

QUALITY COMPARISON OF TWO OPTICAL FLOW ESTIMATION METHODS

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Summary: The content of the article is a quality comparison of two optical flow estimation methods. The comparison was always performed after a modification of the optical flow by thresholding and consequently after the morphological operation. The criterion MSE was chosen for the result quality check and the tool Matlab was used.

Key words: Optical flow, thresholding, mathematical morphology, mean squared error (MSE), background estimation, Matlab.

INTRODUCTION

This article is based on the paper (1) where the program developed for the purpose of the comparison of two optical flow estimation methods – Lucas-Kanade (L-K) and Horn-Schunck (H-S) (Fig. 1) was described. Both these methods are implemented from Matlab version 2010a by means of so-called System Objects.



Source: Author

Fig. 1 – The program for testing methods for the optical flow

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The program was intended for the measurement of time consumption of optical flow estimation and for optimum parameters adjustment at the both tested methods (1). The program was then extended by the objective quality assessment of the both methods.

This article discusses newly implemented calculations and visualizations of the optical flow and results of thresholding and subsequent morphological operations. The statistical method Mean Squared Error (MSE) was selected for qualitative checking of the both methods (H-S and L-K). Using the MSE the error between so-called reference value and the output of appropriate tested method for the optical flow calculation was always calculated. The reference frame is calculated by the Background Estimation method (section 2.1).

1. THE IMAGE SEGMENTATION

The basic procedure of the optical flow estimation was described in (1). After the calculation (estimation) of optical flow, which is suitable for the detection of moving objects, the other step of image processing follows – image segmentation that is necessary for image processing (2). Thresholding and mathematical morphology was used as the primary segmentation techniques.

1.1 Thresholding of optical flow magnitude

The optical flow output was (in both methods) always a complex matrix in form $OF = [u, jv]$, where u are horizontal coordinates and v are vertical coordinates of the velocity vector (of optical flow). Afterwards the absolute values of individual velocity vectors $|OF|$ were computed from the matrix. First this scalar matrix was the subject to thresholding.

Thresholding is a statistical, very quick segmentation technique that was used for the conversion of gray-level frame to the image with two brightness levels. The value 1 is assigned to the points with the brightness value higher than the definite value T (threshold) and the value 0 is assigned to other points. We can define thresholding by the expression (1).

$$I_T(i, j) = \begin{cases} 1 & \text{for } |OF| \geq T \\ 0 & \text{for } |OF| < T \end{cases} \quad (1)$$

where $I_T(i, j)$ is an image function computed by thresholding original image.

The threshold T was calculated by means of Otsu method (3).

1.2 Morphological operations

It is possible to modify further the image, which still contains undesirable artifacts (disconnected elements) by appropriate morphological operations (4) after thresholding. Morphological operations are a serial of operations for digital image processing (removing noise, shape simplification, emphasize the structure, optimal shape reconstruction etc.). These operations are simple and fast and are easy to implement.

The morphological operation is generally a relationship between the image X and a suitable structure element B . Morphological operations are possible to use even for gray-level images. In our case the morphological operations were applied to the binary image. For additional modification the operation *closing* (*dilatation* followed by *erosion*) was used. This operation smoothies contours and fills in small holes and is able to connect nearby objects.

And all this without changing of dimensions. *Closing* transformation is expressed by means of the Minkowski formalism expression (2).

$$X \circ B = \{(X \oplus B) \ominus B\} \quad (2)$$

2. MSE CALCULATION FOR QUALITY ASSESSMENT OF TESTED METHODS L-K AND H-S

For objective comparison of the results of the methods presented in (1), the background calculated with the help of the below described cumulative method. From this background the mask for appropriate frames – the reference value – was separated.

2.1 The statistical background estimation

The method based on the statistical estimation of background parameters was newly implemented for the background estimation. If we assume additive character of brightness value contribution from moving objects, then the image signal can be expressed as

$$a_0 = a_1(x, y) + n(x, y) \quad (3)$$

where a_1 represents amplitude values of image background points and n represents amplitude values of image points of moving objects. The values n have a character of noise.

If we assume statistical independence of random variables in individual time realizations, then for individual realizations (the variance and the mean value) it holds

$$\text{var}\{x_i\} = \sigma^2 \text{ a } E\{x_i\} = \mu \quad (4)$$

where σ^2 is the standard deviation and μ is the mean value of the background.

