COMPLEX CAMERA CHARACTERISTICS ASSESSMENT THROUGH SFR ANALYSIS

DOI: 10.36724/2072-8735-2025-19-2-45-52

Dmitry A. Egorov,
Moscow Technical University of Communications and Informatics, Moscow, Russia, **d.a.egorov@mtuci.ru**

Andrei V. Balobanov,
Moscow Technical University of Communications and Informatics, Moscow, Russia, **andrey_sam@mail.ru**

Elena P. Stroganova,
Moscow Technical University of Communications and Informatics, Moscow, Russia

Manuscript received 12 January 2025;
Accepted 10 February 2025

The study was supported by a grant from the Russian Science Foundation No. 23-29-00302, https://rscf.ru/project/23-29-00302/

Keywords: *Modulation Transfer Function, Closed-circuit television, security camera, image quality*

An important step in selecting Cclose circuit television systems (CCTV) TV camera is evaluation of resolution capabilities of available options, because this parameter is most important one in set that defines ability of external or auxiliary systems to detect and recognise objects and events on camera video feed. Knowledge of the camera modulation transfer function is essential for building robust CCTV to detect and identify threats. Various approaches to extract MTF slope can be used, but some peculiar properties of cameras that used in this area (like closed access to raw images, un ability to fully disable onboard extensive image processing) is making traditional approaches less applicable in stand alone mode, so combination is required to confidently qualify characteristics of camera samples. In this paper we describe protocol and automation means that can accelerate measurements procedures, making them more robust too. Presented results also highlight possible directions of further research.

Для цитирования:
Егоров Д.А., Балобанов А.В., Строганова Е.П. Комплексная оценка характеристик камеры посредством анализа пространственно-частотного отклика // T-Comm: Телекоммуникации и транспорт. 2025. Том 19. №2. С. 45-52.

For citation:
D. A. Egorov, A. V. Balobanov, E. P. Stroganova, “Complex camera characteristics assessment through SFR analysis,” *T-Comm*, 2025, vol. 19, no. 2, pp. 45-52.

Introduction

The significance of surveillance system in enhancing public safety and security cannot be overstated, as they serve as indispensable tools for crime prevention, traffic monitoring, and property protection. As urban areas continue to expand and evolve, the demand for robust and reliable surveillance solutions has intensified, prompting innovations in camera technology. In recent years, the landscape of closed-circuit television (CCTV) security systems has undergone significant transformations, driven by advancements in imaging technology and artificial intelligence (AI). The emergence of system-on-a-crystal (SoC), equipped with onboard neural processing units (NPUs), has further revolutionised CCTV systems by facilitating AI processing at the edge. This development allows for real-time analysis and decision-making within the camera itself, reducing latency and bandwidth requirements. Moreover, the synergy between edge AI and cloud-based AI systems enhances the precision and robustness of detection models, which rely on high-quality images for optimal performance. This article focuses on comparison and evaluation of the modulation transfer function (MTF) measurement by different methodologies in real world scenarios, providing toolset to compare real characteristics of cameras despite image pipeline of camera that enhances perceived quality. MTF is critical parameter in assessing image quality and system performance because it represent detailization of objects in frame, showing potential performance of manual and automated analysis of image [13].

One of the most notable advancements in the realm of CCTV is the mass adoption of high-resolution sensors, such as 8-megapixel (MP) and 12MP sensors. These sensors offer superior image clarity, enabling more accurate identification and recognition of subjects within the surveillance footage. Additionally, the integration of high dynamic range (HDR) capabilities allows cameras to capture detailed images in challenging lighting conditions, improving the overall effectiveness of surveillance systems. But some manufactures not paying enough attention to camera optics characteristics prioritising economical characteristics, which significantly reduces gains from high resolution sensors.

As the adoption of advanced CCTV technologies continues to grow, the importance of MTF measurement for ensuring image quality becomes increasingly critical [18]. Accurate MTF assessments enable integrators and service companies to evaluate performance of available models, ensuring that they meet requirements and can be used with advanced AI models for functionality expansion [1].

Modern revision of ISO12233:2024 standard suggests to use eSFR methodology which is pretty robust and versatile especially in case of availability of raw image from device under test [9, 15, 16]. But test cases in area of CCTV camera often imply that camera is closed system and all measurements should be evaluated with blackbox approach. As suggested in previous research [1] results from traditional edge based methods can be augmented with random pattern MTF estimation techniques, providing deeper insight in image processing pipeline of device under test.

Objectives

Compare MTF characteristics of various CCTV cameras to develop framework for objective characteristic evaluation of CCTV cameras and highlight problems and characteristics that Intrinsic to CCTV cameras.

Related work

Spatial frequency responses can be extracted from multiple test patterns. First and most wide adopted approach is to use slanted edge methods which is widely adopted in ISO 12233 standard line. Edge SFR extraction approach was proposed in 1960s [6] is based on the fact, that if we have edge at shallow angle, we can recalculate coordinates of image samples, such that edge is aligned with one of the axis, providing oversampled edge, so SFR can be extracted up to sampling spatial frequency. This method requires target with a sharp transition (edge) at an oblique angle (usually 6° to 8°) is captured by the imaging system, position and intensity of this edge are analysed across multiple lines [2, 3, 8].

Since the edge is not perfectly orthogonal to the sampling grid, corrections are applied to align the edge with the grid axes. Than oversampled edge sequence is averaged in quarter pixel bins to reduce overall noise and numerical differentiation is applied to extract line spread function from the edge, windowing is also applied to reduce high frequency part distortion, due to breaks on the end of LSF estimation. But main problem is that in resent years computational photography methods had been implemented in various device types including CCTV cameras [1, 4, 12].

