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Determining the Feasibility of Applying Existing Criteria for Solving Operational Problems in the Design of CCTV Information Systems

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ABSTRACT Comparative analysis of the criteria for designing video surveillance information systems was conducted based on international and national CCTV standards. Their greatest differences concern identification and recognition tasks, and the smallest — monitoring and detection. A comprehensive analysis of the impact of the technical characteristics of video cameras on the results of solving CCTV operational problems has not been carried out at this time. Therefore, the current direction of research is to determine the maximum feasibility of using the formed set of criteria. Increasing the resolution of video cameras leads to an increase in the number of pixels per meter of linear field of view. This in turn improves the display quality of the surveillance object at a greater distance from the camera. With the emergence of new information technologies, the resolution of matrices in video surveillance systems will increase. It will lead to qualitative and quantitative changes in the established set of criteria for designing of CCTV information systems. The methodology of estimation of spatial resolution of images of video surveillance information systems (CCTV) is presented in this work. The theoretical foundations for analyzing a set of technical characteristics of video cameras are confirmed by the results of computer modeling using specialized software "IP Video System Design Tool". The overall discrepancy between the calculated and modeled data does not exceed 3%. As a result, it was found that the use of a 25 MP video camera satisfies and exceeds all currently existing criteria for designing CCTV information systems for solving various types of operational tasks and the possibility of human vision. Therefore, with the cheapening and widespread use of video cameras with a resolution of over 25 MP, it will be necessary to review the feasibility of using existing criteria for designing CCTV information systems.

KEYWORDS criteria, operational task, pixel density, matrix, image quality, scene, spatial resolution, modelling.

I. INTRODUCTION

Video surveillance is an information television systems for special purposes integral part. In practice, it is called Closed Circuit Television (CCTV), which is intended for a limited number of viewers.

Manufacturers preferred technical descriptions and specifications, creating recommendations for choosing cameras. As a result, CCTV developers did not take into account the operational requirements (the actual purpose of video surveillance), which is one of the key requirements of any video surveillance system. Today, the main parameter for choosing a CCTV camera is the degree of detail of the image. Today, the main parameter for choosing a CCTV camera is the degree of detail of the image. It depends on the clarity of the display of the object of observation on the appropriate means and is determined by the tasks related to this system.

The appearance in the late 80s of the last century of the term "operational task" not only made it possible to formulate the corresponding categories that differed among themselves in the percentage of the frame that a full-length person occupies, but also to approve the first

criteria that a video surveillance system must meet to solve a particular operational problem.

Rapid development of analog video surveillance and improved image resolution prompted viewing of categories of operational tasks. Operational tasks such as monitoring, detection, inspection, recognition, identification and inspection have already been highlighted in the updated standard BS 8418:2010 [1-3]. The European Committee for Standardization has adopted the standard EN 50132-7:2012 [4, 5] during the design of CCTV in the EU. It has formed criteria for choosing cameras and lenses for them, criteria for determining the number and location of cameras, methods for assessing the scene and lighting, and the criteria for solving the operational task of CCTV correspond to [1]. A characteristic difference between this standard and the previous one was the appearance of an alternative parameter – "pixel density" per unit width of the observation object. This is due to the appearance on the market of cameras that functioned on a different principle than analog ones. The further feasibility of using indicators of these criteria is due to the emergence of

megapixel digital systems and the period during which old systems were displaced from the CCTV market.

Only a new method of establishing compliance with operational requirements is used with the dominance of IP and HD cameras in the market. Percentages have fallen into the background, and therefore are not used for digital cameras. It is customary to specify the resolution requirements in pixels (instead of “TV line” – TVL) – the number of pixels of the image per 1 meter at the distance of observation of the object. Thus, the use of criteria for world standards for compliance with the task of analog systems was dictated by further expediency in their improvement and the total transition to CCTV to new ones, in which the “pixel” replaced the TVL.

“Pixel density” is used in all current CCTV standards as a criterion for solving operational problems. But the values of this criterion for different operational tasks differ [6-8].

