Digital census of Upper Kama towns architectural and urban environment

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Abstract. The paper presents the system and methodology of digital census documentation of architectural heritage, which was first time adapted and applied to the heritage of Upper Kama region. The results and cataloguing process for the historical cities of Usolye and Cherdyn are described. The main objective of the study is the structuring of information through the definition of morphology and architectural features of objects. The cataloguing idea is to describe all the architectural and urban environment elements in the historical cities Usolye and Cherdyn, and attach to the map layer-by-layer using geographic information systems. The catalogs rely on reality-based data collected using architectural survey methods. Heterogeneous information about objects is structured through a system of codes and summarized in a single database. The resulting system of digital documents designed to coherent store and simple search of information about the architecture are introduced in the article.

1. Introduction
Architectural environment contains huge amount of information. The study of the architectural and urban planning environment as well as the arrangement of relationships between objects and its components, demand the systematization of all the data and metadata [1].

The inconsistency of traditional information sources makes the search process and the use of information increasingly complicated. The variety of the tasks of the design process, restoration and research activities often requires knowledge about individual features and the analogues search [2].

Information and digital technologies are based on the mathematical descriptions therefore they require formal categories. As noted by Shubenkov M.V. in his work [3], “the determination of system-forming factors in the structure of architecture as an artificially created spatial environment” is of great importance.

Systematization is the construction of databases, requires a modern approach. With the changing and growing capabilities of digital technology in urban space, resources for new management systems are emerging. New systems require new digital documentation methods: computer modeling, digital data collection, and graphical representation.

Nowadays, the information overload is another problem of the application of new technologies. Growing arrays of heterogeneous data collected on site (3D models, photographs, drawings, drawings, written documents) become a challenge for researchers [4, 5]. The data is collected from various sources in different times created by various institutions in accordance with their professional tasks.
As a result, the necessity for an innovative methodology of collecting and processing information, methods of sorting and data analysis is appearing.

The possibility to use the accumulated information appears when the collected data is classified and organized into a single structure. Structuring and cataloging are necessary conditions for the data storage and efficient use of information.

The article focuses on the development of the digital documentation framework as a mechanism of the classification, description, management of the historical architectural and urban planning environment. This structure is based on the reality-based data about the state of the objects which was obtained by traditional and digital methods of architectural survey.

2. Theory and Methodology

Architectural survey is the process of acquisition and processing of information about historical architectural structures, [6] produces the documentation essential for identification, interpretation, protection, physical preservation of historical buildings, archaeological monuments and cultural landscapes [7].

Approaches to the description of architectural objects were reviewed in the works of A. G. Rappoport [8], G. Yu. Somov, A. Ikonnikov, V. L. Glazychev, I. G. Lezhava [9], V. I. Iovlev [10].

The methodology of the processing acquired information, systematization as applied to architecture was considered in the works of S. Parrinello, S. Bertocci, L. DeLuca [11], F. Remondino, M.A. Evstratenko [12], I.G. Tkachenko [13].

The main problems of forming an architecture information system while structuring the architectural environment data are the determination and naming of each element and component of the structure.

The identification of components occurs in two positions: 1) the absolute location definition (an element in the general structure of the settlement), 2) the relative position (the relationship of the defined element with other same scale elements). It is important to identify not only the well known elements of the architecture classical theory, but also the special details inherent in this place.

The development of the census documents runs in three stages: preliminary research, field work, creation of an atlas. This principle is similar to the SAVE system analysis of the territory (Survey of Architectural in the Environment) [14]. However, the result of the work is basically different. The object is presented not in the form of a paper atlas, but in the form of a digital catalog tied to a digital map through GIS [15, 16].

The procedure for creating a digital catalog includes the following steps:

- Preliminary layout of the territory into sub-territories which are the planning structure elements for subsequent identification of each element. Every unit was assigned an alphanumeric code containing the identifier of the city, the identifier of the block, the identifier of the building or structure. Such coding is required to link cartographic and descriptive materials. (Figure 1)
- Identification and creating an analysis scheme for each architectural unit. The structure of the analysis was recorded in the census document.
- Creating an inventory map disaggregated by several blocks: general information, historical information, visual description, graphic representation, architectural features and structural characteristics of the building, problems and risks.

![Figure 1. Alphanumeric code for architectural object.](image)

The general information for each of the described units was including: the name in accordance with the historical objects register established for the survey territory; address of the object; functional purpose; year of construction, century, architect, architectural style, in case these parameters are
available; security status; owner. Several thematic maps were subsequently created based on these data: the functional (actual) map, the map of construction years, and the map of owners.

Historical information was obtained from archival data and the previous surveys of various years. The following parameters were taken into account: the past functional purpose of the object (if it does not change, the line “change of function” indicates “no”), historical note, historical views, color scheme (if available).

An important part of the analysis is a retrospective review of building functions. The type and function of a building influence on the surrounding environment (especially if the object is located in a context of the surrounding historical buildings) and could change the morphology and functions of adjacent spaces environment. The color scheme and configuration influence on the overall perception of the architectural environment, they were determined by comparison of modern and historical species.

Information about the buildings was supplemented with photographic materials and illustrative diagrams which are recorded in the visual description block. The role of the described building in the group was noted: whether the object was a separate one, its visibility, the compositional role in the general ensemble. Its modern color scheme and environment were described in addition [17, 18].

