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PROBLEMS OF RECOGNITION OF OBJECTS IN PICTURES

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Abstract
The article is devoted to the issues of object recognition in the image. The article provides information on the intermediate images of the images used in the recognition process and their approaches in determining the quality criterion. The effectiveness of the proposed method of recognizing land use objects is demonstrated in the example of a reservoir image using a new hybrid algorithm to identify surface water resources and their mineralization using satellite and drone images, and to identify images of agricultural plant species and increase the accuracy and reliability of satellite image classification. Recommendations for the creation of a system for the identification and monitoring of water bodies, systems and types of agricultural crops of the Republic of Uzbekistan using GIS technology.

Keywords: Image, recognition, pixel, intermediate image, correlation, symbol, syntactic, normalization, satellite.

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Annotatsiya
Maqola tasvirda ob`yektlarni tanib olish masalalariga bag‘ishlangan. Maqolada tanib olish jaryonida foydalanilgan tasvirlarning oraliq tasvirlari va sifat mezonini belgilashdagi yondoshuvlari haqida ma’lumotlar keltirilgan. Sputnik hamda dron imeydjlari yordamida yer usti suv resurslari va ularning minerallashuvini aniqlash hamda qishloq xo‘jaligi o‘simliklarining turlari tasvirlarini tanib olish va sun’iy yo‘ldosh tasvirlari tasnifining aniqligi va ishonchliligini oshirish uchun yangi gibrid algoritmi yordamida suv ombori tasviri misolida, yerdan foydalanish obyektlarini tanib olishning taklif qilingan usuli samaradorligi ko‘rsatilgan. Tanib olishda GIS texnologiyalari yordamida O‘zbekiston Respublikasi suv xo‘jaligi obyektlari, tizimlari va qishloq xo‘jiligi ekinlarini turlarini tanib olish va ularning monitoringini olib borish tizimini yaratish bo‘yicha tavsiyalar keltirilgan.

Kalit so‘zlar: tasvir, tanib olish, piksel, oraliq tasvir, korrelyatsion, belgili, sintaktik, normallashtiriish, sun’iy yo‘ldosh.

ПРОБЛЕМЫ РАСПОЗНАВАНИЯ ОБЪЕКТОВ НА ИЗОБРАЖЕНИЯХ

Аннотация
Статья посвящена вопросам распознавания объектов на изображении. В статье представлена информация о промежуточных изображениях изображений, используемых в процессе распознавания, и их подходах к определению критерия качества. Эффективность предложенного метода распознавания объектов землепользования продемонстрирована на примере изображения водохранилища с использованием нового гибридного алгоритма для определения ресурсов поверхностных вод и их минерализации с помощью спутниковых снимков и изображений с дрона, а также для идентификации изображений видов сельскохозяйственных растений и увеличения точность и надежность классификации спутниковых снимков.Рекомендации по созданию системы идентификации и мониторинга водных объектов, систем и видов сельскохозяйственных культур Республики Узбекистан с помощью ГИС-технологий.

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Ключевые слова: изображение, распознавание, пиксель, промежуточное изображение, корреляция, символ, синтаксис, нормализация, спутник.

Introduction

At present, as the storage capacity of data devices continues to grow, the proportion of information contained in images is also increasing. At the same time, the problem of accessing image content has become extremely urgent, since its solution requires the recognition of images according to a standard. Such a procedure is necessary both for organizing search processes and for recognizing objects. In recent years, GIS technologies capable of storing and processing satellite and drone imagery have been actively applied to identify terrestrial water resources and analyze their mineralization levels.

The complexity of solving the problem of object recognition in images has led to the development of numerous methods. Due to the diversity of existing approaches, questions arise regarding their similarities, differences, and effectiveness in solving specific problems.

