Information system for detecting low-flying air targets and predicting support trajectory

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Abstract

The objective of the paper is to create the information system for computer perception of scenes by developing models of computer perception, methods and architectures for adaptive processing of video streams in computer vision systems aimed at intelligent data processing and its parallelization. The main expected results are as follows: development of methodology for recognizing poorly formalized objects in heterogeneous field of attention in real time; method for separating partially overlapped objects; investigation of the methodology for quality assessment and its development particularly, the selection of the most effective method and improvement of the existing one for quality assessment in computer vision systems, as well as the development of hardware-oriented method for parallelizing video streams based on thermal representation of algorithms; method for synthesizing computer vision system architectures based on the spatial-time algorithms display.

Keywords

trajectory, definition, image, identification, computer vision

1. Introduction

The development of image recognition systems remains complex theoretical and technical problem. Image recognition is used in various fields, including military, security, and digitization of various analog signals (e.g., automobiles with image recognition).

The perception of phenomena in the form of images plays significantly important role in the processes of cognition of the external world. In the preces of biological evolution, many animals solved the problem of image recognition quite well due to their visual and auditory apparatus. As follows from the definition of "recognition" of new objects itself , the learning process precedes it. During learning, creatures get acquainted with a certain

CITI'2024: 2nd International Workshop on Computer Information Technologies in Industry 4.0, June 12–14, 2024, Ternopil, Ukraine

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number of objects and, in addition, receive information from the source about what image each of these objects belongs to. This process is called “learning with a teacher” [1].

More general is “learning without a teacher”, where the system learns spontaneously and performs the assigned task without the intervention of the "teacher". Machine learning without a teacher is formulated as the problem of cluster analysis [2]. For such case, the sample of the objects is divided into clusters (sets having empty intersection) in such a way that each cluster consists of “similar” objects, and different clusters are “significantly” different from each other [3].

Clustering is often used as an auxiliary means for solving classification and regression analysis problems. Some algorithms of classification problems solution combine both learning with a teacher and learning without a teacher [4].

Traditionally, image recognition tasks are included in the range of artificial intelligence tasks. Two main areas are distinguished:

- study of recognition abilities possessed by living beings, their explanation and modeling [5];
- development of the theory and methods of constructing devices designed to solve specific problems for applied purposes [6].

The formal statement of the problem of image recognition is the assignment of the original data to a certain class by means of the selection of significant features characterizing this data from the total mass of non-essential data. While stating the recognition problems, they try to use mathematical language

For optical image recognition, the method of sorting the object view at different angles, scales, shifting, etc can be applied. Another approach is related to finding the contour of the object and investigating its properties (connection, presence of corners, etc.).

Another approach is to use artificial neural networks (multilayer perceptrons, quantization networks, Kohonen maps, recurrent networks [7-9]).

It is known that information systems for the detection of low-flying air targets use high-performance technologies that ensure prompt response to various objects in the air, and the introduction of artificial neural networks [10] in the feedback loop improves the coordination of trajectory tracking, the accuracy and speed of their detection.

The article [11] presents the results of a qualitative study of a neural network, including discrete and distributed time delays. A method for calculating the exponential decay rate for a neural network model based on differential equations with a discrete delay was developed and applied [12, 13].

In the development of information systems for the detection of low-flying air targets, the direction of using sensors [14, 15] is promising, in particular for tracking the trajectory, accuracy, speed of detection of air targets and for assessing the health of operators. An important characteristic of various types of biosensors is stability [16-18]. Scientific studies [19-21] provide examples of modeling sensor responses. Numerical modeling in cyberphysical biosensor systems [22, 23] is important at the stage of their design.

Let's divide the recognition procedure into separate stages:

1. Image perception (obtaining the values of the object characteristic properties).

2. Pre-processing (removing noise, presenting images in black and white colors, cropping unnecessary parts of the image).
3. Characteristics allocation (measurement of the object characteristic properties).
4. Classification (decision-making).

2. Development of the image recognition system

While developing the recognition system, the following stages are involved:
1. Obtaining a training sample (training collection, training sample).
2. 2. Sample of the object representation model.
3. Selection of significant characteristics.
4. .Development of the classification rule.
5. Learning the recognition system (the learning algorithm "collects experience" on the basis of the recognition sample, in order to set correctly the coefficients of the recognition system, the learning algorithm is applied to the training sample, controlling the result of the algorithm).
6. Checking the learning quality.
7. Optimization of the recognition system.

3. Mathematical representation

Let's consider clustering images using the distance function. As the classification criterion, we use the approach based on the classification of images by minimum distance criterion. The case of one standard or the nearest neighbor method. In certain tasks, the objects of several classes (images) tend to be grouped around the certain object that is typical or representative of the corresponding image. A typical example is our case (when the object has typical contours, boundaries, and scaled dimensions).

