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CLASSIFICATION OF INTERACTIVE FUNCTIONS OF THE ELECTRONIC ATLAS: THEORETICAL AND METHODOLOGICAL BASIS OF CREATION

In the more than 30-year history of electronic atlases, only two classifications of interactive functions designed directly for the electronic atlas are widely known. In addition, the theoretical aspects of the development of these classifications have been insufficiently covered, which makes it difficult to improve them further.

The purpose of the article is to develop the theoretical and methodological basis of creating the classification system of interactive functions of the electronic atlas. To achieve this purpose, four intermediate goals were set: finding out whether it is necessary to create a new classification or refine existing ones; formation of the terminological apparatus of the object of research and classification system; formation of a set of classification objects—interactive functions; development of the methodological basis of the classification system.

The place of interactive functions in the system of notions of interactive and atlas cartography was determined, which included consideration of such notions as electronic atlas elements, atlas interaction, electronic atlas representation, electronic atlas interactivity, atlas interaction operator, electronic atlas functionality, and interactive tool. The following basic notions of the interactive functions classification system were established: classification element, classification object, general principle of classifying, and the main feature (basis) of classifying. Essential (interactivity, resultative, visibility, duration, unambiguity) and non-essential (passivity, extensibility) properties of interactive function, its characteristics and varieties are determined. One hundred seventy-nine interactive functions of the electronic atlas have been preliminarily identified, which will be divided into classification groups based on their purpose. The classification will be intended for developers of atlas platforms and authors of electronic atlases. Its development will help solve such tasks as systematization of experience in creating and implementing interactive functions of electronic atlases; evaluation of interactivity and functionality of electronic atlases; review of the theoretical provisions of atlas cartography, finding new interactive functions and connections between existing ones; accelerating the development of electronic atlases by authors-users of the atlas platform; and demonstration of the interactive capabilities of the atlas platform.

The research results can be used at the theoretical level of designing the classification of interactive functions not only for the electronic atlas but also for other applications where the classification object is the interactive function. The proposed terminological apparatus may be of interest to the whole of interactive cartography because such general theoretical notions as interactive function, interactivity, and interaction are considered.

Keywords: classification of interactive functions, theoretical and methodological basis of classifying, electronic atlas, atlas cartography, interactivity.

Introduction. The first electronic atlases (EAs) began to appear in the late 1980s. From static atlases for viewing only, available mainly to research or government agencies and commercial organizations, EAs have gradually evolved into interactive atlas information systems (AIS) and atlas platforms (AtPs), which the entire community of web users is able to use and modify, up to and including the creation of new atlases. In addition to technological innovations, the vision of the EA concept has gradually changed among various cartographic schools, which we analyzed in our previous work (Krakovskyi & Kurach, 2021). The development of the EA concept is one of the key tasks of atlas cartography, which aims to reveal the essence, purpose, functionality, and structure of EA as a specific theoretical model and specific software.

Important elements of the EA concept are interactivity, which is often understood as the ability of the EA to change at the request of the user, and the availability of interactive functions (IFs), which are the drivers of these changes. In particular, in the most common classification of EA (by functionality / degree of freedom) there is a division into view-only atlases, interactive atlases and analytical atlases, where the classification feature is actually hidden in the presence of IFs of a certain type. The vagueness of this classification is the subject of a separate discussion, but it clearly emphasizes the importance of IFs for EA.

The notion of "interactive function" has long been used in cartography, but, in our opinion, remains insufficiently defined in the system of notions of interactive cartography and functionality research. Thus, "interactive functions" and simply "functions" are often used as synonyms, and the terms "tools" and "interaction operators" are used alongside them. Therefore, one of the tasks of the research is the unification of these notions in the atlas context, which is necessary for the formation of the terminological apparatus of the classification of IFs.

The usefulness of creating a classification of IFs is substantiated in the cartographic literature by the possibility of developing a mechanism based on it for the evaluation and comparison of different cartographic systems (CS) and GIS, measuring their interactivity. The classification is also intended to improve understanding of the functioning of different types of interactivity and help developers create more advanced interactive systems and interactive tools, simplify and accelerate the development of CS *(Crampton, 2002; Persson, Gartner, & Buchroithner, 2006).* Finally, the classification allows to visually identify and unify all existing IFs, their combinations, i.e. systematizes the subject area, helping to identify both missing functions and new connections between existing ones, provokes the revision of certain theoretical provisions at the highest epistemological level. The above is also true for the EA, which in this article is considered a kind of CS.

Substantiation of the purpose of classification is only one of the first stage's tasks of creating the classification system of IFs of the EA, which reveals the theoretical and methodological basis of its development. The theoretical aspects of classification in the cartographic literature on electronic atlas cartography are still insufficiently covered. This work is designed to fill this gap and outline the authors' vision of the future classification system of IFs of the EA.

Thus, **the purpose of the article** is to develop the theoretical and methodological basis of creating the classification system of interactive functions of the electronic atlas.

Literature review. Many scientists have dealt with the issues of classification, among which are: W. Jevons, G. Leibniz, W. Quine, H. Reichenbach, I. I. Zhehalkin, and others. General theory of classification, the study of philosophical problems of classification are set out in the works: Subbotin (2001), Omelchenko (2008), and others. Theoretical, methodological and applied aspects of scientific classifications of specific subject areas developed in the works: *(Kharchenko, 1974), (Kurach, 2010, 2011), (Tikunov, 1997), (Topchiiev, 2005).*

In the more than 30-year history of EAs, it is safe to say that there are only two classifications of IFs created directly for EA. This is the best-known classification developed by Swiss cartographers in 1997 *(Bär & Sieber, 1997)* for the electronic version of the Atlas of Switzerland (AoS), which has been repeatedly modified, and the first – the classification of IFs for school EAs *(Ormeling, 1996).* Interestingly, both classifications were based on a master's thesis *(van Leeuwen, 1996),* which identified 40 functions divided into nine groups: general functions, navigational functions, map functions, database functions, atlas functions, educational functions, cartographic functions, map use functions, and other functions.

Bär & Sieber (1997) introduced five groups of functions for AoS: General Functions, Thematic Navigation, Spatial Navigation and Orientation, Visualization Functions, GIS-Functions. The authors briefly described each group and noted that while the first two groups can be attributed to the entire atlas, the last three differ greatly depending on the type and dimensionality of the data. However, neither a list of all functions of each group nor a clear classification structure was created.

