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RELATIONAL PATTERNS IN ATLAS CARTOGRAPHY: EDUCATIONAL-PRACTICAL SYSTEM OF CHOROPLETH MAP

This article describes the relational concepts of modern "choropleth map relational pattern of atlas cartography", presented as Educational-practical system of choropleth map (EPSCM). Such patterns and systems are needed to provide practically useful knowledge about thematic maps for the user groups such as: practical cartographers, students of cartographic specialties, developers of modern atlas systems and (maybe) unskilled users. In the work two kinds of choropleth map pattern relations are described. The epistemological (vertical) relations are defining repetitive relations between representations of choropleth map that exist in the three phases of choropleth map life cycle: research, development and operation. These phases correspond to the conceptual, application, and operational strata of choropleth map existence defined in work. Transformational (horizontal) relations describe repetitive relations that exist between the product (choropleth map) and the process of its creation on some specific Stratum. It is proved that necessary to deal with the so-called main triad of choropleth map solutions framework to achieve educational and practical purposes: products-processes of the current strata (eg, application) and their counterparts in the more highly organized strata (eg, conceptual). To prove the main results the reduction and abduction are used. The reduction is applied to obtain the structure of the solution from the more common solutions of atlas systems. Abduction is applied to (re)prove the validity of vertical and horizontal relations for practically useful choropleth map. As additional evidence is used induction: proposed analogy between the concepts of the choropleth map strata and levels of van Gigch's general systems theory and Bunge's metacartography.

Key words: Conceptual Framework of choropleth map system; application Solutions Framework of choropleth map system; practical example of cartographic relational pattern.

Introduction

Rapid changes of the information technologies are forcing to reconsider approaches to educational, practical and scientific cartographic activities. Especially, these changes are felt in the Web- and Atlas cartographies. As examples of the revolutionary changes in the Web-cartography we are pointing on mass distribution of graphic JavaScript libraries Leaflet, D3 and OpenLayers also as OpenStreetMap and Google Maps map- and geo-platforms. There was even a new cartographic activity, which is denoted by the term "neo-cartography". The attitude of professional cartographers to the neo-cartography is ambiguous [Kraak, 2011]. However, it is hard to deny the availability of new non-classic cartographic phenomena and their influence on cartography.

Atlas cartography is also now forced to operate with a much more complex subject than a set of electronic maps. Such sets in the past decade were mainly distributed on CD/DVD, together with relatively simple map visualization software. As an example of revolutionary technological change in Atlas cartography can be used the latest online version (http://www.atlasderschweiz.ch/atlas-switzerland/, accessed 2021-jan-15) of the Atlas of Switzerland. The next quote from this reference is explaining the essence of these changes: "The main idea behind the new version of Atlas of Switzerland is to build a common platform for online atlases. We named it *Atlas Platform Switzerland* or APS. This framework should have the potential for combining interactive thematic cartography with online 3D atlas technology".

For the development of the modern atlas and cartographic systems are needed the specialists, who have, in addition to the classic cartographic knowledge, also the knowledge that would enable them to work with the above-mentioned non-classic cartographic phenomena. In our view, it is necessary to make certain changes in the classic cartographic education [Berlyant, 2002], [Chabaniuk, Rudenko, 2019]. Practitioners are also needed to quickly relearn and receive additional knowledge. With scientists it is more difficult. If the definition of cartography (is the discipline dealing with the art, science and technology of making and using maps – http://icaci.org/mission/, accessed 2021-jan-15) is not changed, the indicated non-classic cartographic phenomena can be seen as not relating to the study subject of cartography. In our opinion map- and geo-platforms, new generation of Atlas of Switzerland, APS and other modern "non-classic" cartographic phenomenon should be seen as a study subjects of the inquiry domain of the new cartography branch – relational cartography [Chabaniuk, Dyshlyk, 2016b], [Chabaniuk, 2018]. However, this work belongs more to the modern educational and practical cartographic activities, although it contains the proof of the facts of relational cartography. Therefore, we concentrate on educational and practical aspects related to the modern cartographic non-classic phenomena.

In educational and practical activities of many disciplines one of the most effective ways of reception and absorption of knowledge are patterns. The proof of this statement is contained in one of the most common definitions: "pattern is a proven best-practice solution to a known, recurring problem within a given context" [Ackerman, Gonzalez, 2011]. Computer Science is an example of discipline, in which patterns are used everywhere.

In the paper [Chabaniuk, Dyshlyk, 2015], written in 2014, we wondered that patterns unfairly (and still do not clear why) are rarely used in cartography. Through participation in ICC2015 conference we were able to get acquainted with the little known work performed in the University of Wisconsin-Madison. First of all it is the dissertation [Donohue, 2014]. We assume that 'related' works, published in the open sources like [Roth, et al., 2014], [Sack, et al., 2014] do not fully reflect the essence of the dissertation. As far as we know, the main result of [Donohue, 2014] – Chapter 5 "A Web Mapping Pattern Library" – still is not published in the open sources. Cited chapter contains information about the prototype of Web Mapping Pattern Library (see Table 1). Patterns of the Library can be logically named "subject design patterns" or "map design patterns", if the notion of "subject" to be limited by maps. It is logical, since these patterns focus on the "design" of the maps – main study subject of classic cartography.

