VIDEO REGISTER PICTURE EVALUATION TO SUPPORT DRIVERS TRAINING AND EXAMINATION

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Abstract

This paper refers to some problems with digital video recording of picture during driver training and examination process for obtaining driving license. Since 10 April 2006 year, all examining institutions must use video and audio recording devices in Poland. The legal regulations in force do not clearly determine the functional requirements and technical parameters for video recorders; hence the actual devices used do not meet user requirements.

There is main influence on the picture quality have the optical system of the camera. Considerable influence on the quality has an aberration errors. Aberration leads to blurring of the image produced by an image-forming optical system. Aberrations fall into monochromatic and chromatic classes of optical errors. Monochromatic aberrations produced without dispersion. These include the aberrations at reflecting surfaces of any coloured light, and at refracting surfaces of monochromatic light of single wavelength. This paper describes all types of aberration.

Charge-coupled device (CCDs) used as main part of the digital cameras, however, there is now a well-established alternative, the CMOS image sensor. Both CCD and CMOS image sensors, described this paper, capture light using a grid of small photo sites on their surfaces. This paper describes advantages and disadvantages of both transducers.

The authors have made an attempt to determine camera parameters, their location and quality of the picture. In mentioned case the objective and subjective picture validation methods and sample pictures from the cameras will be presented.

***Keywords**: video register, quality picture evaluation, picture transducers*

1. Introduction

According to the Ministry of Infrastructure's Act from the 27-th of October 2005 referring to training, examining and obtaining certificates by the driving instructors and examiners [1], as of the 10-th of April 2006, all centres conducting exams for the B category driving licence, should ensure that the cars used for examining, were equipped with video and audio recording devices. The recorder should at least record forward view through the front windscreen of the examining vehicle, while the viewing angle should not be smaller than 45 degrees. Picture registered must contain the date and time of the exam as well as registration number of the examination vehicle. The sound from the inside of the vehicle should also be stored. However there are no clearly determined functional requirements and technical parameters for the video recorder. The experiences of the users show, that from the types of recorders on offer, very few actually meet user requirements. Lack of requirements for the video recorders definitely hampers an effort to create a tender documentation for the purchase of the new cars. At present there are monitoring devices, consisting of the elements from the CCTV (Closed Circuit Television), being used.

Thus it is necessary, to determine the location and number of cameras, the video recorder should be equipped with, as well as other requirements (amongst them: colour or monochrome, sensitivity, resolution, focusing distance, location, camera direction, admissible picture distortions), minimal picture and sound quality. An important thing is ensuring appropriate quality of the picture being recorded, however the first stage of the tests, in opinion of the authors, should rely on the assessment of the static picture obtained from the cameras and selecting the right ones.

2. Optical errors of the camera

There is main influence on the picture quality have the optical system of the camera. Considerable influence on the quality has an aberration errors described below.

Aberration has several meanings:

- optical aberration, an imperfection in image formation by an optical system,
- spherical aberration, which occurs when light rays strike a lens or mirror near its edge,
- chromatic aberration, caused by differences in refractive index for different wavelengths of light,
- defocus aberration, which occurs when a system is out of focus.

Aberration leads to blurring of the image produced by an image-forming optical system. It occurs when light from one point of an object after transmission through the system does not converge into (or does not diverge from) a single point. Aberration require to correct optical systems to compensate for this phenomena.

Aberrations fall into monochromatic and chromatic classes of optical errors. Monochromatic aberrations produced without dispersion. These include the aberrations at reflecting surfaces of any colored light, and at refracting surfaces of monochromatic light of single wavelength. These include:

- defocus - refers to a translation along the optical axis away from the plane or surface of best focus. Defocus reduces the sharpness and contrast of the image,
- spherical - is a deviation from the norm resulting in an image imperfection that occurs due to the increased refraction of light rays when rays strike a lens or a reflection of light rays that occurs when rays strike a mirror near its edge, in comparison with those that strike nearer the center,
- comatic aberration (coma) - in an optical system refers to aberration inherent to certain optical designs or due to imperfection in the lens or other components which results in off-axis point sources. Coma is defined as a variation in magnification over the entrance pupil,
- astigmatism - is when an optical system has different focus for rays that propagate in two orthogonal planes,
- curvature of field - causes an planar object to project a curved (nonplanar) image,
- image distortion - is a deviation from rectilinear projection, a projection in which straight lines in a scene remain straight in an image. Although distortion can be irregular or follow many patterns.

Chromatic aberrations, where a system disperses the various wavelengths of light:

- axial or longitudinal, chromatic aberration - is caused by a lens having a different refractive index for different wavelengths of light. It causes the dispersion of the lens,
- lateral, or transverse, chromatic aberration.