In 2001, B. Schneider (2001) identified the most suitable GIS-functions for multimedia atlases and carried out their technical implementation for AGAIS (Analytical Geographic Atlas Information System), which was designed to be a supplement for AoS 2. Using the results of work *(Albrecht, 1996),* GIS functions were divided into three groups: Database queries (thematic Boolean queries, topological queries, reclassification), Spatial analysis (graphical overlay, geometrical overlay (by line intersection)), Uni- and bivariate statistics (distribution, correlation). In AoS 3, only the graphical overlay and reclassification functions remained, and the statistical functions were simplified. AoS-online, which we critically reviewed in the paper *(Chabaniuk, Kolimasov, & Krakovskyi, 2021),* demonstrated even greater regression in the context of interactivity.

The second stage of the classification *(Bär & Sieber, 1997)* modification began with B. Schneider's dissertation *(Schneider, 2002*) and ended in 2008 *(Hurni, 2008).* Subgroups were added to the classification groups, and the names of the groups were slightly changed: General functions, Navigation functions, Didactic functions, Cartographic and visualization functions, GIS functions. Among the works of this stage *(Hurni, 2005; Cron, 2006a; Cron, 2006b; Cron, Sieber, & Hurni, 2007; Cron, Wiesmann, & Hurni, 2008),* it is necessary to note separately the master's thesis of J. Cron (2006a) and the appendix to it (Cron, 2006b), which the author proposes to consider a guide to the design and implementation of cartographic functions in interactive atlases. It is in this catalog that the composition of each classification group and the functions themselves are described in detail on the following items: definition, implementation, functionality and interactivity, design, and overall assessment. Each function is accompanied by illustrations from 12 EA (6 desktop (CD) and 6 web atlases), which were analyzed to create a classification. At the end of the description of each group, there is a matrix where the functions are located on the "X" axis and on the "Y" axis control elements (controls) of the graphical user interface (GUI). The corresponding labels in the matrix for each function indicate the required or alternative controls (widgets). We will add that J. Cron (2006a) defines functionality as "the task or the goal which function carries out in the interactive atlas (operational nature of function)", and by interactivity is understood "the flow of information (interaction) between people and machines" or "willingness to interact and the opportunity to interact*" (Cron, 2006a).*

The last edition of the classification *(Bär & Sieber, 1997)* was conducted in the section of the monograph Atlas Cookbook *(Sieber & Cron, 2019).* Apart from certain permutations, its main difference is the division of functions into functions with basic interactivity and functions with advanced interactivity. Moreover, interactivity is defined in terms of a user-oriented approach: "interactivity depends strongly on the tasks and activities users want to achieve. For the use of maps, van Elzakker (2004) distinguishes between: search activities, selection activities, reading activities, analytical activities, adjustment activities and construction activities" *(Sieber & Cron, 2019).* Basic interactivity includes activities such as general visual inspection and comparison of maps, obtaining certain thematic information, searching and locating places, export the visualization results. Advanced interactivity corresponds to more high-level activities (high-level interaction tasks), including detecting and comparing spatial structures and processes, importing and recalculating data, and working with 3D dimension. According to the authors, the functionality of the atlas should answer four main questions: "What?" (a thematic context), "Where?" (a geographical context), "When?" (a time frame of the thematic content), and "Why?" (the informative-didactic component). At the same time, the functionality of the atlas is determined by two aspects: interactivity and a set of functions.

Among the shortcomings of the classification *(Bär & Sieber, 1997)* is insufficient attention to the functions for working with data and "non-cartographic" elements of the atlas. The "mapcentrism" of classification should probably be linked to the vision of Swiss scientists of the concept of the EA, where the EA, in their opinion, is a collection of maps for storytelling, and therefore the map should always dominate the GUI of the EA *(Sieber & Huber, 2007).* It's also important to note that the analysis of EAs was conducted only in 2006, and the latest modification (Sieber & Cron, 2019) does not mention the re-study of modern EAs, except for AoS versions.

Classification groups and functions for the classification of school EAs *(Ormeling, 1996),* most likely taken by F. Ormeling from work *(van Leeuwen, 1996)* without significant changes. Ormeling's contribution is to create a hierarchy of the most desirable functions for school EAs. The presence of groups of cartographic functions along with map functions is not properly explained. In general, in our opinion, there are enough inconsistent elements in the classification, which complicates its interpretation and use.

A kind of continuation of the classification *(Ormeling, 1996)* can be considered work *(Ormeling & van Elzakker, 2009),* in which by combining "map use activities" *(van Elzakker, 2004)* and functions *(van Leeuwen, 1996),* grouped "atlas and map use activities" (in this context, a certain equivalent of IFs of the EA). This division cannot claim to be complete because, firstly, it is based on "mapcentric" material, and secondly, the authors aimed primarily to highlight the relationship between user tasks and user activities.

Although they were developed for the CS in general, without emphasizing EA, the classifications of functions *(Persson et al., 2006)* and *(Balciunas, 2011)* are worth considering in detail. These works, in our opinion, occupy an intermediate position between studies of the functionality or interactivity of the CS (emphasis primarily on IFs and characteristics of the CS) and studies of interaction with the CIS (emphasis shifted to user tasks and interaction operators).

Responding to the call of Cartwright et al. (2001) to create a typology of geospatial interface tasks, Persson et al. (2006) distinguish eight types of interaction and 70 functions distributed between types. The typology is based on the interaction operands approach, in other words, the classification feature for grouping functions is the type of object to which the interaction is directed. However, no further division of functions within the types was performed. This is due to the greater priority of coverage of interaction issues than functionality and empirical analysis of functions.

The first three types of interactions include IFs of the map creation process: interaction with the representation model, interaction with the algorithms for the creation of a representation, interaction with the primary model / database (DB) query. As supporters of the (geo-) communication paradigm of cartography, the authors understand the secondary data model (map) as the representation model, the algorithms as the set of functions for the transition between the primary and secondary data model (for example, modifying the classify method), and the primary model as a DB. The fourth (arranging many simultaneous views) and fifth (dynamic linking with further display types) types of interaction are confined to IFs with multiple representations. The sixth (interaction with the temporal dimension) and seventh (interaction with the (pseudo-) 3D visualization) types are functions with the third and fourth dimensions. Finally, system interaction is the eighth type, which represents the basic functions (not directly related to cartographic operations).

