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**THE STATE OF SERVICE-ORIENTED TECHNOLOGIES FOR THE
GEOVISUALIZATION OF GEOSPATIAL DATA IN UKRAINE AND
TRENDS IN THEIR DEVELOPMENT**

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Abstract. *This article examines the current state of geospatial data visualization technologies and identifies the main trends in their development in the context of digitalization. It analyzes the architecture and functional capabilities of the national geoportal, as well as the network of geoportals operated by local governments and state administrations. The scientific novelty of the work lies in a systematic analysis of the implementation of service-oriented architecture (SOA) and Open Geospatial Consortium standards (WMS, WMTS, WFS, CSW) in domestic digital governance practices. A transition from static mapping to dynamic web-oriented GIS platforms has been identified. The research results, based on an analysis of real-world case studies of urban communities, demonstrate a high level of integration of visualization services (WMTS, WMS) despite a shortage of services providing direct access to objects (WFS, VectorTile). The conclusions drawn contribute to the optimization of spatial planning processes, territorial monitoring, and the making of informed management decisions*

in the context of the digital transformation of the state. The results of the study can be used to improve geoportals and develop geospatial data infrastructure.

Keywords: *geoinformation service; cartography; geoportal; geographic information system; NSDI; geospatial data; geospatial database; integration; service.*

Problem statement. The current stage of development in geoinformation technologies is characterized by a rapid transformation in approaches to the processing, integration, and visualization of geospatial data, with the aim of promptly meeting users' needs for up-to-date and high-quality geographic information. Geovisualization serves as one of the primary tools for supporting management decision-making, spatial planning, territorial monitoring, and ensuring data openness. In the context of the digitalization of public administration and the implementation of open data principles, there has been a demand for the creation and use of geoportals that contain relevant geoinformation services.

In Ukraine, to ensure the interoperability of geospatial data from various producers and holders, a new framework was established—the National Spatial Data Infrastructure (NSDI)—one of whose main components is the national geoportal [1–4]. Its operation provides unified access to basic and thematic geospatial data, metadata, and geoinformation services, which are integrated into a single network of geoportals at various levels. An important feature of this system is its decentralized architecture, which allows for the integration of various data sources and geoinformation systems (in particular, those based on ArcGIS, QGIS, etc.) into a single information environment.

The relevance of this study is also due to the fact that Ukraine has already established a regulatory and technical framework for the development of geoportals; specifically, technical specifications for the creation of the National Geoportal of the NSDI have been developed, and technical requirements for geoinformation services have been approved, which define requirements for functionality, interoperability, metadata structure, and geoinformation services. These technical specifications have

served as a guideline for the development of similar solutions at the regional and local levels.

To date, a national geoportal has been implemented (including in prototype and pilot operation formats), which enables the search, viewing, and access to geospatial data through standardized services (WMS, WFS, CSW, etc.). At the same time, a network of interconnected geoportals is being formed, which includes [1]:

- geoportals of central executive authorities (sectoral);
- geoportals of regional state administrations (RSAs);
- geoportals of local self-government bodies (LSGBs);
- geoportals of enterprises and individual territories.

Such a multi-level system ensures the integration of geospatial data at the national, regional, and local levels and creates the conditions for the formation of a unified national geoinformation space.

LGA and RGA geoportals play a special role in this process, as they are the direct producers and custodians of a significant portion of thematic geospatial data, such as urban planning, land management, and scientific and design documentation. In accordance with current legislation in the field of NSDI, they are required to ensure the creation, updating, standardization, and publication of data, as well as its integration with the national geoportal through geoinformation services. At the same time, the development of local communities' own geoportals is carried out based on standard approaches and technical requirements of the NSDI, which contributes to the unification of solutions and a reduction in costs for creating local infrastructure.

Despite the results achieved, challenges remain regarding data interoperability, ensuring data currency, avoiding duplication, and transitioning from static cartographic products to interactive geoinformation services and analytical platforms. This necessitates further research in the field of geovisualization technologies, particularly regarding the integration of large volumes of geospatial data, the use of web-based GIS, cloud technologies, and service-oriented architectures.

