GEOSPATIAL TECHNOLOGIES IN BIOLOGY AND MEDICINE: ANALYSIS OF GIS REPOSITORY

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Abstract

The paper presents a range of research carried out for the biology and medicine, including health care, using the geospatial technologies, which are documented in GIS repository of scientific achievements of Polish-Croatian cooperation in the field of geographic information systems (GIS). The resultant body of work includes, scientific publications, published in 1994 to 2016, that are the effect of international conferences organized in the framework of said cooperation efforts. An analysis of selected articles was done in accordance with the accepted range of topics in order to categorize and define the research extent. Among the distinguished six subject categories: ecology and biodiversity; sustainable development with GIS; sustainable development and policy; environmental protection and hazards to human health and safety; GIS in medicine and health care; emergency medical treatment with GIS tools, most of the articles were concerned with: ecology, biodiversity, sustainable development with GIS, environmental protection and hazards to human health and safety.

Key words: *geospatial technology, biology, medicine, GIS repository*

Introduction

Geospatial technology such as geographic information system (GIS) have been applied at all scientific fields and practical activities, among others in biology and medicine, too (GAJOS, 2012a).

The purpose of this article is to characterize the studies in the biology and medicine sciences using the GIS technologies, which were carried out under the Polish-Croatian scientific cooperation in the field of GIS (1994–2016). The 1994 was a significant year: it was a beginning of international research efforts in the area of Geographical Information Systems (GIS), with an active participation of Croatia and Poland; Croatian GIS Forum Association was established; GIS experts from Croatia took part in the international conference on Spatial Information Systems GIS/LIS in Commune and Region, organized in Poland in Szczyrk, for the first time. The remaining twenty two of the twenty three GIS conferences took place mainly in Croatia, Poland and last years Italy: GIS Odyssey 2016, Italy: Perugia; GIS Odyssey 2015, Italy: Perugia; GIS Odyssey 2014, Croatia: Crikvenica, Rijeka & Krk; GIS Odyssey 2013, Croatia: Crikvenica & Krk; GIS Odyssey 2012, Croatia and Bosnia and Hercegovina: Metković, Neretva, Mostar & Međugorje; GIS Odyssey 2011, Croatia: Lovran, Kvarner & Istria; GIS Odyssey 2010, Croatia: Brijuni, Istra & Pula; GIS Odyssey 2009, Croatia: Plitvice, Lika & Zadar; GIS Polonia 2008, Poland: Zakopane & Kraków; GIS Odyssey 2007, Croatia: Šibenik, Split, Trogir & Dalmatian Inland – Vrlika, Sinj; GIS Odyssey 2006, Croatia: Šibenik, Split, Krka & Dalmatian islands; GIS Odyssey 2005, Croatia: Opatija, Pula & Istria; GIS Odyssey 2004,

Croatia: Trogir, Kornati, Hvar; GIS Silesia, Poland: Katowice, Sosnowiec, Będzin, Rudy Wielkie, Złoty Potok, Ojców; GIS Odyssey 2002, Croatia: Split, Trogir, Korčula, Mljet, Dubrownik; GIS Polonia 2001, Poland: Warsaw; GIS Croatia 2000, Croatia: Zagreb, Osijek, Lonjsko Polje; Information Management in the New Millennium 1999, Poland: Kraków; GIS in Cultural and Environmental Heritage Management 1999, Great Britain: York; Processing and Protection of Data 1998, Poland: Ustroń; International Geographic Information Systems Conference and Exhibition GIS Croatia 1998, Croatia: Osijek; Freedom of Information and its Limits 1997, Poland: Katowice, Ustroń.

Each conference involves a specific body of work published in hard copy (proceedings, monograph, special issue in journals) and electronically (CD, website). Conference sessions as well as chapters in books related to various problems and disciplines: geoinformatics, cartography, geodesy, cadastre, ecology, forestry, hydrography, oceanology, fisheries, applied economy and other related. The aim of this work was to analyse articles in biology and medicine discipline.