The typology was tested on the basis of AoS 2 and CommonGIS, demonstrating its versatility for both GIS and geovisualization, as well as for CIS.

Functional studies with the participation of A. Balciunas deserve special attention *(Balciunas & Dumbliauskiene, 2011; Balciunas, 2011; Balciunas, 2012; Balciunas & Beconyte, 2015).* So, eight criteria (image review, data review, data visualization, composition of map layout, measuring of map elements, management of information resources, using the information (publishing), data selection and analysis) and 30 indicators were chosen to assess the quality of web maps functionality, where indicators correspond to the specific functions of interactive web maps *(Balciunas & Dumbliauskiene, 2011).* In the following paper *(Balciunas, 2011),* 8 of the above criteria are equated to groups of functions and divided into three types of interactivity: review, modification, management. One year later, the same 8 groups of functions were proposed to evaluate the functionality of national atlas web maps *(Balciunas, 2012).* The grouping of functions was carried out on the basis of their purpose (which was the classification feature). Unfortunately, these works do not provide a list of functions (assessment indicators) and it is not clear which implementation of the function and which cartographic web services are recognized by the author as a reference (which is extremely important for the qualimetric assessment method used by the author).

According to Balciunas & Beconyte (2015), interactivity is "a feature that allows users to interact with map elements. The magnitude of interaction is related to possibilities of a particular user to perform actions on the map elements". Functionality is considered one of the indicators of map interactivity. Its definition has been clarified several times and in the latest version it sounds like this: "functionality can be defined as a characteristic of an interactive electronic map or map system that expresses adaptability of the system to the user's needs concerning spatial information management. Functionality determines the extent to which the user is provided with functions that he or she needs in order to accomplish an undertaken task with the map and answers the question whether and to what extent these functions can be efficiently used" *(Balciunas & Beconyte, 2015).* The object of functional research is a set of functional elements (a set of functions), which are considered part of the map interface, and functionality is equated to the quality of functions. According to the authors, the quality of functions can be quantified and standardized, and it is determined by the quality of implementation (number and types of functions) and the efficiency of use of corresponding interactive map tools *(Balciunas & Beconyte, 2015).*

Methodology. The research methodology at the stage of formation of the theoretical and methodological provisions of the classifying (hereinafter in the meaning "classification as a process") IFs of the EA included four goals, to achieve each of which the corresponding tasks were set. At this stage of the research, general scientific methods of analysis and synthesis, comparison, abstraction, and concretization were used. The methodology of the general theory of classification, the conceptual provisions of interactive cartography, as well as scientific areas, the subject of which is interaction, are involved. A number of tasks were analytical and involved the study and analysis of existing material on the research topic: both theoretical and practical developments (4 classifications and about 40 EAs and geoportals). Among the theoretical tasks should be singled out the improvement and formulation of the basic provisions and terms for the formation of the terminological apparatus of the object of research and classification system. The development of the methodological basis of the classification system required the definition of a number of notions, such as the kind and properties of the classification system, structure, model, etc. Classification of IFs of the EA is considered from three positions: as a method of systematization and cognition; as a system of knowledge of atlas cartography; and as a process of dividing classification objects according to certain features.

Results. The beginning of the classification system's development is the definition of its theoretical and methodological provisions, in particular the establishment of goals and objectives of classifying (Table 1).

***Table* 1. Goals and tasks of classifying interactive functions of the electronic atlas at the stage of theoretical and methodological provisions' formation**

Goals	Tasks
1. Creating a classification: new or improving existing ones?	1) Study of existing classifications of IFs 2) Identification of advantages and disadvantages
2. Formation of the terminological apparatus of the research object and classification system	1) Analysis of existing provisions and definitions 2) Improving and formulating notions
3. Formation of a set of classification objects–IFs	1) Study of the research object: properties, characteristics, and varieties 2) Separating the object from other systems
4. Development of the methodological basis of the classification system	1) Identifying the classification system's kind and properties 2) Development of principles, criteria and requirements of classifying 3) Formation of structure, model, and classification connections 4) Substantiation of the classification system's purpose

The first goal. The general goal of the research is to create a classification system of IFs of the EA, which involves clarifying the need to create a new classification or refine existing ones. The results of the analysis show that today there is only one detailed classification of IFs of the EA, which is updated and corresponds to the current level of EA development. Its main shortcomings are the focus on atlas solutions of its own production, which affects the insufficient account of other views on the concept and interactive capabilities of the EA, as well as the lack of a clear theoretical and methodological basis of the classification development, which complicates its further extension by other research teams. Therefore, to understand and systematize a large number of IFs of modern EAs, it is advisable to propose a new classification system of IFs, the development of which will be based on the provisions of the theory of classification.

The second goal. The main notions of classification are the *classification element*, *classification object, classification groups*, and the *basis* and *general principle of classifying*, the formulation of which is the basis of the terminological apparatus of classification. To perform this task, it is necessary to carefully study the subject area of the future classification, which involves understanding the essence of EA and such initial notions as *EA elements*, *interactivity, interactive functions.*

The latest generation of EAs are so-called atlas platforms (AtPs) or atlas frameworks, which allow multiple creation and updating of EAs (atlases as types), identical in concept and technical implementation. AtP is not just software but a multicomponent system that also accumulates knowledge gained during the development of past projects, theories of cartography and related disciplines, i.e. includes a research component. Thus, the key feature of modern atlas cartography is gradually becoming the development of theoretical provisions and software solutions not specific thematic EAs but models (templates) of EA, which provide means for creating atlases of any theme and purpose. It is logical to conclude that the library of interactive functions of the AtP should not contain any restrictions on the specifics of IFs (for marine, educational, and other EAs).

Among the ***EA elements***, we distinguish two types of elements: content elements and structural elements. The *content elements* include elements that reveal the thematic content of the EA. Their list is not constant, varies from the theme, purpose, and concept of a particular EA, and is open to extension. In our opinion, the content elements of the modern EA can be summarized by cartographic models, charts, tables, text documents, and media files (audio / video / image). These content elements can be grouped by different features (for example, cartographic elements and "non-cartographic" elements) or more detailed. Therefore, cartographic models can include two-dimensional models (cartographic images of various kinds (in particular, schematic maps, cartograms, etc.) and orthophoto maps) and three-dimensional models (3D maps (or even globes), digital terrain models, block diagrams, etc.). It is important to add that these content elements can be presented both separately and as part of other elements (charts or text often accompany the maps, and data tables allow you to build charts on selected indicators).