Table 1

Part of navigation menu of prototype Web Mapping Pattern Library (Donohue, 2014; 124)

Getting started	Data	Representation	Interactivity
boilerplate page layout	load data save export ***map elements*** graticule legend	tile basemap vector basemap choropleth proportional symbol dot density …	pan zoom retrieve overlay/toggle filter …

As an example, [Donohue, 2014] describes pattern "retrieve" marked in red in Table 1. Subject design patterns are also described in the monograph [Peterson, 2012]. In the terminology of Table 1 they are 'map representation design patterns'.

Unfortunately, it is not enough to have the only map design patterns to solve the practical problems. With the use of design patterns are associated two main problems: 1) generality – we need the examples, implemented in today's rapidly changing computing environments, 2) it is not clear how to use and combine several patterns in the final decision, for example, in atlas system. We can assume that the first problem with respect to some elements of Web Mapping Pattern Library is partially solved in the works [Donohue, et al., 2013], [Sack, et al., 2014]. It should be noted that these examples of "Interactive and Multivariate Choropleth Maps" and "Time Series Proportional Symbol Maps" only "ideologically" can be regarded as the implementation examples of the subject design patterns of "choropleth" and "proportional symbol" map representations from Table 1, as the authors did not set themselves this task, most likely. The second problem is not solved in cartography.

In this paper we want to show that for practical activities to create atlas systems is not enough partial "subject" understanding of the map patterns. Developers of atlas systems need some practically useful system of knowledge and constructs, built on different representations of the studied and modeled object. A well-studied construct in classic cartography – choropleth map – is used as an example for demonstrating the relations of this system. We assert and prove that in the system of knowledge and constructs of choropleth map are important such relations, as relations between different representations of choropleth map. Moreover, we prove that the relations of this system can also be considered as patterns. These patterns are called relational. The relational pattern can be defined as a proven best-practice solution to a known, recurring relational problem (or problem of relations) within a given context. The adjective "relational" in the title is a tautology, since the pattern is a relation by the definition. For example, "each pattern is a three-way rule that reflects the relation between a certain context, problems and solutions" [Alexander, 1979; 247]. We use this term to more clearly identify the object of our study: relational patterns in the context of atlas systems (AtS).

2. Problem formulation and research method

We define the cartographic system as a pair (K, R), where K is a set of subjects, which include maps, and R is a set of relations between these subjects as to form a unity or organic whole. With this definition we can formulate a statement of the problem, as the requirements for a system. The desired system – relational pattern of choropleth map – in view of its purpose can be called Educational-practical system of choropleth map (EPSCM), which satisfies the following requirements:

· Users are: 1) professional cartographers, who must learn how to use the modern approaches to construct the choropleth maps; 2) students of cartographic specialties who want to get practical modern skills; 3) end users without cartography or computer education, who want to build simple choropleth maps; 4) developers of atlas systems, which responsibility is quick and efficient creation of a large number of choropleth maps, operating in a modern atlas systems.

· Educational and basic requirements. System contains: 1) necessary educational information about choropleth map; 2) not less than three examples of built choropleth maps; 3) basic elements necessary to operate with choropleth map: base map, glossary, classifiers, data dictionaries, etc.

· The main practical requirements. System contains: 1) solutions to support the research, development and operational phases of choropleth map lifecycle in the context of atlas systems; 2) patterns of choropleth maps construction processes; 3) specimens of „embedding" in real atlas (cartographic) systems.

· Other requirements: 1) get an example of a relational pattern of atlas cartography; 2) use an open source (software) solutions, but with minimum number of JavaScript libraries and frameworks. These solutions should be fully controlled until the storage of installation packages in the system; 3) keep the information to facilitate the spread of the system; 4) easy organization and interface.

EPSCM understood as the (spatial) information system in the broader sense (extended system): the totality of all formal and informal (**spatial**) data representations and processing activities within an organization, including the associated communication, both internally and with the outside world [Falkenberg, Lindgreen, Eds., 1989]. For the purposes of this paper we restrict ourselves by the atlas systems (AtS). The term "atlas system" refers to all paper and electronic atlases (see definitions in [Kraak, Ormeling, 2010; Chapter 9]: read-only atlases, interactive and analytical electronic atlases) and (multimedia) atlas information systems [Hurni, 2017]. The term "multimedia" is in brackets, because non-multimedia atlas information systems practically do not exist.

In the activity on creation of AtS we met two serious "typical relational problems". The first relates to the issues of understanding of whole structure of activity on the creation of a specific AtS. In particular, the first problem relates to the understanding of the relations between the AtS intention, AtS intention implementation process and the result of the intention implementation - the AtS itself. The second, more practical problem relates to the specific issues of AtS creation. In particular, it relates to the use of design patterns in the AtS development process. Both problems have typical solutions. Solution of the first problem is the pattern which we call the "Conceptual Framework" (CoFr). Solution of the second problem is the pattern which we call "Solutions Framework" (SoFr). Relational patterns CoFr and SoFr of AtS on English language are described shortly in [Chabaniuk, Dyshlyk, 2015].