Longitudinal and lateral chromatic aberration of a lens is seen as „fringes” of color around the image, because each color in the optical spectrum cannot be focused at a single common point on the optical axis.

3. Optical transducers

Initially, charge-coupled devices (CCDs) were the only image sensors used as main part of the digital cameras (Fig. 1). They had already been well developed through their use in astronomical telescopes, scanners, and video camcorders. However, there is now a well-established alternative, the CMOS image sensor. Both CCD and CMOS image sensors capture light using a grid of small photo sites on their surfaces. It's how they process the image and how they are manufactured where they differ from one another.

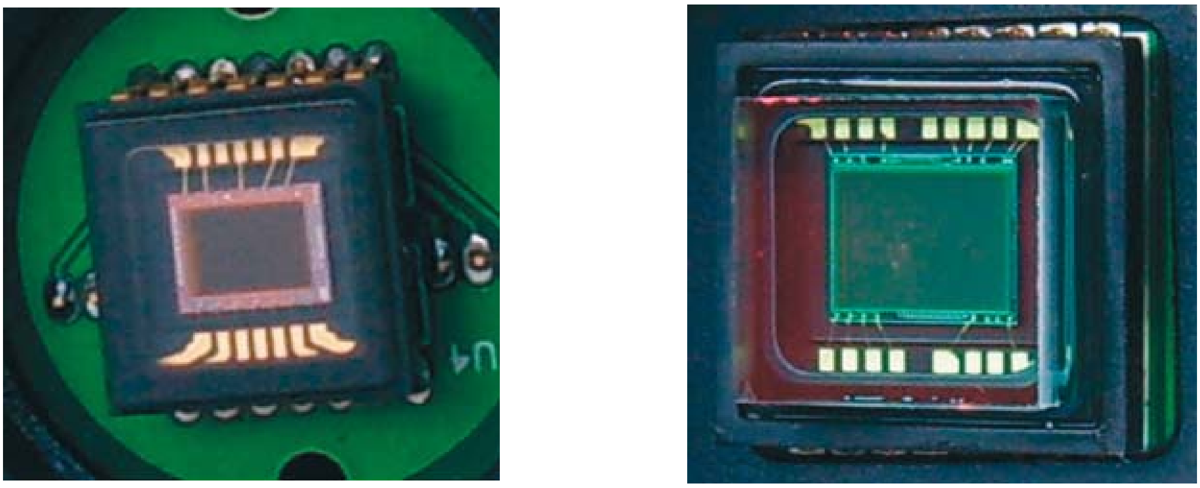

Fig. 1. Examples of CCD matrix

A charge-coupled device (CCD) gets its name from the way the charges on its pixels are read after an exposure. The charges on the first row are transferred to a place on the sensor called the read out register. From there, they are fed to an amplifier and then on to an analog-to-digital converter. Once a row has been read, its charges in the readout register row are deleted, the next row enters, and all of the rows above march down one row. With each row "coupled" to the row above in this way, each row of pixels is read one row at a time. An image is projected by a lens on the capacitor array (the photoactive region), causing each capacitor to accumulate an electric charge proportional to the light intensity at that location. A one-dimensional array, used in line-scan cameras, captures a single slice of the image, while a two-dimensional array, used in video and still cameras, captures a two-dimensional picture corresponding to the scene projected onto the focal plane of the sensor. Once the array has been exposed to the image, a control circuit causes each capacitor to transfer its contents to its neighbor. The last capacitor in the array dumps its charge into a charge amplifier, which converts the charge into a voltage. By repeating this process, the controlling circuit converts the entire semiconductor contents of the array to a sequence of voltages, which it samples, digitizes and stores in some form of memory.

An active-pixel sensor (APS) is an image sensor consisting of an integrated circuit containing an array of pixel sensors. Each pixel containing a photodetector and an active amplifier. An image sensor is produced by a CMOS process, also known as a CMOS sensor. The APS pixel solves the speed and scalability issues of the passive-pixel sensor. They consume far less power than a CCD, have less image lag, and can be fabricated on much cheaper and more available manufacturing lines. Unlike CCDs, APS sensors can combine both the image sensor function and image processing functions within the same integrated circuit.

Sensors (CCD / CMOS) are often refered to with an imperial fraction designation such as 1/1.8" or 2/3". Examples of the CCDs found in modern cameras can be found in Tab. 1.

