GIScience in Poland – Research, Education, Community

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Abstract

The article presents the scientific infrastructure in the field of GIScience in Poland. It shows the history of the development of the discipline, key research topics, academic and research units, and the scope of national and international scientific cooperation.

1 Introduction

The main aim of the paper is to present a brief overview of GIScience in Poland to the international community, taking advantage of the occasion of hosting the 11th GIScience Conference in our country. After a brief description of the historical development of the discipline in Poland, the authors discuss the main trends of research, academic infrastructure, international and national scientific cooperation. There are many scientific institutions in Poland that deal with GIScience research. Presenting the achievements of all of them would probably go beyond the scope of this article. For this reason, more detailed information is provided only for the units from which the authors of the article come.

2 A Brief Historical Overview

The first scientific and technological works in the field of the GIScience in Poland originated in the middle of 1970's. The team of the Geodetic and Cartographic Data Processing Centre (a governmental research and technological institute, GCDPC) started geographical information systems development under leadership of Prof. Jerzy Gaździcki (key researchers: Marek Baranowski and Marek Bogobowicz). The first investigations focused on the automated map generalisation [1] (Baranowski, 1974, Gaździcki, 1975) as well as thematic and topographic mapping (Baranowski, 1980) and large-scale mapping [2] (Gaździcki, 1977, M. Bogobowicz).

During the period when the embargo on high-tech products operated in relation to the countries behind the Iron Curtain, a fully functional geographic information system called SINUS was created in the second half of the 1980s [4]. The system was used in practice for geospatial data acquisition, database development (including CORINE Land Cover and many others) and for environmental mapping for over 10 years in the Institute of Geodesy and Cartography, UNEP/GRID-Warsaw and some other research centres. In 1988 the Spatial Information Systems Department was established at the Institute of Geodesy and Cartography (IGiK). The further development of the SINUS system software and the creation of the first spatial databases for Poland were the main directions of the Department's research.

The Faculty of Geodesy and Cartography of the Warsaw University of Technology (FCC WUT) has been conducting GIScience research since the early 1990s. Specialized GIS Laboratories were established in the second half of the 1990s. At the beginning of the 1990s, the assumptions for the development of the first commercial computer map of Warsaw were developed, the first experiments were carried out in creating a digital topographic database for Poland, and the first comprehensive concepts for the construction of voivodeship spatial information systems, as well as the first elements of geoinformatics software for data management from geodetic measurements and terrain modelling, were formulated. Most of the research results from that period have been implemented, and the systems using their results are still in use today; some research has continued. The creation of the Polish SDI utilised many of the research results.

The first GIS unit at the Jagiellonian University was founded in 1993 and led by Wojciech Widacki at the Institute of Geography and Spatial Management (IGSM). After merging with another department in 2007, the present Department of Geographic Information Systems, Cartography and Remote Sensing was established. The early research fields at the IGSM covered conceptual foundations of GIS and its use in environmental applications. It is worth to mention also studies on computer-based cartography in hydrological applications by A. Dobija [3] in early 1980s.

In 1998, the first computer lab at the Faculty of Geosciences at Adam Mickiewicz University in Poznań (UAM) was launched, which enabled the commencement of teaching geographic information systems. In the academic year 2002/2003, uniform master's studies were launched from the first year of studies in the field of geography: geoinformation specialization, based on the original curriculum of Z. Zwoliński. The study program was verified at the National Center for Geographic Information and Analysis (NCGIA, Santa Barbara, USA) and at the Environmental Systems Research Institute (ESRI, USA), where it received positive opinions.

