Information system using computer vision technology for innovative beekeeping development

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Abstract. The article substantiates the necessity of introducing modern digital technologies into beekeeping processes to systematize and improve the efficiency of the relevant processes of management, control, and organization of operations. For this purpose, an information system has been developed to organize the interaction of beekeepers with state authorities and consumers of products. In addition, using computer vision and Internet of Things technologies in the system, control over the state of apiaries, and works carried out, a system of recommendations for its effective maintenance is formed.

1 Introduction

Around one-third of the world’s food production depends on bees, as they produce honey and pollinate plants, increasing their yield [1]. In addition, cosmetics and medicines are produced based on royal jelly, wax, and venom [2, 3]. Accordingly, it is possible to profit from bee products when organizing a highly efficient apiary. For example, according to statistics, the demand for honey increases yearly due to its use as a sugar substitute [1, 4].

The organization of an effective apiary requires the fulfillment of many conditions related to the selection of bee families, considering the climatic peculiarities of the region, the location of the apiary site and its surroundings (e.g., proximity to agricultural honeybees, wild nectar-bearing or pollen-bearing bees), etc. It is required to constantly monitor the condition of the bee family (e.g., they may be poisoned by chemicals sprayed on the fields), maintain favorable conditions in the hive, maintain the site following seasonal and current weather changes, and ensure that there are no pests that can damage the hive or the bee family [3]. All this requires significant time, labor, and material resources. Using technical and software tools that can partially or fully automate the beekeeper’s activities will increase the efficiency of the apiary.

The development of information technologies and expert systems allows solving the above problems in beekeeping. Thus, the development of an information system can systematize and unify the processes of organizing the activities of a beekeeper at the apiary using information technologies of business process management [5-7]. The integrated use

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of sensors and surveillance cameras for automatic image recognition using computer vision or pattern recognition technologies makes it possible to create an electronic assistant capable of monitoring the current status of objects in the apiary. Such technologies are actively used to modernize different sectors of the national economy to increase labor productivity, economic growth of indicators, and competitiveness of the respective organizations [8-10].

The study aims to develop an information system capable of organizing and controlling processes related to beekeeping. This requires formalizing the problem domain by including all key stakeholders and their responsibilities in such a model. Based on this model, develop and implement an information system architecture. For convenient use of its functional capabilities, it is necessary to create a graphical user interface with a description of the functionality of its elements.

The study’s theoretical significance lies in the systematization of data related to organizing specialists’ activities in the beekeeping field, creating a model of processes suitable for use in other research, and developing software tools. The study’s practical significance lies in developing a software product capable of state, regional, and individual control of beekeeping, demonstrating the achievements of beekeepers and attracting investment in the development of the industry.

2 Materials and methods

A list of key objects and processes specific to beekeeping was required to create a formal model. In studies in which one of the tasks was the formalization of the subject area, methods of structural analysis and step-by-step specification of the research object were used [11, 12] with the subsequent application of the information modeling method to the obtained results [13].

The obtained models were used to create algorithms for information system functioning [14, 15] and to implement computer vision technologies. A data model consisting of multiple object instances with corresponding quantitative characteristics was required to increase the accuracy of the result of such technology [16].

Object-oriented programming methods were used to create the user interface and information system modules related to the management and control of processes. They are used to establish all classes of objects and their behavior depending on the initiating events [5, 7, 14].

3 Results

Structural analysis of the problem domain showed that the main objects involved in the organizational processes of beekeeping are:

1. State authorities of Russia engaged in the development and organization of programs for the industry, as well as the execution and maintenance of veterinary and sanitary passports of apiaries.

2. Associations of beekeepers participating in the formation and implementation of state policy for the development of the industry by providing government authorities with the necessary data, generalizing and disseminating the achievements of science and technology, and domestic and foreign experience.

3. A beekeeper is directly involved in organizing the apiary: its preparation, attracting bees to the hives, maintaining the hives properly, treating and preventing bees from diseases, collecting honey and other products produced by insects, etc.
Based on this, the categories of users of the developed information system are defined. This means that each user must go through the system’s registration procedure, and certain functionalities will be available depending on the established access rules of his role. Multiple roles can be available to the same user at the same time. Let us describe each role’s functionality with a demonstration of the user interface images.

A representative of a government authority of a constituent entity of Russia (Controller). A user with this role can view information about every apiary in the region entrusted to him. This means he can view a list of all associations and beekeepers, know where an apiary is located and who owns it, how many hives are located, and other statistics about each apiary. For easy viewing of relevant information, the labels of all apiaries are placed on a geographical map with the possibility to filter labels by different conditions or to perform a full-text search. The user interface is designed as a web page and is shown in Figure 1.

![Fig. 1. Interactive map of apiaries.](image1)

When selecting an apiary, the Controller can automatically generate or request a report on the farm’s activity.

Beekeepers Association Representative (Observer). The functionality of the Observer is similar to that of the Controller. A user with this role can create events to promote the industry, sell finished products, and add, modify, or delete descriptions from the electronic directory. Such a handbook stores recommendations on organizing apiary activities, methods of bee care, and other background information on the objects and processes of beekeeping. Figure 2 shows a fragment of the directory image available in the web-oriented version of the information system.

