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RAPID SELECTION OF MOVING WAGONS IN THE SEQUENCE OF VIDEO FRAMES BASED ON THE METHOD OF CALCULATING THE OPTICAL FLOW

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Annotation

With the advent of digital video cameras, it has become possible to process measurement data using a computer, which has led to a wide range of new tasks in digital signal processing. Examples of such tasks are perimeter observation and detection of a moving object, recognition of a moving object, and identification of an object. Research and development of algorithms for processing video data, as a rule, requires a time-consuming computational experiment on model and real data of a large volume. Therefore, it is important to correctly organize the computational process when modifying and testing algorithms.

Keywords: image recognition, graphics processor, image identification, optical flow, recognition of cars.

1. INTRODUCTION

In many applications, a dynamic scene is observed by a set of heterogeneous measuring tools, some of which register sequences of images of the scene in their picture plane.

At the same time, various tasks are solved: object detection, object tracking, object identification and recognition, determination of parameters, trajectories and characteristic features of movement.

An important component in solving all these problems is the sub-task of selecting in the sequences of video frames those fragments that correspond to the objects of the scene, first of all-moving. Such fragments of frames will be further considered as moving objects on a two-dimensional field of the image.

As a rule, already on the basis of determining the characteristics of the selected areas, the tasks of detection, tracking, identification, recognition, etc. are solved.

In all problems, movement is naturally considered as a characteristic feature of the selected object. The selection of a moving object is a meaningful task, which, however, can be formalized in different ways.

Usually this problem is referred to [4] to the average level of computer vision, when the pixels are no longer considered in isolation, but are not yet linked into a coherent semantic structure. The upper level implies the presence of the model and the use of logical inference to link (compare) the model and the available data. When solving the problem of selecting objects, it is important to determine which pixels should be recognized for selection and which should be ignored. Obtaining a data representation in which this problem is solved is usually called [5] segmentation, grouping, perceptual organization, Assembly, etc. The term segmentation is quite broad and is usually associated with the idea of a compact representation of the useful content of an object.

So, segmentation is the assignment of pixels to the fragments of images that interest us. As a result, the image is divided into regions (homogeneous in some respects), and the inhomogeneities are interpreted as boundaries between regions. The analysis of the form and parameters of car numbers is carried out after segmentation. The main parameter of movement can be considered the speed of relative movement of the object in the frame space. Most often we are talking about the movement of the" center of mass " of the object or the average object speed of movement of pixels. Note that, as a rule, the forward movement of the object as a whole is considered first, although in many cases it is necessary to take into account the movement relative to the center of mass.

Segmentation methods [5] are known based on pixel analysis, area analysis, contour analysis, and model analysis. We will focus on the segmentation methods based on the analysis of regions. In this case, the features for segmentation can be formed from both the motion characteristics (the velocity field) and from the" static " characteristics of the frame (for example, brightness).

The emergence of single-Board computers that allow scientific calculations makes it urgent to develop effective and stable parallel algorithms that run on a graphics processor and allow you to automate the selection of moving cars in a high-definition video sequence in real time. Such algorithms can be used both for the analysis of measuring information obtained from a high-definition survey camera, and for parallel processing of information from several low-or medium-resolution survey cameras. After the introduction of the NVIDIA Jetson Nano, it became interesting to see how it works and what you can do on it. Why the choice remained on this, the First is the GPU, which has 128 cores, respectively, on the Board you can run GPU-oriented tasks, CUDA or Tensorflow. The main processor is 4 core, and as will be shown below, quite good. 4GB memory shared between CPU and GPU. The second is compatibility with Raspberry Pi. The Board has a 40-pin connector with various interfaces (I2C, SPI, etc.), there is also a camera connector, which is also compatible with Raspberry Pi. We can assume that a large number of existing accessories (screens, motor control boards, etc.) will work (you may have to use an extended cable, because Jetson Nano still differs in size). Third-the Board has 2 video outputs, Gigabit-Ethernet and USB 3.0, i.e. Jetson Nano in General is even slightly more functional than the "prototype". Power 5V, can be taken as a Micro USB, or through a separate connector. There is no WiFi on the Board, which is a certain disadvantage, if you want to use a USB-WiFi module. If you look closely, you can see that the device structurally consists of two modules-the actual Jetson Nano module, and the lower Board with connectors, the connection is made through the connector. Therefore, the development of accurate computationally efficient calculation algorithms, as well as algorithms that provide reliable operational selection of moving objects in real time on the basis of a technical parameter, and the creation of a parallel software implementation of the developed algorithms are urgent tasks.