Simple structures may be easily restored, so additional validation steps are required. And extensive sharpening makes it difficult to extract real MTF characteristics from samples in black box testing approach. To overcome this issue noise based random test sequences can be used. They provide a way to evaluate ability of a camera to properly capture texture surfaces. This is impotent characteristic if we are talking about busy scenes where we have a lot of objects at different scales.

If simple sharpening is applied in extensive amount its effect can be estimated by peaks of gibbs artefact amplitude compared to peak of line spread function, typically its level not grater than -15db, but some cameras image signal processor (ISP) can push its level up to -17db especially in low light conditions (Fig. 2) highlighting edge structure with hi contrast sharp gradients. The effect is demonstrated on pseudo color [21-23] visualisation of differentiated edge below (Fig.1), which provide clear way to roughly estimate ringing along the edge (white haloing) and video compression coder imperfections (blocking effect), which is considered as noise in current approach.

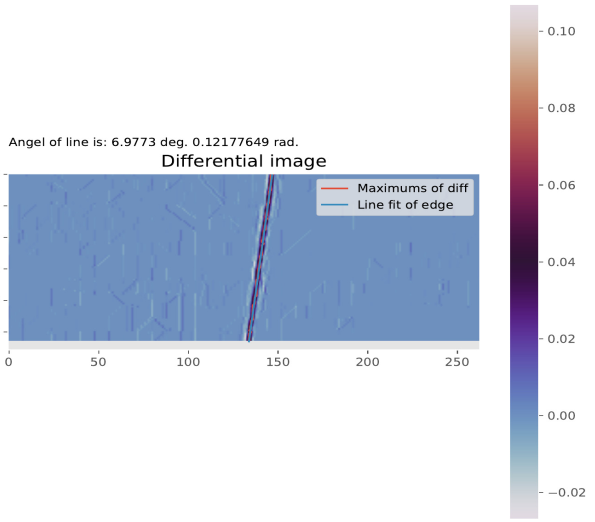

Fig. 1. Line spread visualisation in pseudocolors

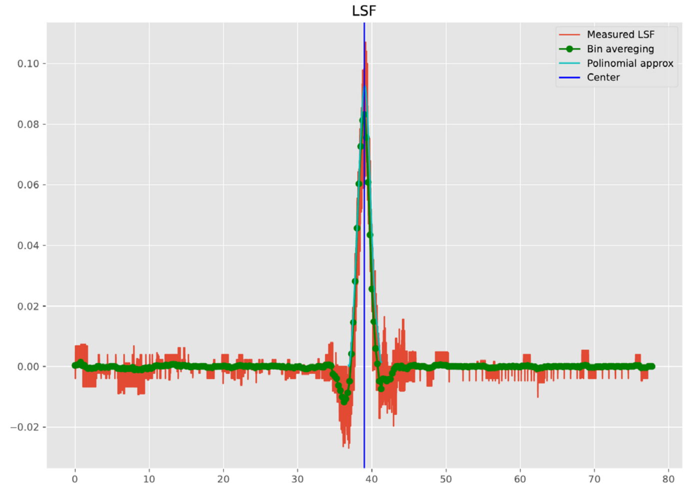

Fig. 2. Line spared function visualisation with averaging

Second "spilled coins" method for estimating MTF involves capturing images of circles with different lightness and size placed in a way that they overlap and create a visually complex pattern. By controlling size and lightness of circles we can achieve certain spectral slope (1/f in most cases to mimic natural scenes spatial frequency content). The resulting image can then be analysed to determine the MTF, by comparing divisions from designed slope. Main disadvantage of this method, in context of CCTV cameras is that it is sensitive to sharpening, and have artificially reconstructable pattern, so it is not practical to use this approach in CCTV field.

Third option is noise method, it is a technique used to estimate the MTF of imaging systems in same paradigm as spilled coins approach, but target is have purely textural nature. It involves creation of this type of pattern by generating random phase spectrum combining it with amplitude spectrum with 1/f spectral slope and then applying inverse fourier transform, which produces required pattern [7]. It has noise appearance, so aggressive noise reduction pipelines, sometimes suppress hi spatial frequencies. But limited MTF estimation range and unavailability to robustly estimate signal to noise ratio, do not allow stand alone usage of this technique. This method had been evaluated in previous research to determine computational pipeline robustness and ability to precisely estimate MTF slope. Results showed low precision on low frequency, but overall error level is suitable for comparison of imaging systems and human visual system sensitivity for low spatial frequency is low according to latest research [17]. And reference juxtaposition of results from noise and slanted edge approach highlights samples with artificial image enhancements like adaptive sharpening.

The noise method offers a practical approach to estimating the MTF of imaging systems by leveraging the modulation effects of random noise. This technique is valuable for understanding how different spatial frequencies are handled by the system, which is crucial for tasks such as image reconstruction and quality control [20].

To fully qualify samples following tooling and protocol was developed: two test targets, with high contrast slanted edge (Fig. 3), low contrast slanted edge (Fig. 4) provide MTF estimation using ISO 12233 methodology, and pink noise target (Fig. 5) provides a way for texture resolution capabilities assessment. In our experiments we used CCTV cameras, that typically have poor performance compared to professional cameras, high and medium range semi-professional cameras. In harsh noise conditions, especially in low light [10,11], high contrast methods provide smoother MTF. Sometimes video encoder performance of samples cameras is not great and have sensible amount of blocking artefacts, in such conditions high contrast slanted edge method is preferred too, and provide good reference for low contrast measurement results, verifying gathered results. Third method is based on noise with amplitude spectrum shaped as 1/f slope, which is typical for natural scenes [19] amplitude spectrum and provides means to evaluate texture performance.