The presence of all *structural elements of the EA*, in contrast to the content elements, is mandatory for each EA, ensuring the functionality of the EA. After analyzing the 30-year history of EA, we concluded that such elements are the visualization block, information and navigation structure, and interface.

The visualization block is responsible for the visual representation of any content elements of the EA. Some content elements of the EA, especially maps, can also be decomposed into structural elements that determine map functionality and should be considered in the initial stages of the conceptual level of EA design. This is a basemap (performs the functions of the geographical and mathematical basis of paper maps), thematic symbolization (thematic layers), legend, and data table (data manipulation block). Each of these elements is multicomponent and can be implemented in different ways in the EA interface. We call for a distinction between structural map elements and map elements, where the latter are considered elements of the layout of the map or cartographic interface (this includes both the scale and the north arrow as well as any additional data or widgets.).

Information and navigation structure involves the creation of a semantic model of the EA, which includes the development of information architecture and navigation models of the content of the atlas *(Parush, Pulsifer, Philip, & Dunn, 2006).* Information architecture is primarily responsible for the method of modeling thematic content (the form of presenting a list of content elements to users). The most commonly used tree structure (the content tree), although matrix, grid, and other structures can be used. The navigation model of the EA provides various options for moving the user between the elements of the thematic content of the EA.

The information and navigation structure of the EA performs the following functions:

- Determines the EA's thematic content and the way it is presented to the user (narrative structure);
- Provides movement between themes (content elements) of the EA and their comparison;
- Allows users to change the order and grouping of the EA's content elements;

- Models the subject area of the EA (not only the "EA control center" but also a means of exploring the real / fictional world);
- Acts as an organizer of spatial content (data);
- etc.

With the growing influence of the theory of HCI (human-computer interaction) on cartography in the 1990s, CS often began to be equated with *cartographic interfaces*. At the same time, the components of the cartographic interface are considered to be a map and tools for manipulating it. You, Chen, Liu, & Lin (2007) call this second component of the cartographic interface the "operational interface": "The operation interface consists of a set of objects that users can manipulate with a mouse or other input devices to activate map functions, such as zooming and panning, to control the map display in the frame". According to Miller (1999), these are "marginalia objects", i.e. those objects that exist outside the bounds of the map object and include display, access, navigation, and interaction tools. There are also views where the map is considered to be an interface to the real world *(Cartwright et al., 2001; Lindholm & Sarjakoski, 1994).* In our opinion, this is an excessive abuse of information terminology in the presence of a more developed and richer in its semantic load, the notion of a "model", familiar to cartography at least in model-cognitive (developed by Soviet scientists) and (geo-) communication paradigms.

Roth (2013) calls cartographic interfaces "the set of digital tools through which the cartographic interaction occurs". And literally in the next sentence, he includes interactive maps and CS in the cartographic interfaces. It is obvious to us that CS cannot be just a "set of digital tools" and therefore an interface or its components. It seems to us that Roth (2013) holds the same opinion, limiting the cartographic interface only to the cartographic interaction it supports; its interface style, or the way in which user input is submitted to the software to perform the interaction operator; and its interface design. Although Roth (2013) draws parallels between interface design and cartographic design, he does not equate them.

According to the Cambridge University Press (n.d.) and the Merriam-Webster (n.d.), an interface can be interpreted as an environment that provides a connection between two independent systems (such as a user and an EA). Thus, we can conclude that the interface of the EA and the EA are not identical entities but separate systems. In practice, the EA interface is the outer shell of the EA, where any content element, and information and navigation structure are inside this shell, which in itself is devoid of subject semantic load. Therefore, when the recipient of the IF is an element of the EA interface (menu, window, icon, etc.), the content of this element is usually not taken into account. The functions of the EA interface seem simple enough: through design solutions to increase the attractiveness of the EA representation, as well as to provide means and tips for users to change the EA representation. However, the usability of the EA interface is often a decisive factor for the user, and therefore, improving the design of interfaces is considered one of the main goals of the study of interaction. A deeper analysis of the EA interface is presented in *(Huber, Jeller, & Ruegsegger, 2005).*

To identify the essence of the notion of "interactive function of the EA", consider it in terms of interaction studies and functionality studies.

In *(Krakovskyi, 2021),* we laid the foundation of the atlas interaction concept. ***By atlas interaction, we mean the process of changing the EA representation, initiated at the request of users.*** Let's take a closer look at the key notions of the definition.

By the phrase "initiated at the request of users" we mean the following:

- The EA is able to change at the request of the user, i.e. it is interactive. Note that there are no non-interactive EAs, as any EA allows the user to at least switch pages (content elements);
- The subjects of interaction are only end users and the EA where users have an active role and are always the initiators of interaction.

The formation of our idea of the "EA representation" was facilitated by two versions of its interpretation. The first belongs to R. Roth (2011), where the science of cartographic representation is opposed to the science of cartographic interaction and is associated with perceptual and cognitive research, cartographic semiotics, and other topics of static cartography *(Roth, 2011).* The second comes from pattern-based relational cartography *(Chabaniuk, 2018),* where "view" is considered a logical pattern formed from views of other patterns. In particular, from the following EA patterns: user interface, solution / content tree, basemap, thematic maps (layers) *(Chabaniuk, 2018).*

Based on the understanding of the EA as a system, we define ***the EA representation as the state of all elements of the atlas and the relationship between them that the user sees at the moment.*** In other words, the EA representation is what the user sees. Since the EA consists not only of maps, the EA representation can be divided into separate representations of certain elements (information and navigation structure, map, text, chart, etc.). Note that if you remove the word "representation" and leave the phrase "changing the EA", the definition of atlas interaction will be quite vague and may indicate, for example, a change in the architecture of the EA, which we do not anticipate.

