

Analysis of CCD Camera Image Quality Based on Ambient Lighting: A Review

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Abstract – Real time image quality is of prime importance as low quality images bring in extreme errors through outside processing and external environmental factors. The reported work provides discussions on various aspects of Charged Coupled Device (CCD) cameras including various factors contributing in image output quality. This study also compares results of different approaches used for image capture by CCD camera under varying lighting conditions. The digital camera response can be modeled as a function of its parameters viz. amplification gain and the exposure time. The relevant discussion on multi-layer surface albedo mode has also been made, which resulted in improvements in face recognition even under poor lighting conditions as albedo possesses some sharp detrimental features. MLSA diversifies the features as a linear sum of many detailed layers to distinguish features of various layers more accurately with layers being adjusted through various individual weights. On similar line, surface roughness measurements were carried out by machine vision technique to further analyze the effect of lighting conditions on CCD camera output quality. The image quality captured through CCD camera was affected mainly by angle of the light source, which essentially caused change in the surface illumination level.

Keywords – Charged Coupled Device, Image Quality, Ambient Lighting Conditions, Image Acquisition, Image Processing.

I. INTRODUCTION

Image quality in a real time vision is of uttermost importance. Low quality images cause extreme errors introduced through further conditioning and routing operations. There are various environmental parameters like sun, ambient lighting, fog, mist, etc. which may affect image quality.

A Charged Coupled Device (CCD) Camera is generally employed in capturing a scene. A CCD is a light sensitive semiconductor device. It comprises of a photodiode array, readout amplifier, and related conditioning and processing electronic circuit [1] – [4]. A CCD device can store and transfer the data received, considering the electrical charges resulted from the photoelectric effect and proportional to striking photons numbers. This creates charges which could be thought of as analogous to light intensity. Its construction and principle of operation were first introduced by W. Boyle and G. E. Smith, AT&T Bell Labs, for bubble memory applications in 1970 [5]. Within a couple of years, other researchers studied various development of this new technological progress discussing various emerging distinct types of CCD devices [6] - [8], including the devices able to capture images [9].

II. OPERATION, ARCHITECTURE, IMAGE OUTPUT ASPECTS OF A CCD CAMERA

CCDs and other solid-state image sensors have been used to detect and scrutinize the interactions between electronics and radiation [3] [4]. As CCD imaging sensors are rigid towards light intensities, color images are acquired by means of three different arrays meant for filtering three different wavelengths corresponding to the primary colors viz. red, green or blue color. The usual method to architecture this acquisition is obtained through a special colored pattern i.e. Bayer pattern in which all the pixels provide a 1:2:1 signal ratio for red, green and blue colors, respectively. After bulk production of CCD devices, such type of image sensors became readily available. They have also been found appropriate for special fields like scientific and medical instrumentation requiring high quality data for conclusive analysis. A major example of CCD application in medicine is related to the captured digital images where photographic films have now been replaced with digital sensors. It caused significant intensifications on the point in absorbed dose range, efficiency and the capability to relate image dealing out techniques [12] [13].

The CCD image sensors can be realized in various architectures such as frame-transfer, full-frame and interline. Each of these architectures has distinct features and characteristics, which is due to their specific approach towards problems of shuttering [14].

In a full-frame device, all of the image area is active with no provision of electronic shutter. Incorporation of a mechanical shutter is needed with the sensor in such a case else the image smears when the device is clocked or is read-out.

With a frame-transfer CCD, half of the silicon area is covered by an opaque mask which is generally employed in form of aluminum. In this way the image is transferred from image area to opaque area or the storage region having an acceptable smear of few percent [15]. This image is further read-out from the storage region while new image is in the process of integrating or is getting exposed in a fresh region. The frame-transfer devices generally don't require mechanical shutters. This mechanism was a regularly used architecture for initial solid-state broadcast cameras.

The frame-transfer architecture has disadvantage in terms of it requiring twice the silicon area equivalent to what is required by a full-frame device as a result it is almost twice expensive. General CCD camera architecture is shown in Fig. 1.

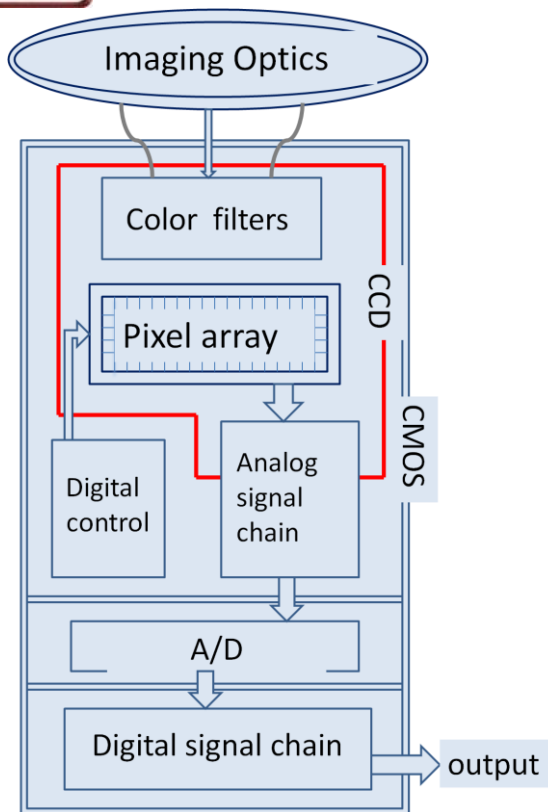


Fig.1. CCD camera architecture

CCDs are employed as light sensing devices containing grids of pixels in applications like digital cameras, video cameras, optical scanners, etc. They normally respond to 70% of the amount of the incident light that means they are having 70% quantum efficiency which make them far more efficient than photographic film (photographic film can capture only about 2% of the incident light).

