Дана стаття присвячена новому методу знаходження порогового значення градієнтних фільтрів, для розв'язання задач визначення геометричних параметрів об'єктів з підвищеною точністю. Алгоритм заснований на використанні даних, отриманих після обробки зображення градієнтними фільтрами, а також реагує на найменші зміни контурів об'єктів зображень динамічних сцен

Ключові слова: центр мас, сегментація, контур об'єкта, поріг градієнтного фільтру, системи штучного інтелекту

Данная статья посвящена новому методу нахождения порогового значения градиентных фильтров, для решения задач определения геометрических параметров объектов с повышенной точностью. Алгоритм основан на использовании данных, полученных после обработки изображения градиентными фильтрами, а также реагирует на малейшие изменения контуров объектов изображений динамических сцен

Ключевые слова: центр масс, сегментация, контур объекта, порог градиентного фильтра, системы искусственного интеллекта

UDC 004.89

DOI: 10.15587/1729-4061.2015.51766

METHOD FOR AUTOMATIC ASSESSING OF THE GRADIENT FILTER THRESHOLD FOR FAST PROCESSING OF DYNAMIC SCENES OBJECTS

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1. Introduction

In computer vision, image segmentation is the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze [1]. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics.

A selection of the threshold for various filters is an important task when designing image processing systems and artificial intelligence systems [2]. Often, parameters of the whole system depend on the accuracy and rate of selecting a necessary threshold value. This problems has a special significance today, because modern systems tend to process huge arrays of information in real time while preserving high accuracy [3–6]. The inadequacy of classic methods [7] for efficient threshold determination is related to the diversity of image types and, sometimes, their low contrast, and selection of a threshold value by an operator significantly decreases the system performance, accuracy, stability and independence.

Modern space expeditions have already started to use laser instead of radio waves to transfer information to the Earth [8]. Ultrahigh frequency radio waves used for communication with space vehicles allow to transfer hundreds of megabytes of information per second, the laser uses even higher frequencies, which allows to transfer gigabytes of information each second. In addition, the radio wave band is being heavily used and thoroughly divided among various services, and the optic wave band is still almost free and is not regulated, which will allow to avoid problems related to the lack of free transmission channels.

Lasers installed on the satellites may easily provide information transmission in the space, between space vehicles, but such information transmission to the Earth is complicated due to the fact that to transfer information, systems use variations in the laser beam frequency. Such signal modulation is protected from distortions caused by sun radiation, but is unstable against earth air turbulences [9]. That is why another principle of laser data transmission is used as well. Instead of variations in laser beam frequency, its amplitude is used. A laser signal thus modulated is less prone to atmospheric disturbances.

In this case, the main task is to accurately direct a very thin laser beam from the moving space transmitter to the earth station antenna from a distance of 30'000–40'000 km. Even a minimal error in beam focusing means transmission failure or a total loss of connection.

2. Analysis of published data and problem statement

Computer vision seeks to enhance the ability of machines to understand the visual world through the development of algorithms for tasks such as object recognition, tracking, and 3D reconstruction from image and video data. These tasks are complex enough that it is often not sufficient to simply regard the raw images as training examples and apply the latest machine learning algorithms. Rather, there is a structure in natural images which should be exploited in conjunction with learning techniques [10].

Image segmentation is a fundamental and widely studied problem in computer vision [11–14]. Continuous efforts have been made to improve the performance of segmentation systems to match human capability; however, it is generally acknowledged that solving the segmentation problem with low-level cues alone might not be possible. There has long been a discussion on solving this seemingly low-level task with high-level knowledge, but a clear and concrete solution is not yet available.

Accepting non-perfect segmentation results allows to use cutting-edge systems to generate over-segmentations (or superpixels) in helping higher-level vision tasks such grouping and labeling. Some representative methods include [15] object recognition, image labeling, and parsing.

A method suggested in this paper is based on the use of information provided by the gradient methods for determining an optimal threshold with a goal to increase forecast accuracy in predicting the behavior of dynamic image objects [16]. At the same time, this approach allows to determine other threshold values depending on the objective as well.

3. Purpose and objectives of the study

The key purpose of this paper is to develop the method for automatic determination of the gradient filter threshold with increased accuracy.

In accordance with the set goal, the following research objectives are identified:

– to develop an efficient algorithm for rapid determination of the gradient filter threshold automatically;

– to implement by software developed algorithm for determining the gradient filter threshold and to apply it to the real images;

– to explore the results of processing of real images obtained by using the algorithm.

