Image processing system in conditions of uncertainty and the training of its operator

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Abstract. In modern information systems, decision making based on image processing is hampered by the impact of negative external and internal factors leading to image blurring, which introduces uncertainty in this process. In this regard, algorithms and models are used to reduce the effect of uncertainty in image analysis. The article presents a new adaptive algorithm for image processing in different wave bands. The article also presents the results of research on the training of operators of image processing systems in conditions of uncertainty. It is proposed to train the operators of these systems on the basis of a competence-based approach using an information system that allows you to create individual training paths for the operators. The implementation of the training information system is proposed to be made on the basis of a web service.

1. Introduction

Quite often, when monitoring the surface of the earth, analyzing the quality of fruit and vegetable crops and the integrity of construction objects, etc., with the help of video, photography, researchers face the problem of poor image quality, and when monitoring the surface of the earth, it is also impossible to observe subsurface objects. These problems can be solved by developing an algorithm.

This algorithm is used in the operator-controlled image processing system. In order for the image processing system to work correctly, the operator must have a certain set of knowledge and skills, and therefore the task of improving the quality of the training of the image processing system operators is updated.

2. Image processing algorithm

Image analysis is the process of extracting the necessary information from an image using automatic systems. In image analysis, the contours of image objects play a huge role. Outlines carry all the basic information about the elements of the image, which is weakly dependent on color and brightness. A contour is a spatially extended discontinuity, a drop, or an abrupt change in brightness values [1].

The developed adaptive algorithm is based on three criteria:

- The selection of the maximum possible number of true boundaries and the minimum number of false boundaries.
- Pixels selected as boundary should be located as close as possible to the true position of the border.
- Unambiguous response to each boundary [2].

2.1. Stages of the Algorithm

The algorithm is performed in 6 stages.

Stage 1. Preliminary stage. Convert the image to grayscale. For this, the YUV model is used [3].

Stage 2. Noise filtering. To reduce the negative effects of blurring the image, noise filtering is necessary. In the algorithm for filtering noise is applied image smoothing. As a smoothing filter, the algorithm uses a Gaussian function [4].

Stage 3. Calculation of values and directions of the gradients. The gradient values in pixels are calculated in four directions: vertical, horizontal and two diagonal. The vector angle is rounded and takes one of the following values: 0, 45, 90, or 135 degrees. The Robinson operator [5] is used to calculate the values of gradients in the modernized Komi algorithm. It is enough to get the result from processing the first four tasks, the rest can be obtained by inverting the first:

\[
\begin{align*}
\mathbf{r}_0 &= \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, \\
\mathbf{r}_1 &= \begin{bmatrix} 0 & 1 & 2 \\ -2 & 1 & 0 \\ -1 & 2 & 1 \end{bmatrix}, \\
\mathbf{r}_2 &= \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}, \\
\mathbf{r}_3 &= \begin{bmatrix} 2 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 2 \end{bmatrix}, \\
\mathbf{r}_4 &= \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}, \\
\mathbf{r}_5 &= \begin{bmatrix} 0 & -1 & -2 \\ -2 & -1 & -2 \\ -1 & -2 & -1 \end{bmatrix}, \\
\mathbf{r}_6 &= \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix}.
\end{align*}
\]

Stage 4. Suppression of the non-maximums. Pixel boundaries are pixels in which a local maximum gradient is reached in the direction of the vector of this gradient. The color characteristics of RGB of such pixels get values (0, 0, 0), which in the model YUV means black. The color characteristics of the RGB of all other pixels get the values (255, 255, 255), which means white in the YUV model [6].

Stage 5. Dual threshold filtering. All pixels that are local maxima in step 4 pass through two user-defined thresholds \( T_{\text{min}} \) and \( T_{\text{max}} \). If the gradient value of a pixel is higher than the upper threshold \( T_{\text{max}} \), then the border in this pixel is reliable, the pixel is the limit. If the gradient value of a pixel is below the lower threshold \( T_{\text{min}} \), then the pixel is suppressed, i.e. pixel receives the values of the color characteristics of RGB (255, 255, 255) and becomes an element of the set of Pixels, whose gradients fall between two thresholds, take a fixed average value and are processed at the final stage [7].

Stage 6. Tracing the ambiguity. At this stage, pixels are processed, the gradients of which are in the range between the thresholds. Selection of groups of pixels is done. Then, a check occurs: if a group of pixels connects to one of the existing boundaries, then the whole group is added to the border; if the group of pixels does not touch any boundary, then it is suppressed. Adding a pixel to a group is carried out according to the following principle: if a pixel is in contact with a group of pixels in one of eight directions, it is added to the group. All pixels that are not in the group are suppressed. This stage is performed using the algorithm developed by us [8].

2.2. The results of the algorithm

Figures 1-2 show the results of the work of the adaptive algorithm in the recognition of IR images.
Advantages of an adaptive algorithm are:

- minimization of the multiple responses to the filter;
- increase in the number of found boundary points;
- improved recognition performance on noisy images, due to anti-aliasing;
- availability of experimentally established optimal values of the parameters of the algorithm;
- the ability to work in real time [9-10].

3. Training of the image processing system’s operator

The evaluation of the quality of the training of the image processing system’s operator only by the amount of the knowledge that he reproduces does not allow him to determine his readiness for independent professional work, since the operator of such a system often does not need repetitive actions, but actions depending on the situation, and therefore, when training image processing system’s operator, it is advisable to use the competence approach.

Competence approach is a set of general principles for determining training objectives, selecting the content of the training system, organizing the training process and evaluating the results of training. When using the competence approach, the main focus is on the formation of needs for the constant replenishment and updating of knowledge, the improvement of skills and abilities, their consolidation and transformation into competences.

