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THE RESOLVING CAPACITY OF THE OPTICAL SYSTEMS IN THE INTELLIGENT SURVEILLANCE SYSTEMS APPLICATIONS

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Today one of the most important priorities of technical sciences is developing of intelligent systems of digital surveillance (ISDS).

ISDS applications are directed at the exclusion of operator. Here are the results of the research which contains the next information: after 12 minutes of continuous monitoring an operator begins to pass 45% of alarm events, and 95% of potential alarm events will be missed in 22 minutes.

The known systems of video analysis allow us to solve the following problems:

1. Alarm events detecting (crossing the lines, entry/exit from the area, unattended object, suspicious behavior, group of people formation);
2. Car license recognition;
3. Face recognition;
4. Trajectory construction;
5. People calculation;

ISDS have their own specific requirements, which depend on the following parameters of the scene:

1. Objects reflection;
2. Scene complexity;
3. Scene activity levels;
4. Scene contrast variation;
5. Scene illumination level.

There are some requirements for optical components of ISDS based on scene parameters data:

- Lens parameters: focal length, angle of view, optical format, resolving capacity, aperture, zoom, depth of field, spectral range;
- Photodetector parameters: spectrum, resolution, optical format, type;
- Illumination sources parameters: spectrum, angle of illumination, brightness, source locations;

Let's consider one of the main requirements of ISDS as the image quality. Criterion of quality of the optical video systems is it's resolving capacity (RC). Overall RC contains lens, monitor RC's and photodetector resolution.

RC lens and the photodetector resolution are key parameters in the design of ISDS. RC lens is the lens capacity to image two closely spaced dot objects apart. RC lens is defined as maximum of test-object spatial frequency in the image where we can see still visible strokes. RC is measured in line pairs per millimeter. Contrast to periodic images is determined by the difference between the maximum and minimum intensity. The greater the contrast, the easier it is to distinguish fine details. RC is usually determined due to the MTF (modulation transfer function). It is necessary to specify the frequency limit for a particular contrast, for example, the frequency of 55 LP/mm at a contrast of 0.2.

For stable face recognition linear dimension between centers of pupils must not be less than 120 pixels. In mm this average dimension is about 65-68. Therefore, it is necessary to distinguish the point at a 0.5 mm. Angular RC of the lens for a distant object is defined by Relay criterion:

$$\gamma_{\text{об}} = 1{,}22 \times \frac{\lambda}{A'}, \tag{1}$$

A′ – Lens aperture, λ – wavelength.

If we know the distance to the object *L* then the necessary RC can be obtained.

Table 1

The calculated values of the RC lens for different distances

F/#	$\gamma_{\text{об}}$, rad.	x, mm	L, m	R, line pairs/mm
F/2,8	0,0053	0,5	31,4	94
F/4	0,0108	0,5	15,4	46
F/5,6	0,0212	0,5	7,8	23
λ=555 nm				

Similarly, it is possible to make optimal choice of the lens for registration, recognition and identification. After the lens is selected, you must choose a photodetector with the required parameters.

Let's try to determine the maximum resolution that can be obtained using the classical CCD Bayer structure (Fig. 2). This can be done by applying signals of different spatial frequencies and examining the maximum contrast of the image.