Research and development of algorithms for processing video data, as a rule, requires a time-consuming computational experiment on model and real data of a large volume. Therefore, it is important to correctly organize the computational process when modifying and testing algorithms. Thus, the creation of a software visual tool system that allows you to partially automate the organization of the computing process is also an urgent task.

Local and global differential algorithms are most often used to calculate the optical flow. Local differential algorithms allow us to quickly calculate the optical flow, but the accuracy of the resulting optical flow in some cases is insufficient for the steady selection of moving objects. Global methods for calculating optical flow are more accurate, but their computational complexity does not allow them to be used in some real-time tasks.

The purpose of the research is to develop algorithms and programs that allow you to consistently identify moving objects and evaluate their parameters in sequences of video frames in real time. The target hardware platform is the NVIDIA Jetson Nano portable computer for machine learning. The developed algorithms must be computationally efficient and stable.

2. ANALYSIS OF ALLOCATION PROBLEMS IN OPTICAL FLOW AND FEATURE EXTRACTION BASED ON THE CALCULATED OPTICAL FLOW.

It is assumed that the video sequence S is a sequence of video frames $(I_1, I_2, \dots, I_k)$, registered at regular intervals $\Delta t = 1$. Each video frame is described as an array of data of I dimension $(q \times x)$. Frame intensity at the point with coordinates $x = (x, y)^T$ equal $I(x) = I(x, y)$. Discrete points of the video frame will be called pixels.

We will call the field of two-dimensional vectors an optical flow $f\ (x) = (f_1, f_2)^T = (u, v)^T$ calculated at each point in the image x.

The optical flux is an estimate of the pixel displacement field and is based on the continuity equation of the pixel flux

$$\frac{\partial I}{\partial t} + f^T \nabla I = 0$$

where are the notations used for partial derivatives

$$\frac{\partial I}{\partial t} = I_t, \nabla I = \left(I_t, I_y\right), \frac{\partial I}{\partial x} = I_x, \frac{\partial I}{\partial y} = I_y$$

Let the transformation of the set of points in the neighborhood be defined for a given neighborhood $\Omega(x)$ in the vector $\boldsymbol{Z} = (z_1, z_2, \dots, z_m)^T$ and back: : $\left\{x_{ij} \middle| x_{ij} \in \Omega(x)\right\} \Leftrightarrow \boldsymbol{Z} = (z_1, z_2, \dots, z_m)^T$.

Let's introduce a vector $\boldsymbol{H} = [\nabla I(z_1), \nabla I(z_2), \dots, \nabla I(z_m)]^T$ size's $(m \times 2)$ and vector $B = -(I_t(z), I_t(z_2), \dots, I_t(z_m))$ size's $(m \times 1)$.

Then the least squares estimation of the optical flow is obtained by minimizing the functional

$$||e||_2^2 = J = (Hf - B)^T W (Hf - B),$$

where W is the weight matrix defined by the neighborhood. This estimation corresponds to the local method of estimating the optical flow, in contrast to global methods, in which the functional minimized throughout the image contains an additional term that provides a smoothing effect for the calculated optical flow. Global methods are more accurate, but calculating the optical flow is more time-consuming. Performance analysis of global methods has shown their inapplicability for calculating the optical flow of high-definition video sequences in real time.