We use in this work two main methods of research: reduction and abduction. Reduction is used in conjunction with the relational patterns CoFr and SoFr. In the case of CoFr it means that if the structure of a particular AtS in the broader sense (AtSb) is corresponding to CoFr, the logical structure of any part of this AtSb also must correspond to CoFr. That is, if choropleth map construction is used in a particular AtS, its structure in a broader sense also must correspond to CoFr. The same arguments hold for SoFr.

For the understanding of a conceptual framework term it is acceptable to use the next definition (https://en.wikipedia.org/wiki/Conceptual_framework, accessed 2021-jan-16): "A conceptual framework is an analytical tool with several variations and contexts. It is used to make conceptual distinctions and organize ideas. Strong conceptual frameworks capture something real and do this in a way that is easy to remember and apply". Good informal definitions are also here: accessed 2021-jan-15, http://medical- dictionary.thefreedictionary.com/Conceptual+framework.

In efforts to create atlas systems we are using the more formal definitions of architectural pattern and framework – from the computer science (adoption from [Booch, et al., 2005], [Taylor, et al., 2010]):

· Architectural pattern is a general, reusable solution to a commonly occurring problem in architecture of atlas system within a given context.

· Framework is an architectural pattern for whole atlas system or some its logical part.

Choropleth map is one of the most widespread constructs used in the atlas systems for the creation of thematic maps and layers. We used this construct many times in many AtS. By applying a reduction to the results of work [Chabaniuk, Dyshlyk, 2015], [Chabaniuk, Dyshlyk, 2014], we obtain the structure of the EPSCM studied in this paper (Fig. 1, EPSCM highlighted with a red rectangle). As it follows from Fig. 1, EPSCM is a subsystem of some more general (in the broader sense) choropleth map system, which must exist in accordance with the CoFr of atlas systems. On Fig. 1 we have left only the elements most important for this work and the relations of this general system.

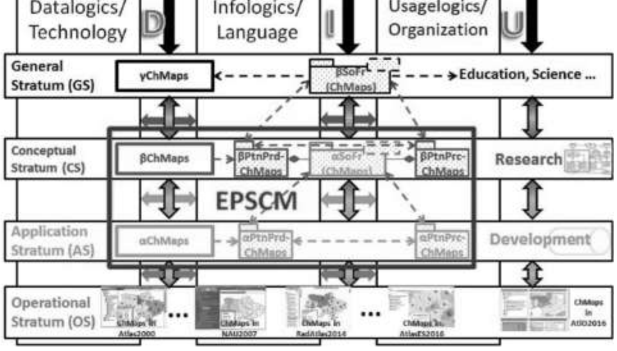


Fig. 1. Structure of EPSCM in some broader (extended) system of choropleth map

Abbreviations and notations of the main elements on Fig. 1: Prd – Product, Prc – Process, Ptn – pattern, ChMaps – choropleth maps, α – application, β – conceptual, γ – general, αSoFr(ChMaps) – application (α) Solutions Framework (SoFr) of ChMaps, βSoFr(ChMap) – conceptual (β) SoFr ChMaps. So: 1) caption αChMaps inside rectangle notate class of application choropleth maps, 2) caption αPtnPrdChMaps inside package symbol notate set of application subject patterns of choropleth maps, 3) caption αPtnPrcChMaps inside package symbol notate set of application process patterns of choropleth maps. The rest of the abbreviations and notations are decoded similarly.

Elements (atlas systems), shown on the Operational Stratum, are as follows: 1) Atlas2000 – Atlas of Ukraine, 2000, CD, eng/ukr; 2) NAU2007 – National Atlas of Ukraine, 2007, DVD, ukr; 3) RadAtlas2014 – Atlas of Radioactive contamination of Ukraine, 2014, desktop/web, eng; 4) AtlasES – Atlas of Emergency Situations of Ukraine, 2014, desktop/web, ukr, 5) AtlO2016 – Atlas shell, 2016, desktop/web/mobile, eng/ukr. CD, DVD, desktop, mobile, web denote here medium on/in which the atlas system is shipped/operated.

In the next section, we are describing most of the elements and relations of EPSCM system. At the same time we will repeat abductive reasoning from [Chabaniuk, Dyshlyk, 2014], [Chabaniuk, 2018] for choropleth maps. As a practical confirmation of our arguments will be used the atlas systems listed above.

3. Primary result description

Two main results are obtained. The first result is a relational pattern of choropleth map – application Solutions Framework of choropleth map αSoFr(ChMaps). With the usage of αSoFr(ChMaps) it is received the second result – test Educational-practical system of choropleth map (EPSCM). αSoFr(ChMaps) is used to build a test choropleth maps shown in interfaces of atlas systems in Operational Stratum on Fig. 1. The test maps are placed in the Products directory of EPSCM and αSoFr(ChMaps) – in Basics directory of EPSCM.