Let us consider M classes that allow images using reference representatives $z_1,\ldots,z_M$.. The Euclidean distance between arbitrary vector x and these images is calculated by the following formula

$$Di = \|x - z_i\| = \sqrt{(x - z_i)'(x - z_i)} \quad (1)$$

Vector x belongs to the class ω_i, if the condition $D_i<D_j$ is satisfied for all $j\neq i$. Let's transform the formula for calculating the distance

$$D_i^2 = \|x - z_i\|^2 = (x - z_i)'(x - z_i) = x'x - 2x'z_i + z_i'z_i = x'x - 2(x'z_i + \frac{1}{2}z_i'z_i) \quad (2)$$

The last formula shows that choosing the minimum distance to the class is equivalent to maximizing the value$x'x - 2(x'z_i + \frac{1}{2}z_i'z_i)$. Therefore, we define the decision functions as follows

$$d_i(x) = x'z_i - \frac{1}{2}z_i'z_i, \qquad \text{i=1,2,...,M.}$$

where $d_i(x)$ is linear decision functions. If we put

$$\omega_{ij} = z_{ij}, \qquad \text{j=1,2,...,n.}$$

$$\omega_{i,n+1} = -\frac{1}{2}z_i'z_i \tag{3}$$

.

I x=(x1,...,xn, 1), then the decision functions are written in the following form

$$d_i(x) = w'x. \qquad \text{i=1,2,...,M.}$$

where $w_i=(w_{i1},...,w_{in}, w_{i,n}+1)$.

In the learning process, all points and their belonging to the corresponding images $a_1,...,a_m$. are memorized

Recognition means that x, which is to be recognized, is calculated by the potentials of each image, i.e. the sum:

$$\Phi_i(x) = \frac{1}{n_i}\sum_{a\in a_i}\varphi_a(x), \qquad \text{i=1,2,...,m,}$$

Where m is number of different images, n is the number of points of the corresponding image used in the learning process, $\varphi_a(x) = \frac{1}{1+\alpha R^2(a,x)}$ is the is the potential created by point a at point x.

We compare the values of $\Phi_1(x), \Phi_2(x), \dots, \Phi_m(x)$ and the point x refers to the image with the highest potential.

In general, case the shape code is written in the form $x_1, x_2,..., x_n$, де $x_i \in \{0,1\}$, i=$\overline{1,n}$, n is the number of receptor field elements.

The point in the receptor space is called the boundary point of the set if its code contains at least one digit, which change transfers the point to another set. Otherwise, the point is called the interior point.

If the above mentioned conditions are met for a set of points, we assume that such points form the compact set: the number of boundary points is small compared to their total number; any two interior points can be connected by sufficiently smooth line that passes only through the interior points.

4. Experimental results and discussion

Graphical presentation of the results of finding the maximum value for the object's vicinity and contour definition.

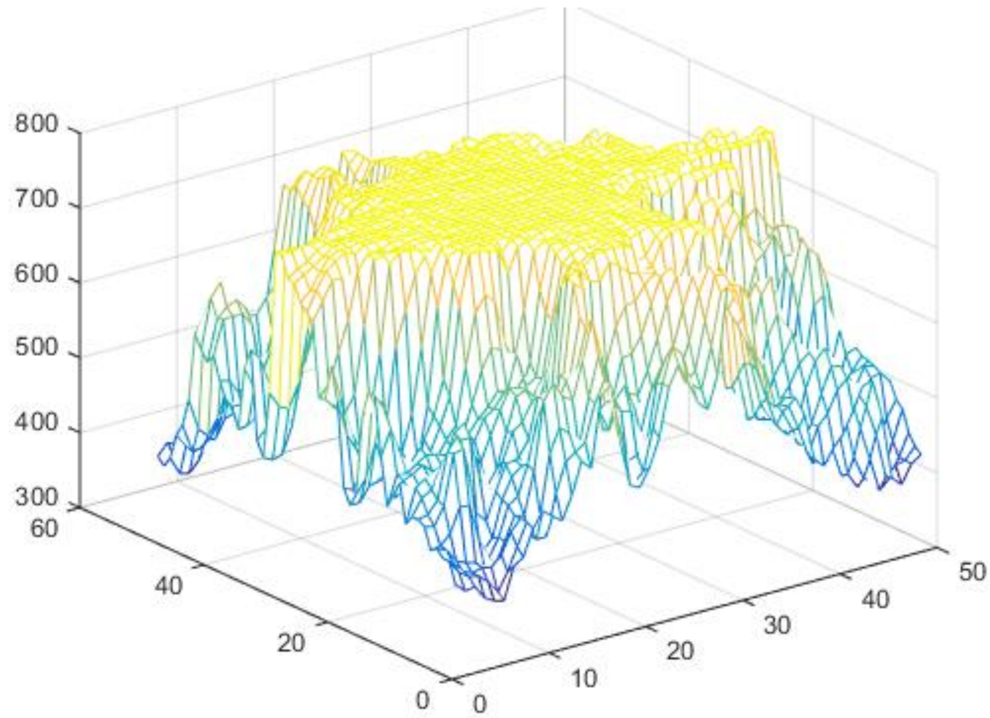

Figure 1: Graphical representation of the results of determining the object contours by maximum levels.