Methods for calculating optical flow are subject to the so-called "aperture" problem, which is caused by large-scale misalignment:

brightness levels change at larger scales than the operators used to determine the gradient. Effective processing requires the representation of images at different scales. Therefore, multi-scale methods are used to calculate the optical flow: the estimation of the optical flow obtained on a rough scale is interpolated to the previous level and refined by analyzing the video frames of the corresponding level.

All modern methods of calculating optical flow use multi-scale representation of video frames. Local methods for calculating the optical flow were chosen because of their high performance and the need to parallelize them.

3. MODIFICATIONS OF LOCAL METHODS FOR CALCULATING OPTICAL FLOW.

Having analyzed the reasons for the inaccuracy of local optical flow estimates obtained by minimizing the functional (1). The main reasons are: a) in the minimized functional (1) there is no smoothing term, b) the gradient matrix H is calculated with errors caused by the approximation of partial derivatives by the convolution operation, C) the vector of the time derivative B is calculated with an error that is greater the greater the speed of the object, d) the condition of constancy of the optical flow vector in the local area is violated at the boundaries of moving objects. Therefore, the system (1) is unstable, and the problem of calculating the optical flow by the local method is generally incorrect.

To overcome these shortcomings, it is proposed to use three main modifications: 1) weighted initial estimates and regularization methods to obtain a stable solution; 2) median filter as an analog of smoothing component in global optical flow calculation methods; 3) combined use of the first two modifications in a multi-scale optical flow calculation method.

In contrast to global methods, the use of these modifications allows us to calculate the optical flow by solving a system of normal equations of small size. The obtained algorithms for calculating the optical flow can be parallelized. In this case, the accuracy of the calculated optical flow is slightly inferior to the most accurate and slower algorithms for calculating the global optical flow and in many cases is sufficient for the problems of selecting moving objects.

The first modification is based on methods for solving incorrect problems and is reduced to adding a regularizing component $\alpha^2||f||$ to the functional to be minimized

$$J_r = \left(\dot{B} - \dot{H}f\right)^T W\left(\dot{B} - \dot{H}f\right) + \alpha^2||f||$$

At the same time$||\dot{H} - H|| \leq h, ||\dot{B} - B|| \leq \delta, ||\dot{H} - H|| \leq h, \left(\dot{B} - \dot{H}f\right)^T W(\dot{B} - \dot{H}f) \leq \rho.$

Here$\dot{\boldsymbol{H}}, \dot{\boldsymbol{B}}$- the measured values, **H, B** – true.

Then the value of α is selected from the ratio. $\alpha = \beta \cdot k^{-1}(\dot{\boldsymbol{H}}^{\boldsymbol{T}}\dot{\boldsymbol{H}})$ **where** $k(\dot{\boldsymbol{H}}^{\boldsymbol{T}}\dot{\boldsymbol{H}})$ the condition number of the matrix $(\dot{\boldsymbol{H}}^{\boldsymbol{T}}\dot{\boldsymbol{H}}), \boldsymbol{\beta}$ is a global constant that is calculated based on the analysis of residual residuals of the functional, analysis of the accuracy characteristics of $h\ and\ \delta$.

The second modification is to apply a median filter to the computed optical flow field in a multiscale optical flow calculation algorithm. The median filter is interpreted as an analog of the smoothing term in global methods for calculating the optical flow, which causes a large size of the filter window (of the order (25 _ 25)). The result of median filtering of the optical flow field is shown in Fig. (1).

Method	RB	G2	G3	HYD	U2	U3	YOS
The original algorithm	23.4	19.65	20.96	24.65	46.69	35.99	12
Median	22.23	18.41	19.47	22.2	45.92	33.87	11.01
Regularized	15.1	8.1	12.8	10.35	28.1	8.75	10.15
Combined	14.92	7.62	12.46	10.47	26.7	12.35	8.2

Table 1: Integral error of the calculated optical flow for the proposed modifications of the algorithm.