Test EPSCM built using AtlO atlas shell. AtlO is an architectural pattern of atlas systems. Its main purpose is prototyping of atlas systems architecture. In particular, AtlO solves the problem of few patterns coordinated usage in one system before implementation of the system itself. For example, test EPSCM is demonstrating coordinated usage of a thematic map and contents tree patterns, as well as other patterns of atlas systems.

Due to problems of volume we cannot describe the implementation of αSoFr(ChMaps) and test EPSCM. Therefore, in this section we will concentrate on describing the basic concepts of these systems: the main epistemological (vertical) and transformational (horizontal) relations of Relational cartography [Chabaniuk, 2018].

3.1. Epistemological (vertical) relations (relations between strata)

We have created first electronic atlas - Atlas of Ukraine – in 2000. It was released on CD in English and Ukrainian languages in 1500 copies. Initially, cartographic functions (including work with choropleth maps) have been implemented by the usage of MapInfo MapX component. This component was placed on the HTML page, and handles all map actions of atlas user. Due to cost considerations, we developed own isgeoMapX component, which repeated the needed MapX features. isgeoMapX works with data files in our particular format, which was not available to other programs.

The result is the classification/instantiation relation between choropleth map in the atlas format (Fig. 3, *a*, Operational Stratum – OS) and choropleth map in MapInfo Professional format (Fig. 3, *a*, Application Stratum – AS). Atlas of Ukraine in 2000 was distributed on CD in an unchangeable format. It means that the atlas user could not make changes of the choropleth map. He could only visualize the states of the map, predetermined and fixed by the developer. In the development phase (or on Application Stratum) choropleth map is processed by using MapInfo Professional. The developer can edit choropleth map and thereby change its state. Changes can be made to a map display (color, legend, division into categories), and the data itself. Clearly it follows from the above description that there is a class of all permissible choropleth maps (here – in MapInfo Professional rules), and an instance of this class in the Atlas of Ukraine. The instantiation is carried out by fixing the desired state of choropleth map and map conversion from MapInfo format into isgeoMapX format.

We note three types of the classification/instantiation relations ⇕ between choropleth maps of Application Stratum (or development phase) and Operational Stratum (or operational phase). These types are notated by letters D, I, U on Fig. 2. The first type relation is called Datalogical (D) classification/instantiation. This relation type is in mind when it comes to files and formats of choropleth maps in two strata. The second type relation is called Infological (I) classification/instantiation. This relation type is in mind when it comes to the habitual cartographer representations of choropleth maps in two strata. This relation type is shown in Fig. 3. There is also a third type – Organizational (U) classification/instantiation relation. This relation type is the most difficult to understand. It defines the relation of choropleth map usage (U), created by the developer on Application Stratum and “instantiated” so that the end user without the knowledge of geo-information products (such as MapInfo Professional) can use the choropleth map on Operational Stratum.

αChMaps choropleth maps class of Application Stratum (see Fig. 1) permits few generalizations. First generalization can be obtained by applying the metarelation and constructing βChMaps choropleth maps metaclass (see Fig. 1). βChMaps will be the element of the Conceptual Stratum. One can imagine an example of more simple generalization than the metarelation. Namely, in addition to MapInfo Professional, MapInfo company supplied the MapBasic development language, which allows the development of a whole family of geo-information applications, including the MapInfo Professional itself. Above is described choropleth maps class of Application Stratum processed by MapInfo Professional (this is subclass of αChMaps class on Fig. 1), It can be generalized to the class of all choropleth maps processed by all applications developed on the MapBasic (this is subclass of βChMaps class on Fig. 1).

To conclude the discussion of vertical relations of EPSCM let us make some important remarks:

1. The relations between the strata depend little on the used software. For example, MapInfo Professional can be replaced by QGIS or similar solutions from ESRI, Inc. The dependence is manifested in the implementation of the relations. So, in modern atlas system relations between strata can be built dynamically, not statically, as it was in 2000. For example, in AtlasES2016 the analyst may edit the choropleth map data on-line on the Application Stratum, and the end-user has possibility to visualize the actual map changes on the Operational Stratum.

2. Conceptual, Application and Operational Strata include artifacts, which have to operate according to the phases of research, development and operation of choropleth maps of atlas systems.

3. The relations between the strata are fundamental in terms of knowledge about choropleth map. Below will be provided information, justifying a system of knowledge about choropleth map, matching strata and relations between them on the one hand, and general systems epistemological levels and the relations between them, on the other.

3.2. Transformational (horizontal) relations (relations within the stratum)

Carrying out the development of Atlas of Ukraine in 2000, we documented all the major processes performed with choropleth maps. By performing these processes, we also got the choropleth map specimens. Later, we used this construct many times in the development of other atlas systems. One of such systems is shown on the Fig. 1 – National Atlas of Ukraine (NAU). Due to the multiple applications we received the application part of αSoFr(ChMaps). On Fig. 1 this application part is presented by αPtnPrdChMaps and αPtnPrcChMaps packages. The scheme of αSoFr(ChMaps) application part usage is shown on Fig. 4, ***a***.

