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ANALYSIS OF EXISTING METHODS FOR SEARCHING OBJECT IN THE VIDEO STREAM

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Systems of "smart" home, surveillance, navigation, limited access are the areas of video stream analysis. One of the important tasks is to select an object in a stream. This task is associated with the tasks of tracking the object, matching the image with the database [1], finding duplicate images [2], connecting frames.

Video analytics is a technology that uses computer vision [3] techniques to automatically obtain various data based on the analysis of a sequence of images.

Data is received from video cameras in real-time or from archived video recordings. The task of identifying dynamic objects is understood as the task of identifying and isolating image areas [4] that change in a sequence of frames. Detection of a specific object refers to the selection of one or more detected dynamic objects. These objects have some characteristics in common with the given search object [5]. Features are selected by a certain algorithm [6].

Tracking is the positioning of a moving object with a camera.

Let's analyze several groups of methods for selecting an object [7]:

– Deterministic methods;
– Probabilistic methods;
– Combined methods.

Deterministic methods give a unique and predictable result for a given input data. They consider the object of observation as an object with signs that do not change over time.

Deterministic methods can be divided into the following groups:

– Search methods by template [8-10];
– Methods of searching for optical flux [11, 12];
– Methods of finding keypoints [13-20].

<u>Searching for objects based on a template</u> assumes that there is an image of the object with selected features (template) and a test image that is mapped to this template.

In the simplest case, the pattern can be a matrix of color intensities that are most characteristic of the object [8].

More complex methods of this group use sets of feature vectors (descriptors), geometric representations of the object, or probabilistic models of objects as a template.

They contain information about pixel intensity distributions. A comparison with a template is a comparison of descriptions of test and template images according to some selected metrics. Search methods for a given pattern work effectively when searching for single objects because when there are overlaps in the description, some features disappear [9].

Optical flux is the structure of the visible motion of objects, surfaces, or edges of a scene caused by the relative motion of the observer (eye or camera) relative to the scene.

There are several main groups of methods for determining the optical flux [21]:

– Differential evaluation methods;

– Phase correlation method;

– Method of comparing blocks.

In practice, methods of comparing blocks are used. This is due to the versatility, low computational complexity, high efficiency, as well as simplicity of hardware implementation of methods of this type [22].

The general procedure for these methods is as follows [23]:

– The current frame is divided into many blocks that do not intersect;

– For each block of the current frame, the search for the most similar blocks in the previous frame;

– The difference between the positions of the current and previous block is called the motion vector of the current block.

To determine the description of the features of the image, it is necessary to refer to the keypoints – the local features of the image [24]. The process of finding special points is carried out using a detector.

A keypoint or special point is an image point that has several properties [14]:

1. Distinctness – the feature should stand out against the background of neighboring points.

2. Repeatability – changes in brightness, contrast, and color gamut should not affect the location of a keypoint on an object or scene.

3. Invariance – keypoints must be resistant to the rotation, zooming, and changing the shooting angle.

4. Stability – the noise of the image, which does not exceed a certain threshold, should not affect the operation of the detector.

5. Interpretability – keypoints should be presented in a format suitable for further work.

6. Quantity – the number of identified keypoints should be sufficient to detect objects.

Descriptor – a description of a keypoint that defines the features of its surroundings, and is a numerical or binary vector of certain parameters [13]. The length of the vector and the type of parameters are determined by the algorithm used. The descriptor allows you to select a special point from their set in the image [16]. This is necessary to build key feature pairs belonging to the same object when comparing different images [20].

Let’s analyze some popular keypoint detectors.

FAST (Features from Accelerated Test) is one of the first heuristic methods to find special points in the image. To decide whether to consider a given point *C* special or not, this method considers the brightness of the pixels in a circle centered at point *C* and a radius of 3 pixels (circle length 16 pixels). Comparing the brightness of the pixels of the circle with the brightness of the center *C*, we obtain for each of the three possible results (lighter, darker, and similar). A dot is marked as special if there are 12 pixels on the circle that are darker or 12 pixels that are lighter than the center. Among the advantages of this detector is its high speed. The main disadvantage of FAST is the sensitivity to noise in the image.