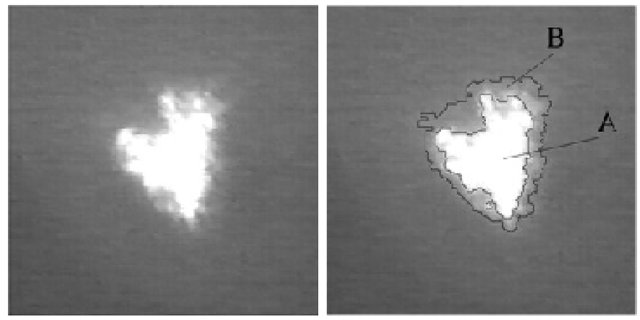
4. Method of Automatic Determination of the Threshold

It is very important to determine the object's COG in processing laser beam. This parameter is convenient to use as a base point. The main problem in processing such images is to select a threshold parameter that will be used to calculate the object's COG (Fig. 1, *a*).

Often it is not clear which part of the image should be used to get a more precise result: A, A+B, or something average between those two (Fig. 1, *b*).

Let us present an elevation map, where a height of each column is equal to the respective point brightness (Fig. 2).

This method is based on the use of a contour obtained by applying a gradient mask on the image containing an object of interest. For this purpose, one of the most efficient gradient methods – the SUSAN method [17] – is used. The main advantages of the SUSAN method include simplicity, accuracy, calculating speed, and good object localization. Using a sliding round window (mask) with a standard threshold value, the detector reaction to edges is obtained as presented in Fig. 3, *a, b*.



a *b*

Fig. 1. A frame of the laser beam dynamic image: *a* — an initial image; *b* — an image divided by conditional borders

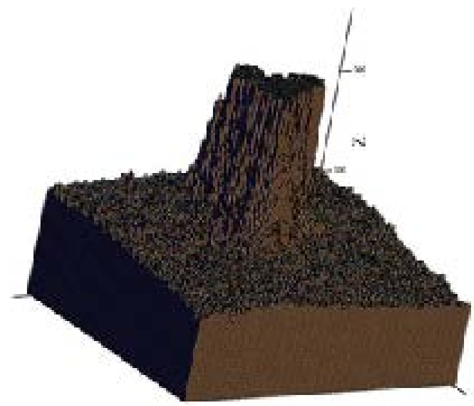
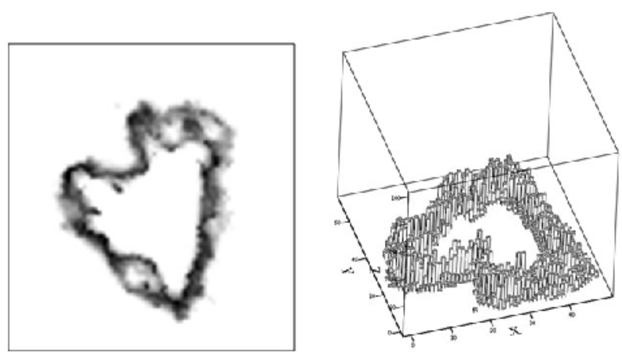


Fig. 2. The 3D-image of the laser spot



a *b*

Fig. 3. Edge detector outcomes:
a — 2D-image and; *b* — 3D-image

In Fig. 3, amplitude shows the detector reaction to the edge. Then, a preliminary COG of the mass of our object is defined [18]. For this purpose, an outer boundary of the image obtained with the image detector described above is used. In this case:

$$x_c = \frac{\sum P_i\, x_i}{P}, \tag{1}$$

$$y_c = \frac{\sum P_i\, y_i}{P}, \tag{2}$$

where P_i is the weight of each point of the body, and $P = \sum P_i$ is a total weight of the body.

Given a high refresh rate, a position of the center of the mass in the dynamic images is changing gradually even for rapid motion. Using this feature, a center of the object for each frame of a training sample is defined under various threshold values by means of an algorithm. A number of elements (frames) in the training sample are selected depending on the type of the dynamic object, a task set and on the initial conditions.

The algorithm works as follows. A number of elements of the training sample Q are set, which normally only insignificantly influences the algorithm output. This number corresponds to the number of parameter values, against which an optimal threshold value is defined. After that, a threshold value range is set, where an optimal threshold value may belong:

$$T \in [L_{min}; L_{max}], \quad (3)$$

where L_{min}, L_{max} are the upper and lower limits respectively.

This range depends on the type of a dynamic image and directly influences the algorithm performance in the beginning of the operation, during the training sample processing. In this connection, it makes sense to perform periodically a preliminary elementary statistical analysis of the dynamic object.

Parameter (s) $S^{(k)}$, necessary for the goal set earlier, is calculated by formulas for values T(i) in the range [L_{min}, L_{max}]. Here, the higher the coefficient k and, respectively, the bigger a number of image parameters considered when processing the image, the more accurate the algorithm outcome is.