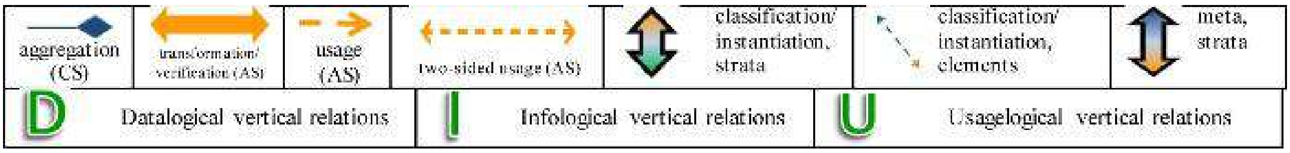
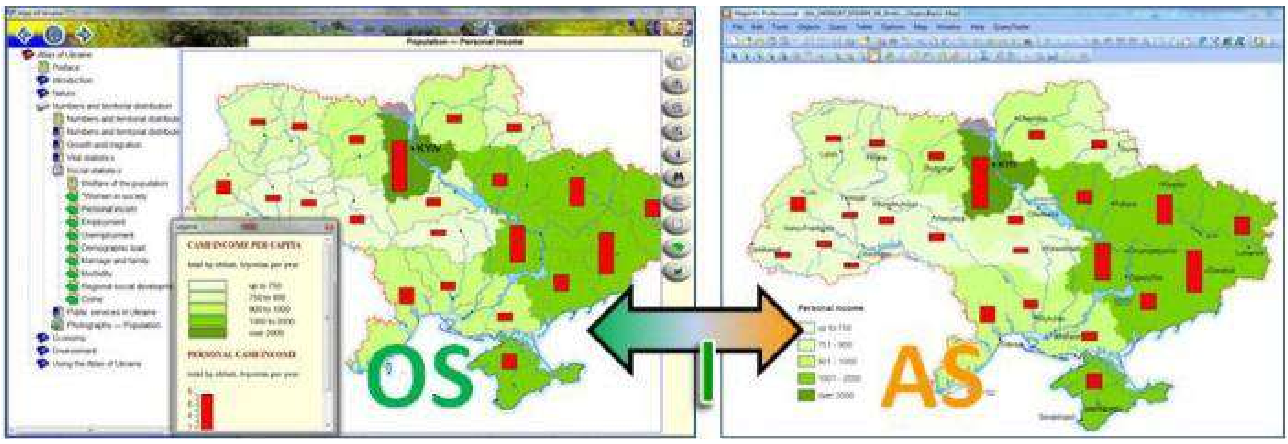
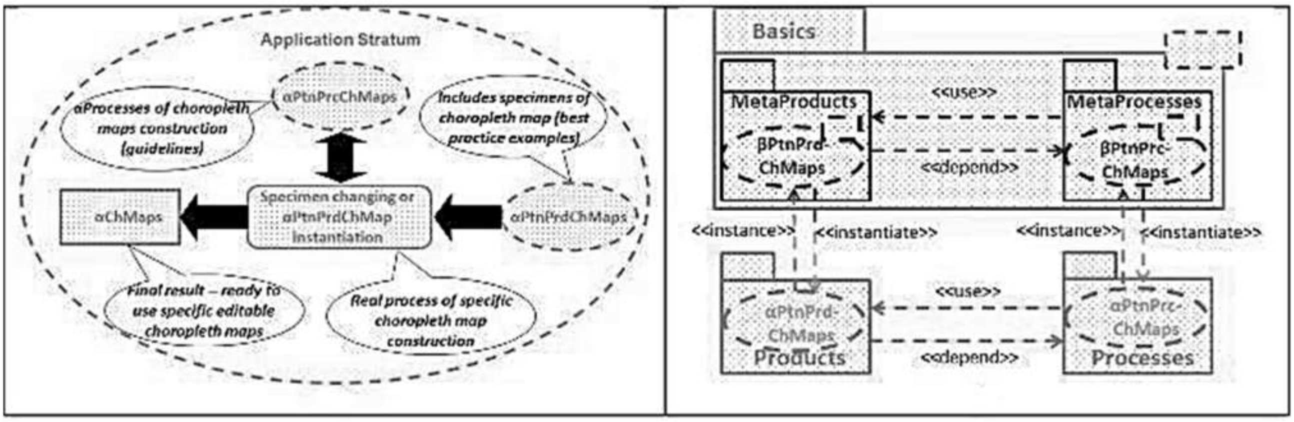


