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METHODS FOR ASSESSING SIGNAL QUALITY IN DIGITAL VIDEO SURVEILLANCE SYSTEMS

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Abstract:

The article presents the results of a comparative analysis of methods for assessing the quality of a video signal, which allow studying and investigating video surveillance systems. The mechanisms for improving the quality of a video image are given, in particular, the effect of stabilization mechanisms on image quality. Graphs of the influence of stabilization mechanisms on image quality are presented. The substantiation of the expediency of using the software method of stabilization, which makes it possible to remove unevenness during jitter, is given.

Keywords: image, CCD video camera, subjective methods for assessing image quality, signal-to-noise ratio., signal-to-noise ratio.

Introduction

Evaluation of the efficiency of video signal processing, that is, the image, is an actual problem, which has not yet been solved. When processing and analyzing images always have to be concerned about their quality. The quality of such a complex object as an image is very important, but at the same time quite a complicated concept. It is evaluated in different ways and in connection with various tasks.

The problem is that the quality criteria used to analyze one-dimensional signals (root-mean-square error, signal-to-noise ratio, etc.) do not always give a good result in the image, since it is necessary to take into account a number of features of a human's visual perception. There are many examples of images for which quality is quantitatively assessed as high, subjectively as low, and vice versa. Visual assessment while reducing the dispersion of the noise component in the image plays an important role, especially if the image processing task is solved for the observer, and not for the computer [1].

Sometimes quality is considered as a characteristic of the image itself and is determined by its own properties (statistical, structural, semantic). The relevant criteria are either subjective or based on the objective characteristics of the image: the shape and parameters of the brightness distribution, the width of the spatial spectrum, etc. Such irrelevant criteria have a rather limited application and are almost never used [1].

In another approach, quality is considered as a measure of the proximity of two images: real and some ideal, or original and transformed. This approach is more constructive, it allows you to evaluate the quantitative changes in the brightness values, the level of image distortions during their transformations (filtering, data compression, etc.), that is, in essence, the quality of the transformation tool itself - the algorithm or the system. This is very important when creating algorithms and image processing systems and evaluating the quality of algorithms [1].

The most commonly used quantitative estimates of image quality include: average difference, normalized correlation, quality of correlation, maximum difference, image accuracy, root-mean-square Laplacian error, root-mean-square error, maximum root-mean-square error, normalized absolute error, normalized root-mean-square error, signal-to-noise ration (SNR), peak SNR and resolution [1].

Conflict setting

The signal-to-noise ratio (SNR) indicates the degree of appearance in the image of the so-called "snow" and indicates the quality of the video output of the CCTV camera. It is measured in decibels (dB) and is presented as an integral evaluation of the signal-to-noise ratio using the formula

$$ISNR = 20 \cdot \lg(\frac{\sigma_{ш}}{\sigma_{ош}}) \tag{1}$$

where $\sigma_{ш}$ –root-mean-square component of the noise, $\sigma_{ош}$ –root-mean-square component of the errors.

The most commonly used objective estimates of image quality also include the signal-to-noise ratio and the peak signal-to-noise ratio, expressed in decibels:

$$SNR = 10 \cdot \lg\left(\frac{\sum_{i=1}^{N}\sum_{j=1}^{M} S_{i,j}{}^{2}}{\sum_{i=1}^{N}\sum_{j=1}^{M}(S_{i,j} - \bar{S}_{i,j})^{2}}\right) \tag{2}$$

where $S_{i,j}$ – a useful two-dimensional component (original undistorted video signal):

$$PSNR = 20 \cdot \lg(\frac{\max(S)}{\sigma_{ош}}) \qquad (3)$$

where S – video signal component; $\sigma_{ош}$ – root-mean-square component of the errors.

With a signal-to-noise ratio of 45 dB, the noise is almost not noticeable. The high signal-to-noise ratio of the camera, and, consequently, the high-quality image, is achieved by a sufficient level of illumination of the object of observation, high-aperture optics, the use of high-quality CCD, and digital noise filtering in the electronic circuits of the CCTV camera. In addition to influencing the image quality and, therefore, the performance of the security television system operator, the signal-to-noise parameter significantly affects the size of the compressed image file in digital systems [2].