3 Research topics

Over the last 50 years, various directions of research have been the subject of interest of the Polish scientific community in the field of GI Science and Technology. The main research areas have covered:

- designing and developing GIS software, geocomputational software and spatial pattern-based analysis (GCDPC, IGiK [4], Wroclaw Institute of Spatial Information and Artificial Intelligence [WISIAI], DG-IGG UAM [17], FCC WUT),
- geospatial data modelling and database development – general geographic db [7], topographic db [8], CORINE Land Cover [5] (IGiK, UNEP/GRID-Warsaw, FGC WUT, WISIAI, Military University of Technology [MUT]),

- research on cyberinfrastructures of spatial information and big data processing (FCC WUT),
- 3D building modelling, indoor cartography and indoor navigation (FCC WUT) [18],
- conceptual works for National Spatial Information Infrastructure [6] (IGiK, FGC WUT, WISIAI),
- performing analyses with the use of GIS technology, related to real estate valuation and the cadastre, development of analytical, valorisation and regionalisation methods and spatial pattern-based analysis (IGiK, FGC WUT, DG-IGG UAM) [20]
- designing geoinformation applications and searching for innovative applications of geoinformation technologies (FGC WUT),
- modelling of smart cities and phenomena occurring in the cities using geoinformation technology (FGC WUT) [13],
- creating algorithms describing natural phenomena, on testing and extending geostatistical, climatic, hydrological and agent-based modelling (DG-IGG UAM) [9], [10],
- environmental and location decision support systems, the participation of social, public and voluntary factors in geoinformation analyses (DG-IGG UAM [14], FCC WUT),
- land use and land cover change studies and landscape studies based on Earth observation data and spatial analysis (IGiK, DGISCRS-IGSM UJ),
- historical GIS (DGISCRS-IGSM UJ) and GIS in archaeology (Institute of Archaeology UJ; field data acquisition with airborne or terrestrial laser scanning and photogrammetry, spatial databases and spatial analysis),
- substantive and geospatial support for thematic maps: hydrographic, sozological and geomorphological (Faculty of Geosciences AMU) [11], [12],
- GIST in atmospheric sciences with a focus on remote sensing of atmosphere, spatial analysis and geostatistics (AMU).

4 National academic infrastructure

In the middle of the first decade of the 21st century, a group (over 15) of scientific institutions under the leadership of the Institute of Geodesy and Cartography created a cooperation platform called the GIS Consortium. The main goal of this consortium was to coordinate research in the field of geoinformation and to undertake efforts to initiate and implement joint projects in this substantive field. Several projects have been then initiated. One of the most important was named "GIS University". The basis of this project was the GIS curriculum for senior and young academy teachers at Polish universities in order to transfer the latest knowledge in the field of GIScience, with particular emphasis on geospatial data modelling.

In the years 2018–2021, as part of the Center for Scientific Geospatial Analyses and Satellite Computations (Centrum Analiz Geoprzestrzennych i Obliczeń Satelitarnych, CENAGIS), the Faculty of Geodesy and Cartography built a spatial information infrastructure unique on a national scale and one of a few globally (similar to the American CyberGIS). One of its key goals is to assemble scientists from all research units in Poland on a common work platform, obtain synergies in GIScience research, and launch a national scientific spatial information infrastructure. The Centre uses an advanced IT infrastructure that allows for big data geospatial analyses. The platform provides access to virtual machines with Windows or Linux systems and a collection of specialised software (including the commercial software package, Hexagon). A modern Jupyter Lab programming environment facilitates carrying out various analyses, enabling operation on big data. The data storage involves the Hadoop Distributed

File System (HDFS), relational databases (e.g., PostgreSQL) or NoSQL databases. One of the basic components of the big data subsystem is Apache Spark enabling the implementation of distributed data processing and Apache CloudStack software which provides infrastructure management tools in the cloud model. The system repository includes a lot of reference and thematic data from the Polish SDI, ESA, open community resources, commercial companies and scientists' data from research projects.

A consortium called Geospatial Scientific Analysis Network, established to bring the research together, aims to consolidate and coordinate the research program in the field of geoinformation in Poland. It consists of twenty-four research units from all over Poland. On the one hand, CENAGIS seeks to increase the scale, quality, and efficiency of GIScience research in Poland and reduce its costs (joint infrastructure for many research centres). On the other hand, its goal is to enable the commercialisation of research by maintaining a close relationship with entrepreneurs. The new infrastructure intends to allow companies to develop and test new products and to popularise access to the technologies of members and partners of the CENAGIS consortium.