The biggest discrepancy, which is traced in world standards with CCTV, concerns identification and recognition tasks, and the smallest – monitoring and detection. Pixel density in video surveillance and pixel density of monitors are different things. The resolution of monitors is determined in pixels per inch, and the “pixel density” parameter of the camera takes into account the size of its matrix, the number of pixels of the matrix, the focal length of the lens and the distance to the surveillance object.

The following practitioners: Oleksiy Gonta, Vlado Damjanovski, Yuriy Gedzberg, Oleksandr Popov, John Bigelow and others were engaged in the influence of the parameters of video cameras on the image quality of the object in the course of solving various problems.

An image of a group of people [9, 10] modeled in the “CCTV Designer” program during the research of the operational task of “detection,” obtained by video cameras with different resolutions showed that for any size of objects on the monitor screen there are restrictions on the choice of video camera resolution. So for the resolution of the video camera 704×576 , there is not enough detection to solve the problem, since there is a strong pixelation of the image. Using a 4 megapixel camera with a resolution of 2560×1600 has no advantage during “detection” compared to a 2 megapixel camera with a resolution of 1920×1080 . When solving the problem of “detection,” you need to monitor the screen resolution, which should be no worse than the resolution of the video camera.

The research of the effect of camera resolution on the “recognition” of an object indicates [11, 12] that in the same focal lengths of video cameras (the size of a person on the monitor screen remains constant) the resolution of the images obtained differs significantly. The image quality of 2 megapixels of the camera is sufficient for detailed “recognition,” and a frame of 4 megapixels of the camera allows you to solve the problem of “identification” of a person.

The theory of changing the density of spatial resolution and the question of transformation of TVL in a pixel were reflected in subsequent researches [9, 10, 13-15].

The theory of changing the spatial density of pixels implies finding such a distance from the camera to the object at which the number of pixels per 1 meter of the width of the surveillance sector (linear field of view) will be a predetermined value. It is worth noting that the theory of changing the density of spatial resolution is widely used in practice by CCTV designers to calculate the possibility of “detection” or “identification” any object to which the user may have interest (person, license plate, playing card, denomination of the banknote, etc.).

Analysis of information sources showed that the “pixel density” is used as a modern criterion for solving various types of CCTV operational problems, and their values differ in existing standards. The “pixel density” parameter of the camera takes into account the size of its matrix, the number of pixels of the matrix, the focal length of the lens and the distance to the surveillance object.

It has been found that increasing the resolution of video cameras leads to an increase in pixel concentration by 1 meter of linear field of view and improves the quality of display of the object of observation at a greater distance from the camera. In accordance with this, it is assumed that with the advent of new technologies, the number of pixels of the matrix can reach a value that will “blur” the modern understanding of the distribution of CCTV operational tasks and, accordingly, the question of the further feasibility of using existing criteria will arise.

II. PROBLEM STATEMENT

The analysis of information sources of practitioners-researchers of CCTV on the influence of technical parameters of video cameras on the image quality of the object in solving various types of operational tasks of CCTV made it possible to establish that the issue of determining the maximum expediency of using these criteria was not considered and is relevant. Practical interest arose in determining the value of the resolution of the video camera. The criteria for modern standards with CCTV will be revised or discontinued. It is worth focusing on the capabilities of human vision, which are also limited.

Spatial resolution change theory is implemented in two ways: analytical and computer modeling (using a specialized program that allows the design of CCTV). It is taken as a basis for solving the task.

III. ANALYTICAL DESCRIPTION

Designers and customers must determine the task that each camera (monitoring, detection, inspection, recognition, etc.) should solve in accordance with the requirements of the current standards. When selecting the viewing area, calculate the camera and lens parameters, which in the viewing area will correspond to a sufficient “pixel density” for the selected task. It is necessary that the calculated value of “pixel density” meets the specified standard value for achieving the image quality specified by this standard during the design of any information system. It is impossible to guarantee the fulfillment of the requirements of the standard if only the focal length of the lens is taken as a basis. The characteristics of the matrices should be taken into account.