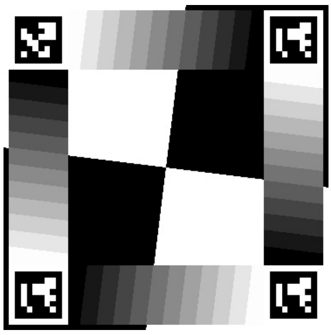

Fig. 3. High contrast Slanted edge pattern with ArUco alignment markers and OECF estimation regions

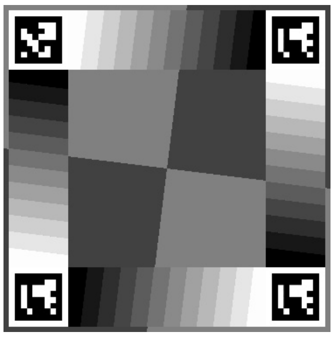

Fig. 4. Low contrast Slanted edge pattern with ArUco alignment markers and OECF estimation regions

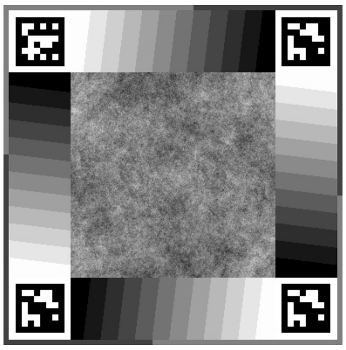

Fig. 5. Noise pattern with ArUco alignment markers and OECF estimation regions

One of the key component to improve MTF measurement consistency is test target processing automation [5]. To provide automated tooling for recognition and test target extraction ArUco marker was chosen as they prove resilient over time, have great performance and simple API in OpenCV library. To prevent and detect geometric distortion, increase detection reliability 4 markers was placed at corners of test target.

Other important characteristic that needs to be extracted before MTF estimation is opto electrical transfer function (OETF). To estimate this function 12 grayscale strips was pleased on the edges, reflectivity of each strip was tested with spectrophotometer in emissive measurement mode to ensure results precision. By analysing registered lightness values against measured reflectivity coefficient inversion gamma correction transformation function can be calculated. Slight rotation was introduced for future work, to compute low contrast MTF and ringing level as function of brightness.

This element also provides means to calculate signal to noise ratio at different lightness levels, duplicating pattern four times provides more reliable way to estimate OECF and signal to noise ratio by increasing measurement sample size. To evaluate performance in different lighting conditions, 3 levels of lighting was chosen 1000, 100, 10 lumen. It is sufficient for detecting poor light performance and covers typical lighting conditions for CCTV camera as values above and below this range not typical for installation environments. Infra red illumination is typically triggered before signal to noise ratio becomes too bad, and MTF evaluation in conditions of no visible light is beyond the scope of this research.

Thirty two camera samples was gathered for evaluation. All samples have ether dome or bullet form factor, have fixed or variable focal length non replaceable optical system. For legal reasons brands and models are hidden but they can be provided on request under NDA agreement.

To compare samples characteristics following table was created:

Table 1

Measured characteristics of camera samples

	TVL_1	TVL_2	TVL_3	NATIVE_ TVL	RINGING x100	SNR_1	SNR_2	SNR_3	DR
CAM_0	1010	970	1020	1080	372.27	31.12	31.91	31.98	35.97
CAM_1	1040	1030	1010	1080	376.73	33.56	34.2	33.5	36.64
CAM_2	950	910	940	1080	588.57	34.98	36.47	36.52	36.97
CAM_3	950	910	990	1080	378.07	36.79	35.29	35.67	36.93
CAM_4	940	900	920	1080	561.78	32.29	32.92	33.01	43.94
CAM_5	1790	1710	1730	2160	598.56	29.47	28.33	29.08	33.85
CAM_6	1540	1480	1510	1620	317.55	30.5	33.48	29.95	36.18
CAM_7	750	780	570	1440	400.48	27.82	31.26	31.3	50.25
CAM_8	940	900	910	1056	361.79	29.96	29.85	31.35	33.47
CAM_9	1130	1130	1120	1520	728.57	30.99	30.65	30.82	45.24
CAM_10	990	1060	980	1080	868.8	33.16	31.93	31.51	30.03
CAM_11	460	990	900	1080	488.17	25.91	25.73	27.52	48.55
CAM_12	1080	1080	1080	1080	743.76	22.7	23.34	24.17	39.85
CAM_13	1870	1840	1830	1944	1097.25	28.61	28.77	28.79	34.44
CAM_14	1640	1660	1670	1944	504.75	32.18	31.93	32.53	33.18
CAM_15	1080	1080	1080	1080	365.44	22.71	22.15	21.5	37.5
CAM_16	1930	1944	1910	1944	867.88	30.4	30.11	29.46	44.58
CAM_17	1100	1140	1170	1620	260.09	27.41	25.49	27.1	30.73
CAM_18	1590	1570	1610	1620	379.71	30.39	32.46	32.25	33.66
CAM_19	1620	1620	1620	1620	516.29	28.23	28.51	28.78	28.47
CAM_20	1080	1080	1080	1080	402.31	32.8	33.11	31.1	36.2
CAM_21	890	750	860	1440	430.51	24.54	26.71	25.56	44
CAM_22	1390	1370	1310	1520	603.64	27.11	27.34	26.74	35.7
CAM_23	1490	1440	1420	1520	1223.17	28.71	28.7	27.08	34.53
CAM_24	600	570	620	1080	1068.23	34.15	34.22	35.84	39.01
CAM_25	1080	1080	1080	1080	345.14	34.1	33.91	33.71	37.79
CAM_26	1080	1080	1080	1080	555.61	32.35	33.5	32.94	39.58
CAM_27	1080	1080	1080	1080	469.75	32.52	32.61	32.8	35.84
CAM_28	280	1440	290	1440	245.22	30.61	33.58	31.51	34.67
CAM_29	620	600	620	1080	1028.97	32	35.28	35.38	36.63
CAM_30	630	620	640	1080	1014.04	34.6	34.71	34.6	39.58
CAM_31	1080	1080	1080	1080	433.33	28.47	27.4	28.6	35.47

In table above (tb.1) TVL_1 is resolution in television lines of full width half modulation at 10lux illuminance of test target, and TVL_2, TVL_3 corresponds to 100 and 1000 lux. NATIVE_TVL is resolution of imaging sensor,

RINGINGx100 is ratio of ringing amplitude to line amplitude multiplied by 100 (for visualisation purposes). SNR_1, SNR_2, SNR_3 is mean signal to noise ratio at 10, 100, 1000 lux illuminance respectively. DR is estimated dynamic range on reflective test target at 1000lux.