— Literature Review. Existing image representation methods constitute one of the core components of recognition systems [1]. Since it is impossible to construct an exact mapping from the numerical values of the image pixels to the semantic feature space of the scene, it becomes necessary to introduce certain intermediate levels of image representation [9]. Such a system is typically understood as a formal model that includes algorithms for deriving explicit characteristics of objects belonging to a particular class [2]. Accordingly, the process of object recognition from images can be interpreted as a sequential transformation of data — beginning with the initial representation of the image as a pixel array, passing through a series of intermediate representations, and concluding with the semantic description of the image [10].

Intermediate image representations can be classified into the following types [3]:

- low-level;
- symbolic;
- contour-based;
- structural.

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Knowledge-based image representations may be considered as the final stage in image recognition problems. Knowledge-based approaches are typically distinguished as a separate group [4]. The key characteristic of such methods is that the knowledge-driven representation is used not only as the output of the recognition system, but also directly within the recognition process itself. In other words, these approaches operate under controlled data flow, either "top-down" or conversely "bottom-up", depending on the supervision mechanism.

Hierarchical methods can also be classified as a separate group [5], with the possibility of simultaneously utilizing several of the aforementioned intermediate image representations.

In addition to the question of which intermediate representations are used in the recognition process, another important aspect arises — how image descriptors are constructed within the chosen representation space. At this point, we can define the criterion of descriptor quality as the highest-level characteristic of recognition methods, since it determines which features of the image are formed within a given representational framework. The most common approaches to defining a quality criterion include:

• heuristic;
• Bayesian;
• entropy-based [5];
• theoretical and informational approaches [6].

The choice of intermediate representation type and the method of defining a quality criterion does not constitute a complete description of the image recognition methodology — rather, it is a part of the optimization algorithm for the quality criterion itself [7]. However, due to the insufficient theoretical study of this problem, the systematization of this component remains a relevant research challenge today.

— Research Methodology.

Despite the diversity of approaches, image recognition methods can generally be divided into three groups. The first relies on direct comparison with a reference (standard); the second is based on feature space analysis and processing models; and the third studies the “structure” of images (the so-called syntactic approach). In practice, the first two classes are often combined into a single group.

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The final stage of image processing is recognition. The input to this stage is the set of images obtained after noise reduction and segmentation. Typically, these images differ from the reference standards in terms of geometric distortions, illumination variations, and residual noise.

Four main methods are predominantly used to solve image recognition problems:

1. Correlation Method.

This approach is based on making decisions according to the criterion of similarity to reference images. It is widely used in navigation systems for image identification and tracking, as well as in various economic sectors — particularly in water management, where satellite imagery is analyzed to identify vegetation types, salinized soils, and the volume of water resources. It is also one of the most computationally expensive approaches, as it requires scanning the input space and performing multistage cross-correlation with the reference database. In other words, it consists of enumerating all input signals and comparing them with the corresponding reference templates. Below is a schematic representation of object recognition using the correlation method.

