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# Functional requirements for an intelligent system for monitoring the impact of beaver activity on ecosystems

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**Abstract**. The consequences of beaver activity affect the condition of natural and anthropogenic systems. The paper presents a brief description of possible consequences of beaver settlement in the natural territory. The monitoring of the number of individuals, the control of the environment and the possibility of forecasting its changes require the development of specialized software tools. The paper presents a description of the main functionalities of such a system and a list of users to whom they are available. These include the detection of beaver habitats, the prediction of environmental changes due to the construction of dams and reservoirs, and the regulation of animal fishing processes. In addition, lists of data are presented, the use of which will make it possible to realize the presented functionalities. The proposed intelligent system will allow forest specialists to monitor the state of natural areas, to specify the list of measures to ensure the preservation of natural and anthropogenic objects. From the point of view of state management, it is possible to create an up-to-date and constantly updated register of beavers and to control their fishing.

## 1 Introduction

Beaver activity has a pronounced environment-forming activity, which comes into conflict with human interests by flooding valuable forests, damaging roads and railroads, destroying reclamation networks, etc. [1]. The beaver has a rapid dispersal rate, disturbing coastal ecosystems, the restoration of which takes quite a long time [2, 3].

Beaver activity is of interest to different researchers. For example, some works claim that the construction of dams and dams impede the processes of water and ice passage in spring time, provoking floods [Veterinary and Life: https://vetandlife.ru/sobytiya/nuzhno-li-regulirovat-chislennost-bobrov] or in case of forest fires, the territory watered in this way can restrain the spread of fire [Argumenty i Fakty weekly newspaper: https://aif.ru/society/nature/pochemu_bobry_stroyat_plotiny]. As noted in research, the beaver's range is expanding every year and its numbers are increasing, which encourages it to settle more often on artificial watercourses and streams along communication facilities [1, 3]. All this has a negative impact on human economic activity.

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In order to ensure balance in ecosystems where beaver activity is present, specific regions of Russia have introduced a quota for beaver hunting. For instance, in the Kemerovo region, hunters are allowed to exterminate 50% of the beaver population in public hunting grounds, which amounts to 1,932 individuals [Department for the Protection of Wildlife in Kuzbass: https://depoozm.ru/index.php/dokumenty/prikazy-departamenta/1120-prikaz-departamenta-po-okhrane-obektov-zhivotnogo-mira-kuzbassa-ot-28-06-2024g-63-ob-utverzhdenii-kvoty-dobychi-bobra-v-obshchedostupnykh-okhotnichikh-ugodyakh-kemerovskoj-oblasti-kuzbassa]. However, beaver fur is not particularly demanded, which reduces the interest of hunters to this commercial species. In addition, the beaver has few enemies in the wild, as it is large enough for small predators, and it is not included in the feeding spectrum of large predators due to its semi-aquatic lifestyle. All this ensures the constant growth of the beaver population and the need for its monitoring and control of the consequences of its vital activity.

Intelligent systems are effective means capable of objective control of processes, forecasting changes in their states on the basis of current and archival data. In fact, such a system is a means of reproducing human intellectual possibilities based on the collection, storage, processing and presentation of information [4, 5]. This makes it possible for the system to solve objectives under conditions of uncertainty, with difficultly formalized or eurestic conditions, to learn on the results analysis of its activity and to carry out “intelligent interaction” with the user [6-8]. The modern developmental stage of technological, everyday and other processes of human life is associated with their digital transformation [9, 10].

Thus, **the aim** of the work is to develop a concept that provides digital monitoring of beaver distribution, assessment of the impact of their vital activity on ecosystem processes and control of their population. This requires to fulfill the **objectives** to identify the key aspects of the research object that affect the change in the state of beaver population, their distribution rate and environmental impact; to determine the categories of intelligent system users and their functional possibilities.

**The object of research** is the processes that affect the state of the ecosystem from the vital activity of the beaver family.

**The theoretical significance of the research** lies in the systematization, structuring and formalization of data necessary for developments related to the management of biological and natural resources, climate change and ecosystem resilience modeling.

**The practical significance of the** research is determined by the creation of the concept of digital transformation of the processes of monitoring the state of ecosystems, of which beaver families are a part. Based on this, a digital resource can be developed to provide state regulation and definition of works on management of objects and processes of restoration of the corresponding ecosystems.

## 2 Materials and Methods

The formulated problem in the research is unstructured, i.e. attributes and characteristics of resources, quantitative and qualitative dependencies between them are not precisely defined. Based on this, the objectives set in the research were carried out by using the method of system analysis. It provided an interdisciplinary approach to solving such a problem, which is related to organizational, economic, informational and technical aspects. As noted in research in which the design and development of software was carried out, using the method of system analysis establishes cause-and-effect relationships between objects, processes and their states, develops options for solving problems taking into account the constraints, risks or uncertain environmental conditions [7, 11, 12].

The procedures of abstraction, concretization, analysis, synthesis, formalization, composition, decomposition, structuring, classification, step-by-step refinement, modeling and verification were used within the framework of system analysis. The listed procedures

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are general scientific and are actively used in digital transformation of processes of different subject areas (for instance, agriculture [11-13], sustainable development of urban areas [7, 14], forecasting of environmental changes [15, 16]).

## 3 Results

Most often, a beaver family is a pair of adult parents with five to seven beaver cubs (however, there are single individuals) [Directorate for Specially Protected Natural Areas of Krasnoyarsk Krai: https://www.doopt.ru/?id=3811]. Individuals live in dens dug in steep banks. Under water they make tunnels several tens of meters long, ending with living rooms. If the territory is swampy, beavers build “huts”, which can reach up to three meters in height and ten meters in width (fig. 1).