Tab. 1. Dimensions of the example CCD sensors

Type	Aspect Ratio	Width [mm]	Height [mm]	Diagonal [mm]	Area [mm^2]	Relative Area
1/6"	4:3	2.300	1.730	2.878	3.979	1.000
1/4"	4:3	3.200	2.400	4.000	7.680	1.930
1/3,6"	4:3	4.000	3.000	5.000	12.000	3.016
1/3,2"	4:3	4.536	3.416	5.678	15.495	3.894
1/3"	4:3	4.800	3.600	6.000	17.280	4.343
1/2,7"	4:3	5.270	3.960	6.592	20.869	5.245
1/2"	4:3	6.400	4.800	8.000	30.720	7.721
1/1,8"	4:3	7.176	5.319	8.932	38.169	9.593
2/3"	4:3	8.800	6.600	11.000	58.080	14.597
1"	4:3	12.800	9.600	16.000	122.880	30.882
4/3"	4:3	22.500	18.000	28.814	405.000	101.784
Other image sizes						
APS-C	3:2	25.100	16.700	30.148	419.170	105.346
35 mm	3:2	36.000	24.000	43.267	864.000	217.140
645	4:3	56.000	41.500	69.701	2324.000	584.066

4. Cameras and the recorders used in the mobile video registering systems

Electrical equipment installed in the vehicles should meet technical and functional requirements, which will ensure their correct functioning in the car operating conditions. Thus they will not result in any endangering of the road traffic safety. According to the PN-EN 55022 [3] Polish Standard, they can not adversely affect the operation of the onboard vehicle devices. Additionally these devices should be adapted to the operating conditions of the vehicle. Apart from shaking caused by the uneven roads, they have to be resistant to low and high temperatures as well as its changes, occurring during the use of the vehicle. This problem has a particular significance in the case of recorders which especially have to be adapted to the operations in such operating conditions. They form a group of so called mobile devices that differ from the devices used in the stationary monitoring system in design and the use of electronic subcomponents. One of the digital recorders adapted for use in the vehicle is MRX-1004A from the APER firm. According to the manufacturer it is shock and vibration resistant. Can be supplied with 12 V current, directly from the car electrical system. It can have 4 cameras plugged in, while picture data is registered on its hard disc or on the Compact Flash (CF) card. Recorder allows also copying data from the hard disc to the Secure Digital (SD) memory card. Particularly useful is the use of CF cards, due to an easy data transfer and making copies outside the recorder. This is especially important in case of examining drivers for the B category driving licence, because that data must be stored for administrative purposes, according to the Act, for the period of at least 14 days from the date of the exam. Technical data of the recorder is presented in the Tab. 2.

Vehicles monitoring systems usually utilize colour cameras, of vertical resolution not acceding 520 picture lines. Depending on the type of the camera optical and electronic system used, the quality of the picture from various models can differ significantly, even in case of the devices of the same resolution.

5. Assessing quality of the static picture

To assess the quality of cameras, one uses reference pictures. During the work conducted at the Motor Transport Institute the *Delta CCTV Test* testing picture was used, developed by „DELTA" firm from Poznań (www.delta.poznan.pl), with the overall dimensional proportions 4:3.

Tab. 2. Technical data of the APER MRX-1004A recorder

No.	Name	Description
1.	Maximum resolution	720 x 288 pixels
2.	Maximum recording speed	25 picture frames / s
3.	Range of admissible operating temperatures	from +5 °C to +40 °C, humidity 90 % (without condensation
4.	Supply voltage	12 V (allowable.: 8-28 V)
5.	Dimensions	210 x 43 x 145 mm
6.	Number of video inputs	4
7.	Number of audio inputs	1
8.	Number of video outputs	1
9.	Additional plug-ins	LAN, USB, RS-232

The quality of the picture recorded, apart from the camera, is affected also by a type and parameters of the compression algorithms used in the recorder, as well as quality of the transmission track between the camera and the recorder. The device described uses MJPEG compression, relying on the recording picture sequence, subjected to encoding to JPEG format. In order to assess the picture quality, the above mentioned test picture was used. Pictures obtained from four cameras, used with this video recorder, are shown on the Fig. 2.