Materials and methods

Titles of conference sessions and topics in conference books kept changing to reflect emerging new GIS developments and applications across various scientific disciplines and walks of life. The review of 46 books: 20 multiauthorial monographs and 26 collective publications including 912 articles descriptions helped to distinguish following 15 thematic areas (GAJOS, 2013): Globalization and Social-Economic Problems. Transition and Challenge in the New Europe. Economics and Regional Development; Geodesy – Cadastre – Cartography; Geoinformatics Systems. Information Technology; Cultural and Natural Heritage Management; Environmental and Earth Resources Management. Structure and Function of the Geographical Environment; Agriculture and Forestry; Sea and Water Management; Ecology; The State and Local Level Administration & Management (Municipal Projects); Space and Law. Legally Protected Regions. Geoinformation and Law. Informatics, Law & Communication; Spatial Information Systems in Practice; Infrastructure for Spatial Information in Europe; Emergency Management, Post-War and Post Disaster Reconstruction Projects; Smart City; Others.

With a view to the topic biology and medicine, area of Environmental and Earth Resources Management. Structure and Function of the Geographical Environment and Ecology were covered by research. A detailed analysis was done of articles in these thematic area which were published as GIS Conferences materials in 1994 to 2016 to select only paper connected with GIS in biology and medicine.

The research proceedings relied upon article categorisation intended to determine research directions. Categorization is the process in which ideas and objects are recognized, differentiated, and understood. Categorization implies that objects are grouped into categories, usually for some specific purpose. Ideally, a category illuminates a relationship between the subjects and objects of knowledge (Wikipedia. Categorization).

To run the categorisation process, the body of literature analysis and critics method was used. The literature review as a scientific examination method is used to review scientific works and for peer review. The objectives and functions of the literature review are: description and evaluation of current knowledge for a given topic (research status); arranging the knowledge through categorisation etc. to identify any hitherto missed regularities, relations, facts, phenomena; reveal cognitive gaps uncharted areas; seek inspiration, research subjects; identify new research directions (ANKEM, 2008). The detailed review of selected articles helped classify them into proper categories.

To present the results the bibliometric research method was used. This method is a statistical application for quantitative studies of facts, phenomena and processes related to texts and information (DIODATO, 1994).

In this article it was analysed the scientific researches concerning geospatial technologies in biology and medicine, including health care, which were presented on GIS meetings and located in GIS repository http://gis.us.edu.pl/.

Results and discussion

The outcome of the research into the literature on the problems connected with using the GIS applications in biology and medicine distinguished six thematic categories: ecology and biodiversity, sustainable development with GIS, sustainable development and policy, environmental protection and hazards to human health and safety, GIS in medicine and health care, emergency medical treatment with GIS tools (Table 1.). In Table 1. the eligible number of articles (in the form of bibliographic citations included in the references) in each category, which set the course for biology and medicine carried out during twenty three years of GIS cooperation, is shown too. Detailed research issues within each category are described in the following discussion.

Table 1. The results of categorization of articles published in GIS repository (1994–2016)

Categories	Articles (in References)	No. of articles
Ecology and Biodiversity	Rahmonov et al., 2016 Bydłosz et al., 2013 Ciecierska et al., 2013 Dynowski, et al., 2012 Źróbek et al., 2012 Michalski, Głowacka, 2008 Nevenić, Rakonjac, 2008 Michalski, Głowacka, 2007 Głowacka, Michalski, 2007 Pernar et al., 2006 Dadić et al., 2004 Krstulović Šifner et al., 2004 Głowacka et al., 2004 Litwin et al., 2004 Rahmonov, et al., 2004 Caputa et al., 2004 Michalski, Głowacka, 2003 Halls, 2003 Rahmonov, et al., 2003 Jaślar et al., 2002 Rahmonov et. al., 2002 Pachuta, Olęcki, 2001 Rahmonov, Caputa, 2001 Będkowski, Chojnicki, 2001 Schneider-Jacoby, 2001 Jelaska et al., 2000 Grubešić et al., 2000	27
Sustainable Development with GIS	Ostaficzuk, 2008 Michalska, Michalski, 2008 Mašek et al., 2008 Ivanović, 2007 Mišura et al., 2004 Michalski, 2004 Boico, Petraček, 2003 Nevenić, Bajagić, 2003 Popijač et al., 2001	9
Sustainable Development and Policy	Szewc, 2003	1
Environmental Protection and Hazards to Human Health and Safety	Styblińska, 2012 Styblińska, 2011 Michalska, Michalski, 2010 Ostaficzuk, 2009 Michalska, Michalski, 2009 Absalon, 2007 Horzela, 2005 Dziemba, 2005 Dvoraček et al., 2004 Leśniok, Puszczewicz, 2003 Gotal et, al. 2002 Zmysłowski, 2002	12
GIS in Medicine and Health Care	Gajos, 2012 Styblińska, 2001	2
Emergency Medical Treatment with GIS Tools	Wolny et al., 2003	1

