation tool, developed for health (cancer) studies and related analyses, environmental and education studies
Geomedia	General purpose database-driven GIS suite (Intergraph)
GS+	Geostatistical analysis
GWR	Geographically weighted regression (S. Fotheringham, C. Brunsdon, M. Charlton)
IDRISI	Raster-based product, especially for environmental sciences. Remote sensing, land management.

ILOG Dispatcher	Vehicle routing, scheduling and dispatching (Logistics) suite. Part of the ILOG optimalisation product set
ISATIS	Geostatistical software for the Earth sciences
LEDA	Algorithmic suite including extensive range of graph (network) analysis utilities. Provides the network analysis kernel for at least one GIS package
Manifold	General purpose, very extensive toolsets, vector focused with raster support. Cross industry, OGC compliant
MapCalc	Raster-based mapping and analysis package, with very low cost variant for teaching use
MapInfo Professional	General purpose, vector focused with raster support. Open Geospatial Consortium. Cross industry/Marketing; HotSpot Detective (J. Ratcliffe) for crime analysis. (OGC) compliant
MATLab	Matrix/mathematical package with optional mapping toolbox, image processing toolbox and statistics toolbox; free spatial statistics toolbox (L. Pace)
Oriana	Statistical analysis of circular datasets
Surfer	Surface building and modelling package, very strong on gridding, geostatistics and visualisation. Earth sciences. Grapher, from same provider (Golden Software)
Terraseer	Space-time and statistical analysis packages. Health
TransCAD/ Maptitude	TransCAD is the transportation-focused implementation of the Maptitude package, with very strong network analysis and related facilities. Transport, Marketing
TNTMips	Generic cross-platform GIS developed from image processing background. Large analytics toolset. Free "Lite" version for non-commercial use
Vertical Mapper	Geographic data analysis tools which displays, manages and interprets grid-based continuous spatial information within MapInfo Professional

Tab. 3. Sample non-commercial software tools (modified according to Smith et al. 2007)

Product*	Product type, area of use and product authors
CMAP	Crime mapping and analysis program (CMAP) software toolkits and documentation
CommonGIS	Java based GIS package with strong thematic mapping and exploratory data analysis facilities (this is the successor to the Descartes software)
Crimestat III	Crime event analysis, vector (N. Levine)
Fragstats	Analysis of ecological raster data
GAM	Geographic Analysis Machine — cluster hunting software
GeoDa	Exploratory spatial data analysis, vector (L. Anselin)
GRASS	Geographic Resources Analysis Support System. Open source GIS with both raster and vector support. Earth sciences
Landserf	Surface analysis package,cross-platform (J. Wood)
LOLA	Locational analysis
MASON	Multi Agent Simulation Of Neighbourhood. Open source agent-based simulation package, cross-platform
NetLab	Neural network software library for MATLab (Nabney)
NetLogo	Open source multi-agent simulation package, cross-platform (Wilensky)
Repast	Open source agent-based simulation package, cross-platform
Rookcase	Excel add-in for computing simple spatial autocorrelation (M. Sawada)
SAGA	Open source GIS designed especially terrain analysis. Powerful raster analysis and programmability
SANET	Spatial analysis on a network (A. Okabe et al.) – an ArcGIS toolbox
S-Distance	Network and locational analysis (S. Sirigos)
SaTScan	Spatial, temporal and spatio-temporal analysis of geographic data. Particularly designed for disease pattern analysis and surveillance
SITATION	Facility location software (M. Daskin)

SPLANCS	Spatial analysis of point patterns. (R-Plus version is free)
StarLogo	Open source agent-based simulation package, cross-platform
STARS	Space-time analysis of regional systems. Some techniques mirror those in GeoDa (unrelated to the STARS logistics package)
SWARM	Open source agent-based simulation package, cross-platform
TAS	Terrain Analysis System – compact, stand-alone program.
Vincenty	Excel spreadsheet for computing ellipsoidal distances (download link)
WinBUGS/ GeoBUGS	Bayesian statistical analysis package that uses Markov Chain Monte Carlo. Health
Xpress-MP	General purpose modelling and optimisation suite (free student edition)
ZDES	Zone design system. University of Leeds, UK

*Programs are available free but may require registration or may be free for academic users only.

Conclusion

Technological development induces the appearance of new theoretical and methodological concepts and solutions in the field of cartographic visualisation and program applications based on new geoinformatic technologies that call for the interdisciplinary collaboration of demographers, geographers, informatics and other specialists studying population.

The use of new geovisualisation and geospatial analysis techniques (as Exploratory Data Analysis or Exploratory Spatial Data Analysis, etc.) is conditioned by the appropriately structured and accessible spatial registers of population. Their harmonisation for the needs of demographic research is more and more actual as the progress goes on.

The limitations in the data range (shortage of, inaccessibility and inadequate quality of structured geographically referenced large-scale demographic databases) and some other restraints (financial difficulty of the microcensus data collection and processing, insufficient standardisation of geographic references of demographical data, fewer applications and services targeted at the demographical segment) have gradually been eliminated. Definitely, this is not a question of being short of human potential of demogeographers, cartographers and geoinformatics who work on the creation of new resources and forms of demographical data presentation.

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