In the case where the linear field of view H_{fv} and the number of pixels of the matrix n_{mp} in its width are known, the number of pixels n_{fv} , which are per its unit width, is determined:

$$n_{fv} = \frac{n_{mp}}{H_{fv}} = \frac{n_{mp}}{L \frac{h_m}{f}}, \quad (1)$$

where L – distance to the object of observation (m);

h_m – width of video camera matrix (mm);

f – focal length of the lens (mm).

It is advisable to take into account the aspect ratio when determining the number of pixels in the width of the matrix.

The number of pixels in width for a 4:3 matrix is determined by the following expression:

$$n_{mp} = \sqrt{\frac{n_m}{0,75}}. \quad (2)$$

Hence, the expression for spatial resolution change will take on the following form:

$$n_{mp} = \frac{\sqrt{\frac{n_m}{0,75}}}{L \frac{h_m}{f}}. \quad (3)$$

The final expression for calculating the focal length, depending on the type of task and the distance to the object of observation, will take on the following form:

$$f = \frac{L h_m n_{fv}}{H_{fv}}. \quad (4)$$

IV. METHODS AND RESULTS OF RESEARCH

The focal length of the lens was chosen for spatial resolution variation calculations. It was 12 mm, and the size of the matrix was 1/2". The step of changing the resolution of the matrix is 5 Mpx, and the distance to the potential object of observation in the range from 5 to 100 m with a step of 5 m.

Modeling of change in spatial density of pixels was carried out in the environment "IP Video System Design Tool 11.0" [16]. In order to confirm the obtained calculated data, the system was simulated using the following initial data:

- focal length of the lens 12 mm;
- distance to the object of observation (human figure model) from 20 to 60 m in steps of 5 m;
- video camera matrix size 1/2";
- matrix format 4:3;
- video camera resolution: 5 Mpx, 10 Mpx and 19 Mpx.

Note that there is no 20 Mpx video camera in the application database. Given this, the value of 19 Mpx was adopted as the closest to the required.

The model of the human figure was exhibited at a distance of 20 m from the CCTV camera and, after taking readings of the spatial density of pixels, was shifted 5 meters further. The pixel density value was displayed together with the generated image of the human model at the bottom left of the application window.

The results of spatial resolution change calculations are shown in Table 1, and their graphical dependencies are shown in Figure 1.

The simulation results ranging from 20 to 50 m are presented in Table 2.

TABLE 1. Spatial density calculation results for a 4:3 matrix with a size of 1/2" ($f=12$ mm).

Matrix resolution n_m , Mpx	5	10	15	20	25	30	
Number of pixels n_{mp} , pieces	2581	3651	4472	5163	5773	6324	
Distance to the object L , m	5	968	1369	1677	1936	2165	2371
	10	484	684	838	968	1082	1185
	15	322	456	559	645	721	790
	20	242	342	419	484	541	592
	25	193	273	335	387	433	474
	30	161	228	279	322	360	395
	35	138	195	239	276	309	338
	40	121	171	209	242	270	296
	45	107	152	186	215	240	263
	50	96	136	167	193	216	237
	55	88	124	152	176	196	215
	60	80	114	139	161	180	197
	65	74	105	129	148	166	182
	70	69	97	119	138	154	169
	75	64	91	111	129	144	158
	80	60	85	104	121	135	148
	85	56	80	98	113	127	139
90	53	76	93	107	120	131	
95	50	72	88	101	113	124	
100	48	68	83	96	108	118	

TABLE 2. Pixel spatial density values.