Source: Own elaboration.

The application of GIS tool in nature conservation and environmental sciences has a long tradition (GAJOS, SIERKA, 2012; DADIĆ et al., 2014; GAJOS et al., 2014). The result of such investigation are very important as background of climate change and accelerated anthropopression. The majority of papers has a documented results in form of electronic maps during longer period of environmental monitoring. That materials are essential for the further natural processes monitoring, which is the essence of GIS use in environmental sciences and researches (BANASZEK et al., 2014; CZAJA et al., 2014; RAHMONOV et al., 2014).

Within featured groups are dominated papers from the category of **ecology and biodiversity** with 27 analyzed articles. The most of the researches refer to the environmental conditions and the functioning of vegetation and soil ecosystem under different humane impact on the various environment (NEVENIĆ, RAKONJAC, 2008; CIECIERSKA et al., 2013; BYDŁOSZ et al., 2013; RAHMONOV et al., 2016) and proposals for their protection (BYDŁOSZ et al., 2013;) for example in case of Allium ursinum, Veratrum lobielianum, Isoetes lacustris (GRUBEŠIĆ et al., 2000; DYNOWSKI et al., 2012). For Isoetes lacustris authors claim that GIS techniques for registering submerged plant communities produced more accurate data than those acquired with traditional methods. Precise boundary demarcation of plant communities is necessary for environmental monitoring programs, including determination of the succession or regression rate of submerged plants over the years. The problem of wetland inventory using remote sensing methods and GIS technology were presented by PERNAR et al. (2006).

The problem of environmental GIS data bases as a practical tool for natural resources protection and land management was presented in several articles (MICHALSKI, GŁOWACKA, 2003; RAHMONOV et al., 2004; GŁOWACKA et al., 2004; MICHALSKI, GŁOWACKA, 2007; GŁOWACKA, MICHALSKI, 2007; MICHALSKI, GŁOWACKA, 2008). The proposition of creating thematic maps with available cartographic materials including information about land cataster, forest section, ortophotomaps and previously registered areas was covered by different forms of nature protection (for example NATURA 2000) and are commonly used and presented in detailes (LITIWN et al.; 2004; ŹRÓBEK et al., 2012). Some ecological problems of protected areas in Tajikistan (RAHMONOV, et al., 2003) and Poland (JAŚLAR et al., 2002; RAHMONOV et. al., 2002) were presented too.

The category ecology and biodiversity also include marine ecology. E.g. Estimation of spatial distribution of small pelagic fish in the Croatian water of the Adriatic Sea was done by using hydro-acoustic methodology supported by GIS technology and numerical objective analyses. The main objective was to obtain enough biological information about commercially important species in the Adriatic Sea as a base for proper long-term sustainable management of this part of the Croatian renewable living resources (JELASKA et al., 2000; DADIĆ et al., 2004; KRSTULOVIĆ ŠIFNER et al., 2004).

Noteworthy the papers concerning the monitoring of single species or their association by using of GIS (GRUBEŠIĆ et al., 2000; DYNOWSKI et al., 2012; BYDŁOSZ et al., 2013; RAHMONOV et al., 2016) results as unique.