Thus, research into the state of geospatial data geovisualization technologies and trends in their development, taking into account the practical implementation of the

NSDI, national geoportal, and the network of geoportals of local self-government bodies and regional state administrations, is relevant and of practical significance.

The aim of this study is to analyze the current state of geospatial data visualization technologies and to identify the directions and trends in their development, taking into account the functioning of the national geospatial data infrastructure.

Materials and methods of research. The primary research method is systematic analysis, which is applied to examine the architecture of modern geoinformation systems and geovisualization services. In particular, the approaches laid out in the Open Geospatial Consortium standards were analyzed, specifically the OpenGIS Service Architecture specification, which defines the conceptual foundations for building interoperable geoservices in an open information environment. This allowed us to consider geovisualization as a component of service-oriented architecture (SOA), where the key elements are services for accessing, processing, and displaying geodata.

The comparative analysis method was used to compare international and national approaches to the implementation of geovisualization. Within the framework of this method, the implementation of OGC Web Services (OWS) was investigated, specifically:

- visualization services (WMS, WMTS);
- data access services (WFS);
- cataloging services (CSW).

The comparison was conducted taking into account their implementation within the National Spatial Data Infrastructure, including the operation of the national geoportal and local geoportals. This made it possible to assess the level of compliance of Ukrainian solutions with international interoperability standards.

To assess the current situation in Ukraine, the case study method was applied, within the framework of which the following were analyzed:

- the operation of the national geoportal;
- the implementation of geoportals by regional state administrations (RSAs);

– the implementation of local government geoportals (LG).

This made it possible to identify practical aspects of geoservice usage, the level of data integration, as well as issues of interoperability and standardization.

Thus, the applied set of methods allowed for a comprehensive investigation of both the theoretical foundations of geovisualization (based on Open Geospatial Consortium standards) and the practical implementation of these approaches in Ukraine within the framework of developing the national geospatial data infrastructure, which ensures the validity of the conclusions drawn regarding the current state and prospects for the development of this scientific research area.

Analysis of recent research and publications. An analysis of current scientific research suggests that the development of geoservices and geovisualization technologies is moving toward distributed, service-oriented cloud environments that enable the integration of heterogeneous geoinformation resources.

In this regard, interoperability is considered a fundamental requirement for geoservices and geospatial data.

Studies [4–6] confirm that standardization based on ISO and Open Geospatial Consortium standards (WMS, WFS, CSW) is the foundation for creating unified geoinformation environments, as there is a need to integrate a large number of heterogeneous data sources and ensure their reuse in various application tasks.

The works [7–9] demonstrate the dominance of web-oriented GIS based on service-oriented architectures (SOA, REST API), which is explained by the need for remote access to geodata; the scalability and flexibility of web technologies; and the ability to integrate with other information systems.

The works [10, 11] emphasize the active development of geospatial data infrastructures and geoportals as access points to services and metadata (Fig. 1). As a result, geovisualization is transforming from a data display tool into a full-fledged analytics and decision-support platform.

A separate area of research is the development of multi-scale geospatial data representation (Multi-Representation Databases, MRDB) [12–16], which reflects a trend toward moving from storing data at a fixed scale to dynamic generalization and

support for multiple levels of detail. This, in turn, requires the application of methods for automating the generalization of geospatial data, including the use of artificial intelligence technology [17].

