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Assessment of Video Quality in the Process of Events Identification in the Transportation Systems

P. ŁUBKOWSKI, D. LASKOWSKI
MILITARY UNIVERSITY OF TECHNOLOGY, Gen. W. Urbanowicza 2, 00-908 Warszawa, Poland
EMAIL: piotr.lubkowski@wat.edu.pl

ABSTRACT
The process of monitoring vehicle traffic and detecting traffic incidents and traffic obstructions requires access to information from sensors located at various points of monitoring and data acquisition systems constituting elements of contemporary Intelligent Transportation Systems (ITS). Unmanned aerial vehicles (UAVs) are increasingly becoming an element of ITS used in reconnaissance, preventive or rescue operations. Ensuring the efficiency of transportation in conditions of increased traffic requires providing users with multimedia information about: meteorological conditions prevailing on roads, traffic, current events and difficulties, and information on the availability of parking spaces. In each of the mentioned cases, the reliability and quality of information provided with the use of UAVs is an extremely important issue. Therefore, the provision of video surveillance services with a predictable level of quality and reliability is an important challenge for UAVs practical implementations. Thus, the fundamental research problem considered in the publication is the analysis of the impact of environmental and technical parameters on the quality and reliability of the UAVs video monitoring service provided in a real operating environment.

KEYWORDS: surveillance services, quality of identification, transportation systems

1. Introduction

Video Surveillance Systems (VSS) are currently the necessary components of transportation systems used in monitoring of vehicle traffic and detecting traffic incidents and disruptions [1]. They allow observation of people or objects in real time and registration of events for later analysis. A characteristic feature of these systems is continuous operation, where a relatively short break in the system operation can lead to a significant degradation of its effectiveness [2]. The UAVs are increasingly elements of complex systems of monitoring and data acquisition. They are currently one of the fastest growing means of imaging recognition. The growing popularity of UAV results from their technological and financial attractiveness, low costs (production and operation), high level of technological advancement and versatility of applications.

UAV technology associated so far with military activities is more and more commonly used in public and national utility facilities as well as in commercial establishments, factories and businesses or warehouses [3]. UAVs are also used in the activities of search and rescue and related natural disasters. An important area of use of UAVs is also agriculture and environment protection. Finally, the important example showing a great use and capabilities of UAVs is the transportation system [4, 5].

Requirements for video surveillance systems are defined in functional and quality constraints [6]. Quality assurance at the network level (QoS - *Quality of Service*) is extremely important because it allows prediction of the size of the available bandwidth and the level of losses at the application layer. However, in the case of monitoring systems used for public security purposes, the quality of video reception called as QoE (*Quality of Experience*) is much more important. However, QoE quality does not cover only a subjective perception of video content, but also the effective implementation of pre-set functions. It therefore requires precise definition of quality indicators covering all possible interferences and at the same time considering the human factor. Maximizing the quality of video reception focuses on the optimization both the network and performance parameters. In the second group of parameters, *Peak Signal-to-Noise Ratio* (PSNR), *Structural SIMilarity* (SSIM) or qualitative indicators describing the quality of perceived *Mean Opinion Score* (MOS) are significant. The issues of video quality measurements are reflected in the recommendations and standards [7, 8], they are also the subject of many scientific publications [9, 10]. Ensuring QoS quality with respect to the network layer and QoE with respect to the application layer is a major challenge for video surveillance systems. This is particularly important for UAV control systems and data collection from sensors mounted on UAV.

2. Risk Assessment of UAVs Implementation in Video Identification

Monitoring system's ability to correctly detect and identify threats is one of the essential factors determining the efficiency, effectiveness and reliability of its operation. Hence, in the process of information visualization additional risks and caused by them consequences that have a direct impact on this process should be taken into consideration. This so-called risk analysis is part of the applications validation pro-cess which is presented later in this paper.