GIS tools were widely used in various types of environmental researches like conservation and monitoring of landscape elements, even underground gallery with fauna (SCHNEIDER-JACOBY, 2001; CAPUTA et al., 2004). The general problem concerning application of GIS for ecologist presented HALLS (2003), RAHMONOV, CAPUTA (2001), BĘDKOWSKI, CHOJNICKI (2001), PACHUTA, OLĘCKI (2001) and NEVENIĆ, BAJAGIĆ (2003).

The category of **sustainable development with GIS**, with 9 analyzed articles, concern such problems as man, his living space and sustainability and a possible role of GIS in improving of our life space (OSTAFICZUK, 2008), creating a map of the industrial influence using GIS (MICHALSKA, MICHALSKI, 2008) and the study of sustainable rural development of Erdut Municipality (MAŠEK et al., 2008). In this category was also described application of GIS in development of renewable energy sources in Croatia (IVANOVIĆ, 2007). The author in details presented the problem of sustainable energy policy in background of energy crises. Sustainable development of marine ecosystem needed in detail information system of fisheries concerning their population and occurrences in Croatia (MIŠURA et al., 2004) in two main segments: marine fisheries and freshwater fisheries. The problem of implementation of GIS for improvement of mass production life cycle products assessment include sustainable development aspects and other branches of economy (BOICO, PETRAČEK, 2003; MICHALSKI, 2004). The implementation of GIS for forest sustainable development for the needs of the forest seed production in Croatia was done (POPIJAČ et al., 2001).

In the category of **sustainable development and policy** we found just one position under title of juridical regulation of the access to the environmental information in Poland (in the Light of the Directive 2003/4/EC). Article presented basic notion in the field of ecological information. It means information on the state and protection of environment, is one of the most important information which is accumulated and processed in GIS. In this aspect important is the freedom of public access to the information on the environment and environmental authorities, because it makes possible the impartial evaluation of rationality and effectiveness of the activities. As a consequence of this results are also national legislation and their harmonization. Model juridical solution for this problem were presented by the Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to the environmental information and repealing Council Directive 90/313/EEC (Official Journal L 041, 14/02/2003 P. 0026 - 0032). Author of the paper presents the principles of the Directive and try to give answer to the question does Polish law fulfil its requirement (SZEWC, 2003).

The problem concerning category of **environmental protection and hazards to human health and safety** are widely presented (12 articles). They touched man-made hazard. A number of articles were devoted on nuclear power like the Fukushima Daiichi power plant and other perspective of nuclear power plants. The Great East Japan Earthquake called as Japanese: "Eastern Japan Great Earthquake Disaster" (Higashi Nihon Daishinsai) or the 2011 off the Pacific coast of Tohoku Earthquake changed our thinking about the safe nuclear energy and nuclear power plants and opened the doubts and threatens. The paper consider some problems connected with nuclear power plants in light of Japanese earthquake and tsunami Apocalypse (STYBLIŃSKA, 2011, 2012).

The applying of GIS in modeling and pollution of soils also was considered. Effective prevention of mercury pollution should be supported by data on the scale of mercury emissions to air, water and soil, and data on the impact of these emissions on human health and the environment presented by MICHALSKA, MICHALSKI (2010) and LEŚNIOK, PUSZCZEWICZ (2003). This will enable database based on GIS, which allows to assess compliance with the emission limit values and the impact of these emissions on selected environmental categories. Environmental mercury pollution is one of the most important problems in the industrial areas. The authors of this paper carried out a literature survey about mercury pollution of Silesian environment. Its presented that contents of the contaminant exceeded allowed level. Preliminary examination and chemical analysis of the soil samples from the selected areas confirmed it. It is necessary to analyze more of the soil samples in order to obtain strict image of mercury pollution status around one of the Silesian combined heat and power plant. The aim of these activities is to create decomposition model of the mercury pollution. It will be possible by implementation GIS, what is discussed in the paper (MICHALSKA, MICHALSKI, 2009). Some problems in the background of globalized concepts of environmental sustainability was describe by OSTAFICZUK (2009). He mentions the following issue: 1. growing content of CO2 in the atmosphere, 2. renewable energy sources, 3. communication corridors, 4. unbalanced positions of Man and Nature.