The principle of background estimation is based on the new estimation of parameters from the sum

$$S_N = \frac{1}{N} \sum_{i=1}^N x_i \quad (5)$$

where we expect

$$E\{S_N\} = \frac{1}{N} \sum_{i=1}^N E\{x_i\} = \mu = \textit{konst.} \quad (6)$$

And the value μ within the scope of individual realizations does not change and since for one partial contribution holds that

$$\text{var} \left\{ \frac{x_i}{N} \right\} = \text{var} \frac{\{x_i\}}{N^2} \quad (7)$$

then for the sum of the series of all the contributions it holds

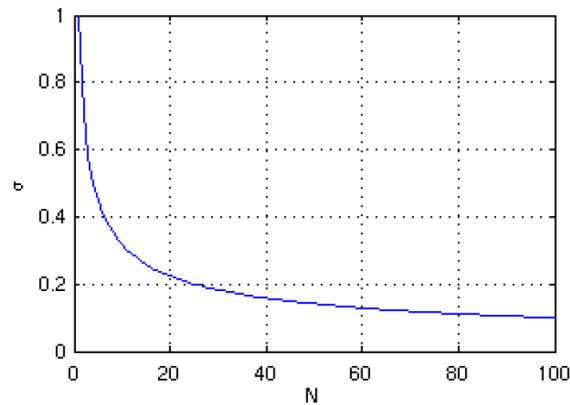
$$\text{var}|S_N| = \frac{\text{var}\{x_1\}}{N^2} + \frac{\text{var}\{x_2\}}{N^2} + \dots + \frac{\text{var}\{x_N\}}{N^2} = N \cdot \frac{\sigma^2}{N^2} = \frac{\sigma^2}{N} \quad (8)$$

If the background in the sum (8) does not change, the standard deviation of estimation decreases like $\frac{1}{\sqrt{N}}$ (Fig. 2).

It is obvious from Fig. 2 that the estimated background can be calculated from several few consecutive frames.

The estimation background method was included in the process for a dynamic estimation of parameters owing to decreasing the sensitivity of ambient conditions. The

calculation of background is in normal conditions realized by the sum of 20 to 30 previous frames.



Source: Author

Fig. 2 – Fall in the value σ depending on the number of sums of realizations

2.2 The mask determination of moving objects

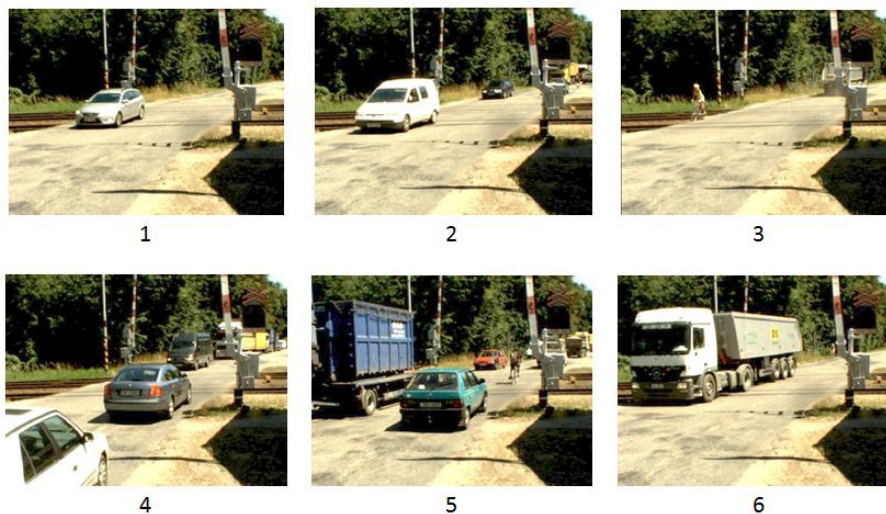
The principle of obtaining a mask is based on the model of background subtraction from the current frame. It is possible to detect the moving objects with this method at the highest accuracy. Its advantage is a low sensitivity to a change of ambient conditions (the change of daytime, shifting shadows etc.). The calculation of the reference frame is then given by the difference

$$I_{ref} = |I_{bgr} - I_{curr}| \quad (9)$$

where I_{bgr} is the background frame and I_{curr} is the current frame with expected objects.

2.3 The measured results of the quality verification of the methods

The testing procedure was performed in the set of 1000 frames representing various traffic situations on railway crossing. Afterwards the frames were sorted out to 6 categories according to the content. Fig. 3 represents 6 chosen cases from individual categories.