Over all overlapped MTF in frequency range normed to sample frequency (for visualisation and comparison purposes) gathered from high and low contrast slanted edge demonstrated on Figures 6, 7.

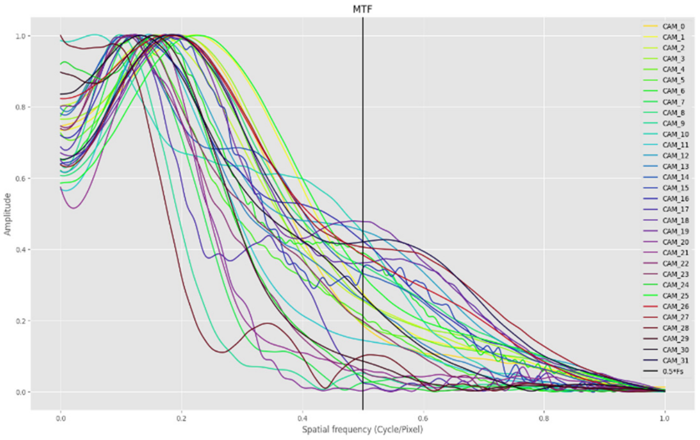

Fig. 6. All samples MTF from hig contrast target

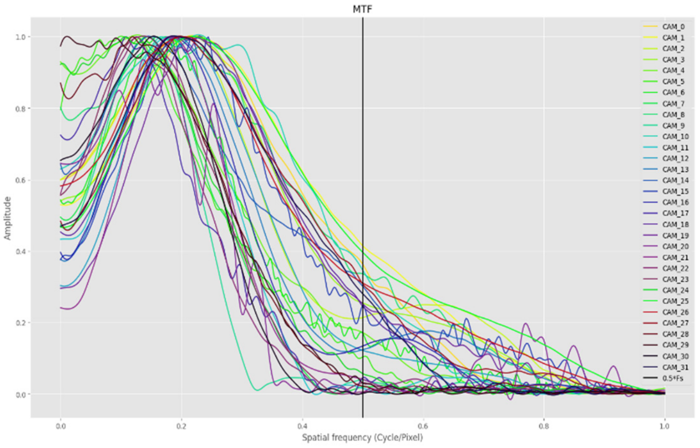

Fig. 7. All samples MTF from low contrast target

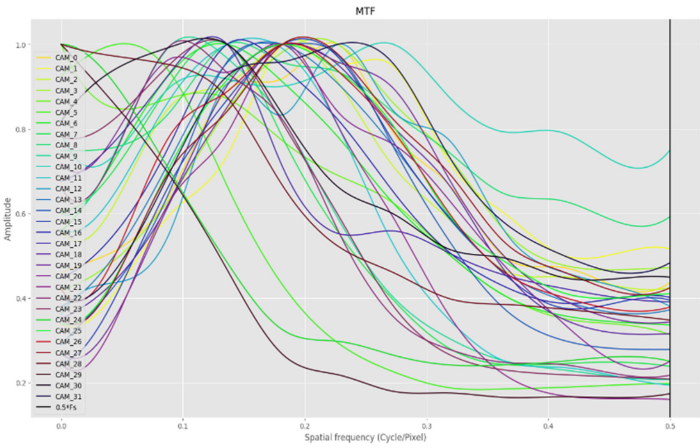

Fig. 8. All samples MTF from noise target

As samples have quit different characteristics and target use cases, they was splitted in to 3 grades by native resolution of image sensor. Zero grade contains cameras with resolution greater than 1700 TVL, first grade is all samples with resolution above 1080 TVL and second grade is 1080 TVL (This resolution is typical for 2mp cameras and often considered minimal by modern technical requirements for CCTV system)

To properly assess samples, let's visualise each grade MTF separately, for more relevant insights.

The grade visualised on (Fig. 9) contains samples with 8mp and 5mp camera samples, typically devices this devices advertise as hi end solutions, have superior lens quality and more auxiliary features. As expected for small imaging sensors with very high pixel density, MTF attention begins at approximately 0.2 of sampling frequency and progress rapidly toward half of sampling frequency especially in low light conditions. MTF correlation with lighting conditions is more noticeable on hi resolution samples with advanced ISP onboard.