Fig. 2. Names of main relations between elements and strata



a b

Fig. 3. ChMap 'Personal Income' in:
a – Atlas of Ukraine 2000; b – MapInfo Professional



a *в*

Fig. 4. αSoFr(ChMaps): a – usage scheme of application part, b – main triad

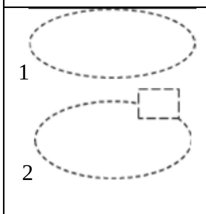
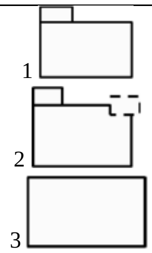
In the second half of the last decade, there have been revolutionary changes in information technologies (IT) for the Web. A new era of the Web, which is referred to as Web 2.0, appeared. One of the two most important characteristics of Web 2.0 is Internet platforms [O'Reilly, 2006]. Known geo- and map-Internet platforms are OpenStreetMap, Google Maps, Bing Maps and others. Internet platforms support the API, which can be used by simple open source JavaScript libraries. The most popular such libraries for geo- and map- platforms are Leaflet (accessed 2021-jan-16: http://leafletjs.com) and OpenLayers (accessed 2021-jan-16: https://openlayers.org). In our atlas solutions of the past decade it was principal to use dominant at that time HTML4 and Internet Explorer together with the ActiveX technology from Microsoft. These solutions relate to the Web 1.0 epoch. The above-mentioned IT changes has led to the standardization of HTML5-CSS3-JavaScript triad and as a result, changes to the αSoFr(ChMaps).

In addition to changes in αPtnPrdChMaps and αPtnPrcChMaps, in the current decade is an important complementation of αSoFr(ChMaps) by elements of the Conceptual Stratum, as shown in Fig. 4, *b*. Note that complementation by elements βPtnPrdChMaps and βPtnPrcChMaps is not mechanistic. Shown in Fig. 3b elements form the so-called main αSoFr(ChMaps) triad, where “triad (from Greek τριάς, τριάδος) is unity that is formed by three separate members/parts” (https://ru.wikipedia.org/ wiki/Триада, accessed 2021-jan-07, translation from Russian). Triad αSoFr(ChMaps) is determined by three main dualisms: “product-process”, “product –metaproduct” and “process-metaprocess”. Dualism “metaproduct – metaprocess” is not the main as far as it is regarded only in tandem with the dualism “product – process” and is the consequence of other main dualisms.

One of possible choropleth map subject design patterns from βPtnPrdChMaps (see Fig. 4, *b*) is described in [Peterson, 2012; 150–151]. It is shown also in the Table 1, column ‘Representation’, record “choropleth”. [Peterson, 2012; p. 109] stress that “term *pattern* refers to a promulgated cartographic technique that is reusable, customizable, and proven to be effective. This is the same sense of the word *pattern* as used in software design field, where design patterns allow for more efficient programming, since practitioners are not spending time reinventing solutions that others have already designed”.

Table 2

UML notation (Booch, et al., 2005)

Notation	Meaning
 1 2	1. Cooperation – named collection of classes, interfaces and other elements, which are working together, in order to ensure certain behavior, which is something bigger than the behavior of the sum of these elements. 2. Parameterized cooperation
 1 2 3	1. Package – general–purpose mechanism for organizing elements into groups 2. Parameterized package 3. Class

As for choropleth map (subject) design pattern [Peterson, 2012; 150] says: “A choropleth map represents a continuous variable via color progression (graduated color scheme) within discrete features such as countries, states, or watersheds…The choropleth technique is usually applied to area features but can also be applied to line and point features… Choropleths are easy to create in most mapping software …”. MapInfo Professional is the example of such mapping software, in which is realized choropleth map construction. Dualism “product–metaproduct” is described in the previous subsection as relation choropleth map in MapInfo Professional – choropleth maps in MapBasic applications.

Product-process dualism can be defined simply as follows:

· The Product cannot be created without the Process. Or in other words: created by the project team Product cannot be created without the Process understandable to team members.

· In the activities on creation of information (automated) systems Process has no sense without the Product created thanks to it.

This dualism is shown on Fig. 4, *b* by <<use>> and <<depend> relations. More information about meaning of these relations can be found in [Booch, et al., 2005]. Excellent example of product-process dualism is presented in [Sack, et al., 2014]. The product in this example is one of possible implementations of choropleth map application pattern from αPtnPrdChMaps. Fully commented source code of this choropleth map implementation pattern is available on GitHub (accessed 2021-jan-16: github.com/uwcart/cartographic-perspectives). The process in this example is main topic of cited paper – tutorial, which is describing all steps of choropleth map creation. Meaning of the term 'tutorial' is the same as "guideline" from [Ackerman, Gonzalez, 2011].

Tutorial from [Sack, et al., 2014] is one of possible ChMaps αProcess patterns, which belongs to the αPtnPrcChMaps from Fig. 4. This αProcess pattern is an instance of (<<instance>>) corresponding βProcess or metaprocess pattern from βPtnPrcChMaps. The possible example of this corresponding βProcess pattern is described in [Peterson, 2012; 150] starting from the sentence "The major cartographic consideration is how to break up data into ranges that make sense, which depends on the numerical distribution of the data – especially when it contains outliers or a skewed distribution. Different strategies for breakpoints exist. To begin with …"

In real projects of atlas systems development we need much more processes and their patterns. First of all we need whole creation process. In computer industry are well-known βProcesses patterns, named as "life-cycle development models" (LCDM). Usually LCDM consists of four phase process patterns: "initiation" (research), "construction" (development), "delivery" and "maintenance and support" (operation). Each phase process pattern consists of stage process patterns. Each stage process pattern consists of task process patterns. In each real project LCDM should be "instantiated" by the corresponding αProcess patterns before the beginning of project. So, tutorial from [Sack, et al., 2014] may belong to some instantiation of development phase sub-process pattern.