Nowadays video surveillance networks are characterized by such features as frequent changes in topology, the mobility of users and providers, the use of wireless links and limited processing power and capacity of network nodes. Additionally, the working environment of the sensor should be taken into consideration, which in the case under consideration is a video camera that is in the UAV equipment. Proper operation of the sensor is influenced by factors such as lighting, distance between object and the sensor or the presence of background objects that make identification process difficult. Not without significance are also the already mentioned technical parameters, the sensitivity of the sensor, focal length, resolution and compression used. Hence, the following threats related to reliable data identification should be considered: lack of proper object lighting (insufficient sensitivity of the transducer) or no infrared operation mode, too long distance between the object and the camera (no proper selection of the focal length), no possibility of object specification (insufficient sensor resolution) or no extraction possibility (low resolution, sensitivity). These threats can lead to the following problems related to visualization process (Fig. 1):

- false rejection - an object that has its model in the database is unrecognized and rejected because it does not have its counterpart,
- misclassification - an object that has its model in the database is not properly assigned to another model in the database,
- false acceptance - an object that does not have its model in the database is assigned to a model that already exists in the database.

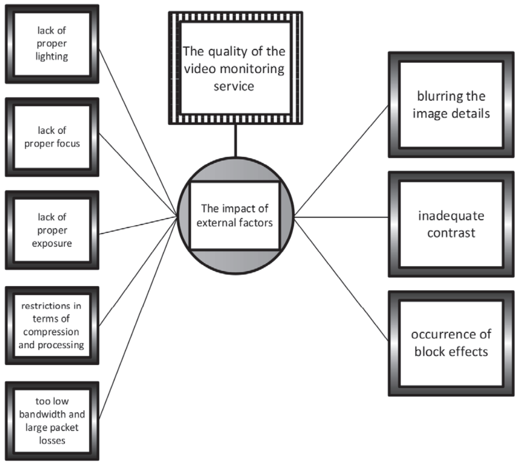

Fig. 1. Analysis of threats and problems of the quality of video reception in the aspect of the influence of external factors [own study]

These issues were considered during the research, although it seems impossible to avoid some of the threats, especially when considering the impact of external factors. Therefore, in the process of quality evaluation of the video transmission service using UAV, the "no-reference" method was used, which allows quality testing in relation to a degraded image. In the research implementation process, the VQM (*Video Quality Monitor*) application was used [11]. VQM enables assessing video quality based on the chosen method and present the results in the form of perceived QoE video quality.

3. Testing and analysing the results

For the experiment, the existing infrastructure of the laboratory monitoring network has been used (Fig. 2) [1, 2]. Reasoning about the correctness of network components specification about data transmission reflecting information from the monitoring system is based on a statistical estimation of reliability of the software and hardware platform forming the service chain.

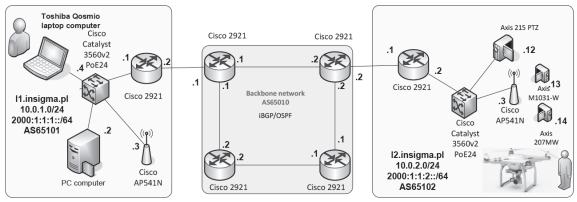

Fig. 2. Diagram of the testbed environment [own study]

Products of renowned suppliers of hardware and software for both the systems and applications are the components of the test platform. Therefore, it appears reasonable to conclude that the specified measuring system is a correct and highly reliable testbed.

In the monitoring domain (marked as l2.insigma.pl) including three stationary monitoring points, a mobile element was implemented with the use of Phantom 3 Professional UAV [12]. The UAV model used in the research is equipped with a compact 4K camera with a resolution of 12 megapixels. The technical specification indicates the possibility of recording video sequences in MP4 and MOV (MPEG4AVC / H.264) at a maximum bit rate of up to 60 Mbit / s. The camera is equipped with a professional lens that provides a field of view with an angle of 94 °. To control an unmanned aerial vehicle (drone), the DJI GO app is used, launched on a mobile operator's position equipped with a remote-control drone set. The application allows controlling UAV based on five intelligent flight modes. It is equipped with an extensive user interface providing information not only about the chosen flight mode, but also about the essential functional and technical parameters of UAV (Fig. 3). The implementation scenario of the UAV presented in Figure 2 corresponds to the actual conditions for the use of drones, which are usually delivered to the monitored area to register the video sequence and transfer it to the position of the operator of the transportation systems VSS.