5 Faculties and scientific / educational profiles

Research in the field of GIScience has been conducted at the Institute of Geodesy and Cartography (IGiK) since 1988, when the first GIS research facility in Poland was established. In the first years, work focused on the development of GIS software called SINUS, which was functionally resembling the ArcInfo package that was being developed at that time. In the following years, research was carried out in the field of designing and creating spatial databases, designing regional geoinformation systems, and then supporting the scientific development of the national spatial information infrastructure compliant with INSPIRE [6], [8], [19]. Recently, works have been carried out on the creation of Virtual Hubs, facilitating access to distributed geospatial data resources. IGiK also participated in the development of body of knowledge in the field of Earth Observation and GI Science Technology. Depending on the period, the research staff dealing with GIScience issues at the Institute counted from 7 to 12 scientists.

At the WUT, dozens of scientists and a dozen doctoral students deal with GIScience issues. Such keywords as geoinformatics and GIS, remote sensing, cartography, photogrammetry, cadastre, and spatial management primarily determine their scientific profile. Similarly, at the AMU, dozens of scientists and a dozen doctoral students deal with GIScience issues. Such keywords as geoinformation and GIS, remote sensing, cartography, geostatistics, and spatial planning and management primarily determine their scientific profile.

At the WUT, Currently, approximately 1,300 students are studying at the Faculty of Geodesy and Cartography of the Warsaw University of Technology in three fields of education: Geodesy and Cartography, Spatial Planning/Spatial Management, and Geoinformatics. The course of study "Geoinformatics" is implemented at the Bachelor level. The teaching of GIScience also occurs in the other two fields of study at both Bachelor and Master of Science levels. At the Warsaw University of Technology students interesting in the field of GIScience can study three specialisations in the geodesy and cartography course and obtain a master's degree in *Cartography and Geographic Information Systems, Spatial Information Systems, Mobile Mapping and Navigation Systems* (in English).

The course prepares the specialists to create modern products and solutions with spatial databases and other 3D spatial models, navigation systems, and advanced visualisation methods (including 3D visualisation) playing a crucial role. Students should ensure proper

communication within interdisciplinary project teams (IT specialists, surveyors, cartographers, photogrammetrists, geologists, geographers) and other specialisations' representatives. The graduates should also be prepared to create new innovative geoinformation products and properly apply standards in geographic information.

The DGISCRS-IGSM UJ participates in several study programmes run at the Faculty of Geography and Geology, providing basic and advanced courses on various aspects of GIST. The flagship courses comprising the core content of knowledge and skills are:

- Geoinformatics within *Geography and spatial management* study programme (undergraduate, BSc),
- a set of four courses, i.e. *Spatial data modelling and spatial databases, Spatial data acquisition and spatial information infrastructures, Spatial analysis and modelling in GIS, Cartography and Geovisualisation*, provided within "Geography" and "E-spatial management" study programmes (graduate, MSc).

Outside the DGISCRS-IGSM UJ, several other units of IGSM provide education in the field of GIST, mostly in various application domains (e.g., remote sensing in climatology, terrain modelling in geomorphology and hydrology, land use planning in regional development). A broader overview of the educational offer of Polish universities in the field of GIScience can be found, among others, in [15] and [16].

6 Scientific cooperation and organisations

Polish GIScience researchers collaborate with many research centres around the world. They co-implement numerous projects financed by European research and development funds. Cooperation with international scientific organizations is also influencing the national progress. The most important of them are The Global Spatial Data Infrastructure Association (GSDI) until 2018, Association of Geographic Information Laboratories in Europe (AGILE) - IGiK and FGC PW are members, International Cartographic Association (ICA) - IGiK is a national member, International Society Photogrammetry and Remote Sensing (ISPRS). Some Polish scientists were elected to the authorities of selected organizations. As part of the Erasmus Programme, all academic centres have signed agreements with numerous foreign universities. Since 2004, the Department has been carrying out the post-graduate on-line studies in GIST within the framework of the UNIGIS network.

The DGISCRS-IGSM UJ has a wide network of international collaboration, including three educational or research networks (UNIGIS, https://unigis.net/; CEEPUS CEE-GIS https://www.ceepus.info; EARSeL https://earsel.org/) and several research-oriented collaborations. The most important partnerships include Humboldt University in Berlin (Germany), Salzburg University (Austria), KU Leuven (Belgium), University of Wisconsin-Madison (USA).