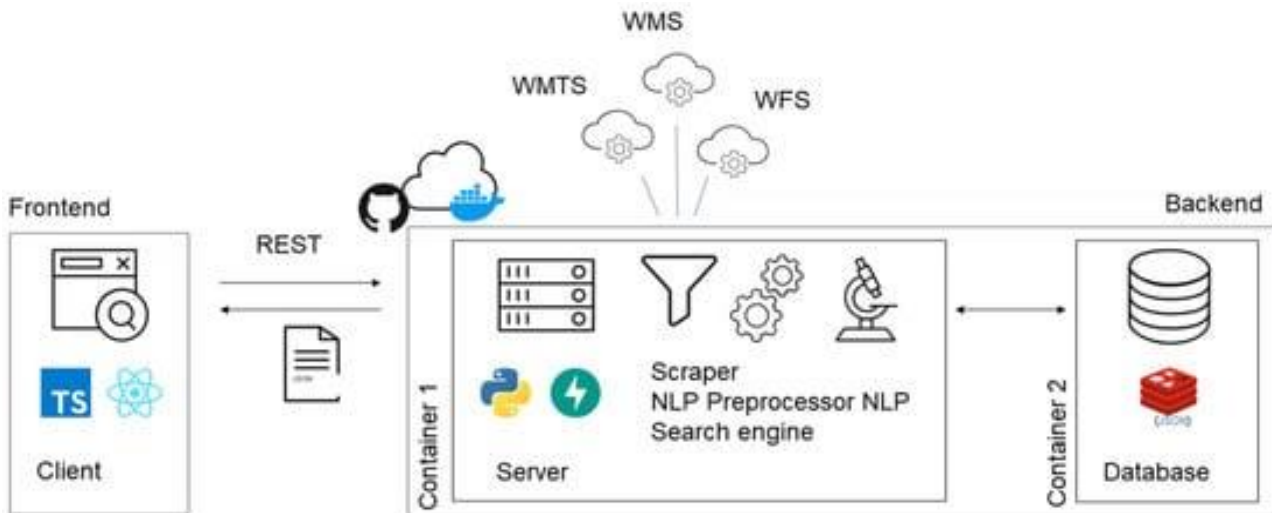


Fig. 1. Example of a system architecture using REST API

Source: [10, p. 6].

Modern geoservices are evolving as open, distributed, scalable, and intelligent systems based on Open Geospatial Consortium standards, ensuring the integration of heterogeneous geospatial data within a unified information environment. This development is driven by:

- the growth in data volumes;
- the need for their integration and reuse;
- the development of web and cloud technologies;
- the automation of processing and visualization;
- the digitization of territorial management.

Presentation of the main research material. The vast majority of geoportals operated by local self-government bodies and regional state administrations, as well as the national geoportal, have been developed based on the “publish/find/bind” concept characteristic of service-oriented systems (Fig. 2). This approach involves the interaction of three main components:

- geoservice providers;

- users;
- catalogs (registries) of geodata and services.

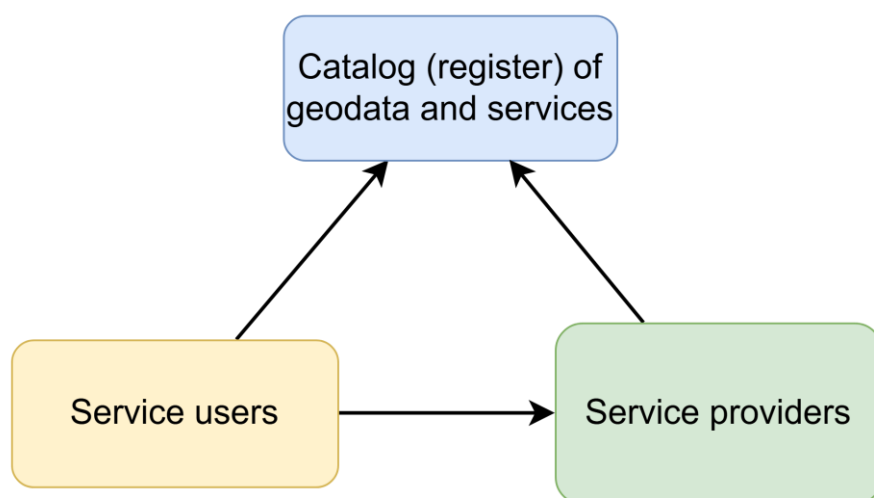


Fig. 2. Schematic diagram of the “Publish-Find-Bind” approach in service-oriented architecture (SOA)

Source: Adapted by the author based on [1, p. 251].