ORB (Oriented FAST and Rotated BRIEF) is a combination of a modified FAST algorithm and a BRIEF descriptor. This detector uses a modification of FAST-9; the radius of circle 9 was the most efficient in terms of performance. Once potential keypoints are identified, a Harris angle detector is used to refine them. This detector is invariant to rotation transformations but is sensitive to scale transformations [17].

BRISK (Binary Robust Invariant Scalable Keypoints) is a combination of the AGAST algorithm (FAST modification) and the BRIEF descriptor.

To achieve invariance to the change of scale, finding the maxima occurs not only in the original image but also in the multiscale space of the image [16]. The advantages of this detector include its invariance to the transformations of rotation and scale. The disadvantage is the lower speed compared to the ORB.

A-KAZE (Accelerated-KAZE) is a modification of the KAZE method.

The idea of this method is to create a series of intermediate images at different scales by applying different filtering of the original image.

To construct a nonlinear multiscale space based on the equations of nonlinear diffusion, the use of the Fast Explicit Diffusion (FED) scheme is proposed. Detection of singular points is performed by calculating the determinant of the Hesse matrix for each filtered component of nonlinear scale images of the original image. Among the advantages is its invariance to scale transformations and rotations. Disadvantages include sensitivity to image blur.

Probabilistic methods perceive an object with variable features in a sequence of frames. These methods use an approach based on the concept of state space. A moving object has a certain internal state that is measured in each frame. In the simplest case, the state is the position of the object in the image. To estimate the next state of the object, you need to summarize the measurements as much as possible. Determine the new state, provided that a set of measurements for the states was obtained in the previous frames.

Typical examples of such methods are methods based on Kalman’s filter and particle filter.

Probabilistic methods of observation:

– Allow you to predict the state of the object in the image without saving all the data about previous states;

– Allow perceiving an object with variable features in the video sequence;

– Are resistant to image noise, to change several image characteristics of the object, such as brightness, rotation, zoom.

Probabilistic methods are used in practice as additional methods to increase the resistance to changes in the image of the object.

The peculiarity of **combined methods** is that they consist of several methods, combining methods according to the highest performance of different criteria. They are more resistant to noise and various distortions of the object. Combined methods can combine deterministic and probabilistic methods [8, 9]. This type of method can be divided into two groups: methods with a teacher and methods without a teacher.

The combined methods include:

– Viola-Jones method;

– TLD method.

The Viola-Jones method refers to methods with a teacher. The learning phase is very slow, the search is fast. This method uses Haar's features. Fast calculation of signs is reached using an integral representation of the image. The boosting algorithm is used to select features. The Viola-Jones method uses a scanning window approach: the image is scanned by a search window, and then a classifier is applied to each position of the window. The system of training and selection of the most important features is fully automated and does not require human intervention, so this approach works quite quickly.

The TLD method is a method of reliable long-term support of previously unknown objects in the natural environment. It withstands gaps between frames, rapid camera movement, complete disappearance, and then the appearance of the subject. The approach used in this method is called Tracking-Modeling-Detection (TMD). It combines adaptive object tracking with detector training in the recognition process. Once an object has been captured using any capture method, the trajectory of the object begins to be tracked by two processes. They build an object detector. The TLD method is a method without a teacher, but the learning process is there. Learning happens in the process. Object detection and classification are performed using a randomized forest.

To date, there are no perfect algorithms for detecting an object in a video stream. Speed, resource consumption, sensitivity to distortion, and interference – all these criteria are very important when choosing a method that will work in real-time [25]. It is the method of finding keypoints that are optimal for the task of detecting an object in a video stream, because low sensitivity to distortion and interference, as well as high computational speed, distinguish this group of methods among others.

Analysis of the conditions of use of object search methods shows that these methods must meet the following requirements:

– Invariance to design transformations of the image of the object;

– Computational complexity must be minimally achievable for the application of real-time problem-solving [26-28].

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