The concept of interaction as a dialogue, which is understood as a cycle of communication acts channeled through input/output from the machine perspective, or perception/action from the human perspective *(Hornbæk & Oulasvirta, 2017),* has become the most widespread in the cartographic literature. This cycle of communicative acts or stages of interaction is usually represented by the scheme of D. Norman's stage of actions *(Norman, 1988).* In particular, in the work of R. Roth (2011), where cartographic interaction is considered in isolation from cartographic representation. In our opinion, this scheme is suitable only for the interpretation of interaction in a broader sense as the use (session) of the EA, which should take into account the user's ability to read the map (EA elements) and change it, which is not the same competence. When formulating goals and objectives as well as perceiving and interpreting the results of interaction, the user focuses on the EA representation, not actions to change the representation. The user's default goals and objectives are to explore the real or fictional world (which is modeled using the atlas, its content elements),not the interface and its elements. Therefore, we proposed to narrow the understanding of interaction to the approach based on operators *(Roth, 2011),* i.e. the stages of specifying an action and executing the action (*Roth, 2011*, Fig. 3.1)*,* or look for alternative concepts. For example, Hornbæk & Oulasvirta (2017) conducted a study of the notion of interaction, which identified seven approaches to the interpretation of this notion. In our opinion, the concept of tool use deserves special attention, which interprets the interaction as manipulation (use) of technology for some aims beyond the tool itself *(Hornbæk & Oulasvirta, 2017)*.

The purpose and, as a consequence, the result of atlas interaction is the EA representation, which satisfies a user task *(Zhang, Kraak, & Blok, 2016)* / objective *(Roth, 2011)*. However, this EA representation is not necessarily a solution to the user task, but it is always the best environment for solving it. Thus, if the user task is to identify all the ranges of medicinal plants in a given area, then zooming and panning will change the map representation of the EA in such a way as to create the best conditions for identifying ranges (according to the user). However, the process of identifying ranges (solving the user task) will be carried out by the user through visual analysis and always after the stage of interpretation of the results of interaction. The result of atlas interaction often coincides with the solution of the user task in cases where it is not a research task but a preparatory action (setting up a workspace) or recording research results. Relevant examples are *Change the font size of the EA interface* and *Export thematic layer data*.

Let us emphasize that the atlas interaction is precisely a process. The first stage of this process is the development by the user of a strategy to change the EA representation or the choice of interaction operators and their logical sequence (the absence of a strategy is also a strategy). The second stage is the search and activation of IFs of the EA by the user, which correspond to the selected interaction operators. The atlas interaction session continues until the user proceeds to interpret the atlas interaction result. The interpretation phase is already part of the use session of the EA outside of the atlas interaction session. If the user, having evaluated the EA representation after the interaction session, is satisfied with the result and completed the task, the session of using the atlas is completed, and the atlas interaction session is considered successful. If the result of the atlas interaction does not match the user task, then the atlas interaction session is unsuccessful and may be restarted by the user. It is also necessary to remember the cases when the session of atlas interaction is recognized as successful but the user task cannot be solved. So, the use session of the EA can consist of several atlas interaction sessions, where atlas interaction can be evaluated by a number of characteristics, such as effectiveness (ratio of the successful atlas interaction sessions to unsuccessful), productivity (duration of atlas interaction session(s)), etc.

The first stage of atlas interaction is more influenced by user interactivity and the quality of the EA representation, and in the second stage, the interactivity of the EA is added to the first two. By ***interactivity,*** we mean ***the degree to which users or EA are able to provide interaction.*** Thus, we adhere to the concept of interactivity as a property that can be considered a user property or an EA property. The interactivity of both subjects of atlas interaction can be determined separately and in advance. However, the greatest interest and practical value is to find the optimal interactivity, which is determined for each concrete group of users and the concrete EA based on information about their individual interactivity, which can be quantified (especially for the EA). ***We associate the interactivity of the EA exclusively with the technical capabilities of the EA and propose to determine it by a set of indicators that form a continuum from low interactivity to high.***

Let's return to the ***operators of atlas interaction***. Operators or actions *(Gotz & Zhou, 2009)* are usually called separate, with generalized meaning, user actions to explore the subject area, performed using the system. For example, in Roth's (2011) interpretation, operators denote the generalized content of a specific group of functions or the functions themselves. In particular, he identified twelve work operators (reexpress, arrange, sequence, resymbolize, overlay, reproject, pan, zoom, filter, search, retrieve, calculate) and five enabling operators (import, export, save, edit, annotate). It is sometimes argued that the list of operators for interactive data visualization systems (where CS are often included) may be theoretically the same. But as shown in *(Zhang et al., 2016),* which analyzes taxonomies of interactive tasks (operators) for information visualization, geovisualization, and visual analytics, there is no unanimous opinion on the list and, especially, the names of the operators. We think that the typology of operators should be revised for EAs as well.

Thus, ***by the operator of atlas interaction, we mean the general meaning of the change of EA representation***. The use of operators is useful when studying atlas interaction in a user-centered approach, that is, to find out how users think. However, operators are uninformative in evaluating the interactivity of the EA. For example, the execution of the operator "zoom" doesn't answer the question "how" this action was performed because, as we know, zooming can be performed in modern CS in different ways. Also, failure to perform the operator doesn't necessarily mean that the user doesn't understand how to achieve the task, but rather indicates a gap between user interactivity and EA interactivity or poor quality of EA representation (in particular, the EA interface) or both. Therefore, to improve EA and regulate its interactivity, developers need more concrete, elementary fixators of user actions to change the EA representation. Such fixators can be IFs, which, in contrast to events *(Gotz & Zhou, 2009),* are not inferior in semantic load to the interaction operators.

In our interpretation, ***the interactive function of EA denotes the concrete change of the EA representation***. Recall that changing the EA representation can change all EA elements (for example, the *Select Language* function changes the interface language and language of all content elements) or only separate elements (for example, the *Rename Thematic Layer* function changes only the map layer name (content element)). In both cases, what the user saw on the screen before and after activating the IF is different, and therefore the EA representation has changed. However, it is possible to estimate the extent of the change and to separate the element(s) of the EA which representation has changed directly. We also emphasize that any request, regardless of its meaning (adding, deleting, etc.), to which the EA is able to respond will be considered a change of the EA representation.