The problem of water transformation and management in Poland at the turn of the 21st century (ABSALON, 2007) and in Croatia (DVORAČEK et al., 2004) was presented. Authors presented the reason of transformation. This effects of both the decline of many water consuming industry branches and more economical water management by the existing industry and residents. A significant improvement is being recorded in the municipal infrastructure, sewage systems in particular. It is essential to recognize how the regulations of the Water Framework Directive will influence both water management and changes resulting from economic development (ABSALON, 2007). The sustainability of water was signalized with proposal for satisfactory potable water quality in the city of Varaždin (GOTAL et, al. 2002).

Significant place took the paper connecting with noise hazard. The subject of article is presentation of problems connected with noise threat of inhabitants in place of their residence as well as degree of preparation of local governments in big and average cities in Poland for creation and exploitation of acoustic maps (HORZELA, 2005). The traffic noise hazard from the transit road has influence on the chosen division of the bigger agglomeration, where detached houses are built over and many public services influence their activity. Population of inhabitants has been divided in six groups of age which are differentiated by their professional activity. All distinguished groups of inhabitants took part of their activities in the different area agglomeration and in the different time periods where they were exposed on the noise hazard characteristic for the specific place and day-time. (DZIEMBA, 2005)

Aircraft noise hazard modeling. Such inverse method can be utilized to evaluate the noise hazard by the moving noise sources produced. Airplanes are strictly moving along their takeoff or touchdown paths. The speed of flight is known. The power of the engines is known too, than the acoustic power of the airplane can be determined as a time function. Placing the noise source, an airplane, at the specific field point, the inverse acoustic field can be modelled. Pushing the microphone along the takeoff or touchdown path and integrating obtained time function of the noise level; the noise exposition level can be determined for each airplane separately. The superposition all obtained noise expositions level gives the total noise hazard value (ZMYSŁOWSKI, 2002).

GIS in medicine and health care are new fields and for this reason the paper here belonged to rare or very rare. The article from this category analyzed the use of GIS in biomedicine and health care on the basis of chosen articles of the Polish and the international scientific journals in the period of 2007 through 2010. Group of articles from journals in the field of geoinformation were studied. Critical method study analysis has been carried out (GAJOS, 2012b). GIS is a combination of hardware and software for capturing, storing, checking, integrating, manipulating, analyzing, and displaying data that relate to each other by location on the earth's surface. These features have encouraged medical professionals for more interest in GIS and adopting GIS span to the health care spectrum – from public health departments and public health policy and hospital organization, medical centers and health insurance organizations. The

tremendous potential of GIS benefit the health care and medical information and enormous possibilities of Internet technology were the purpose of some papers (STYBLIŃSKA, 2001).

The category of **emergency medical treatment with GIS tools** was represented with one paper under title of Telematics and telemedicine as the background of the emergency medical treatment. It was described the critical medical treatment on the nowadays-wireless technologies background. Its weaknesses and advantages were presented on geographical wide medical system, describing the modern data flow and data security solutions (WOLNY et al., 2003).

Conclusions

The total of 52 articles raising the issues of GIS application in the biology and medicine, including health care, were subject of research. The outcomes of such analysis allowed the conclusion that these studies were of multi-faceted nature, with research facilities including both elements scientific and technological. The research was largely focused on thematic categories such as: ecology and biodiversity, sustainable development with GIS, sustainable development and policy, environmental protection and hazards to human health and safety, GIS in medicine and health care, emergency medical treatment with GIS tools. Analysis showed that most of the articles were concerned with biology (ecology, biodiversity, sustainable development with GIS). , environmental protection and hazards to human health and safety. GIS in medicine is a new field and the paper here belonged to very rare. More presented is application of GIS in human health and safety in aspect of environmental protection and hazards for health. The aim of research was among other to determine the directions of research being conducted. Studies indicate that more work should be done on the use of geoinformation technology in medicine and health care.

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