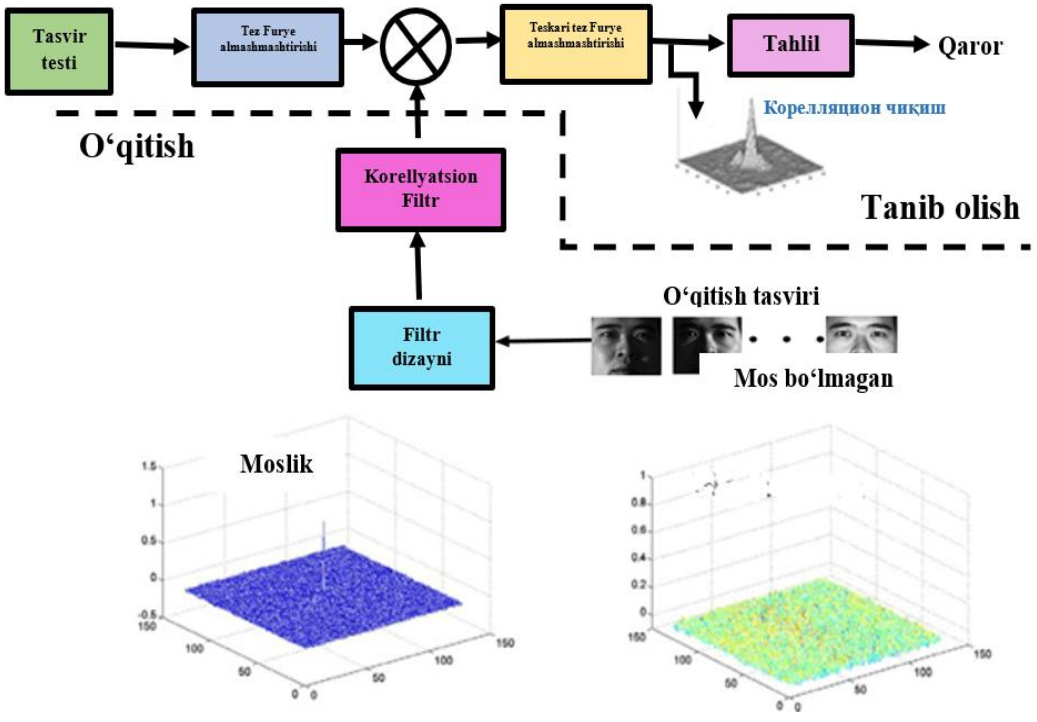

Figure 1. Correlation-based object recognition scheme

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Feature-based approach

These methods are based on transitioning into the feature space and therefore require significantly less computational effort. Depending on the task, correlation-based processing is applied to the features extracted from both the reference and the input image. This leads to the problem of merging and jointly processing heterogeneous feature types of different scales obtained from various measurement tools (metric, statistical, logical, textural, etc.) to solve the recognition task.

A feature is defined and computed as a function of the value(s) from one or multiple pixels, representing numerically some important characteristic properties of the object. Image features may be classified as follows:

1. **General (generic) features** — practical properties such as color, texture, and shape. These are further subdivided into:

• **pixel-level features** — computed at every pixel (e.g., color, position);

• **local features** — computed within a specific window or a limited region of the image;

• **global features** — computed over the entire image, usually statistical measures such as histogram, mean, variance, and higher-order moments.

2. **Application-specific features** — related to domain-driven characteristics, such as plant species, water management structures, geosystems, etc. These are formed based on the general features but tailored to a specific field of study.

Moreover, all features can be conditionally divided into **low-level** and **high-level** categories. Low-level features can be directly extracted from the original image, while high-level features are derived based on the low-level ones.

The **correlation–feature hybrid method** involves statistical processing of extracted features. Initially, a **partial correlation method** is applied to different segments of the reference image; subsequently, the correlation coefficients obtained in the signal domain are treated as feature descriptors.

The **core problem in feature-based methods** is the selection of optimal features. They are generally derived based on the following natural criteria [8]:

• Features of images belonging to the same class may slightly differ (due to noise and interference).

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• Features of images from different classes must differ significantly.
• The feature set must be minimal (as reliability, complexity, and processing speed depend on the number of features).

The **syntactic approach** is based on extracting structural and grammatical features. If distinguishable elements (features) are isolated in the image, a set of rules is introduced to link or compose these elements — with identical rules applied to both the reference and input images. The analysis of the resulting grammar provides the basis for decision-making.

Each recognition approach has its right to exist, and each possesses its own set of algorithms adapted to specific application domains — depending on the nature of the differences between reference and input images, environmental interference in the observation area, computational capacity, and decision-making speed requirements. In the theory of image recognition, **feature-based** and **syntactic** methods remain the most widely adopted approaches.

Normalization

The task of image normalization is defined as determining the parameters of geometric transformations that completely align the image. In practice, this is achieved algorithmically by altering the spatial position of the image acquisition system or by applying an inverse transformation to the input image. The transformation procedure is carried out using normalization operators — known as normalizers — while the calculation of transformation parameters is determined by functionals operating on a set of images.