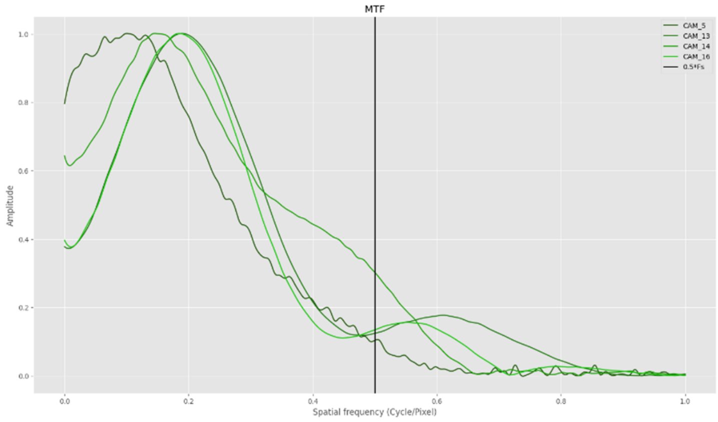

Fig. 9. Grade 0 samples MTF from low contrast target

On visualisation of grade 1 samples (Fig. 10) we are observing samples with 4mp sensors. Overlapped MTF visualisation, shows significant spread of low and high frequency content. Main insight that clearly visible is peak shifting towards high frequency with reduction of DC component and low frequency. This means that different strategies used by vendors to visually boost image quality. Some times vendors uses extremely aggressive ISP pipeline with significant sharpening, which is proven by ringing levels and Noise based MTF shape.

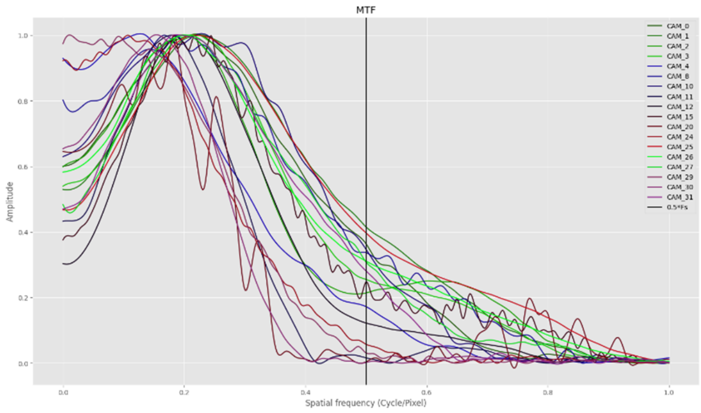

Fig. 10. Grade 1 samples MTF from low contrast target

Figure above (Fig. 11) contains largest number of samples, and show significant performance variation of base models from different vendors. Due to cost efficiency and typical minimum system requirements and this models have highest installation rate. So testing importance is highest in this category, because of large quantity variation. Only way to create future prof system is to select models with best possible performance among base models.

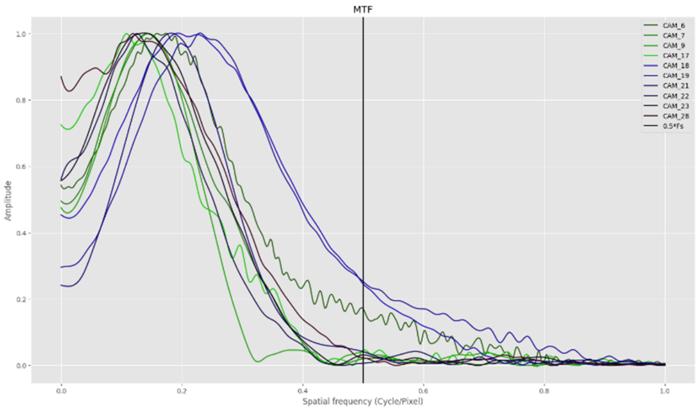

Fig. 11. Grade 2 samples MTF from low contrast target

Significant drop in resolution is common to samples in grade 0 (Fig. 12), probably happening due to poor optic quality. From figures (Fig. 13, 14) we can conclude that native resolution of camera sensor, does not fully represent camera resolution ability, and testing evaluation is crucial for choosing best model among available.