Special software has been developed for receiving video data from the thermal imaging camera via USB port to personal computer. During the process of work, the video data, frame-by-frame video data analysis with the definition of the shape contour for each frame is carried out, and the trajectory of the monitored object's further movement is predicted. If the coordinates of the predicted movement of the object differ from the actual value, the trajectory is recalculated.

The task is to distinguish in this binary image the connected boundaries of the target object contour among the noise and boundaries of competing sets of pixels. To reduce the noise effect and minimize the amount of data, the a grid with a certain fixed spacing is superimposed on the binary image, the value of which is determined by the required algorithm speed and approximation accuracy, as well as the relative sizes of the target objects. This this makes it possible to get rid of boundary breaks and noise smaller than the grid spacing.

At the next stage, complete mathematical description of the connected elements of the boundaries represented in the image is performed. In order to do this, we developed graph structure and implemented by software the method of its dynamic replenishment during exploratory search for connected local extremes of the image gradient. The search was carried iterative in the 8-connected domain by graph optimization - straight elements without branches are represented by single edge (Figure 2).

a) b)

Figure 2: Recognition of object contour at different positions in space: a – object to the left of the observer, b – object to the right of the observer.

For each constructed connected boundary graph, the cycle search is carried out. This cycle covers and is the closest one to the image area known as that one belonging to the object. The speed of the algorithm operation is very significant, so it is inefficient to search for all possible cycles and choose the one that meets the requirements. The search procedure immediately moves along the graph in such a way that the first found cycle covering the area of interest is also the closest one.

The essence of the paper is to provide support by controlling the rotary platform where the monitored device (such as thermal camera) is located. The task of the motion control subsystem is to control the rotary device in order to keep the identified object in the center of the screen.

It is obvious from Fig. 3 the system includes:

– control object (rotary platform);
– technical vision system;
– subsystem of optimal control mode selection;
– system of visual information processing;
– motion control subsystem.

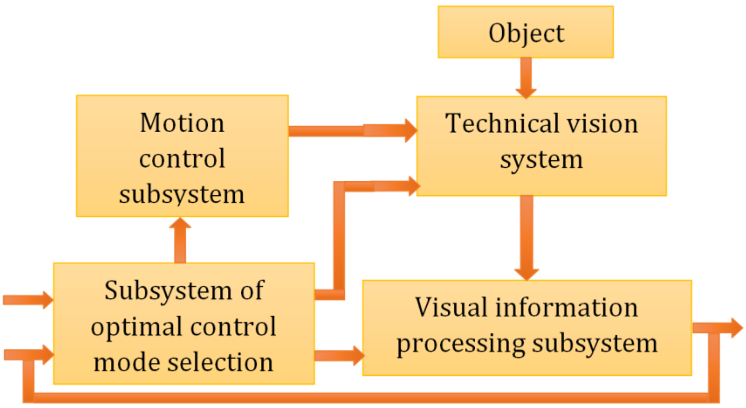

Figure 3: Model of adaptive control system for rotary system

The optimal mode is chosen by finding the minimum of the objective function Z(P,D) for each moment of mode change. Thus, this research area makes it possible to automate the process of detecting low-flying air targets and predict the supporting trajectory.

Conclusions

The system for recognizing objects by thermal images has been developed. Special software processes the data from the thermal imaging camera, calculates the deviation of the image from the observation center, and sends control action to the motion control subsystem. The effectiveness of the proposed system has been confirmed by a number of experimental investigations regarding the support of dynamic objects with uncertain motion trajectory.

The scientific novelty of the given investigation is the decision-making in the intelligent information system which takes into account the multistage nature of solving the problems of manipulating objects and navigating the system. The decision-making system perceives changes in the environment where the monitored object is located and produces such schemes for solving problems that would correspond to the changes in the operating environment. The above mentioned approach requires the occurrence of a new property of decision-making systems for detecting and supporting the objects, namely, the ability to rebuild (adapt) flexibly the operation depending on changes in the environment, changes in the goal or individual subgoals, in the state of the information system itself. The applicaton of visual control methods makes it possible to adapt the operation of the devices due to the widespread use of visual information about the state of low-flying air targets and prediction of the supporting trajectory.

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