![Fig. 2. Fragment of an electronic guide to beekeeping.](image2)

Such an electronic directory is available to all users of the information system.
The beekeeper is the owner of an apiary. Based on this, all information about his household is available to him. When a user with this role is logged in, a window opens with the map centered on the location of his apiary, as shown on the mobile application screen Figure. 3.

![Fig. 3. Beekeeper mobile app screen with apiary map.](image)

This map shows all the hives located on the plot. Clicking on each label opens a tooltip with a brief description of the status of the corresponding hive. This information includes the temperature inside the hive, the humidity, and mass. The user must click the arrow to view detailed information and change parameters. A window will open, graphically showing the change in hive weight over the selected time period, temperature and humidity inside and near it, bee count, etc. A real-time view shows the current status inside and outside the hive (with sound). Obtaining up-to-date data to generate statistics is only possible if there are installed sensors inside the hive and in the apiary and cameras. In addition to statistical information about the hive, it is possible to view a list of tasks that have been completed or are pending. Additionally, information about insects seen near the hive is shown. Figure 4 shows the corresponding screen of the mobile application.

![Fig. 4. Mobile application screen describing the status of the hive in the apiary.](image)

Insect recognition is accomplished using computer vision technology. The image captured from the camera located in the area of the arrival board is recognized, and a text
A description is captured in the database. An event is only fixed if it has a deviation from the standard. For example, a pest that threatens the bee family or the condition of the hive has been detected. At this point, a warning is sent to the Beekeeper.

In addition, if an apiary perimeter camera is installed, the data on trespassers and pests is captured, and a notification is sent to the Beekeeper.

Object recognition is also possible in free manual mode. For example, a beekeeper can point a cell phone’s camera with a mobile app installed at an object. The use of pattern recognition technology on the image will allow to establish with some accuracy the object’s belonging to certain insect species, as shown in Figure 5.

![Fig. 5. Mobile application screen for insect recognition.](image1)

Guest. The mobile app allows an unregistered user to access certain functionality to popularize beekeeping. He can view background information about insects, basic information about apiary structure, activities carried out by beekeepers to sell finished products and use the insect recognition tool (as shown in Figure 5). Additionally, the Guest can get background information on the recognized insect (Figure 6).

![Fig. 6. Mobile application screen with the insect description.](image2)

Such a description, for example, will help to know how aggressive the insect is, what consequences the bite causes, etc.
**Worker.** If the apiary is large or the *Beekeeper* is outsourcing the work, they may be assigned the role of Worker. Users with this role have access to a work calendar option, the content of which is determined in a mixed mode. Thus, part of the tasks can be assigned by the *Beekeeper* and part by the information system. The information system determines the task based on the data received from the installed sensors (e.g., when honey harvesting is required, temperature conditions need to be adjusted, etc.). The system automatically prioritizes tasks and arranges them accordingly in the general list (from top to bottom, from most to least important). Figure 7 shows the mobile application screen with the list of tasks in the apiary.

![Fig. 7. Mobile application screen with a list of tasks in the apiary.](image)

Tasks assigned in manual mode are marked completed by the *Worker*. Tasks defined by the system based on sensor readings are completed after analyzing the change in the corresponding indicators. Periodic tasks related to seasonality weather changes (even if received from external sensors) are considered completed when their status is changed by the *Worker*.

**Owner.** If there are no users on the apiary who fulfill the role of *Worker*, the roles of *Worker* and *Beekeeper* are combined for the convenience of using the resources and capabilities of the information system. This allows us to see the current status of the apiary and the tasks that need to be performed in a single profile.

4 Discussion

As a result of fulfilling the tasks formulated based on the established goal, a software product that systematizes and unifies the processes occurring in the apiary for the efficiency of their implementation was obtained. In addition, one resource brings together consumers and suppliers of beekeeping products, as well as bodies that control activities in the industry. This simplifies the exchange of reporting documents and unifies their content [17]. All the above results coincide with those obtained in related studies [5, 6, 14].

The distribution of functionalities depending on the user’s role in the system allows for organizing efficient access to resources, confirmed in several studies [15, 16]. Developing a graphical user interface that provides several types of display depending on the user’s role and usability of functionalities is in line with the results of modern software product development [7, 9].

It should be noted that the obtained software product can be used as a tool for training specialists in beekeeping. This finds confirmation in the studies related to the organization
of practice-oriented learning in organizations of secondary special and higher education [18-20].

5 Conclusion

Beekeeping contributes significantly to producing berries, vegetables, fruits, plant seeds, and fodder crops by pollinating entomophilic crops. Thanks to pollinating bees, yields of specific crops are significantly increased, and the quality of seeds and fruits is improved. For this purpose, bees are kept in a multitude of agro-industrial complexes. In addition, the products of bee activity are actively used to produce food, cosmetics, and medicines. Beekeeping is also developed in the private sector. All this demonstrates the need to develop the industry.

The developed software product combines modern digital technologies and processes related to the organization and control of activities in the beekeeping industry. All this allows us to realize the concept of “smart apiary” and the Internet of Things, combining computing devices into a single network for data collection and transmission for further processing and development of management decisions with minimal human involvement in these processes.

References

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