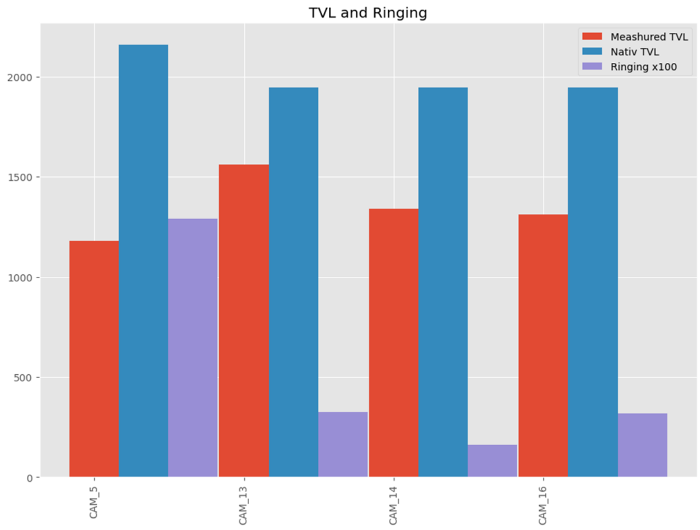

Fig. 12. Grade 0 LSF and ringing compare

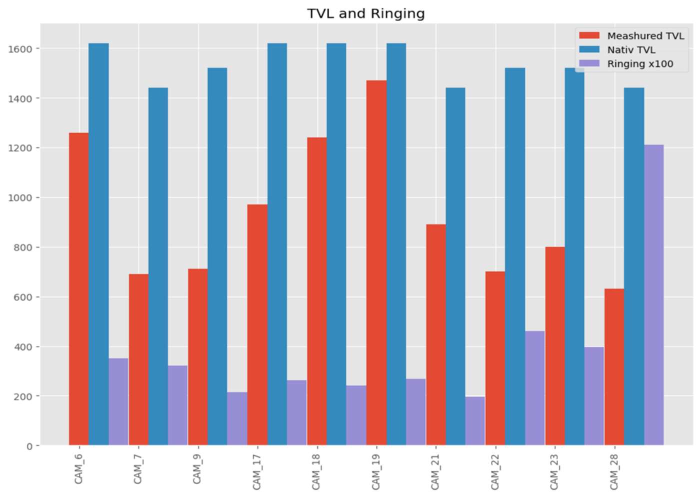

Fig. 13. Grade 1 LSF and ringing compare

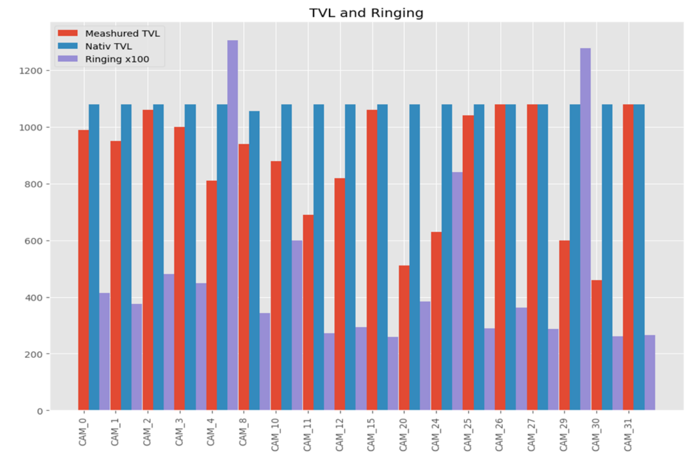

Fig. 14. Grade 2 LSF and ringing compare

Results

2MP cameras from second grade use image signal processing intensely to mask out poor optical resolution of lenses used in that models because this models are typically limited by budget, low sensor noise performance is sometimes masked by adaptive noise reduction algorithms that have quiet significant hi spatial frequency content attenuation, that can be spotted by analysing MTF from different test targets proposed in protocol above. Cameras from first two grades as shown above have much shallower spectral slope. This is strong evidence that main limitation of small form factor camera is optical system, while full width at half modulation of line spread function is noticeably wider.

Over all this review shows current state and limitation in different segments of CCTV camera market, and provides useful insights for system design, highlighting importance of testing procedure, to make right choice of supplier by correct price to value estimation based on objective criteria. All sample have noticeable amount of sharpening in image processing pipeline, LSF have sensible ringing on the edge. This phenomenon is probably happening due to marketing consideration and effect on human visual system in typical multi-view installation should be evaluated, because of possible masking effect can be happening, reducing threat recognition performance of security personnel.

Conclusion

This paper shows significant of testing procedures before choosing CCTV cameras, but current procedures have some limitations and does not provide methods to choose between similar samples. Further research should be carried out to implement hybrid methodology (to extract MTF up to sampling frequency, from noise based patterns reliably). Low contrast MTF against lightness offset analysis seems to be perspective, and planned to be researched. Advances in ISP onboard pipeline brings more threads to CTTV cameras consumers as visually appealing picture can miss critical details due to poor hardware performance. This further amplifies significance of testing procedure especially for standard projects and large scale deployments, to maximize system capabilities.

Acknowledgment

The study was supported by a grant from the Russian Science Foundation No. 23-29-00302, https://rscf.ru/project/23-29-00302/

References

[1] D. A. Egorov, V. D. Fedorov, I. V. Vlasuyk, A. M. Potashnikov and A. I. Mozhaeva, "A Novel Method for Estimating the Spatial Frequency Characteristics of Cameras Based on Generative Random Sequences," *2022 Systems of Signals Generating and Processing in the Field of on Board Communications*, Moscow, Russian Federation, 2022, pp. 1-5, doi: 10.1109/IEEECONF53456.2022.9744396.

[2] P. D. Burns and D. Williams, Camera Resolution and Distortion: Advanced Edge Fitting, Proc. IS&T International Sym. on Electronic Imaging, Image Quality and System Performance XV, IQSP-171, 2018.

[3] K. Masaoka, "Accuracy and Precision of Edge-based Modulation Transfer Function Measurement for Sampled Imaging Systems*," IEEE Access*, vol. 6, pp. 41079-41086, 2018.

[4] I. Vlasyuk, "Method of controlling the spatial characteristics of television cameras," *Metrologic and measuring equipment in communication*, vol. 6, pp. 13, 2005.

[5] Sarah Kerr, "Recommendations For the Detection and Analysis of the ISO 12233:2023 e-SFR Slanted Star." *Electronic Imaging*, 2024, pp. 271-1 - 271-6, https://doi.org/10.2352/EI.2024.36.9.IQSP-271

[6] R. A. Jones, "An Automated Technique for Deriving MTFs from Edge Traces," *Photogr. Sci. Eng*., 1967, no. 11, pp. 102-106. J. C. Dainty and R. Shaw, Image Science, Academic, NY, ch.

[7] Sasaki Shizuki, Masaoka Kenichiro, Koike Yasuhiro, 38-3: Design of Random Depolarization Films Based on Modulation Transfer Function Measurements. SID Symposium Digest of Technical Papers. 2023. 54. 547-550. 10.1002/sdtp.16615.

[8] D. Williams and P. D. Burns, "Low-frequency mtf estimation for digital imaging devices using slanted edge analysis," *SPIE-IS&T EI Symp*. 5294, pp. 93-101, 2004.

[9] ISO 12233:2024, Photography – Electronic Still Picture Imaging – Resolution and Spatial Frequency Responses. ISO, 2024.

[10] K. Ponomarenko, D. Egorov, V. Kudryashov, A. Egorova, I. Vlasuyk, "Impact of Camera Characteristics and Settings on Precession of AI Object Recognition Models," *2024 Systems of Signals Generating and Processing in the Field of on Board Communications*, Moscow, Russia, 2024, pp. 1-7, doi: 10.1109/IEEECONF60226.2024.10496772.

[11] D. Lee et al., "Precision and characteristics of satellite spatial quality estimators' measurement using an edge target imaged with KOMPSAT-3A," *Remote Sens*., vol. 16, no. 24, p. 4660, 2024. DOI: 10.3390/rs16244660.