A combined local differential algorithm for calculating optical flow is obtained by combining median filtering and regularized estimation of the optical flow vector at each of the levels in a multiscale approach. It is shown that in this case the accuracy of the calculated optical flow field is the highest of all the proposed ones

The results of the work were used at the stations of "Nazarbek", Tashkent region.

Conclusion

A computational experiment was carried out, the main goals of which were: comparison of the accuracy of the optical flow calculation by the proposed combined algorithm compared to the existing ones, comparison of the execution speed, evaluation of the reliability of the proposed algorithms for selecting moving objects. The calculation speed was evaluated using the NVIDIA graphics processor.

The analysis of the results of the performed experiments shows that when using the combined method of calculating the optical flow, the integral error of the flow decreases by 48% compared to local differential methods and increases by 148% compared to global methods. At the same time, the speed of the developed algorithm is approximately 20 times faster than the speed of global methods for calculating the optical flow.

Optical flow calculation speed

The processing speed of a video sequence on a graphics accelerator (in frames / sec) by some methods of calculating the optical flow

The developed combined algorithm makes it possible to significantly reduce the number of skipped objects during the execution of the algorithm for selecting moving objects. In the first analyzed case, the average number of missed objects in the frame decreased from 0.22 to 0, and in the second case from 0.6 to 0.17.

The results of the experiments show that the task set in the work was solved, the developed algorithms and their software implementation allows you to select objects with the specified indicators of reliability and speed of execution.

The main objectives of the experiment: comparing the accuracy of the calculation of the optical flow of the proposed algorithm with existing to date, comparing the execution speed of the proposed algorithms calculations existing to date, to assess the suitability of the proposed methods for allocation of objects, the illustration of the proposed modifications of the algorithms and objects and evaluation of their applicability.

A comparison of the calculation speed with some modern algorithms for calculating the optical flow is shown in table 2. All calculations were performed on a graphics accelerator (NVIDIA GTX 275). TVL1 is a global variational method, Humber-L1 is a modified TVL1 method, in which the TV metric is replaced with the H1 metric for more accurate determination of object boundaries, combined is the method proposed in this paper.

Comparison of calculation errors with the same optical flow calculation algorithms is shown in table 3. This used standard video sequences developed in 2006 by a group of American scientists (Black and others) to compare the accuracy of calculating the optical flow by various methods.

The analysis of the measurement results presented in tables 1, 2, 3 shows that when using the combined method of calculating the optical flow, the calculation error is reduced by 48% compared to the local differential method, and increases by 138% compared to global methods. At the same time, the speed of the developed method is approximately 20 times faster than the speed of global methods for calculating the optical flow, and is almost as fast as unmodified local methods.

To provide a comparison of algorithms for detection of moving objects was used simulated and real video sequences. According to the main characteristics (noise level, illumination, size of objects, speed of movement), the model sequences corresponded to the real ones.

Image size	TVL1	Humber-L1	Combined
512X512	5.3	1.3	121
1024X1024	1.3	0.25	32
2048X2048	0.33	0.05	8

Table 2: speed of calculation of optical flow by various algorithms(in frames/sec)

Method	RBW	GV2	GV3	Hydr	U2	U3	yos
Combined	14.92	7.62	12.46	10.47	26.7	12.35	8.2
TVL1	11.41	4.12	10.75	14.85	23.35	18.77	4.74
Humber-L1	7.18	2.14	5.14	6.17	15.9	7.42	2.32

Table 3: Comparison of the developed algorithm with modern global algorithms for calculating the optical flow by the value of the integral error

In addition, the developed algorithms were applied to the problem of isolation of a single fast-moving object in conditions of strong noise. The use of standard correlation methods in these conditions leads to multiple false goals. Calculating the optical flow allows you to get additional information about the movement of the camera and predict the position of a moving object in the next frame, which allows you to select a moving object using kalmon filtering.

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