Therefore, CCD Camera is used in various applications. While it is used for obtaining high quality images in real urban traffic scenes where tunnels, shadows of trees and buildings are present, it also improves robustness of face recognition with respect to reference samples in poor lighting conditions [16]. These are also found suitable for monitoring the conditions of machined surfaces employing machine vision technique. The captured images of the machined surfaces were analysed through image metrology software TRUEMAP thus getting real time measurements [17].

However, CCD devices have disadvantages when talked in terms of real time processing of stereo vision. Furthermore, a region of interest is difficult to set where lighting conditions are to be adapted [18]. (10)

III. DISCUSSION ON STATE OF ART ON CCD CAMERAS VIS-A-VIS IMAGE QUALITY

M. Negru and S. Nedeveschi [19] proposed a fresh approach for adapting camera response with respect to environment's lighting condition. They modeled the digital camera's response as a function of its parameters viz. square gain and exposure time. The said camera model was formulated for CCD grey scale digital cameras,

but the same could also be employed in CMOS sensors. The Modeling of camera results in improvement in image quality with number of reconstructed 3-D points being also on higher side [20].

Zhao-Rong Lai, Dao-Qing Dai and Chuan-Xian Ren [21] proposed a multilayer surface albedo (MLSA) to tackle face recognition in bad lighting situations. Here, the surface albedo or texture was divided into many sub-layers to separate and represent features of different scales in specific manner. In addition, layers were separated by various weight parameters established worldwide. A criterion function was produced for selection of these layer weights. It resulted in enhanced recognition performance even in poor lighting after obtaining a very refined albedo. MLSA had the best ROC curve, highest discriminating ratio and recognition rates. It was found effective in controlled as well as uncontrolled illuminations and also if it was mixed with other complicated variations. Hence, it was very much applicable to real-world scenario.

B. S. Prasad, S. P. Kumar and K. R. R. M. Reddy proposed optical surface finish parameters from the images obtained by the scattered light pattern reflected from machine surfaces is correlated with the actual roughness of the surface. Here, lighting conditions like the light source angle to the work piece and the angle of surface were varied and its influence on optical surface finish parameter were studied. Here, Ra (stylus roughness) correlated with a (amplitude parameters). Here, effects of machined surface due to its position change were also discussed. Surface roughness parameters were analysed with image metrology software TRUEMAP. It concluded that machined surface had a maximum significance on light source angle [22].

IV. INFERENCES & CONCLUSION

The adaptations in camera response w.r.t. varying lighting situations [19] is very useful, however, still it has got some anomalies such as variations in real time processing for stereo vision and availability of less number of frames.

Another problem is the lack of distinguishing ability of the developed algorithms over the years to mark a region of interest. However, this could be solved by utilizing CMOS sensor along with acquisition of 10 bit images directly from the frame grabber.

In a work carried out using CCD camera employed for evaluating machined surface, reflecting surface of the captured image has been given more importance while varying the various angles of source light and surface. Measurement of surface texture in a real-time environment is carried out through optical methods. However, for analysis of surface roughness through machine vision technique, scattered light pattern reflected from surface of machine is required to be captured, thus optical surface-finish parameters obtained from captured images are correlated with the actual roughness parameters. In this case, image need to be captured again at appropriate lighting condition. With these limitations in mind, authors analysed the effects of lighting conditions on machined surfaces as

its position changed going through various levels of illumination. It could be concluded from the finding of the paper that machined surface had a maximum significance on light source angle [22].

In a work dedicated to face recognition by means of CCD camera in poor lighting conditions, an experimentally determined multi-layer surface albedo technique was used. In this work, various layer weights were compared and analysed and it was found it was responsive to controlled as well as uncontrolled illuminations while it operated using various weights of selective layers done on the basis of a criterion function having an independent training set. In one of the previous work, a study was made to analyze how illumination variations affect the large scale variations of an image and extract small features in the surface albedo (texture). Despite being non-robust, the albedo possesses some sharp detrimental features. Still, to further enhance the robustness of albedo, MLSA diversifies its span as a linear sum of many detailed layers so as to differentiate features of various layers more accurately. Afterwards, these layers are adjusted by individual weights. A criterion function was proposed in the work reported in [21], in which the authors developed an algorithm to select the layer weights using an independent training set irrespective of controlled illuminations. MLSA responded to uncontrolled variation of illumination mixed with complicated variations like pose, occlusion, expressions, etc. A refined albedo improves recognition in bad lighting. Thus, MLSA solves the problem of image quality under variable light conditions very effectively.

In nutshell it could be concluded that image quality captured through CCD camera gets affected hugely by the ambient lighting conditions, which includes angle of the light source, light intensity, background image complexity, etc. The change in the surface illumination level of the target surface will cause major effect in the CCD captured image quality.

ACKNOWLEDGMENT

We thank Director, CSIR-CSIO Chandigarh, India for supporting the research reported in this paper.

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