The task of providing the operator with the required quality of operation of the image processing system is defined as follows:

\[ Z = \langle P, M_{act}, M_{req} \rangle, \]  

(2)

where \( M_{act} \) – the current (actual) model of the state of the system, \( M_{req} \) – model of the required system’s state, \( P \) – algorithm of actions for transferring the system from the current to the required state:

\[ P = \langle N_S, A_S, O_S, S_S \rangle, \]  

(3)
where $N_S$ – set of the elements of the system, $A_S$ – set of typical operations on the system, $O_S$ – set of relationships of the system, $S_S$ – branch of states of the system [11].

The algorithm used now assumes that the image processing system’s operator has all the necessary skills, knowledge and skills, but this does not always correspond to reality, especially at the preparation stage, and as a result of the study of the problem of improving the quality of operators training, a set $K_{req}$ of the elements were introduced, of which are the operator’s competencies and are necessary (required) for a correct system operation:

$$P = \{N_S, A_S, O_S, S_S, K_{req}\}.$$  \hspace{1cm} (4)

Within the framework of training, competences are divided into current ($K_{act}$) and required ($K_{req}$), and the task of training is to ensure that the required competencies are included in the set of current competencies of the operator.

Unlike the traditional training model, where the task of the future specialist is to master the sum of discrete knowledge and skills that are not always associated with real practical activities, the competence approach focuses on the result of training and puts the future ID operator with its needs at the center of the process, abilities and interests, which leads to the question of the formation of an individual training trajectory.

The formation of an individual trajectory involves the construction of such a model of training, which would be focused on a particular person with his individual abilities, characteristics of perception, receiving and mastering the material, interests and needs. That is why the building of individual training trajectories makes it possible to fully take into account the individual abilities and capabilities of the image processing system’s operator and helps to achieve the most effective results.

In the formation of an individual trajectory for the preparation of the image processing system’s operator, the use of simulation methods is effective. The basis for constructing a simulation model for preparing an image processing system’s operator is the methods of the set theory, on the basis of which an analytical model was developed for preparing an image processing system’s operator, which is presented below.

The image processing system’s operator is presented in the form of its current competencies ($K_{act}$) and personal qualities ($C_O$):

$$O = [K_{act}, C_O].$$  \hspace{1cm} (5)

The preparation of the image processing system’s operator – is an informational impact on it, the set of variants of which is defined as $A$:

$$A = [F, H, V].$$  \hspace{1cm} (6)

where $F$ – branch of training’s forms, $H$ – branch of training’s methods, $V$ – branch of control’s forms.

A set of options for informational impact on an image processing system’s operator consists of a set of forms and methods of preparation and forms of control, which are determined by the function $S$, based on the personal characteristics of the operator:

$$S = f(A, C_O).$$  \hspace{1cm} (7)

The selected forms, training methods and forms of control are one of the arguments of the function of changing the state of the student $T$, which also includes the operator’s current competencies, as a variable, and the required competencies, as a reference for current competencies:

$$T = f(K_{act}, K_{req}, S).$$  \hspace{1cm} (8)
The formation of individual trajectories during training carries a significant additional load on both the future operator and his training instructor, however, the information system easily handles this task, and automating the training information system further reduces the load on the instructor.

The method of implementing such an information training system depends on the available capabilities and goals. As an example, below are the advantages of the operator training information system implemented on the basis of a web service.

As the analysis of didactic features, functions and properties of information systems has shown, only the web-service-based training system combines in its didactic potential the signs of instrumentality and interactivity, the interactive function and properties of openness, independence, cross-platform, functionality and flexibility [12-15]. Based on this, the operator training information system implemented on the basis of a web service will have the following advantages:

- the use of the training system at a convenient time and in a convenient location on any device, regardless of its software, including on a mobile phone;
- the ability to actively interact with the participants of the training process with the system and with each other;
- the use of individual training trajectories with the possibility of their subsequent adjustment based on the success of the training object, as well as the possibility of participants influencing the training process;
- the ability to edit the training material using a technical component that does not require special knowledge in the field of information technology, as well as creating a new one based on existing templates;
- the display and the transfer of information not only in text, but also in graphic, audio, video, animation format, as well as the use of interactive elements, which allows the use of most of the sensory components of the operator;
- the possibility of training and control for an unlimited number of participants who work in a computer environment in accordance with their personality-oriented model;
- at the same time to use the system of training of operators by participants of several levels of training, but taking into account their age and psycho-physiological features;
- the free and fast navigation through the training material, the possible transitions from one section to another, as well as on additional resources of the Internet on the covered problems.

4. Conclusion

Software implementation of the Kanni algorithm allows you to select objects, both on clear and blurry images, and also recognizes the elements of these objects in images.

The results of the study should be applied in technical vision systems for searching and monitoring environmentally hazardous objects.

The quality of research is influenced by such parameters as the resolution of images of the infrared range of the instrument, the range of the instrument, angle of shooting, and weather conditions. The main hindrances in image analysis are third-party heat sources entering the frame: residential buildings, equipment, living objects.

The results of the study showed that it is necessary to work out the software code of the algorithm to reduce the rounding of the corners of the borders of objects, which leads to damage or destruction of the boundaries at the junction points.

For the correct operation of the image processing system, in which this algorithm is used, its operator must possess a number of necessary competences obtained as a result of professional training.

In training the image processing system’s operator, it is advisable to use a competency-based approach using a web-based information system with the possibility of creating individual training paths for operators. Thus, the use of the competence approach allows the future image processing system’s operator to obtain the competences necessary for its future working activity, the formation of individual training trajectories using a centralized information system, that makes the training process
more efficient, and its implementation on the basis of a web-service what facilitates quality achievement of set didactic goals.

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