Resolution, Mpx	5	10	19	
Distance to the object, m	20			
	25			
	30			
	35			
	40			
	45			
	50			

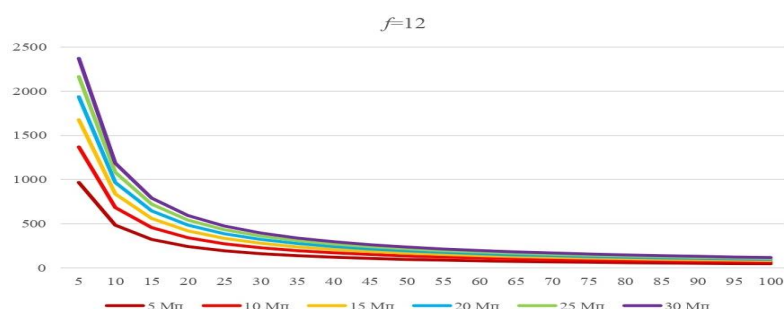


FIG. 1. Changing Spatial Resolution.

The results of modeling the change in spatial density at 19 Mpx before comparison with the calculated values were not taken for obvious reasons. Analysis of other results (5 and 10 Mpx) obtained by calculation and simulation indicated a discrepancy in values at the corresponding distance from the camera in the range from 5 px/m to 2 px/m.

V. CONCLUSION

A person is able to identify a familiar person at a limited distance not exceeding 30-35 m, and numerical values above the above CCTV standards. It was found that the application of a 25 Mpx camera meets and even covers all existing criteria for solving various types of operational problems and the capabilities of the human visual apparatus. Thus, the further feasibility of using currently operating approaches in the design of these systems can be discussed in the event of the appearance on the market of video cameras with a resolution of 25 Mpx and their mass use.

AUTHOR CONTRIBUTIONS

T.T., O.K., L.P., I.K., N.Z. – conceptualization, methodology; T.T., O.K., L.P., I.K., N.Z. – investigation; T.T., O.K., L.P., I.K., N.Z. – writing (original draft preparation), T.T., O.K., L.P., I.K., N.Z. – writing (review and editing).

COMPETING INTERESTS

The authors declare no competing interests.

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Обумовлення доцільності застосування існуючих критеріїв вирішення оперативних задач при проектуванні інформаційних систем CCTV

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АНОТАЦІЯ На основі міжнародних та національних стандартів проведено порівняльний аналіз критеріїв проектування інформаційних систем відеоспостереження (CCTV). Найбільші їх відмінності стосуються завдань ідентифікації та розпізнавання, а найменші – моніторингу та детектування. На даний час не проводився комплексний аналіз впливу технічних характеристик відеокамер на результати вирішення оперативних задач CCTV. Тому, визначення граничної доцільності використання сформованої множини критеріїв є актуальним напрямком досліджень. Збільшення роздільної здатності відеокамер призводить до збільшення кількості пікселів на 1 метр лінійного поля відеоспостереження. Що, в свою чергу, покращує якість відображення об'єкта спостереження на більшій відстані від камери. З появою нових інформаційних технологій зростатиме роздільна здатність матриць систем відеоспостереження. Це призведе до якісних та кількісних змін сформованої множини критеріїв проектування інформаційних систем CCTV. У даній роботі подано методику оцінювання просторової роздільної здатності зображень інформаційних систем відеоспостереження (CCTV). Сформовані теоретичні основи аналізу множини технічних характеристик відеокамер підтверджено результатами комп'ютерного моделювання. Для цього використано спеціалізоване програмне забезпечення «IP Video System Design Tool». Загальна розбіжність отриманих розрахункових та змодельованих даних не перевищує 3%. В результаті встановлено, що використання 25 Мп відеокамери задовольняє та перевищує всі існуючі на даний час критерії проектування інформаційних систем CCTV для вирішення різноманітних оперативних задач та можливості людського зору. Тому, при здешевленні та поширенні відеокамер із роздільною здатністю понад 25 Мп необхідно буде переглядати доцільність використання діючих критеріїв до проектування інформаційних систем CCTV.

КЛЮЧОВІ СЛОВА критерії, оперативна задача, щільність пікселів, матриця, якість зображення, сцена, просторова роздільна здатність, моделювання.