Normalization methods in image recognition occupy an intermediate position between correlation-based and feature-based algorithms. Unlike in the feature-based approach, the image itself is not analyzed during normalization; instead, it is replaced by another image belonging to the same equivalence class. However, unlike correlation-based methods, the input images are replaced by multiple normalized variants. Each normalized image is typically closer to its reference standard (in terms of group transformations), which significantly reduces the number of correlations required in the final recognition stage.

At present, the most promising direction in normalization theory is the class of **sequential methods**, based on the stepwise computation of complex

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transformation parameters and the use of **partial normalization operations** at each stage. Figure 2 presents the general diagram of the image recognition procedure.

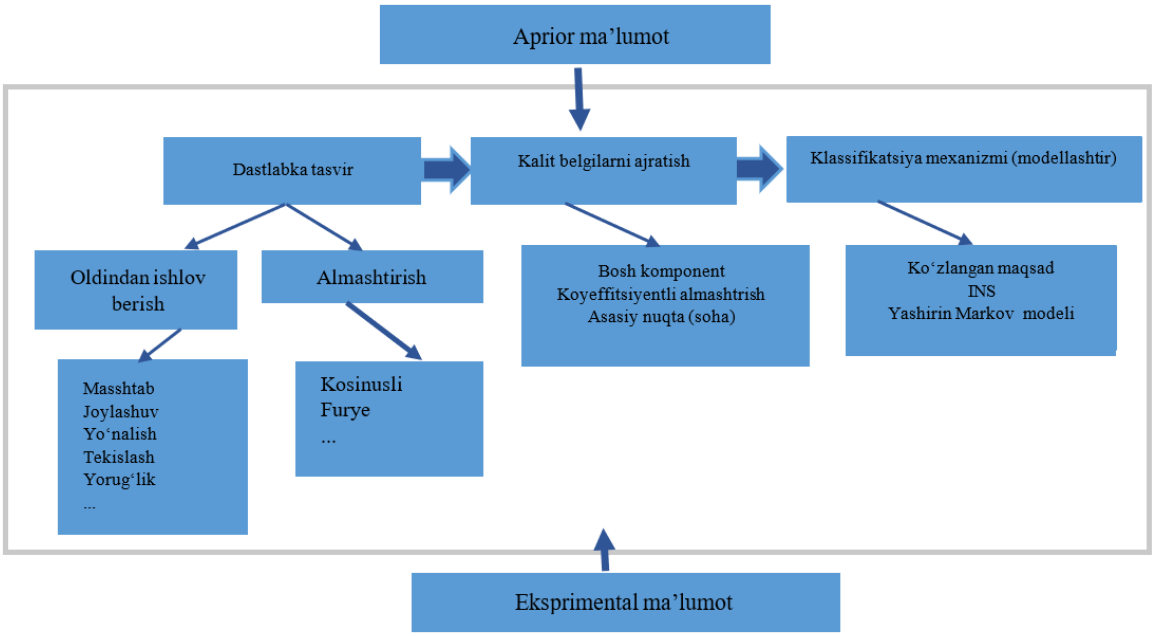

Figure 2. General scheme of the image recognition process

Analysis and Results

In image-based object recognition, satellite and drone imagery enables the detection of surface water resources, determination of their mineralization levels, as well as recognition of various agricultural crop types. Furthermore, it becomes possible to compute the characteristics of surface water resources and assess their mineral composition using meteorological station data combined with accurate mathematical models [11].

To improve the accuracy and reliability of satellite image classification, a novel hybrid algorithm is proposed [12]. The efficiency of the proposed method for recognizing land-use objects is demonstrated below using the example of a reservoir image, as shown in **Figure 3** [13].