All of the presented research units are also engaged in extensive scientific collaboration, including projects under Horizon 2020 as well as various networks and individual bilateral agreements.

Social activity in the field of GIScience is focused around the Polish Association for Spatial Information (PASI) [https://www.ptip.info/en-ptip]. It was established in 1970, initially as the Club of Users of Computational Techniques in Geodesy, and after 1990 it adopted its current name. It is an interdisciplinary association that supports the harmonious development of geomatics, effective creation and application of spatial information systems, and acts for the universal availability and comprehensive use of spatial data in Poland. The Association actively supports the development of geoinformation infrastructures, and also

works to disseminate knowledge about geoinformation. The main activities of PASI include the organization of annual conferences, seminars, workshops and training, as well as the publication of Annals of Geomatics and other occasional issues. The 30th national conference on geoinformation will be organised in late autumn 2021.

The leading figure of the Association is Professor Jerzy Gaździcki, who was its initiator and founder. Until 2018, he served as the President of the PASI, and is currently an Honorary President. He is the person who had the greatest impact on the development of GIScience in Poland. It is also worth mentioning that the currently functioning Polish Spatial Information Infrastructure has been designed and coordinated mainly by the Professor.

The Committee on Geodesy of the Polish Academy of Sciences (PAS), established in 1952, is a self-governing representation of the scientific discipline - geodesy and cartography - integrating scientists over the country. The range of activities of the Committee on Geodesy includes significant problems in the geodesy and cartography scientific discipline. In particular, the Committee's tasks include GIScience topics. For several decades the Committee of Geodesy has had a Section of Geoinformation (formerly known as the Section of Geodetic Informatics and later as Geoinformatics). A key role in the creation of this section played professors Jerzy Gaździcki, Stanisław Białousz and Wojciech Pachelski. For two terms the section has been chaired by Dariusz Gotlib . The Committee publishes research papers in its journal, "Geodesy and Cartography". The Commission of Geoinformatics, Polish Academy of Arts and Sciences in Kraków was founded in 1998, chaired by Professor Janusz Kotlarczyk. The Commission brings together scientists who use geographic information in their research work, with most of its current members representing AGH University of Science and Technology in Kraków. The scope of research disciplines represented in the Commission ranges across several fields of science (natural sciences, engineering and technology, agricultural sciences, social sciences). Currently, the Commission is chaired by Jacek Kozak (formerly Józef Jachimski and Tadeusz Chrobak). The Commission publishes research papers in its journal, Geoinformatica Polonica.

Scientific and technical activities and cooperation in the field of GIScience are also focused on the following social organizations, like Association for Polish Cartographers (APC) [http://www.polishcartography.pl], led by Joanna Bac-Bronowicz, Cartographic Branch of Polish Geographic Society (publisher of Polish Cartographical Review) [https:/www.kartografia.org], led by Marek Baranowski, Polish Society for Photogrammetry and Remote Sensing, led by Aleksandra Bujakiewicz, and some acting within other professional societies.

7 Conclusions

The article briefly discusses the scientific potential of four Polish centres conducting research in the field of GIScience and educating students in this discipline. This review does not cover many aspects of the activity conducted in Poland. Due to the limited space, such issues as important publications (only few references related to the selected citations have been presented) , profiles of individual researchers, scientific geospatial data resources or the existing technological base were not addressed. For the same reason, the profile of many scientific units and technological centres that are significant in our country, such as the Military University of Technology, Wrocław Institute of Spatial Information and Artificial Intelligence, Faculty of Geography and Regional Studies of the University of Warsaw, Faculty of Mining Geodesy and Environmental Engineering of the AGH University of Science and Technology and other research and academic centres in Warsaw, Wrocław, Kraków, Poznań,

Lublin, Łódź, Olsztyn, Szczecin or Gdańsk has not been described. The scientific community of GIScience is dynamically growing and its development is strongly supported by new legal regulations which open all geospatial official data for research purposes. We hope to undertake a broader work on a more complete, more source description of the scene of this discipline in Poland soon.

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