To identify the IF, the principle of the maximum possible decomposition of the change of the EA representation should be followed. First, the meaning of the change (e.g., centering, relocation, rotation) is determined, which, unlike the atlas interaction operators (e.g. moving), is not generalized. Further specification consists of answering the questions "what exactly is changing?" as well as "how is it changing (in what manner)?" and "where exactly is changing?". The answer to "what exactly is changing?" is mandatory and denotes the object to which the function is directed. This object can be an interface, information and navigation structure, thematic layer, map symbols of a specific layer of the map, charts, data table of the thematic layer, etc. The use of traditional operands based on type-centric or state-centric approaches is considered inappropriate here due to factors identical to operators, namely insufficient detail, which will not allow evaluation of the interactivity and functionality of the EA. The answer to "where exactly is changing?" is an additional clarification, which indicates that the object that is changing belongs to a certain element of EA. For example, the *Resize Font* function lacks detail, as it can be applied to the entire EA (all content elements) or only to a certain text document (a separate content element). So, we have at least two functions. Clarification of "how is it changing (in what manner)?" is necessary for such (groups) of functions as *Filtering*, where further decomposition into functions *Filtering by attribute*, *Filtering by type*, etc. is possible. If further decomposition is not possible, the IF is formed by composing allocated elements (*Resize font of text documents*).

In cartography, ***functionality*** is usually understood as the ability and degree to which the map (atlas) allows you to solve a certain list of tasks according to its purpose *(van Elzakker, 2004).* However, the interpretation of functionality, especially in conjunction with interactivity, is ambiguous. Thus, Balciunas & Beconyte (2015) equate functionality to the quality of functions, where functions are the object of functional research, and consider functionality as one of the indicators of map interactivity. Instead, Sieber & Cron (2019) are convinced that functionality is determined by interactivity and usability, as well as a set of EA functions.

In our opinion, the EA functionality is a broader concept than interactivity, but it does not necessarily include the latter. The EA interactivity is characterized by a set of indicators that reflect the degree to which EA is able to provide atlas interaction. Although the presence of IFs is a prerequisite for interactivity, to evaluate interactivity, it is sufficient to operate with the indicator of the number of IFs (set of functions), as considering the concrete possibility of changing the EA representation, not the best option for implementing a concrete change of EA representation (qualitative indicator). For example, the presence of the *Select Basemap* function means only the possibility of changing the basemap of the EA, but does not affect the list of possible basemaps and the map load of these basemaps. These settings are part of the EA representation design, not the EA interactivity.

To evaluate the functionality of EA, on the contrary, it is necessary to consider all the factors that affect the solution of user tasks, i.e. to consider all the stages and components of the use of EA. Evaluation of IFs is only one of the components of the evaluation of functionality, where we tend to equate functionality with the quality of the EA. When evaluating the IFs of the EA in terms of functionality, it is important to take into account not only the number of IFs, but also their implementation and effectiveness, i.e. qualitative indicators.

It should be noted that when defining functionality, in contrast to interactivity, you can use the notions of *"function"* and *"interactive function".* In the first case, it is about the goals/tasks for which a particular EA is suitable, and in the second, it is about a concrete change of the EA representation. To start the IF of EA, the user needs to find and activate the corresponding EA interface elements (in particular, the GUI widgets). Some functions require only one widget (for example, the *Legend* function requires only one icon), while others require a combination of widgets (for example, the *Basemap Selection* function requires an icon and a drop-down list).

The term ***"tool"*** is often used alongside "functions". As it was established, a function is a process, and a tool is always a means. In the case of EAs, tools are means of performing IFs. We suggest using the term "tool" only at the level of the EA interface, where it denotes concrete interface elements to activate the corresponding IFs. For example, to activate the *Measure Distance* function, you need to use the *Ruler* tool, which is represented by an icon, involves selecting points on the map using the cursor, and contains an algorithm for calculating and demonstrating distance in pre-selected units.

Now, after formulating and improving the initial notions of the object of research, we define the system of notions of the IFs classification. The *classification object* is an IF. The *classification element* is the element of IF (a certain taxonomic level of IF decomposition). The *general principle of classifying* IFs of the EA is the systematization of IFs by purpose. The *main feature (basis) by* which the objects of the classification set are distinguished is interactivity as one of the properties of the EA. A system of features of IFs will be defined for the distribution of classification elements into classification groups.

The third goal. Properties are usually divided into essential (the disappearance of these properties turns the object into another) and non-essential. Among the ***essential properties of the IF***, let us allocate *interactivity* (here in the general meaning as the ability to change the EA representation), *resultative* (the use of the IF leads to a certain result, namely the change of the EA representation), *visibility* (IF denotes a process perceived by the user's senses), *duration* (any change of the EA representation takes a certain period of time), and *unambiguity* (IF has a clear meaning and denotes a concrete change of the EA representation). An essential property is also called a quality (an object cannot, while remaining itself, lose its quality), but it is a relative notion because the same quality for some objects can be a quality (essential property) and for others simply a property (non-essential). In this paper, we do not see quality as an essential property but as a specific characteristic. The ***non-essential properties of the IF*** include *passivity* (the activation of the IF occurs at the request of the user, but this is not an imperative), *extensibility* (IF, without changing its essence, can be extended to operands of the same type or further concretization is possible), etc. The proposed list of essential and non-essential properties is not exhaustive and is open to extension. In practice, properties are often identified in the process of classifying, when it is necessary to establish the relationship of similarity between a specific set of elements.

Although characteristics and properties are often understood as synonyms, in our context, it would be appropriate to distinguish between these notions. We consider the ***characteristic of the IF*** to be an indicator obtained by evaluating a certain set of the IF properties (first of all, essential ones). Such characteristics of the IF are *quality* as the degree of suitability to solve the task (evaluation of the quality of the IF can be carried out, for example, by the qualimetric method *(Balciunas & Dumbliauskiene, 2011)*), *efficiency* (for example, the ratio of duration and resultative or quality), as well as more subjective characteristics of the IF based on user experience, such as *usefulness*, *popularity*, etc. The proposed characteristics of the IF should be considered as examples that need further clarification.

Speaking of the ***varieties of IFs***, we in any case already distinguish IFs, grouped by specific features. Thus, we can distinguish IFs *by origin*: GIS-functions (functions that are traditional for GIS-software: analysis of data statistics, database queries, etc.), cartographic functions (zooming, switching thematic layers, adjusting their transparency, etc.), functions from the science of information visualization (changing the chart type, linking data to a chart, etc.), general / system functions (devoid of subject specificity and used in any software product (authorization, change language, data import, etc.)). The most popular way to group IFs is *by purpose*: navigation functions (zooming, panning, centering, etc.), data manipulation (filtering, sorting, database query, etc.), map manipulation (change of classification method, change of map type, selection of projection, etc.) and many other variations, depending on the subjective views and preferences of specific authors. Another example is the grouping of IFs *by operand*, as in the paper *(Persson et al., 2006)*.