In our case, laser spot centers are calculated by formulas (1, 2) for threshold values T(i) for each route image. According to data obtained, diagrams of the required parameter variation in the training sample are constructed for all threshold values used. A parameter of the threshold selection is calculated for each diagram according to formula:

$$\delta = \frac{\sum_{i=1}^{Q-1} \left| S_{i+1}^{(k)} - S_i^{(k)} \right|}{Q}. \quad (4)$$

After that, a threshold is selected, for which coefficient δ is minimal:

$$T_{opt} = f(\min\{\delta_i\}) \mid i \in [1; Q]. \quad (5)$$

The suggested method is recommended for further use by the expert system, in parallel with its own operation, with a goal to maintain a threshold value on the optimal level in case of dynamic perturbing factors.

5. Simulation results and conclusions

For simulation of the method, the integrated software development environment Delphi Code Gear RAD Studio by Borland Corporation is used, because it offers the widest possibilities for producing software products for most platforms.

After the program loading and setting a range for the threshold, the program calculates parameters of interest for various threshold values with a preset step and writes those values in a table (Table 1). The program can determine a maximal range for threshold values.

While processing of the real images, changes in the geometric parameters of the objects will be insignificant from frame to frame. And the big change in their values will indicate the fallacy of selecting the threshold. From the above results, it follows that the optimum threshold value will be in the beginning of the line, in which the total change of the control parameter (in this case the center of mass) will be the smallest.

After processing all images from the training sample and forming the table, the software determines an optimal threshold value for a given type of the dynamic image according to the method described above and sends this value to the expert system for further processing.

To check the effectiveness of the algorithm, let's apply it for the determination of the optimal threshold when predicting the behavior of the objects of moving images. Prediction of the coordinates behavior of laser beams spots was conducted by using linear regression analysis of least squares and other forecasting techniques [19]. By using linear regression analysis, the construction of the line that most closely reflects the series of data points, where the smallest data point is rejected, is carried out. Forecasting results are presented in Fig. 4.

After comparing the results of predicting the behavior of the center of laser beam spots with statically and automatically selected thresholds, it was noted that the developed method can reduce the prediction error to a minimum.

Table 1

Tabular dependence of the coordinates of the laser beam center on the threshold value

Name	Img 10.bmp			Img 11.bmp				Img 20.bmp	
Tr	X	Y	S_1^2	X	Y	S_2^2		X	Y
L_{min}	64,74631	61,65841		65,14652	59,38408	2,674544	...	65,87738	59,15695
L_{min+1}	65,72716	60,35595		65,81339	59,41501	1,027171	...	66,53706	58,38958
...	...	...		...	...	...	...	...	...
5	67,01761	59,57074		66,97727	60,88276	1,352361	...	67,76152	58,7179
6	67,43816	59,98134		67,40785	60,92208	0,971062	...	67,98508	59,10498
7	67,8998	59,8889		67,88311	60,68457	0,812359	...	68,39254	59,06057
...	...	...		...	...	...	...	...	...
L_{max-1}	50,02516	63,04822		74,51316	74,4386	35,87838	...	63,46154	76,29864
L_{max}	47,47287	61,1292		75,41327	73,53061	40,34181	...	67,48765	79,51852

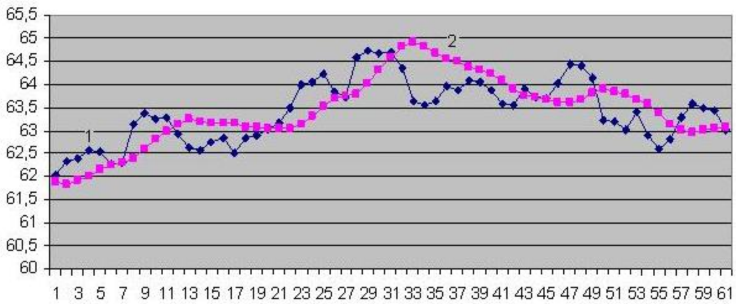


Fig. 4. The results of X coordinate forecasting method of least squares: 1 — actual value; 2 — predicted value (fragment route №10)

6. Conclusions

During the research process, the method for automatic determination of the gradient filter threshold with increased accuracy was developed. In accordance with this, the following research objectives have been resolved:

– an efficient algorithm for rapid determination of gradient filter threshold that has allowed automatically find an optimal threshold value and provides an opportunity to adjust it in the processing of frames sequences of moving images was developed;

– using the developed software, the necessary data to analyze the effectiveness of the proposed method of processing of real images was obtained;

– obtained results helped to ensure the performance and effectiveness of the algorithm used in the determination of geometrical parameters of dynamic image objects.

Conducting the research showed that this method can be used by the expert system, in parallel with its own operation, with a goal to maintain a threshold value on the optimal level in any field which needs increased accuracy of results.

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