[12] P. Müller, A. Braun, "MTF as a performance indicator for AI algorithms?" *J. Electron. Imaging*, vol. 35, no. 16, pp. 125-121, 2023. DOI: 10.2352/EI.2023.35.16.AVM-125

[13] Masaoka Kenichiro, "Enhancing Accuracy and Precision in Omni-Angle Edge-Based Modulation Transfer Function Measurements," *IEEE Access*, 3035. PP. 1-1. 10.1109/ACCESS.2025.3532119.

[14] Amilia Riska, Anam Choirul, Mahdi, Karrar Naufal, Ariij Dougherty Geoff., "Evaluation of the edge profile shifting based on statistical approach to improve the edge-based MTF measurement," *Jurnal Technology*, 2024.

[15] Fan Yuan-Peng, Wei Lei, Wang Yu-Hao, Hu, Zi-Qiang & Li, Lin. (2023). Improved method for modulation transfer function measurement of Bayer color cameras. Applied Optics. 62. 10.1364/AO.504655.

[16] Park Daesoon, Yoo Daehoon, "Precision and Characteristics of Satellite Spatial Quality Estimators' Measurement Using an Edge Target Imaged with KOMPSAT-3A," *Remote Sensing*. 2024. No. 16. 4660. 10.3390/rs16244660.

[17] Anastasia Mozhaeva, Michael J. Cree, Robert J. Durrant, Igor Vlasuyk, Aleksei Potashnikov, Vladimir Mazin, Lee Streeter, "A contrast sensitivity model of the human visual system in modern conditions for presenting video content," *PLOS ONE*, 2024. 19(5): e0303987. https://doi.org/10.1371/journal.pone.0303987.

[18] I. V. Vlasuyk, A. M. Potashnikov, A. V. Balobanov and V. D. Fedorov, "Estimation of Efficiency of Video Signals Processing algorithms in Television Cameras when Transmitting Moving Objects," *2020 Systems of Signals Generating and Processing in the Field of on Board*

Communications, Moscow, Russia, 2020, pp. 1-5, doi: 10.1109/IEEECONF48371.2020.9078631.

[19] A. Y. Kudryashova, A. S. Adzhemov and I. V. Vlasuyk, "Application of Weber-Fechner Law in Image Transmission in the Field of Onboard Communications," *2019 Systems of Signals Generating and Processing in the Field of on Board Communications*, Moscow, Russia, 2019, pp. 1-6, doi: 10.1109/SOSG.2019.8706774.

[20] D. Egorov, A. Egorova and A. Potashnikov, "Efficiency Evaluation of Noise Based Camera Measurements Algorithms," *2023 Systems of Signals Generating and Processing in the Field of on Board Communications*, Moscow, Russian Federation, 2023, pp. 1-4, doi: 10.1109/IEEECONF56737.2023.10092086.

[21] V. V. Ivanchev, I. V. Vlasuyk, E. P. Stroganova, "Objective assessment of colours' warmth," *T-Comm*. 2024. Vol. 18. No. 1, pp. 44-50. DOI 10.36724/2072-8735-2024-18-1-44-50.

[22] A. M. Potashnikov, I. V. Vlasuyk, "Method of equal contrast color space construction for a given information visualization system and control conditions," *T-Comm*, 2020. Vol. 14, no.4, pp. 15-22.

[23] Bogachkov I.V. A detection of strained sections in optical fibers on basis of the brillouin relectometry method. T-Comm. 2016. Vol. 10. No.12, pp. 85-91.

КОМПЛЕКСНАЯ ОЦЕНКА ХАРАКТЕРИСТИК КАМЕРЫ ПОСРЕДСТВОМ АНАЛИЗА ПРОСТРАНСТВЕННО-ЧАСТОТНОГО ОТКЛИКА

Егоров Дмитрий Аркадьевич, *Московский технический университет связи и информатики, Москва, Россия,* **d.a.egorov@mtuci.ru**

Балобанов Андрей Владимирович, *Московский технический университет связи и информа-тики, Москва, Россия,* **andrey_sam@mail.ru**

Строганова Елена Петровна, *Московский технический университет связи и информатики, Москва, Россия*

Аннотация

Важным этапом при выборе камер видеонаблюдения является оценка оптической разрешающей способности формируемого изображения, поскольку этот параметр является наиболее важным в наборе, определяющем способность внешних или вспомогательных систем обнаруживать и распознавать объекты и события в видеопотоке. Знание частотно-контрастной характеристики (ЧКХ) камеры необходимо для построения надежных систем замкнутого телевидения (CCTV) для обнаружения и идентификации угроз. Могут использоваться различные подходы к извлечению формы ЧКХ, но некоторые специфические свойства камер, используемых в этой области (такие как отсутствие доступа к необработанным изображениям, невозможность полного отключения встроенной обработки изображений), делают традиционные методы менее применимыми в автономном режиме, поэтому для достоверной оценки характеристик образцов камер требуется комбинированный подход. В этой статье мы описываем процедуру и средства автоматизации, которые могут ускорить процессы измерений, а также сделать их более повторяемыми. Представленные результаты также освещают возможные направления дальнейших исследований.

Ключевые слова: *передаточная функция модуляции, CCTV, камера безопасности, качество изображения.*

Литература

1. *Egorov D. A., Fedorov V. D., Vlasuyk I. V., Potashnikov A. M., Mozhaeva A. I.* A Novel Method for Estimating the Spatial Frequency Characteristics of Cameras Based on Generative Random Sequences // 2022 Systems of Signals Generating and Processing in the Field of on Board Communications, Moscow, Russian Federation, 2022, pp. 1-5, doi: 10.1109/IEEECONF53456.2022.9744396.