In order to form a library of IFs, and in the context of this research, for a set of classification objects (interactive functions), we analyzed in detail about 40 EAs and geoportals over the past 20 years. A detailed list of resources can be found at the following link: *https://bit.ly/3wL35uu*.One hundred seventy-nine IFs of the EA have been preliminarily identified.

The fourth goal. By ***kind,*** the future classification is *special, artificial, intensional, multilevel, empirical,* and *taxonomic*. The classification of the IFs is *special* because it relates to a narrow subject area – atlas cartography. Artificial kind indicates the best presentation of information for practical purposes in a searchable form. Detection and identification of objects of the classification system are based on a general property–interactivity–so the classification is *intentional*. Preliminarily, we can assume that the classification system will be *multilevel* with the allocation of a chain of taxa, for example, *type-class-genus-kind*. Taxonomic categories do not denote real objects, but a certain rank or level of classification or hierarchical level, show the place of a classification element or group in the system. On the feature of "kind of knowledge used", classification is *empirical* since it is based on obtaining knowledge from available sources, such as practically developed EAs and scientific publications on the topic.

Among the ***general properties*** of the classification system of IFs are the following: *complexity, integrity, focus, openness, persistence, flexibility,* and *effectiveness*.

The distribution of IFs into classification groups according to a set of features forms the complex structure of the classification system of IFs. *Integrity* is manifested in the ability of the system to provide or discover new knowledge, which implies the existence of previously unknown objects and connections. Not just a statement of existing experience, but the ability to anticipate new knowledge indicates the *focus* of the system. The classification formed in this way will be open for further updating and improvement. The modern information world is very dynamic, and taking into account the possibility of making additions and updates should provide *flexibility* to the system, but it should be borne in mind that making radical changes can lead to the destruction of the system. A guarantee of *persistence* is the possibility to introduce transitional classification groups into the classification system without destroying its overall structure. The introduction of transitional taxonomic units such as subtypes, subclasses will provide a condition of persistence. Compliance with the system *effectiveness* property is crucial and is related to the purpose of the classification. A clear awareness of the range of users and a focus on better communication of information, combined with minimal search time, will increase the effectiveness of classification.

In developing the classification system of IFs, the following ***classifying requirements*** are specified: *requirements for the goals* (resultative and realism); *integrity requirements* (completeness of decomposition and sequence of decomposition); *adequacy requirements* (correctness of features); *general requirements* (compactness, simplicity and clarity, visibility, unambiguous names of groups, bases and elements). The requirement of resultative of the classification is aimed at obtaining concrete results that will ensure the achievement of goals. The classification system should have a targeted effect and solve concrete classification problems. Compliance with the requirements of resultative and realism is provided by the careful development of the classification structure, analysis of the object, and the existing experience of classifying. The completeness of decomposition is provided by finding the smallest indivisible elements of the classification system and in the sequential grouping of these elements by selected features, moving from the bottom up, that is, inductively. One of the most important tasks of classification is the correct choice of classification features; that is grouping of elements by essential features, which involves, inter alia, abstraction from the secondary ones. The key to abstraction is the establishment of clear boundaries for both the research and the classification system. General requirements refer to requirements that contribute to the usability of the system, i.e. its visibility and logical orderliness. Clarity in the names of classification elements and groups will provide the compactness of the classification, and unambiguity will avoid duplication of notions in the names and ambiguity in the interpretation of features. The use of taxonomic units of classification will logically arrange the elements into groups and subsystems.

In order to determine the ***structure*** of the future classification, it is critical to carefully study not only the object of classification but also the hierarchical organization of classification elements and their connections. At the initial stage of the development of the classification system, it can be assumed that the structure will be *combined*, namely, *faceted* and *sequential*. The facet structure is based on the principle of ordering by facets, according to the features of classification in our case. The main object of classification–IF–is located in the center of the facet structure, and the facets correspond to classification groups according to various features, connected with the center by *radial relations*. The structure of classification groups is more likely to be formed on the basis of a *sequential structure*, where the basic principle is "each with the previous, each with the next".

In practice, identifying all possible IFs, the list of which cannot be permanent, is a difficult task, and the result is temporary. Since one of the properties of the classification is the possibility of its extension, it is advisable to limit the classification of IFs only to scientific and general-purpose EAs, taking national and regional atlases as a standard. With this approach, it is extremely important to meticulously create a classification structure of the classification that will allow its modification for EAs and the list of IFs of any theme and purpose.

It should be noted that the AtP approach to creating EAs has a notable limitation related to the AtP developers' vision of the EA concept. For example, one team of AtP developers may attach significant importance to such EA content elements as charts, while another will consider these elements only as a supplement to maps. As a result, the number of available IFs of these two AtPs will differ. The volume of the IFs library of the AtP is also influenced by the experience of creating EAs of various themes and purposes, which certainly differs from team to team.

In order for the classification to be universal, it is extremely important to take into account all views on the concept of the EA and possible IFs. However, the creation of a classification involves not only the fixation of empirical material of different origins (which is sufficient for the library of IFs), but also its organization on a certain principle (selection of classification features and grouping methods). The latter, one way or another, is carried out under the influence of the subjective views of the authors of the classification. Therefore, unfortunately, it is not possible to develop a classification mechanism that could achieve the status of a pattern (template) and could be repeatedly applied at this stage of consolidation of various cartographic schools.

The practical impossibility of creating a unified classification of IFs today is not a problem because it plays primarily an auxiliary role for AtP developers, being an artificial classification. The ***purposeof*** its ***development*** is to clearly systematize the experience of creating and implementing IFs in EAs created using the concrete AtP. The obtained result can be considered as a source for evaluating the interactivity and functionality of the developed EAs (primarily within the products of the one AtP). In addition, the classification provides materials for analytical research. Its very creation is a research work, which also affects the revision of the theoretical and practical provisions not only of the development and use of the IFs, but also of the EA and the AtP itself. The finished classification of IFs of the AtP is useful for authors of thematic EAs, who get the opportunity to quickly find the necessary functions and connections between them. We are skeptical about the significance of the classification for end users, since it is more important for them to know the IFs and the functionality of the concrete EA, which are usually described in detail in the accompanying documentation and user manual.