Other mandatory is management process and its patterns. There are also other processes. "Process-metaprocess" dualism is realized by <<instance>> and <<instantiate>> relations. Some examples of these relations are described above. More information on βProcess and αProcess patterns can be found in [Ackerman, Gonzalez, 2011].

4. Additional proof and discussion

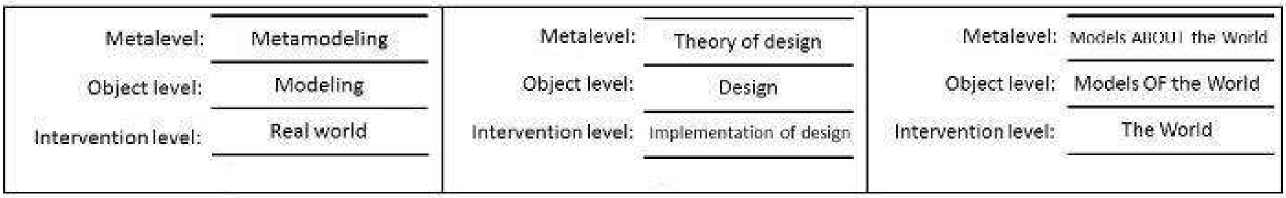
4.1. EPSCM strata analogies in general systems theory and metacartography

To search for analogies in general systems theory the monograph [van Gigch, 1991] is used. In this monograph in the context of the issue of system design are considered three inquiring systems, which are respectively: 1 – studies reality; 2 – works at the level of modeling; 3 – operates at the level of metamodeling. Each of the systems considered at their level. Levels were called, respectively: 1 – Intervention level; 2 – Object level; 3 – Metalevel. The monograph has three parts, studying three pointed inquiring systems. Relations between the levels are also studied. In particular [van Gigch, 1991; 256–257], Fig. 11.1 (Fig. 5, *a*), Fig. 11.2 (Fig. 5, *b*), Fig. 11.5 (Fig. 5, *c*): "A dialectic relationship exists between the two elements of each dyad (object level-metalevel, model-metamodel, world-metaworld, etc.) because each element is said to originate in inquiring systems of different levels of abstraction or logic… when we neglect the metalevel, we also overlook the process of design that takes place at the metalevel and by which lower-level inquiring systems are formulated. This neglect can lead to dysfunctions and to system failures."

Particular attention is paid to the influence of upper levels on lower [van Gigch, 1991; 257]: "The imperative of the metasystem paradigm … is to study each object-level system from an external perspective which, in this instance, we call the metalevel. To apply this imperative is to metamodel. It is not sufficient just to model; we must metamodel, i.e., we must complement the formulation of models with an inquiry which raises the level of logic and of abstraction. By doing so, we consider the origin and underpinning of our modeling and formulate justifications for its scientific claims. Failures in modeling (and of the disciplines which adhere to the traditional forms of modeling) can be attributed to the inadequacy of their epistemological inquiry. To question the epistemology of design is to question the prevailing paradigm. As is shown in Fig. 11.2 (Fig. 5, *b*), designing and questioning the process of design takes place at inquiring systems of high levels of abstraction".

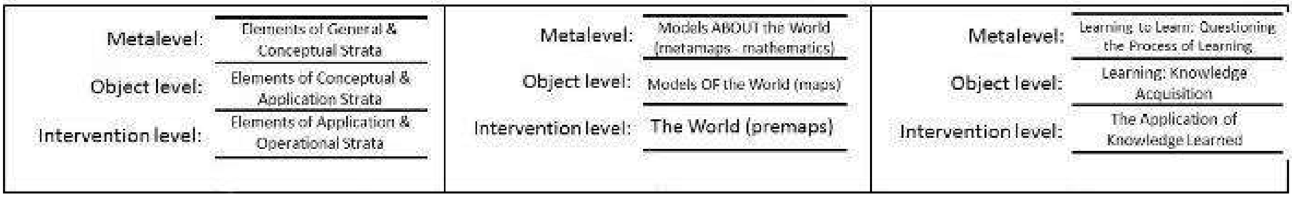
Fig. 6, a shows one of the possible correlations between the levels of [van Gigch, 1991] and atlas systems strata. We used the adjective "possible", to reflect the fact that shown on Fig. 1 construction depends on the phenomenon under study, and the researcher point of view.

