Estimation of the probability of correct determination of the coordinates of an object in computer modeling of methods for selecting their images

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Abstract. The article discusses the issues of computer modeling of methods for selecting images of objects. It considers a test video sequence with given background and object parameters. The issues of computer simulation of the formation of such a video sequence, as well as the process of selecting an image of an object and measuring its coordinates are discussed. Examples of test images and graphs of the obtained dependencies of the probability of the correct determination of coordinates depending on the specified parameters of the object and background are given.

1. Introduction
Computer modeling of image processing algorithms is widely used in designing in television and optoelectronic systems. The modeling of the processing of time-varying video sequences is of particular interest. One of such tasks is the problem of selecting images of objects against an inhomogeneous background [1] and assessing the probability of determining their coordinates correctly. When modeling, it is possible to use the following options for video sequences [1, 2]: a real video plot (figure 1a), a video plot with a real background and a synthesized object (figure 1b), and a video plot with a synthesized background and an object (figure 1c).

![Figure 1](image-url)

Figure 1. Frames from test video sequences: real video – a, video with real background and synthesized object – b, video with synthesized background and object – c.
The advantage of the first option is the reality of the test video sequence. The disadvantage is the impossibility of varying the input parameters, in particular, such as the signal-to-noise ratio, image contrast with respect to the background, background dimensions, background unevenness, the speed of moving the object relative to the background, changing the size of the object, etc.

The advantage of the second option is the reality of the background and the possibility of varying the input parameters of the image of the object. The disadvantage is the impossibility of varying the input parameters of the background image.

The third option, unlike the first two, provides the ability to vary the input parameters of the background and the object.

This work discusses the test video sequence with the given input parameters of the background and the object. The issues of computer simulation of the formation of such a video sequence are discussed, and the process of selecting an image of an object and assessing the probability of a correct measurement of its coordinates depending on given input parameters.

2. Results and discussion

The block diagram of the modeling process is shown in figure 2.

![Block diagram of the modeling process](image)

**Figure 2.** Block diagram of the modeling process.

The circuit contains the following functional modules that are quite simple to implement in the MATLAB package [3]:

1. module for setting the initial conditions,
2. module for generating a dot image of an object,
3. object image scaling module,
4. rotation module of the image of the object,
5. non-uniform background image generation module,
6. Gaussian noise generation module,
7. module for determining the reference coordinates of an object,
8. module of forming a test image with a given local contrast and signal-to-noise ratio,
9. module for determining the coordinates of a selection object,
10. tracking zone formation module,
11. output computation module.
5) module for generating an image of an inhomogeneous background,
6) Gaussian noise generation module,
7) module for generating a test image with a given local contrast and signal-to-noise ratio,
8) module for determining the reference coordinates of the object,
9) object selection module,
10) module for determining the coordinates of the selected object,
11) module for forming a tracking zone,
12) output parameter calculation module.

In the initial conditions setting module, the following parameters are set: the size \((x, y)\) of the image matrix, the number of frames in the video sequence, the coordinates \(X_0, Y_0\) of the point where the object appears in the frame and the frame number, the approximation speed, the image rotation speed, the local contrast value \(K\), the signal-to-noise ratio \(\Psi\), background movement speed, dimension of its fragments and magnitude of unevenness.

Initially, the image \(F\) of the object with a unit signal level on a zero background is generated in the module for generating a point image of the object. A logical unit is written to a pre-formed array of zeros at the address corresponding to the given initial coordinates for this purpose.

The generated logical signal of a dot object is used further in the scaling module to simulate the process of approaching an object with a video surveillance point. The image size of the object is increased by dilating the logical signal \(F = \text{imdilate}(F, c)\) with periodic (after a given number of frames) mask size increase \(c = \text{ones}(z0, z0)\) with steps of 1, starting from a single value.

Simulation of the change in the position of the object in the frame (figure 3) is performed in the rotation module by periodically performing the standard operation of rotating the image \(F\) by a given angle \(R0\) with a “fill” of the angles formed in the image with a black (zero) background: \(F = \text{imrotate}(F, R0, \text{crop})\).

Figure 3. Simulation of a change in the position and size of an image of an object in a frame.