The assessment of the received video quality was carried out by the operator of the monitoring system (domain l1.insigma.pl) using the VQM application running on a personal computer. The application performs the MOS quality assessment based on the method without reference (Fig. 4). In addition to the MOS quality, the application also provides values for quality indicators such as *blur*, *blockiness*, *contrast* and *bitrate*.

The mentioned indicators together with the general assessment expressed in the MOS scale allow to map the correlation of the observer's feelings realizing the perception of the presented video sequence, i.e. QoE.

Fig. 3. The user interface of the DJI GO application [own study]

To determine the quality of video surveillance service implementation using UAV a set of test scenarios were developed. On this basis, tests have been carried out to determine the specified quality indicators as a function:

- video recording format used;
- work in various weather conditions;
- use of various image exposure modes (filters);
- of the flight mode used.

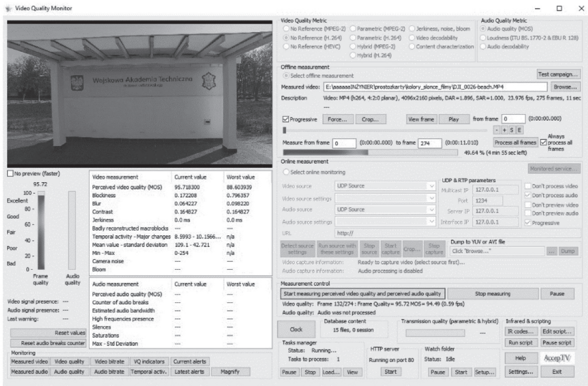

Fig. 4. The interface of the Video Quality Monitor [own study]

The results of tests regarding quality assessment as a function of the video recording format used are shown in Fig. 5. The analysis of the video quality curve indicates that the change of format between the MOV format and the MP4 format does not affect the perceived video quality. However, with a deeper evaluation of the minimum and maximum MOS values, you can point to a slight advantage of the MOV format (Table 1).

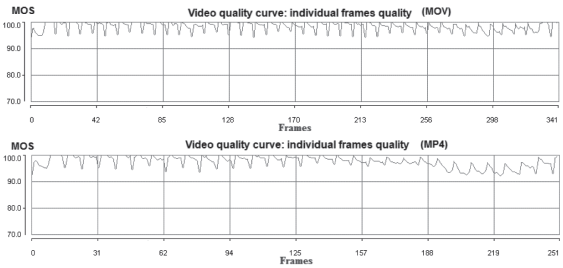

Fig. 5. Comparison of the individual quality of frames as a function of the registration format [own study]

Table 1. Comparison of the perceived quality values [own study]

Video recording format	Perceived video quality		
	Min	Max	Mean
MOV	94,001	100,000	97,063
MP4	92,113	100,000	96,580

Analysis of another group of quality indicators confirms slightly worse quality of video recorded in MP4 format. The measurement results regarding quality indicators concerning block effects and blur are shown in Table 2, while the results for contrast and bit rates in Table 3. Based on the results presented in the table, it must be concluded that for none of the presented indicators (except for the contrast indicator, where the overrun is small) there were no exceeded threshold values, which are respectively:

- for blurring – 3;
- for block effects – 2;
- for contrast – 0 ÷ 0,15.

It is also worth noting that in both cases a bandwidth of 60 Mb/s was obtained, i.e. the maximum with which the UAV camera image registers and transmits video stream. This confirms the lack of impact of the implementation environment on the implementation of the monitoring service using UAV.

Table 2. Values of QoE quality indicators – blockiness and blur [own study]

Video recording format	Blockiness			Blur		
	Min	Max	Mean	Min	Max	Mean
MOV	0,054	0,495	0,152	0,00	0,192	0,010
MP4	0,064	0,541	0,165	0,00	0,230	0,034

Table 3. Values of QoE quality indicators – contrast and bit rate [own study]

Video recording format	Contrast			Bit rate
	Min	Max	Mean	[Mb/s]
MOV	0,153	0,228	0,189	60,18
MP4	0,139	0,239	0,184	60,57

Subsequent results show the results of tests for determining the impact of weather conditions on the perceived quality of monitoring service realized with UAVs. The tests were carried out for two cases. The first measurements took place under excellent weather conditions, in the second with a significant cloud cover. It should be noted that UAVs can be operated in various environmental conditions and under various atmospheric conditions, and any disturbances in the transmission continuity or distortion of image clarity can directly affect the offered level of security. The measures MOS values are shown in Fig. 6.