**Fig. 1.** A beaver hut in a wetland (source weekly newspaper “Argumenty i Fakty”: https://aif.ru/society/nature/pochemu_bobry_stroyat_plotiny.)

For the safety of their dwelling beavers build dams to raise the water level in the reservoir, support and regulate its level. They are constructed below the beaver dwelling from tree trunks, branches, and brushwood bound with clay, silt, and other found materials. Sites where trees grow closer to the bank edge are used as dam sites. The shape of the dam depends on the current velocity, its length is 20-30 m, width at the base - 4-6 m, at the crest - 1-2 m, height on average reaches 2 m (cases up to 5 m have been recorded) [Bryansk Forest Reserve: https://libryansk.ru/bobrovaya-plotina.22841]. Fig. 2 shows an example of a dam built by beaver.

**Fig. 2.** Beaver dam (source Oksky State Reserve: http://oksky-reserve.ru/press/news/2017/03/16/news_264.html)

Determination of beaver settlement sites is an objective for monitoring the state of their population and the degree of its impact on the environment. Accordingly, one of the functions of the intelligent system should be to recognize such places in images. As analyzed data in this case can be both images from satellites and from unmanned aerial vehicles flying to monitor the state of forests or other types of farms. As noted in the analyzed works, the software implementation of such an approach requires a data model, which should be based on qualitative and quantitative characteristics of the object of observation [8, 16].

Access to such a possibility may be, for instance, for forestry specialists (national parks, wildlife sanctuaries or other natural objects) and regional government representatives dealing with natural resources. The need for forestry specialists to have access to such a function is justified by ongoing monitoring of the condition of territories or infrastructure (for instance, bearings of power lines, roads). Population data at the regional level is required to determine beaver quotas for hunters and to plan activities related to population management or land maintenance.

In addition, the collection of data on beaver locations makes it possible to form a regional or federal registry. To refine the data, in addition to results analysis of satellite or drone images, it is possible to add on-site photographs. Such images can be taken by hunters, forestry staff or other specialists who have discovered the place of the beavers' suspected residence. The intelligent system will automatically analyze the uploaded image and conclude whether the object belongs to beaver activity. If the results analysis is positive, a new record will be created in the database and a mark will be made on the map of beaver habitats.

Another key function of the intelligent system should be the possibility of predicting environmental changes from beaver activity. For instance, changes in the number of forest plantations. Beavers feed only on plant food: bark, leaves, rhizomes of aquatic plants, birch and willow shoots [Directorate for Specially Protected Natural Areas of Krasnoyarsk Krai: https://www.doopt.ru/?id=3811]. If the animal has no possibility to reach leaves, it fells these trees, the bark of which is nibbled and the trunk is used for dam construction.

The construction of dams increases the area of waterlogged areas, which affects the biodiversity of the respective areas. The consequences of such changes may have a negative impact on nearby agricultural facilities or other anthropogenic objects. For instance, in the Novosibirsk region, beavers have changed the course of a river over time. As a result, the river washed away a highway and the bearings of power lines, leaving two settlements without electricity [ForPost News Service: https://sevastopol.su/news/v-rossii-bobry-izmenili-ruslo-reki-obestochili-sela-i-utopili-tehniku].

The use of simulation models that make it possible to predict changes in the characteristics of objects under given conditions is actively used in the creation of intelligent systems associated with difficult-to-predict processes (for instance, in agriculture, environmental monitoring, etc.) [11, 13, 16]. Such models require qualitative and quantitative characteristics of objects located in the studied territory. Such characteristics may include: the number and composition of forest plantations; the volume of annual runoff, flow velocity, slope and drop parameters of a water body; the composition and number of individuals of inhabited animals, etc. The values of these indicators will need to be added manually to the system by a forestry specialist. This requires the development of a convenient user interface. Based on the data obtained and the simulation model used, the system will generate a forecast of changes in the state of the territory at a given time interval. Based on this, a decision should be made on the works to be performed to preserve the natural balance and exclude emergency man-made and natural situations.

Beaver is a commercial species, then the designed software product should provide information about the places where hunting is allowed and record its results. This makes it possible to control not only the beaver population, but also to monitor hunters' activities and make decisions on measures regulating the extraction of commercial animals.

## 4 Discussion

Software development is a complex process, which is a set of interrelated stages, the sequence, content and timing of which depend on numerous factors [10, 12, 14]. One of them includes the complexity of the subject area. As noted in works related to the creation of digital products in the field of agriculture or environmental monitoring, the difficulty of development is associated with the presence of random processes, the formalization of which requires a systematic analysis of numerous characteristics [4, 5, 9, 17]. All this justifies the importance and necessity of performing the requirements and subject matter analysis and design phases.

The presented work identifies the key functional possibilities of the software product and the list of users for whom they are available. In works devoted to the digitalization of various processes, it is noted that the results obtained in this way are the basis for functional and operational specifications [4, 7]. The validity of such results is explained by the correct use of the stated research methods and consistency with the research related to beaver life activity and its impact on the natural and anthropogenic environment.

## 5 Conclusions

There is no consensus among researchers about the regulation of the beaver population. They agree that it is necessary to monitor their vital activity in order to prevent or reduce the negative impact on the ongoing transformation of ecosystems and anthropogenic objects. This can be done only with the use of specialized software capable of analyzing large amounts of data in real time and making effective decisions on the management of relevant processes based on the data obtained.

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