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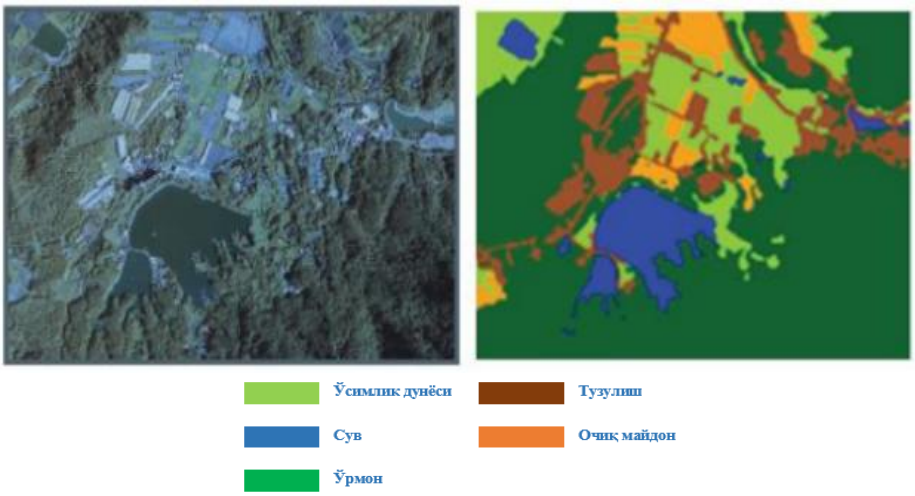

Figure 3. Aerial view of the area and the result of image analysis

Using the above-mentioned models and GIS technologies, it becomes possible to develop a monitoring system for water management infrastructures, hydraulic systems, and agricultural crop fields within the Republic of Uzbekistan — as illustrated in **Figure 4** [10].

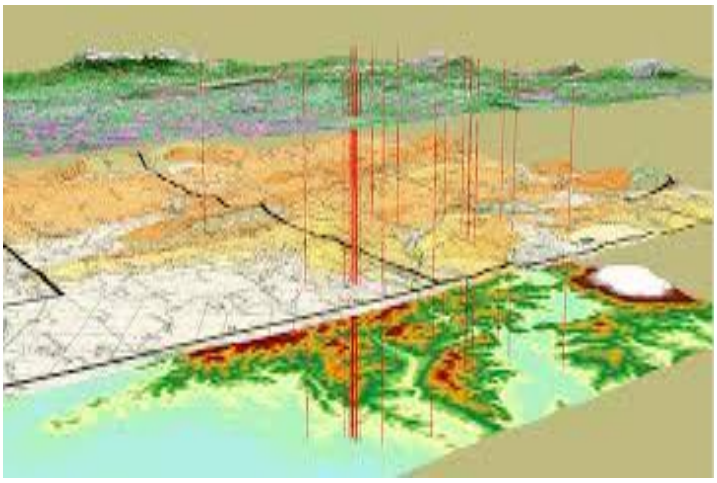

Figure 4. Recognition of agricultural crop types using satellite and drone imagery

— Conclusion and Recommendations.

The study of object recognition in images allows us to draw the following conclusions:

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1. The types of intermediate image representations used in the recognition process were identified, and their roles within the recognition pipeline were analyzed.
2. Various approaches to defining the image quality criterion — including heuristic, Bayesian, entropy-based, theoretical, and information-theoretic methods — were presented and their strengths and limitations were evaluated.
3. The following methods for solving object recognition problems in images were studied and analyzed:
4. • Correlation-based;
5. • Feature-based;
6. • Correlation–feature hybrid;
7. • Syntactic;
8. • Normalization methods.
9. Using the example of a reservoir image, the effectiveness of the proposed recognition method for land-use objects was demonstrated, and recommendations were provided for developing a monitoring system — based on GIS technologies — for identifying and tracking water management infrastructures, hydraulic systems, and agricultural crop types in the Republic.

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