The facades in an orthogonal projection and axonometric views were provided for each object. This allowed to record and further analyzes the scale of doors and windows, the location of the decor, the general condition. These drawings were presented in the graphic representation block [19, 20].

Architectural and structural features of the building were described on the basis of visual observation. Information was refined using the instrumental methods of examination. This system for collecting information simply allows you to add or change information about the object: fixing materials and condition of the foundation, walls, roofs, coating, the presence and location of decorative elements is noted.

Following adverse climatic and ecological conditions are dangerous for the architectural heritage of Upper Kama region: flooding, humidity, slope instability, chemical pollution, and biological factors. Therefore, it is important to note the risks and problems of the existence of an architectural object. In the census document they were noted in the block "problems and risks".

Once the digital catalogue fulfilled by required content, thematic schemes and maps were created using geographic information systems (QGIS, ArcGIS). While thematic map creation special attention was paid to the surrounding landscapes description and the implementation of each architectural unit to the environment. The next parameters were taken into account: natural and architectural dominants, physical and visible boundaries, accessibility, functional zoning of the territory, colour characteristics of the environment.

3. Case studies, data processing

Digital census analysis was carried out for two historical cities of Upper Kama region (Russia, Perm area) Usolye and Cherdyn. These two cities have rich history. Preserved architecture monuments of Russian baroque style, Old Ruthenium patterns (style ouzorotchê), classicism style, make Upper Kama region a real pearl of the cultural heritage of Russia. However, poor state of most of these architectural objects indicates necessity of urgent restoration. But to get fund in small provincial Russian cities for restoration is complicated matter. Digital cataloguing allows preserving heritage by creating digital twins that exist in virtual reality.

The objective of this work was structuring and cataloguing data about the architectural sites Usolye and Cherdyn through the description of typology, physical characteristics and state. For the moment collected information about 40 architectural objects. The list of parameters for each city was adjusted in accordance with local conditions (the number of parameters for each city is given in Table 1).

For instance, the historical part of Usolye is based on the island and most of the historical buildings are located in the coastal zone. It was therefore essential to assess the risks of flooding. Data about the years of construction, materials, and the owners of objects was recorded.
Cherdyn is distinguished by a clear orthogonal planning structure, remaining from 1828. Buildings located in the blocks create a continuous building front. The main parameters of buildings and elements for the census analysis are high, colour schemes, and decorative features.

| Blocks of census document | Usolye, number of parameters in block | Cherdyn, number of parameters in block |
|---------------------------|----------------------------------------|----------------------------------------|
| General information       | 13 + situational plan and environment general view | 7 + situational plan and environment general view |
| Historic information      | 3 + historical general views, types of decorative items | 3 + historical general views, types of decorative items |
| Visual description        | 6 + photos of modern species            | 6 + photos of modern species            |
| Graphic representation    | 2 (main facades, plan, axonometric are recorded) | 2 (main facades, plan, axonometric are recorded) |
| Structural and architecture features | 10 + photos or drawings of architectural details | 10 + photos or drawings of architectural details |
| Risks and problems        | 6                                       | 2                                       |

Required parameters of the objects were defined and included in the census document, which is filled in interactive mode. Essential data, photos, diagrams, drawings was entered using buttons and drop-down menus. These census documents are filled for each object individually. This census documents created using two software products FileMaker Pro and Microsoft Excel, are shown in Figures 2 and 3.

Figure 2. The census document of Nikolskaya church in Usolie, FileMaker Pro.
Cataloguing was carried out included six thematic blocks that form a database for documenting and visualizing information in GIS.

Parameters for creating various atlases are extracted from the database during the final stage. For example, an atlas of decorative elements for Cherdyin was created. The atlas based on the map with alphanumerical codes of buildings. The facades of historical objects were analyzed for creating the decorative elements atlas. Each decorative element has got a number in accordance with the location: 1-pilasters, 2-windows, 3-eaves, 4-party wall (Figure 4). After that if there are several forms an additional clarifying number is assigned (for example, 1.4).

Eventually heterogeneous data about the object are collected in a single directory and tied to the map using a system of codes. Attributes in the GIS table are unambiguously determined parameters, other parameters such as historical notes, photographic materials, schemes, have to be displayed additionally. Displaying such information and linking it at different scales requires additional development.

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**Figure 3.** The census document, Microsoft Excel.

**Figure 4.** The decorative elements atlas.
4. Conclusions
The relevance of this study is inextricably linked with the interdisciplinary nature of knowledge about architectural heritage. Digital cataloging of the architectural objects of Usolye and Cherdyn allowed structuring the available information, supplemented with the found documents, and create a database for the objects of the heritage as well.

The presented censuses documents system can be useful not only for creating coherent storage of information about architecture, but also simplify its search, create a digital twin, both of separate architectural objects and urban environment as a whole. Creating a general picture of the historical settlement environment is available in combining collected information using the developed system of parameters with 3D models built from point clouds (ground laser scanning, photogrammetry). Digital cataloging allows interpreting and classifying objects according to their role in the historical environment and interaction with the context they are located in. The weaknesses and the general state of the urban environment can be observed while evaluating all the information in general, thereby hence the determination of priority measures and development directions for the territory.

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