The signal-to-noise ratio shows how good the video signal of a video camera can be, especially in low light conditions. Noise can not be avoided, but it can be minimized. Basically, it depends on the quality of the CCD, electronics, and external electromagnetic effects, but also to a large extent on the temperature of the electronics. The metal body of the camera largely protects against external electromagnetic influences. Strictly speaking, external electromagnetic effects, as a rule, are stationary processes, so they cannot be attributed to noise; they are called pickups or interference. Sources of noise inside the video camera are both passive and active components, so "noise" depends on their quality, system design, and, to a large extent, on temperature. That is why, specifying the signal-to-noise ratio, the manufacturer should also indicate the temperature at which the measurements were taken [2].

The signal-to-noise ratio of a CCD video camera is not measured in the same way as in television broadcasting or during signal transmission. In a broadcast signal, the signal-to-noise ratio is the signal-to-noise ratio accumulated when the signal is transmitted from the transmitter to the receiver. It is defined as the ratio (in dB) of the amplitude of the signal corresponding to the scale of brightness gradations to the root-mean-square value of the voltage imposed by random noise measured in the frequency band from 10 kHz to 5 MHz. There are special devices designed to directly measure this value when using the test line signal [2].

For CCD video cameras in CCTV television, the signal-to-noise ratio of more than 48 dB is considered good. It should be remembered that a 3 dB change in the signal-to-noise ratio means approximately 30% noise reduction since the level of the video signal does not change. And when comparing a video camera, in which the signal-to-noise ratio is 48 dB, with a video camera, in which, for example, this value is 51 dB, the latter will give a significantly better image, which will be especially noticeable at low light levels. Speaking of the signal-to-noise ratio, we always assume that the AGC is disabled. If you do not allow significant heating of the camera, the noise will be less. For comparison, this value is given: CCD video cameras in television broadcasting have a signal-to-noise ratio of more than 56 dB, which is extremely good for an analog video signal [2, 3].

The criterion of visual perception is based on the results of the examination. The usual quality assessment procedure involves the presentation of a set of pairs of images (analyzed and ideal) to expert observers who make judgments at the level: «distortions are imperceptible», «noticeable, but do not degrade», «degrade, but do not interfere», «slightly interfere» etc. Individual estimates are processed and averaged. There are special techniques that exclude the «addiction» of experts in the course of experiments, their addiction to specific subjects, etc.

Conducting such an examination is always a difficult task, and its results are very approximate. For special images (which, for example, are obtained by remote sensing), experts should be specialists in solving relevant applied problems of video analysis [3].

But the main drawback of the subjective criterion is the lack of quantitative assessments. It does not allow solving problems of optimization of image processing systems in the space of continuously changing parameters. Here it is only possible to sort out the options and that is not very big. It is desirable that the criterion has a simple analytical form and is simply calculated from the presented images. This requirement is met by a number of criteria, discussed below. In a number of image quality indicators, the spatial (linear) resolution or resolution index plays a special role.

This criterion forms the basis of standard methods for determining the quality of images obtained by photographic remote sensing systems. The usual way to experimentally estimate the value of this indicator is as follows. A test image – a measure consisting of a set of line objects of various sizes is input to the system. The image that has passed through the information path is presented to the observer (operator-decoder). The observer is given the task of specifying the smallest object with still distinguishable stripes (strokes). The minimum width of a distinguishable stroke is the desired value of the linear resolution index [3].

In addition, the presence of a human observer makes it difficult to conduct experiments and generates subjective errors of assessment. It is obvious that the improvement of the image quality assessment procedure should follow the path of formalizing the linear resolution index (that is, replacing the observer with its mathematical model), as well as expressing this criterion through such characteristics of the image and the through path that can be measured using fairly arbitrary real brightness fields.

With the help of intelligent programs embedded in the video camera, the quality of video signals is improved.

Of all the technical means of security currently available, only television systems can immediately show what is happening at the moment in the protected object. A properly designed television system allows real-time, momentary assessment of the situation in controlled areas reduces the response time to an emergency situation, and ensures the adoption of the most appropriate measures to protect and counteract the circumstances [3].