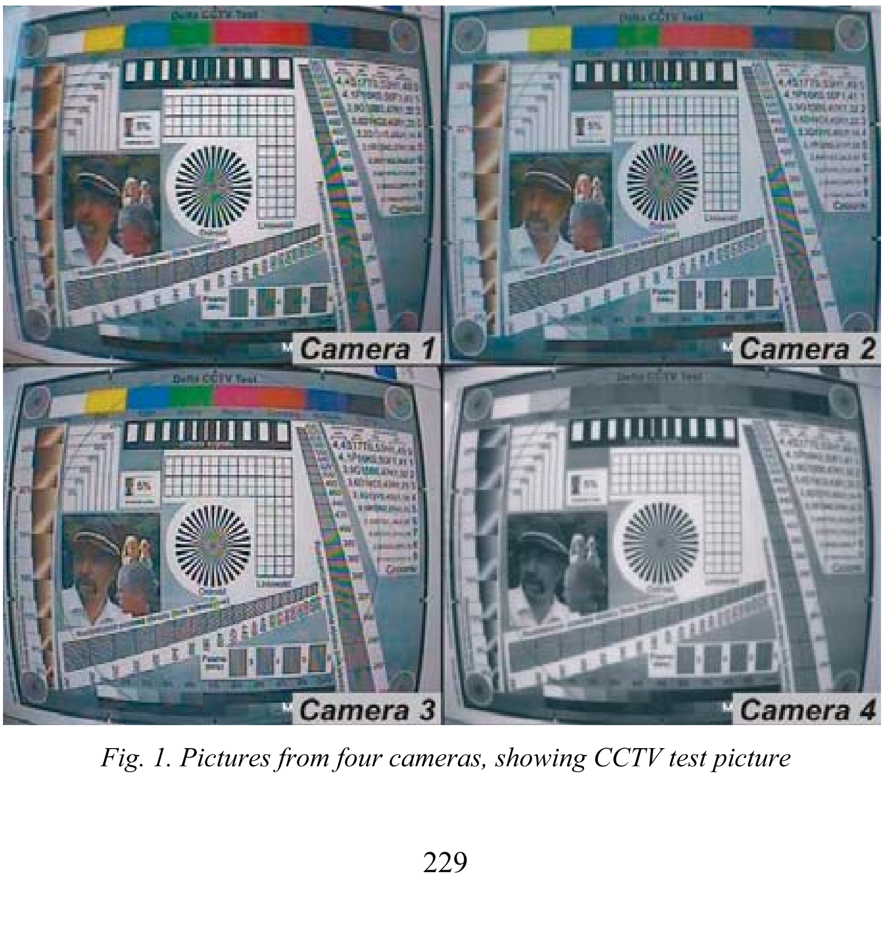

Fig. 1. Pictures from four cameras, showing CCTV test picture

Three colour cameras were used of vertical resolution, 520 lines (camera 2), 520 lines (camera 3), 480 lines (camera 1) and one monochrome camera of 700 lines (camera 4) resolution.

Locating Test Picture on the control monitor screen has been chosen in such away, so that it takes the whole height of the screen and the black framing of the picture is not seen. Identical principle should also have been used for the remaining edges of the picture, but significant geometrical distortions of the picture made such adjustment impossible. According to the requirements of the PN-EN 50132-2-1 Polish Standard [4] geometrical distortions of any part of the picture should not be more than 2%. This requirement has not been met for any of these cameras.

Maximum resolution has been determined from the section, for which it was still possible to distinguish black lines and white spaces between them.

Based on the pictures registered by the cameras, the assessment was made of the picture - connecting cables - picture recorder set. Section of the registered picture, showing lines used for determining vertical resolution, has been shown on the Fig. 3.

Following resolutions of the TVL (picture lines) were obtained:

- 460 TVL - camera 1 (480 lines acc. to the producer),
- 460 TVL - camera 2 (520 lines acc. to the producer),
- 480 TVL - camera 3 (520 lines acc. to the producer),
- 440 TVL - camera 4 (700 lines acc. to the producer).

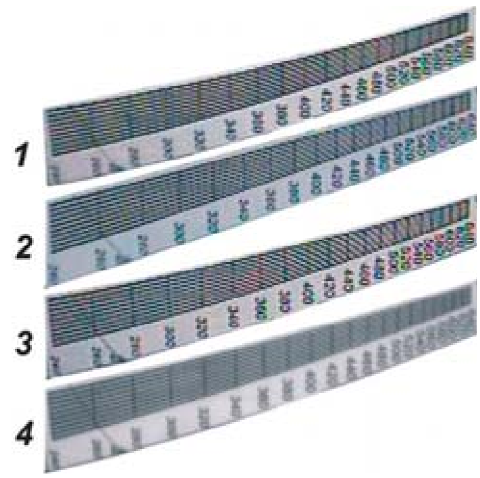

Fig. 2. Fragments of the picture used for the purpose of estimating the vertical from the cameras

6. Assessment of the pictures sequence quality

Due to the limited data transmission speed and required capacity of the data carrier, where the date is filed, the algorithms used are of so called lost data compression [2]. This causes significant deterioration of the picture and sound quality. Reconstructed data file differs from the original and it becomes necessary to evaluate its quality from the aspect of the degree of date compression. Before being used the compressed data is decompressed. The criterion of decompressed data quality is dependent on the compression techniques used, but it is impossible to formulate unified, commonly useful quality criteria and the extent of admissible degrees of compression. The necessary condition is to maintain clarity of the reconstructed picture as far as the elements, essential for assessment of the person taking the exam for the driving licence, are concerned. An important aspect, which must be taken into consideration while assessing the quality of the picture registered by the video recorder, is quality of the original picture, by which here is meant the uncompressed picture from the camera, or cameras co-operating with compression and filing module of the video recorder. Therefore, first stage aiming at determining minimum quality picture has to take into consideration defining the quality of the picture obtained from the camera.