2. *Burns P. D., Williams D.* Camera Resolution and Distortion: Advanced Edge Fitting, Proc // IS&T International Sym. on Electronic Imaging, Image Quality and System Performance XV, IQSP-171, 2018.

3. *Masaoka K.* Accuracy and Precision of Edge-based Modulation Transfer Function Measurement for Sampled Imaging Systems // IEEE Access, vol. 6, 2018, pp. 41079-41086.

4. *Власюк И.В.* Метод контроля пространственных характеристик телевизионных камер // Метрология и измерительная техника в связи. 2005. № 6. С. 13.

5. *Sarah Kerr.* Recommendations For the Detection and Analysis of the ISO 12233:2023 e-SFR Slanted Star // Electronic Imaging, 2024, pp 271-1 - 271-6, https://doi.org/10.2352/EI.2024.36.9.IQSP-271

6. *Jones R. A.* An Automated Technique for Deriving MTFs from Edge Traces, Photogr // Sci. Eng., 1967, no. 11, pp. 102-106.
7. *Sasaki Shizuki, Masaoka Kenichiro, Koike Yasuhiro*. 38-3: Design of Random Depolarization Films Based on Modulation Transfer Function Measurements // SID Symposium Digest of Technical Papers. 2023. No. 54, pp. 547-550. 10.1002/sdtp.16615.
8. *Williams D., Burns P. D.* Low-frequency mtf estimation for digital imaging devices using slanted edge analysis // SPIE-IS&T EI Symp. 5294, pp. 93-101, 2004.
9. ISO 12233:2024, Photography-Electronic Still Picture Imaging- Resolution and Spatial Frequency Responses. ISO, 2024.
10. *Ponomarenko K., Egorov D., Kudryashov V., Egorova A., Vlasuyk I.* Impact of Camera Characteristics and Settings on Precession of AI Object Recognition Models // 2024 Systems of Signals Generating and Processing in the Field of on Board Communications, Moscow, Russian Federation, 2024, pp. 1-7, doi: 10.1109/IEEECONF60226.2024.10496772.
11. *Lee D. и др.* Precision and characteristics of satellite spatial quality estimators' measurement using an edge target imaged with KOMPSAT-3A // Remote Sens., vol. 16, no. 24, p. 4660, 2024. DOI: 10.3390/rs16244660.
12. *Muller P., Braun A.* MTF as a performance indicator for AI algorithms? // J. Electron. Imaging, vol. 35, no. 16, pp. 125-121, 2023. DOI: 10.2352/EI.2023.35.16.AVM-125
13. *Masaoka Kenichiro*. Enhancing Accuracy and Precision in Omni-Angle Edge-Based Modulation Transfer Function Measurements // IEEE Access, 2025, pp. 1-1. 10.1109/ACCESS.2025.3532119.
14. *Amilia Riska, Anam Choirul, Mahdi Karrar, Naufal Ariij, Dougherty Geoff*. Evaluation of the edge profile shifting based on statistical approach to improve the edge-based mtf measurement // Jurnal Teknologi. 2024.
15. *Fan Yuan-Peng, Wei Lei, Wang Yu-Hao, Hu Zi-Qiang, Li Lin*. Improved method for modulation transfer function measurement of Bayer color cameras // Applied Optics. 2023. 62. 10.1364/AO.504655.
16. *Park Daesoon, Yoo Daehoon*. Precision and Characteristics of Satellite Spatial Quality Estimators' Measurement Using an Edge Target Imaged with KOMPSAT-3A // Remote Sensing. 2024. 16. 4660. 10.3390/rs16244660.
17. *Anastasia Mozhaeva, Michael J. Cree, Robert J. Durrant, Igor Vlasuyk, Aleksei Potashnikov, Vladimir Mazin, Lee Streeter*. A contrast sensitivity model of the human visual system in modern conditions for presenting video content // PLOS ONE. 2024, no. 19(5): e0303987. https://doi.org/10.1371/journal.pone.0303987
18. *Vlasuyk I. V., Potashnikov A. M., Balobanov A. V. Fedorov V. D.* Estimation of Efficiency of Video Signals Processing algorithms in Television Cameras when Transmitting Moving Objects // 2020 Systems of Signals Generating and Processing in the Field of on Board Communications, Moscow, Russia, 2020, pp. 1-5, doi: 10.1109/IEEECONF48371.2020.9078631.
19. *Kudryashova A. Y., Adzhemov A. S. Vlasuyk I. V.* Application of Weber-Fechner Law in Image Transmission in the Field of Onboard Communications // 2019 Systems of Signals Generating and Processing in the Field of on Board Communications, Moscow, Russia, 2019, pp. 1-6, doi: 10.1109/SOSG.2019.8706774.
20. *Egorov D., Egorova A., Potashnikov A.* Efficiency Evaluation of Noise Based Camera Measurements Algorithms // 2023 Systems of Signals Generating and Processing in the Field of on Board Communications, Moscow, Russian Federation, 2023, pp. 1-4, doi: 10.1109/IEEECONF56737.2023.10092086.
21. *Иванчев В.В., Власюк И.В., Строганова Е.П.* Объективная оценка теплохолодности цветов // T-Comm: Телекоммуникации и транспорт. 2024. Том 18. №1. С. 44-50.
22. *Поташников А.М., Власюк И.В.* Метод построения равноконтрастного цветового пространства для заданной системы отображения информации и условий контроля // T-Comm: Телекоммуникации и транспорт. 2020. Том 14. №4. С. 15-22.
23. *Богачков И.В.* Обнаружение натяженных участков в оптических волокнах на основе метода бриллюэновской рефлектометрии // T-Comm: Телекоммуникации и транспорт. 2016. Vol. 10. № 12. С. 85-91.