During the development of the national geoportal of the National Spatial Data Infrastructure (NSDI), access to geospatial data and metadata was provided through user e-identification and authentication mechanisms using the following tools:

- a search service for geospatial data, metadata, and geoinformation services via a web client and the metadata catalogue API (CSW);
- a metadata viewing service via a web client and the metadata catalogue API (CSW);
- services for viewing geospatial data as digital maps via a web client and APIs of map tile services (WMTS) and/or web map services (WMS).

The national geoportal implements mechanisms for downloading vector data, which allow users, through e-identification and authentication functions in their personal accounts, to access specific datasets together with updates using the following tools:

- Web Feature Service (WFS) for downloading geospatial objects, providing vector models in standard formats (GML, GeoJSON, GPKG, KML, etc.);

- Web service for geographic names (WGS / WFS-G) used to obtain vector data from registers of geographical names, streets, and addresses or geospatial databases;
- Web Coverage Service (WCS) for accessing digital elevation models, raster data from remote sensing, and other spatial distributions describing continuous phenomena;
- Web Processing Service (WPS) supporting analytical functions for data transformation, analysis, and modelling available on the geoportal.

During testing, two modes of access to geospatial data and metadata in the national geoportal system of the NSDI were verified:

1) Interactive mode, which allows users to work with geo-service web clients of the portal. This type of access enables users to create queries, view results, and store or document them directly on their computers.

2) Automated mode (electronic interaction), which provides direct communication between users' geoinformation systems and geoportal services. Data exchange is carried out through standard URLs and application programming interfaces (APIs) based on the standards of the Open Geospatial Consortium (OGC).

At the local level geoportals, geospatial data are published by local government authorities that own or manage these datasets. The data are provided through geoinformation services that comply with unified requirements for functions, core operations, and APIs, in accordance with the specifications of the Open Geospatial Consortium (OGC).

The study analyzed six geoportals of urban territorial communities to determine the number of datasets published via WMTS, REST API (GeoJSON), and VectorTile services. The sample was formed based on the criteria of public accessibility via open search engines, the availability of relevant metadata, and the technical feasibility of connecting to API interfaces.

For example, the "Buildings and Structures" dataset of the Zhytomyr City Council is published as VectorTile and WMTS services (Fig. 3). Additionally, an API Server environment for the Khmelnytskyi City Council geoportal was implemented to facilitate data exchange via the REST API service (Fig. 4).

Table 1 – Number of datasets published on local government geoportals

#	Geoportal Name	Geoinformation Service	Number of datasets on the geoportal
1	Official Geoportal of the Chernivtsi City Council	WMTS	2
2	Official Geoportal of the Chernivtsi City Council	REST API (GeoJSON)	30
3	Official Geoportal of the Chernivtsi City Council	VectorTile	30
4	Official Geoportal of the Zhytomyr City Council	WMTS	26
5	Official Geoportal of the Zhytomyr City Council	REST API (GeoJSON)	77
6	Official Geoportal of the Zhytomyr City Council	VectorTile	77
7	Geoportal of the Lviv City Council	REST API (GeoJSON)	8
8	Geoportal of the Lviv City Council	VectorTile	8
9	Geoportal of the Lviv City Council	WMTS	37
10	Geoinformation System of the Rivne City Territorial Community	REST API (GeoJSON)	11
11	Geoinformation System of the Rivne City Territorial Community	VectorTile	9
12	Geoinformation System of the Rivne City Territorial Community	WMTS	9
13	Geoinformation System of Uzhhorod City Assets	REST API (GeoJSON)	22
14	Geoinformation System of Uzhhorod City Assets	VectorTile	22
15	Geoinformation System of Uzhhorod City Assets	WMTS	5
16	Official Geoportal of the Khmelnytskyi City Council	REST API (GeoJSON)	40
17	Official Geoportal of the Khmelnytskyi City Council	WMTS	160

Source: Developed by the author.