The correct decision-making and the correct assessment of the situation are significantly influenced by the quality of video signals, that is, images because, besides the alarm sensors, only a high-quality image can help respond to an emergency situation in time.

Research results

One of the methods to improve the quality is the installation of smart cameras, which incorporate functions into the device that allows reducing noise in images. These additional features of the camera include technology DNR, WDR, digital stabilization, and some others.

The basis of the traditional technology DNR is the time analysis of the video signal. The DNR algorithm works by comparing one frame with another and eliminating those tiny features of an individual frame that break out of the correct flow of the video sequence. In other words, this method identifies those pixels that change from frame to frame without any reason. The meaning of this transformation is that due to the mixing of frames, the overall noise level in the image is reduced.

In general, the traditional DNR eliminates only the noise and unwanted data found in the near part of the scene. Only objects that are close to the camera are processed to eliminate visible noise, and everything that belongs to the background remains unprocessed [4].

There are two ways to suppress noise:

- 2D noise reduction. The brightness of the neighboring pixels of one frame is corrected; special mathematical calculations determine how much this change corresponds to the noise parameters and, if the probability of noise is high, reduce the difference in brightness by the calculated value;

- 3D noise reduction. Calculations are made not only for one frame but for several consecutive frames, which allows for a more accurate selection of noise because it changes in time and is easier to track. This technology is considered more modern and more efficient [4].

The D-WDR technology allows you to obtain a high-quality image of both the bright and dark parts of the frame (Fig. 1) . The fact is that the number of grayscales (mid-tones) that a video camera can transmit is only part of the full spectrum from pure white to pure black. And if both bright and dark areas are present in the frame (for example, a bright sky on a sunny day and an object in the shade), the video camera is forced to calculate the exposure trying to cover the maximum gradations of brightness. As a result, bright objects appear darker (closer to gray) and darker ones are lighter (also closer to gray). Thus, the image contrast is lost [4].

The technology of expanding the dynamic range just allows you to transfer all grayscale in all areas of the frame with maximum accuracy while maintaining contrast, but there is a loss of detail.

Any stabilization system that allows improving the quality has two components: the “jitter” determinant and the frame recovery mechanism without jitter. There are three types of stabilizers: mechanical; optical; digital.

a) the D-WDR function is turned off

b) the D-WDR function is turned on.

Fig. 1 Application of D-WDR function

The digital stabilizer determines the offset by analyzing the image obtained from the matrix. For this, its real size should be substantially larger than the effective one, so that at small offsets the frame does not go beyond the matrix. An image with a smaller area is recorded on the carrier, which “jumps” across the matrix from frame to frame according to a certain displacement vector (Fig. 2). Compared with optical stabilization, the disadvantages of this method are obvious: firstly, not the entire matrix area is used, which leads to a deterioration of the signal-to-noise ratio in low light conditions, secondly, it is not possible to eliminate intraframe blurring (which, however, charging only long exposures and quite a strong shaking).

The principle of the software stabilizer, on the one hand, resembles a digital stabilizer in the camera, but there are a number of significant differences. First, the trajectory of the camera can be determined in a relaxed atmosphere, analyzing as many past and future frames as you like, and the optimally smoothed trajectory will be devoid of any snaps. Secondly, a well-designed stabilizer can use the adaptive zoom function to «hit the frame».