The generation of a background image \(T0\) with a given unevenness and with a given dimension of fragments with smooth borders can be quite simple by generating a sinusoidal signal \(T = U_{max}\sin (wt + \phi)\) in each line of the image frame. Then, the resulting image matrix is transposed and summed with the original matrix. Thus, the magnitude of the inhomogeneity is determined by the amplitude of the sinusoidal signal \(-2U_{max}\) and the dimension of the background fragments \(-\) by the frequency \(w\). The movement of the background is simulated by changing the phase shift \(\phi\) in each frame of the video sequence. An example of images of the generated background is shown in figure 4. The noise generation module provides the formation of a Gaussian noise image frame with zero mathematical expectation and unit dispersion and is implemented by the standard function \(N0=\text{randn}(x,y)\).
Figure 4. Simulation of a change in the heterogeneous background: a) parameter \( w=0.1 \), signal-to-noise ratio \( \Psi=7 \); b) parameter \( w=0.05 \), signal-to-noise ratio \( \Psi=7 \); c) parameter \( w=0.05 \), signal-to-noise ratio \( \Psi=1 \).

In the module for generating a test image with a given local contrast and signal-to-noise ratio, the value of \( U_c \) of the object signal is calculated by the formula \( U_s = \frac{2U_{max}K}{1-K} \). The value of the standard deviation of noise \( \sigma \) is calculated by the formula \( \sigma = U_c / \Psi \sqrt{2} \), and the test image itself (figure 5a) in each frame of the video sequence is formed as a sum \( F_{test} = U_s F + T_0 + \sigma N_0 \).

Figure 5. An example of a frame of a test video sequence with given input parameters – a) and frames of the resulting video sequence b) and c).

The module for determining the reference coordinates of the object is designed to measure the coordinates of the source binary image \( F \) of the object in each frame of the generated video sequence. The coordinates of the object are determined in accordance with [4] by the formulas \( X = \frac{X_{max}+X_{min}}{2} \), where \( X_{min}, X_{max} \) are the coordinates, respectively, of the extreme left and right points of the image of the object and \( Y = \frac{Y_{max}+Y_{min}}{2} \), где \( Y_{min}, Y_{max} \) are the coordinates, respectively, of the extreme upper and lower points of the image of the object.

In the object selection module, the studied selection method is modeled by appropriate processing of test \( F_{test} \) images of the video sequence. A binary image of the selected object is formed at the output of the module.

The selected binary image of the object is used to determine the coordinates in the corresponding software module, organized similarly to the module for determining the reference coordinates. Additionally, in the module for determining the coordinates of the selected object, the coordinates of the object tracking zone are formed for subsequent control of the effectiveness of the simulated method.

The simulation result is recorded in the module for calculating the output parameters. In this case, for a rough estimate, the probability of the initial binary image of the object entering the tracking zone...
formed during the selection process is calculated. The probability of coincidence of the coordinates of the selected object with the original binary image is calculated for the average estimate. The probability is calculated as the difference between the coordinates $X_0$, $Y_0$ of the original binary image of the object and the coordinates $X$, $Y$ of the selected object in the specified allowable interval $\Delta=\Delta X=\Delta Y$ for an accurate estimate.

Figure 6 shows an example of the obtained graphs of the dependences of the probability of correctly determining the coordinates $p(t)$ on the signal-to-noise ratio $\Psi$ for two compared methods of selecting images of objects.

For visual control of the effectiveness of the simulated method (figure 5b, c).

3. Conclusion

The test video sequence of the situation considered above allows obtaining a quantitative and qualitative assessment of the effectiveness of the studied method of selecting an object against an uneven background under conditions of changing the size and position of the object in the video surveillance field.

![Figure 6](image)

**Figure 6.** Example graphs of the dependences of the probability of correctly determining the coordinates $p(t)$ on the signal-to-noise ratio $\Psi$.

The test video sequence is implemented quite simply by the standard functions of the MATLAB package and provides the probability of correctly determining the coordinates of the object with a different set of input parameters such as contrast, signal-to-noise ratio, the size of the background fragments, the range of changes in the size of the object, the magnitude of the background inhomogeneity, which allows comparing the effectiveness of different selection methods.

References

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