Second stage should consider the quality of the picture, subject to compression by the recorder. The picture obtained as a result of processing the original picture is of a „good" quality usually when visually it looks pleasantly natural (without heavy distortions), or it is useful for some purposes. However there is no universal measure allowing to determine quality of the reproduced picture in each case. There are three methods used to determine quality:

- objective measurements of distortions (otherwise known as automatic measures) - measurable quantities or vector ones defined automatically according to a set dependence,
- subjective quality measures (otherwise known as observation measures) - psycho-visual quality assessment, curried out by a group of specialists (users),
- statistical simulation measures - more complex, referring to a particular application, evaluations based on as faithful as possible simulation of the real conditions of the picture analysis as well as statistical analysis of the classification tests results.

In order to evaluate the pictures, a sequence from four cameras has been recorded installed in the Opel Astra I estate. The sample picture from the recorder equipped with 4 cameras is shown on the Fig. 4. The picture sequence obtained allows a further study.

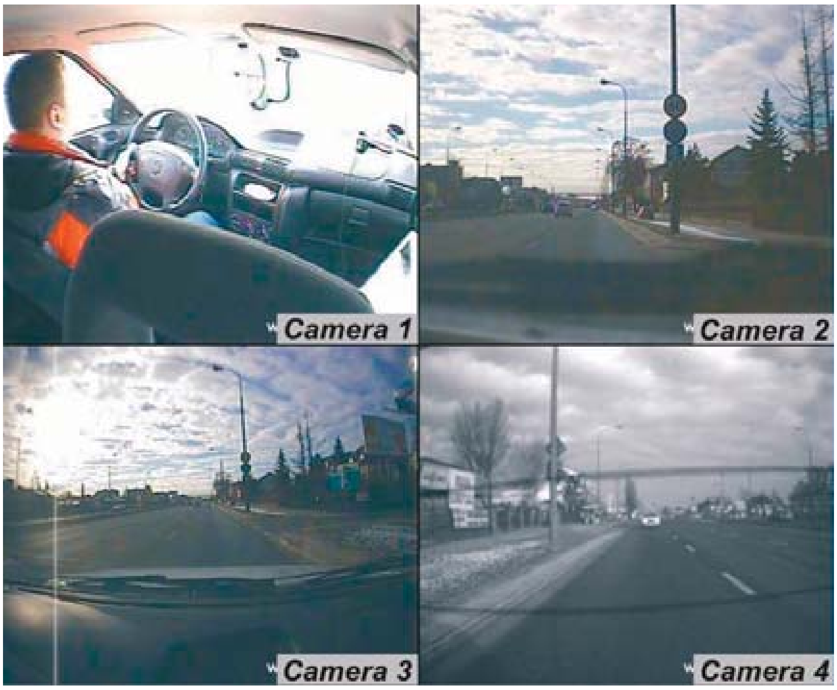

Fig. 3. Sample picture registered using recorder equipped with 4 cameras

7. Summary

Motor Transport Institute is conducting work on developing minimal requirements for the video recorders used during the exams for the exams for the B category driving licence. These devices can be utilised also during the training process. For this purpose, apart from the tests aimed at establishing the optimal number and locations for the cameras, there will also be method developed to assess the picture quality and minimal requirements for that. In the authors' opinion, in order to do that, it is essential to combine objective and subjective picture quality assessment methods. Such approach will ensure taking into account the experts opinions (from the subjective-observational assessment) and will enable obtaining numerical values, using which will be defined minimal picture quality. First stage of tests should however rely on defining static requirements, such as the amount and location of the cameras as well as their technical parameters. The article presents evaluation of the vertical resolution of the cameras and a sample picture registered during tests. The tests being conducted are only an introduction to defining requirements for the video registers.

The next stage of the tests is conducting, by a group of experts, an evaluation of the pictures' quality, according to the procedures recommended by ITU (International Telecommunication Union). Pictures obtained will be used for defining a minimal quality, using automatic assessment method („objective").

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