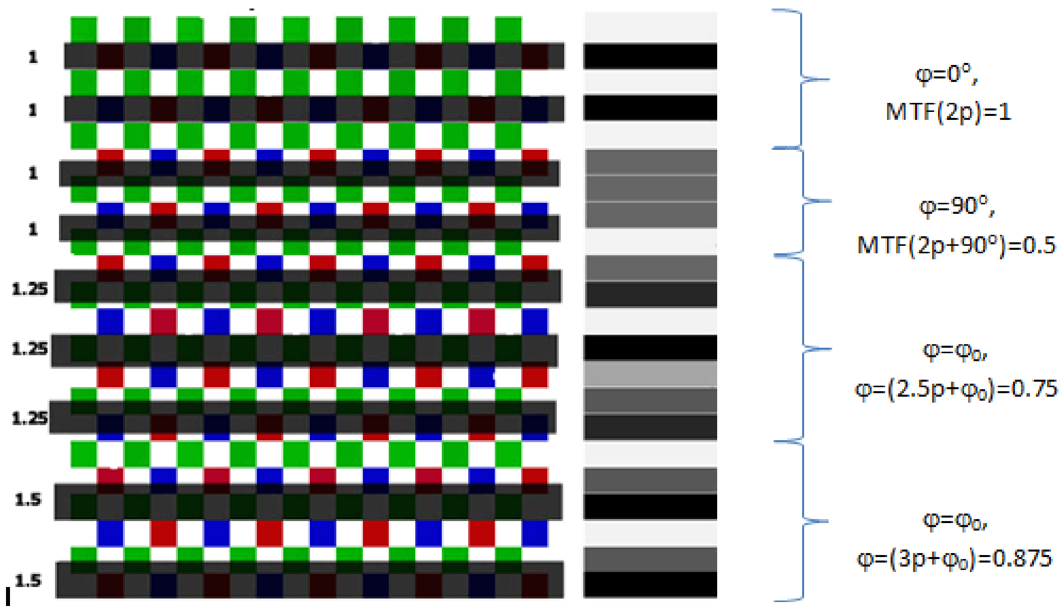

Fig. 1. Bayer structure

The highest frequency of a signal that can be discerned with regular structure defined by Nyquist-Kotelikov criterion is a signal that has maximum and minimum cell size:

$$f = \frac{1}{2p}, \tag{2}$$

p – cell size.

That frequency can be recognized by the phase shift φ=0° or φ=180°. But at φ=90°, maximum and minimum will be evenly distributed over the two adjacent rows and contrast K=0. On average, with a random value of φ contrast at the output will be equal to the contrast obtained by φ=45°and will be 50% of maximum. In the absence of a signal processing circuit filter or anti-aliasing filters, MTF in the spatial frequency of the signal with period equal to twice that of the cell size is dynamically unstable, and the average is 0.5: MTF (2) = 0.5.

Spatial frequency with a period equal to 2.5p causes that some Max and Min in the signal output are also obscured with varying contrast, depending on the phase of the signal. Consequently, this system is also dynamically unstable, the recognition of the frequency and the contrast of the output depend on φ relative to the regular structure of the photodetector matrix. The average value of contrast at a frequency of 1/2,5p is approximately equal to 75%, which can be written as MTF (2.5) = 0.75.

With a period equal to 3p the signal at the output of the photodetector is relatively stable, weakly dependent on φ [5]. In the best phase MTF = 1, in the worst MTF = 0.75. The mean value of MTF (3) is 0.875. We can say that at this spatial frequency we can see stable detection threshold.

We should bear in mind that the Nyquist-Kotelikov criterion, ensuring accurate recovery signal by its reference, is only valid if:

– the spectrum of the input signal is limited to a maximum of sinusoidal frequency equal to or greater than twice the upper frequency range;

– the function is finite, to restore the signal you want to use ideal low-frequencies filter [5].

These conditions are not met in image processing. It’s therefore necessary to use correction factors.

It’s possible to calculate the maximum resolution of the CCD or CMOS sensor (Table 1), without the additional filters for image processing (3).

$$\gamma_S = \frac{N_W}{L_W \times 3}, \qquad \gamma_{NS} = \frac{N_W}{L_W \times 2}, \tag{3}$$

где N_W – number of pixels on the long side of the frame, L_W – PD-matrix size on the long side of the frame.

Table 2

Parameters of the different types of CCD and their RC

CCD	Size, mm	Resolution, pixel	Dynamically stable resolution, line pairs/mm	Dynamically unstable resolution, line pairs/mm
Sony® ICX-413AQ CCD, 1,8"	23,55x15,72	3020 x 2016	43	64
Sony® ICX-412AQ CCD, 1/1,8"	7,08 x 5,31	2048 x 1536	96	144
Sony® ICX-674	8,8 x 6,6	1940 x 1460	74	110

Interline CCD, 2/3”				
Sony® ICX-285AL Interline CCD, 2/3”	8,77 x 6,6	1360 x 1024	52	78
Sony® ICX-205AK CCD, 1/2"	6,32 x 4,76	1360 x 1024	72	108

It’s desirable to match the RC lens and resolution photodetector or slightly exceed it. [1]

Conclusion. Requirements for video analysis algorithms for optical systems have their own specifics. For correct work of video analysis algorithms that solves the problem of registration of persons and recognition and identification of objects, you need high quality images of the scene and all embedded objects. To assess the quality of the image the term resolution and RC of the optical system are used.

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