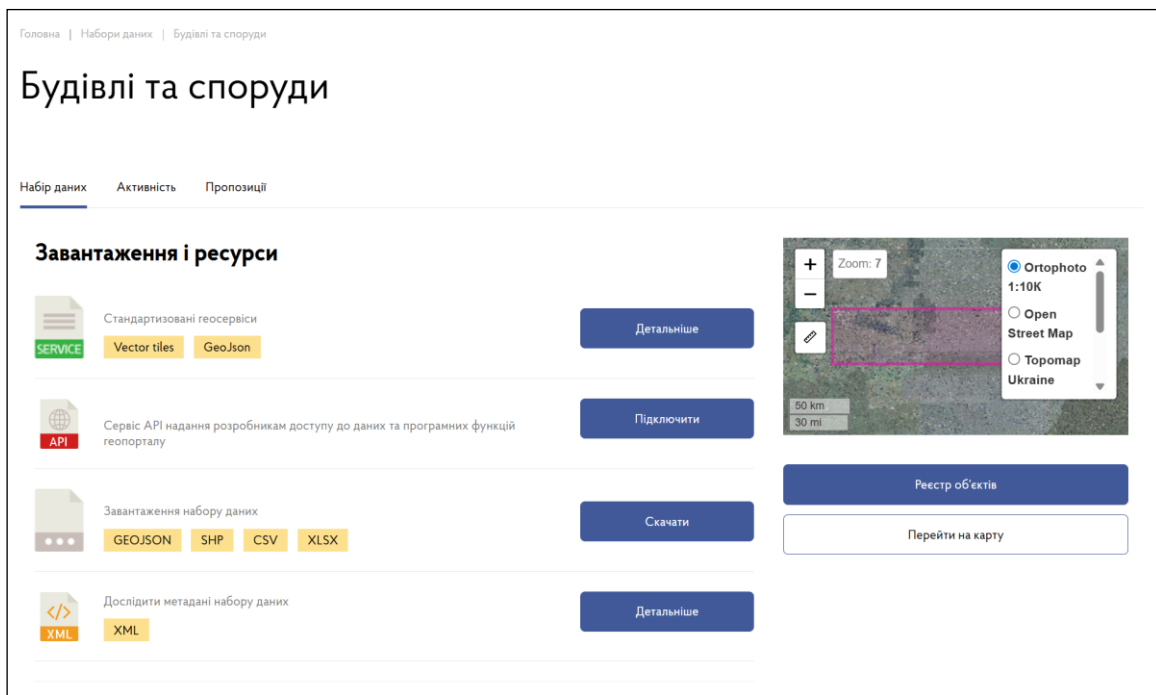


Fig. 3. Fragment of the web interface of the “Buildings and Structures” dataset.
Source: Zhytomyr City Council Geoportal.

Get
Set

API KEY	<input type="text" value="7836245842"/>
Table	<input type="text" value="data_architecture.architecture"/>
Offset	<input type="text"/>
Limit	<input type="text"/>
Filter	<input type="text"/>
Order	<input type="text"/>
ID	<input type="text"/>
XY	<input type="text"/>

Спеціальні фільтри

cd - сьогодні `cdate=cd`, -cd - вчора `cdate=-cd`

cw - поточний тиждень `cdate=cw`, -cw - минулий тиждень `cdate=-cw`

cm - поточний місяць `cdate=cm`, -cm минулий місяць `cdate=-cm`

cq - поточний квартал `cdate=cq`, -cq минулий квартал `cdate=-cq`

cy - поточний рік `cdate=cy`, -cy - минулий рік `cdate=-cy`

Fig. 4. Fragment of the web interface of the API Server environment.
Source: Khmelnytskyi City Council Geoportal.

The National Geoportal also features visualization services based on WMS and WMTS-type geoinformation services. This has made it possible to configure connections to datasets already published on existing geoportals at the national, regional, and local levels.