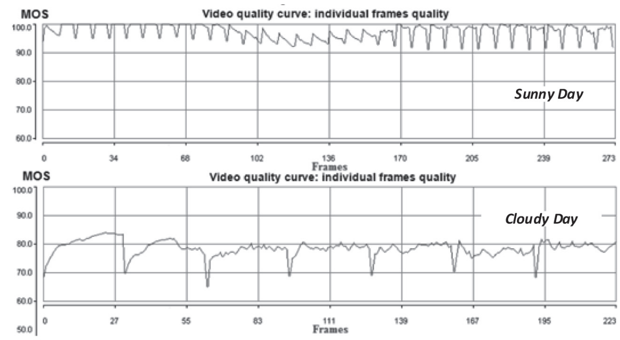

Fig. 6. Comparison of individual quality of frames as a function of weather conditions [own study]

The impact of weather condition on the perceived quality is presented in Fig. 7. The analysis of the obtained results clearly indicates deterioration of quality when the weather conditions deteriorate. The MOS value drops to the level of 70-80, at specific times even up to 65. However, observing the MOS values in Table 4, it should be noted that the mean MOS value for worse weather conditions is maintained at a level above 75, which is a satisfactory result.

Fig. 7. Comparison of individual quality of frames as a function of weather conditions (sunny day/cloudy day) [own study]

Table 4. Comparison of the perceived quality values [own study]

Weather conditions	Perceived video quality		
	Min	Max	Mean
Cloudy day	64,708	83,720	76,575
Sunny day	90,749	100,000	95,025

Table 5. Values of QoE quality indicators – blockiness and blur [own study]

Weather conditions	Blockiness			Blur		
	Min	Max	Min	Max	Min	Max
Cloudy day	0,054	0,495	0,152	0,00	0,192	0,010
Sunny day	0,064	0,541	0,165	0,00	0,230	0,034

Table 6. Values of QoE quality indicators – contrast and bit rate [own study]

Weather conditions	Contrast			Bit rate
	Min	Max	Mean	[Mb/s]
Cloudy day	0,073	0,222	0,150	5,37
Sunny day	0,148	0,248	0,193	60,74

When comparing the quality indicators listed in Table 5 and Table 6, a special difference in the average value of the blurry can be noticed, which is much higher for the tests carried out on cloudy day. This means more distortion showed by a clear visualization of the edges of macroblocks (pixels), which results directly from the inferior quality of video frames. This is because the brightness of the frames is very low. The contrast value indicates the difficulty of distinguishing detail in a video image in which there is a significant number of macro blocks of the same brightness.

Another area of testing was to analyse the quality of QoE in relation to the applied various image exposure modes (filters). The used UAV which is Phantom 3 Professional enables using a three different types of exposure: Black/White, Beach and Classic. They differ in the type of lens aperture used as shown in Fig. 8. The results of the measurements carried out are shown in the next figure (Fig. 9). As predicted, the type of image filtering used does not have a significant impact on the achieved QoE quality. The confirmation of the above conclusion are the results of the quality measurement presented in the MOS scale, which are presented in Table 7. The obtained value of MOS is in the range of 94-96 which means the excellent image quality.