Source: Author

Fig. 3 – Chosen situations for the MSE calculation

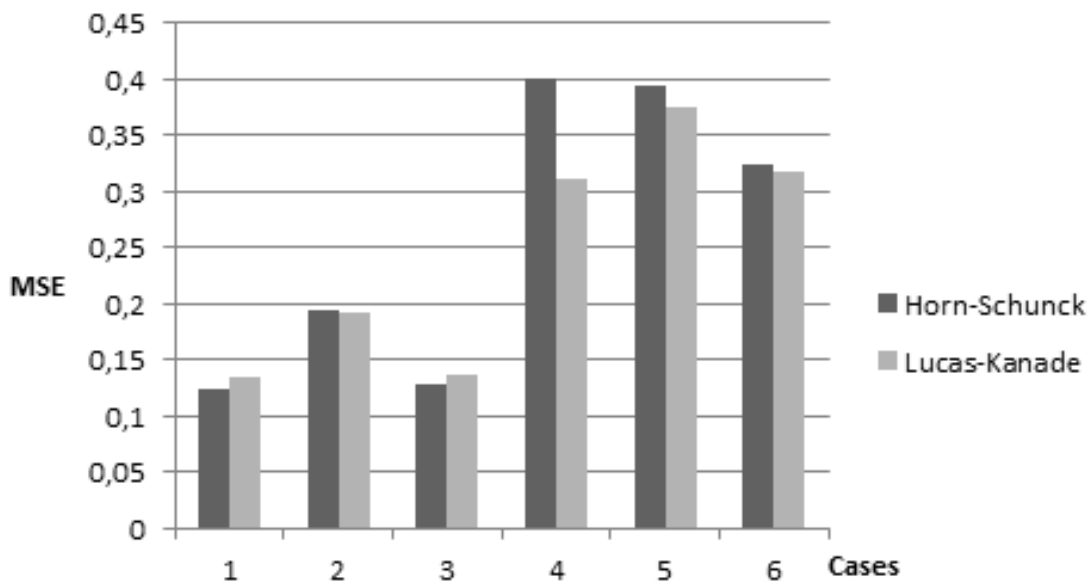
The number of varying image points of the object mask was chosen as a standard. The magnitude of the difference in relationship to the reference mask represents an error of the designed method. For that reason the statistical criterion MSE was chosen. This objectively assesses the quality in relation to the reference mask.

The calculated reference frames (expression (9)) after thresholding were then compared with the methods for optical flow estimation by means of MSE (after thresholding operation and morphological closing) by the expression (10).

$$MSE = \sqrt{\frac{\sum_{i=1}^R \sum_{j=1}^C (ref_{ij} - curr_{ij})^2}{R \cdot C}} \quad (10)$$

where ref_{ij} and $curr_{ij}$ are pixel values of the reference mask and the mask of just compared method, and the product $R \cdot C$ is the total resolution of compared frames.

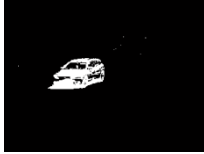

















Tab. 1 contains results of the both compared methods and calculations MSE for 6 chosen cases (Fig. 3). The masks acquired from the reference background image subtracted from the current frame are displayed in the first column. The results of H-S and L-K methods are displayed in the second and third columns including MSE. For the better transparency and comparability the calculated MSE values are presented by the chart in the Fig. 4.



Source: Author

Fig. 4 – Chart of MSE calculations

Tab. 1 – MSE calculations for selected situations

No.	Reference	Horn-Schunck	Lucas-Kanade
1		 MSE = 0.1245	 MSE = 0.1355
2		 MSE = 0.1953	 MSE = 0.1914
3		 MSE = 0.1281	 MSE = 0.1379
4		 MSE = 0.3998	 MSE = 0.3118
5		 MSE = 0.3949	 MSE = 0.3754
6		 MSE = 0.3235	 MSE = 0.3181

Source: Author

CONCLUSION

The object of this article was to compare the outputs of the two most often used methods for optical flow estimation and to evaluate the quality of designed object mask. On the base of quality comparison by means of MSE and of calculated results it is possible to state that the both methods show similar results (differences are only in percentage units). The both methods are then comparable from this point of view and therefore the quicker Lucas-Kanade method is more recommended for the further image processing steps.

The measurements were made on a representative image set, nevertheless there were not fully considered effects of various light conditions. Outputs from the optical flow estimation method will be used in the further phases of image recognition by higher algorithms.

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