Conclusionsand outlook. The article reveals the content of the theoretical and methodological stage of creating the classification system of IFs of the EA. The formation of the theoretical and methodological provisions of the research involved the accomplishment of four intermediate goals, for each of which concrete tasks were identified. The first goal was to analyze the existing classifications of IFs and the theoretical basis of their creation. Among the two classifications of IFs directly intended for EA, it was found that only the classification *(Sieber & Cron, 2019)* has been developed in detail and corresponds to the current level of the EA development. It was decided not to improve this classification, but to create a new one. This is due to three factors: the authors cover almost no theoretical and methodological principles of classification development, which complicates its improvement by other research teams; we do not completely agree with the vision of the EA concept and the interpretation of the initial notions; we have a different idea of the mechanism of classifying IFs and the allocation of classification groups.

The second goal was to form the terminological apparatus of the research object and classification system. To achieve it, the place of the IF in the system of notions of interactive and atlas cartography was initially defined, which implied the consideration of the following notions: EA elements, atlas interaction, EA representation, EA interactivity, atlas interaction operator, EA functionality, interactive tool. The IF of the EA is defined by us as the concrete change of the EA representation. After that, the basic notions of the classification system of IFs were established: classification element, classification object, general principle of classifying, and the main feature (basis) of classifying.

Fulfillment of the third goal involved the formation and study of a set of classification objects – IFs. Essential (interactivity, resultative, visibility, duration, unambiguity) and non-essential (passivity, extensibility) properties of the IF are determined. The characteristic of the IF is called an indicator obtained by evaluating a certain set of the IF properties (first of all, essential ones). Examples of such characteristics are offered as quality, efficiency, usefulness, and popularity. The varieties of IFs of the EA by origin, purpose, and operands are determined. The formation of the IFs library (the set of classification objects) was carried out empirically and was based on the analysis of both EAs (the full list is available at: *https://bit.ly/3wL35uu*) and literature sources on the topic. One hundred seventy-nine IFs of the EA have been preliminarily identified.

The methodological basis of the classification system was determined after the formation of the terminological apparatus of the classification system and the allocation of the set of classification objects. By kind, the future classification is special, artificial, intensional, multilevel, empirical, and taxonomic. Among the general properties of the classification system, the following were allocated: complexity, integrity, focus, openness, persistence, flexibility and effectiveness. In developing the classification system of IFs, the following classification requirements were specified: requirements for the goals (resultative and realism); integrity requirements (completeness of decomposition and sequence of decomposition); adequacy requirements (correctness of features); and general requirements (compactness, simplicity and clarity, visibility, unambiguous names of groups, bases, elements). At the initial stage of development of the classification system of IFs, it can be assumed that the structure will be combined, namely, faceted and sequential. The classification will be intended for developers of AtPs and authors of EAs. Its creation will help to solve the following tasks:

- Systematization of experience in creating and implementing IFs of EAs;
- Evaluation of interactivity and functionality of EAs;
- Review of the theoretical provisions of atlas cartography, finding new IFs and connections between existing ones;
- Accelerating the development of EAs by authors-users of the AtP;
- Demonstration of the interactive capabilities of the AtP.

The scope of the classification will be limited to scientific and general-purpose EAs but will include possible extension to EAs of any theme and purpose.

The second stage of creating the classification system of IFs of the EA is the practical implementation of the classification, which will be reflected in future publications. The research results can be used at the theoretical level of designing the classification of IFs not only for the EA but also for other applications where the classification object is the IF. The proposed terminological apparatus may be of interest to the whole of interactive cartography because such general theoretical notions as IF, interactivity, and interaction are considered.

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КЛАСИФІКАЦІЯ ІНТЕРАКТИВНИХ ФУНКЦІЙ ЕЛЕКТРОННОГО АТЛАСУ: ТЕОРЕТИКО-МЕТОДОЛОГІЧНІ ЗАСАДИ СТВОРЕННЯ

За понад 30-річну історію існування електронних атласів широковідомі лише дві класифікації інтерактивних функцій, призначені безпосередньо для електронного атласу. Крім того, теоретичні аспекти розроблення цих класифікації були висвітлені недостатньо, що ускладнює їхнє подальше удосконалення.

Метою статті є розроблення теоретико-методологічних засад створення класифікаційної системи інтерактивних функцій електронного атласу. Для досягнення мети було поставлено чотири проміжні цілі: з'ясування питання необхідності створення нової класифікації чи доопрацювання існуючих; формування понятійно-термінологічного апарату об'єкта дослідження та класифікаційної системи; формування множини класифікаційних об'єктів – інтерактивних функцій; розроблення методологічних засад класифікаційної системи.

Визначено місце інтерактивних функцій у системі понять інтерактивної та атласної картографії, що передбачало розгляд таких понять: елементи електронного атласу, атласна взаємодія, представлення електронного атласу, інтерактивність електронного атласу, оператор атласної взаємодії, функціональність електронного атласу, інтерактивний інструмент. Встановлено такі основні поняття класифікаційної системи інтерактивних функцій: класифікаційний елемент, класифікаційний об'єкт, загальний принцип класифікування, головна ознака (основа) класифікування. Визначено суттєві (інтерактивність, результативність, наочність, тривалість, однозначність) і несуттєві (пасивність, розширюваність) властивості інтерактивної функції, її характеристики та різновиди. Попередньо ідентифіковано 179 інтерактивних функцій електронного атласу, які будуть розподілені за класифікаційними групами на основі їхнього призначення. Класифікація буде призначена для розробників атласних платформ та авторів електронних атласів. Її створення допоможе вирішувати такі завдання: систематизація досвіду зі створення та імплементації інтерактивних функцій електронних атласів; оцінювання інтерактивності та функціональності електронних атласів; перегляд теоретичних положень електронного атласного картографування, знаходження нових інтерактивних функцій і зв'язків між існуючими; пришвидшення розробки електронних атласів авторами-користувачами атласної платформи; демонстрація інтерактивних можливостей атласної платформи.

Результати дослідження можуть бути використані на теоретичному рівні проєктування класифікації інтерактивних функцій не тільки для електронного атласу, але й інших застосунків, де класифікаційним об'єктом виступає інтерактивна функція. Запропонований понятійно-термінологічний апарат може бути цікавим для всієї інтерактивної картографії, оскільки розглядаються такі загальнотеоретичні поняття, як інтерактивна функція, інтерактивність, взаємодія.

Ключові слова: класифікація інтерактивних функцій, теоретико-методологічні засади класифікування, електронний атлас, атласна картографія, інтерактивність.