Fig. 8. Comparison of individual quality of frames as a function of different types of exposure (Black/White, Beach and Classic) [own study]

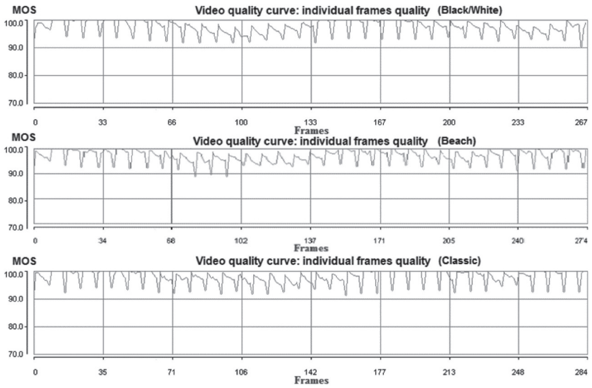

Fig. 9. Comparison of individual quality of frames in the presence of different filters [own study]

Table 7. Values of perceived video quality [own study]

	Perceived video quality		
	Min	Max	Mean
Black/White	89,963	100,000	95,378
Beach	88,604	100,000	94,959
Classic	91,043	100,000	95,487

The UAV used in the research provides 5 intelligent flight modes. They are respectively: Waypoint, Point of Interest, Home Lock, Course Lock and Follow Me. The flight modes enable the operator to properly plan monitoring tasks and then implement them appropriately in accordance with the adopted schedule. Due to the fact that each flight mode has different dynamics of its implementation, they were also tested in the evaluation of perceived quality. The recorded values of quality indicators are presented in the Table 8 while changes in the MOS values are shown in the Fig. 10.

Table 8. The values of quality indicators in the function of intelligent flight mode [own study]

	Blockiness	Blur	Contrast	Bitrate
	Mean	Mean	Mean	[Mb/s]
Waypoint	0,202	0,087	0,209	60,01
Point of Interest	0,148	0,055	0,195	59,87
Home Lock	0,232	0,108	0,206	60,14
Course Lock	0,138	0,039	0,153	60,19
Follow Me	0,372	0,076	0,208	59,95

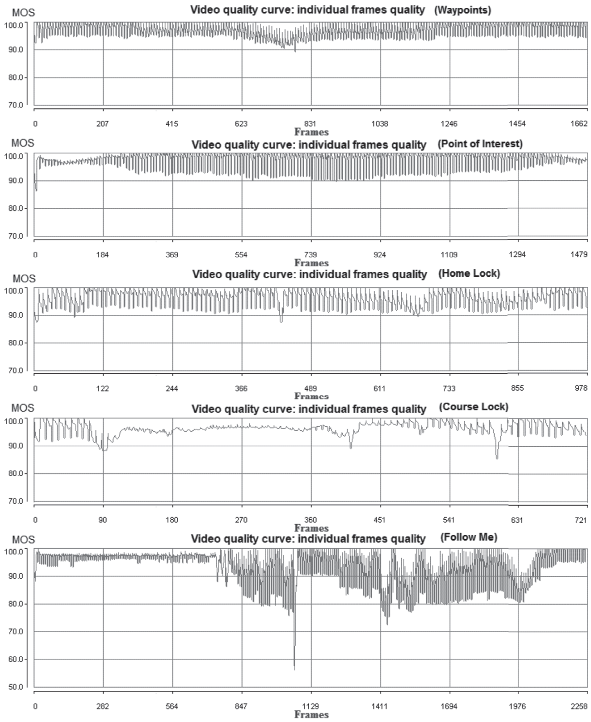

Fig. 10. Comparison MOS values in the function of intelligent flight mode [own study]

As it can be seen, the obtained results confirm that the change in the flight mode does not affect the QoE quality. The deterioration of the QoE quality in the Follow Me mode result from the fact that the flight was more dynamic that causing the rapidly changes in the image. As a result, the image has more *blockiness* distortions than other that resulting in lower QoE. This, of course, results in lowering the MOS indicator value for this flight mode (Fig. 10).

4. Conclusion

The article presents the results of work related to the implementation of the video monitoring service using UAV. The research problem presented in the paper concerned the evaluation of the quality of video transmissions from UA, which were made using the method without references based on the VQM application. The results of the experiments confirm that the proposed research concept can be used to assess the quality of video obtained from UAV in the real operating environment. This is extremely important, especially in the case of growing popularity of UAV implementation in dedicated monitoring systems used in public and national utility facilities, agriculture and environment protection a transportation system.

The obtained results are determinant for further studies in using UAVs in transportation systems.

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