In this article, the elements of van Gigch's Intervention level are choropleth maps in implemented atlas systems. As an implemented atlas system can be considered the element of the Operational Stratum (eg NAU2007 on DVD), and the corresponding elements of Application Stratum. One of these elements of Application Stratum is an edited version of NAU2007 (in formats of MapInfo Professional, Adobe Illustrator etc.), from which was made NAU2007 on DVD. Therefore, on Fig. 6, a is shown the correspondence between the "Intervention level" and "Elements of Application & Operational Strata". Similarly can be attributed the correspondence between: 1) "Object level" and "Elements of Conceptual & Application Strata"; 2) "Metalevel" and "Elements of General & Conceptual Strata".



a *в* *c*

Fig. 5. The relations between: a – modeling and metamodeling; b – design and design theory; c – cognition and metacognition



a *в* *c*

Fig. 6. The correspondence between van Gigch's levels and: a – the strata of atlas systems (see Fig. 1); b – premaps, maps and metamaps (Bunge, 1967); c – levels of learning (van Gigch, 1991; Fig. 11.4)

Analogues of the above inquiring systems 2, 3 are studied in the Russian language cartographic literature [Aslanikashvili, 1974], [Liutyy, 2002]. [Aslanikashvili, 1974] introduced and [Liutyy, 2002] studied the system of language of map (inquiring system 3), which is interpreted by means of cartographic elements (inquiring system 2). [Aslanikashvili, 1974] introduced the concept of metacartography (inquiring system 3), which was studied by generalizations with the help of relation "meta", applied to the elements of cartography (inquiring system 2).

In English literature, we refer to the "Chapter 2. Metacartography" [Bunge, 1967]. Bunge called the relations between the elements of inquiring systems 1–3 as traverses. Applying the traverses to the mapping elements (up and down), he received shown in Fig. 6, ***b*** levels of: 1 – premaps; 2 – maps; 3 – metamaps (more precisely, mathematical generalizations of maps). However, Bunge studied not thematic but primarily topographic maps, so the concepts of his metacartography levels are almost coincide with the concepts of general systems levels of van Gigch.

4.2. Discussion

In this subsection we discuss the issues that seem to us most urgent at the moment.

Complexity. The construction shown in Fig. 1, as well as EPSCM and αSoFr(ChMaps) themselves (at least a description of the basic relational concepts) seem quite complex to understand. The question naturally arises, how it can understand the users listed in the requirements to EPSCM? In this regard, we can say the following:

- agree, complexity exist. This is most likely cause permanent complexity, because it is a modern atlas system. In contrast to the individually created a separate maps, the system is created by the lot of developers. Furthermore, systems consist of many interconnected elements;
- this complexity can be differentiated. When it comes to educational use, then the full construction is enough to understand the teacher. Students will receive a simple task. The same can be said about the practical application. In this case, the teacher role should play the project manager. The hardest are unskilled individual users. To reduce the complexity of perception there is a package Publications. This package contains elements that describe the subject in a simplified form.

Atlas restrictions. We limit the use of described constructions by AtS boundaries in order not to prove the necessity of the use of patterns. We proceeded from the fact that the in AtS creation processes patterns need is obvious. Indeed, many different choropleth maps present in atlas systems. If you treat them as art works, the AtS is unlikely to be created. Here we have in mind first of all that the AtS are created for mass use. We doubt that the mass user will be able to appreciate the art of the creator of the original choropleth map - as art works. However, we do not suppose that described choropleth map pattern is only for atlas cartography and cannot be used in cartography in general

Justice of analogies with the general systems theory. We suppose that the general systems theory can be applied to the cartographic (information) systems as can be found two-sided mapping between them. Thus, in [Chabaniuk, Dyshlyk, 2016a], we describe this mapping for a base map that includes topographical subsystem. Of course, a critical and meticulous reader will see that choropleth (thematic) maps are not topographic. In this case, you should thoroughly investigate analogies between the general systems theory and metacartography [Bunge, 1967], [Aslanikashvili, 1974]. Are they true or not? If so, can be true also analogies for thematic maps

The importance of the triad. We could not give enough attention to the main triad of the choropleth map Solutions Framework. This is especially true for rationale to use dualisms product-metaproduct and process-metaprocess. Here are two arguments:

· Web 1.0 and Web 1.0+ (such is indicated an approximation to the Web 2.0) application choropleth map Solutions Frameworks are significantly different in information technology, as well as the architecture of the solution in the end user's AtS. At the same time, end-user representation of choropleth map and its "interactive visualization" functionality in the Atlas of Ukraine in 2000 (Web 1.0) and, for example, in AtlasES 2016 (Web 1.0+) remained almost the same. This suggests that there are concepts and solutions which are common to the choropleth maps like Web 1.0 and Web 1.0+ (Web 2.0). These common concepts and solutions exist in a given case on Conceptual Stratum that should definitely be taken into account;

Chapters 1–4 of the dissertation [Donohue, 2014] devoted to the justification of the results of Chapter 5 referred to in our work above. In particular, the necessity of studying by cartographers (!) the triad HTML5-CSS3-JavaScript and Leaflet library. In fact, there is nothing strange. The fact that the Conceptual Framework of AtS has the following property: the higher strata are decisive for the lower strata (see also quote [van Gigch, 1991; 257] above). In our studied construction the triad HTML5-CSS3-JavaScript library and Leaflet are the elements of the EMSCM General Stratum. This means that knowledge of the relevant elements of the higher strata needed to build high-quality and long-lived solutions on the lower strata.

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