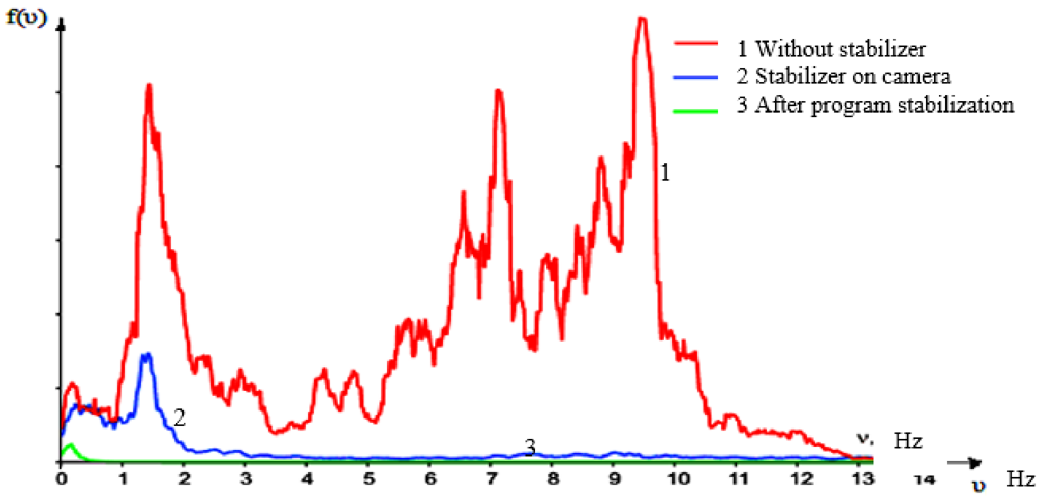

Fig. 2 Oscillation spectrum of a frame with the camera stabilizer turned on and off, as well as after software stabilization

The size of this area may vary in time - this is adaptability. If the motion in the frame (more precisely, on its edges) is absent, then this filling of the edges works very well: you can shoot a distant stationary object with jitter in a half-frame - the stabilization process will glue together a single «panorama» from this set of frames and will slowly move along it sight.

Conclusion

A comparative analysis of existing methods for assessing the quality of video images has been carried out.

Ways of developing mechanisms for assessing image quality are given.

Methods improving image quality are given.

The prospect of using a software stabilizer is shown, which makes it possible to shoot a distant object with trembling in a half-frame and remove unevenness.

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ՏԵՍԱԴԻՏԱՐԿՄԱՆ ՀԱՄԱԿԱՐԳԻ ԹՎԱՅԻՆ ՏԵՍԱԽՑԻԿԻ ԱԶԴԱՆՇԱՆԻ ՈՐԱԿԻ ԳՆԱՀԱՏՄԱՆ ՄԵԹՈԴՆԵՐԸ

Սաֆին Ռ.Տ.[1], Մարկոսյան Մ.Վ.[2], Սատիմովա Ե.Գ.[3], Պավլովա Տ.Ա.[4], Գարմաշովա Յ.Մ.[4]
[1]Ղազախստանի փրանսպորտի և կապի համալսարան
[2]Երևանի կապի միջոցների ԳՀԻ
[3]Ազգային միջուկային հետազոտությունների համալսարան՝ ՄԻՖԻ
[4]Ալմաթիի էներգետիկայի և կապի համալսարան

Ներկայացված է տեսաազդանշանների որակի գնահատման մեթոդների համեմատական վերլուծությունը, որոնք հնարավորություն են տալիս ուսումնասիրելու և հետազոտելու տեսադիտարկումների համակարգերը: Բերված են տեսապատկերների որակի բարձրացման մեխանիզմները, մասնավորապես ստաբիլացման մեխանիզմների ազդեցությունտ պատկերների որակի վրա: Ներկայացված են պատկերների որակի վրա կայունացուցիչների մեխանիզմների ազդեցությունների գրաֆիկները: Բերված է ծրագրային ստաբիլացման մեթոդի կիրառման հիմնավորումը, որը թույլ է տալիս հանել ոչ գծայնությունները դողոցքների ժամանակ:

Բանալի բառեր. պատկեր, լիցքով կապող սարքով (ԼԿՍ) (CCD) տեսախցիկ, պատկերի որակի գնահատման սուբյեկտիվ մեթոդներ, ազդանշան-աղմուկ հարաբերակցություն:

МЕТОДЫ ОЦЕНКИ КАЧЕСТВА СИГНАЛА В ЦИФРОВОМ ВИДЕО СИСТЕМЫ НАБЛЮДЕНИЯ

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Представлены результаты сравнительного анализа методов оценки качества видеосигнала, позволяющих изучать и исследовать системы видеонаблюдения. Приведены механизмы повышения качества видеоизображения, в частности влияние механизмов стабилизации на качество изображения. Представлены графики влияния механизмов стабилизации на качество изображения. Приведена обоснование целесообразности использования программного метода стабилизации позволяющего снять неравномерности при дрожании.

Ключевые слова: изображение, ПЗС-видеокамера, субъективные методы оценки качества изображения, отношение сигнал/шум.

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