On the detailed metadata card for each dataset published on the NSDI geoportal, users can obtain a link to connect a layer via these services or directly download the data in available formats. It should be noted that the availability of REST API (GeoJSON) and VectorTile services on the analyzed geoportals does not constitute an alternative to the WFS service, as the latter is a standardized solution that should be implemented as a priority for the core geospatial datasets of the community.

Thus, it has been established that various types of geoinformation services have been implemented on the geoportals of local self-government bodies and regional state administrations, enabling users to utilize geospatial data to meet their own needs.

Additionally, the NSDI geoportal implements CSW services to facilitate the discovery of geospatial data sets and services based on metadata content and to display their content obtained from other geoportals, in accordance with the relevant metadata structure, taking into account the minimum set of metadata search criteria defined in the technical requirements for metadata of datasets and geoinformation services.

The catalog of geoinformation services provided by data holders contains information about the services available on the NSDI geoportal:

- 1) CSW services designed to enable the discovery of geospatial data sets and services based on metadata content and to display that content;

- 2) visualization services, such as WMS, for the distribution and use of geospatial data sets by public entities and third parties, as well as for the publication of geospatial data sets via the national geoportal;

- 3) Download services, such as WFS and WCS, for the distribution and use of geospatial data sets by public entities and third parties;

- 4) transformation services, using standard technologies for SOAP web services defined via WSDL, and the WS-Addressing specification, utilizing the RIF format for

defining transformation schema conformities, XML markup language for configuration elements, and GML for the source schema of the transformation.

The administrator of the national geospatial data infrastructure ensures the discovery of and access to web services through the national geoportal under its jurisdiction and performs testing and monitoring of these services.

Conclusions. Based on the reviewed existing geoportals and their geoinformation services, the overall state of development of geovisualization technologies and its main trends have been identified:

- a rapid pace of geoportal implementation in government agencies and local self-government bodies through February 2022;

- the functionality of the National Geoportal enables data holders to upload metadata and connect geoservices from their own geoportals, and allows users to utilize them;

- active use of web-based GIS and cloud technologies by local self-government bodies;

- practical absence of WFS-type geoservices, especially for basic geospatial data, which is mandatory under current legislation in the field of NSDI.

Thus, today geovisualization technologies are used in the geoinformation environment for the purpose of making management decisions and ensuring government transparency; however, issues regarding the creation and operation of geoinformation services for basic geospatial data at the national and local levels remain unresolved.

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Р.О. Зіненко

СТАН СЕРВІСНО-ОРІЄНТОВАНИХ ТЕХНОЛОГІЙ ГЕОВІЗУАЛІЗАЦІЇ ГЕОПРОСТОРОВИХ ДАНИХ В УКРАЇНІ ТА ТЕНДЕНЦІЇ ЇХ РОЗВИТКУ

Анотація. У статті досліджено сучасний стан технологій геовізуалізації геопросторових даних та визначено основні тенденції їх розвитку в умовах цифровізації. Досліджено архітектуру та функціональні можливості національного геопорталу, а також мережі геопорталів органів місцевого самоврядування та державних адміністрацій. Наукова новизна роботи полягає у системному аналізі впровадження сервіс-орієнтованої архітектури (SOA) та стандартів Open Geospatial Consortium (WMS, WMTS, WFS, CSW) у вітчизняну практику цифрового врядування. Виявлено перехід від статичного картографування до динамічних веб-орієнтованих ГІС-платформ. Результати дослідження, що ґрунтуються на аналізі реальних кейсів міських громад, демонструють високий рівень інтеграції сервісів візуалізації (WMTS, WMS) при дефіциті сервісів прямого доступу до об'єктів (WFS, VectorTile). Сформовані висновки сприяють оптимізації процесів просторового планування, моніторингу територій та прийняття обґрунтованих управлінських рішень у контексті цифровізації держави. Результати дослідження можуть бути використані для вдосконалення геопорталів і розвитку інфраструктури геопросторових даних.

Ключові слова: геоінформаційний сервіс; картографія; геопортал; геоінформаційна система; НІГД; геопросторові дані; база геопросторових даних; інтеграція; сервіс.