Development of specific acquisition techniques for field imaging
- Applications to outcrops and marbles -

Vincent LEBRUN, Jean-François NIVART, Enrico BONINO, Eric PIRARD

Laboratoire MICA, Université de Liège, 45 Avenue des Tilleuls
B-4000 Liège
mica@ulg.ac.be
http://www.ulg.ac.be/mica

ABSTRACT

This paper, propose some important technical aspects that must be taken into consideration when developing macroscopic imaging techniques. Two specific applications are developed: temporary geological outcrops imaging and marble inspection.

KEYWORDS

CCD camera, controlled illumination, colorimetry, field imaging,

INTRODUCTION

The use of CCD cameras for scientific purposes is more and more widespread, especially in the field of quantitative microscopy. Like any other scientific device, each step of the acquisition procedure must be controlled and calibrated (Pirard, et al. 1999). For macroscopic applications (field imaging, industrial vision) the problem of image acquisition is even more critical due to specific constraints (uneven illumination, optical properties of imaged objects, type of optical device…). Actually, each application will present particular acquisition problems. It is thus necessary to adapt the procedure to the goal of the research.
The aim of this paper is to present some guidelines that govern the development of a complete acquisition system for macroscopic imaging. Some general principles will be presented and applied in two specific applications: the image archiving of temporary geological outcrops and the characterization of marbles by image analysis. In these studies, the common goal is to characterize the spectral and geometrical signatures of objects. Lighting and color calibration are among the principal preoccupations.

PRELIMINARY DISCUSSION

In order to keep control on all parameters of the acquisition process, the choice of a flexible hardware system is fundamental. In the present case of a CCD camera with a frame grabber, one must be able to control the electronic parameter of acquisition (exposure time, gain and offset). In this paper, the possibility to work with other type of sensors (scanner, digital photography…) is not discussed. On the other hand, one has decided to use black and white camera, reconstructing color images from three separated acquisitions with red, green and blue filters. Choosing black and white camera in place of 3CCD color camera opens the perspective of working with other filters than RGB. Moreover, it gives a full knowledge of the transmitting curves of the filters, which is not the case with color camera. Finally, it allows to calibrate the acquisition parameters separately the red, green and blue images.

LIGHTING

Taking images in the field or in a room requires eliminating all external lighting variations. It is thus necessary to construct a hermetic box isolating the field of view in a controlled artificial lighting (fig. 1). A quantitative measurement on color, spectral response or texture of an object is possible only if the lighting is homogenous, diffuse, white and stable in time.

In theory, a perfectly diffuse and homogenous lighting can be achieved by placing the object in an integrating sphere or under an infinite lighting plane. In practice, indirect lighting diffused by the walls of a box creates a rather homogenous lighting of a surface placed in the box.

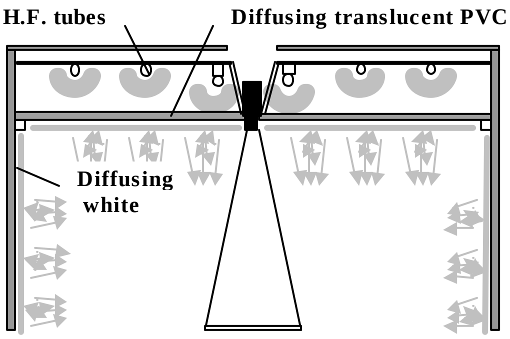


Fig. 1 : Diffuse and homogenous lighting on a surface placed in a diffusing box

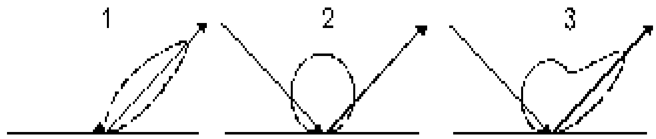
In the present applications, the goal is to obtain a light spectrum as close as possible to normal daylight. The light intensity must be stable at long-term (low aging drift) but also at short term (frequency). Luminescent tubes of daylight type can be a good compromise between daylight appearance and time stability. One must choose high frequency ballasts in order to eliminate the 50 hz residue. Such a lighting system has still no intensity tuning. The use of a CCD with a wide dynamic range can compensate the resulting lack of flexibility.

NATURE AND STATE OF IMAGED SURFACES

The behavior of the light hitting a surface depends on the nature and the state of the surface. The intensity of reflection of light on a mineral surface is proportional to the reflectance coefficient, which is an intrinsic property of the mineral nature. The state of a surface (roughness) is responsible of its diffusing power. Every natural surface produces reflection lobes with diffuse and specular components (Fig. 2). These parameters influence some technical choices and sometimes constrain the whole acquisition system. Observing high reflective surface requires a less powerful lighting and less sensitive CCD. Imaging polished surfaces induces the need of separating the specular and diffuse components.

A third parameter of surfaces influencing the modalities of acquisition is their planeity. Irregular surfaces induce a variable distance between the objective and the imaged object, causing problem of sharpness heterogeneity. This factor must be taken into account when choosing the optics.

Fig. 2: Influence of surface state on reflection lobe



1) *perfectly specular lobe (theoretical perfect polish)*
2) *perfectly diffuse lobe (theoretical perfect roughness)*
3) *composite lobe (practical state of natural surface)*

OPTICS

The correct choice of focal length is a difficult compromise between magnification, field of view, geometrical aberration and field depth.

Rays passing close to the center of the optical system have different path lengths than those passing further away from the center. This causes the central part of the sensor to receive a higher intensity of light. This phenomenon is called vignetting and depends on the width, the aperture and the thickness of the optics.

In some applications one must also consider the option of a telecentric objective. In these special lenses, an additional diaphragm placed at the focal distance reduces the angular tolerance of passing rays. Only rays almost-parallels to the optical axis are retained (Fig. 3).

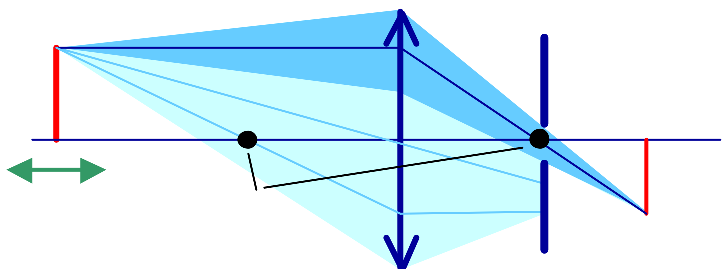


Fig. 3 : Telecentric optics

Red, green and blue gelatin filters (Kodak: WRATTEN 47B, 58 and 25) are used to rebuild colored images. If the transmission curves of the filters are known, it is possible to calibrate them in the official RGB system for colorimetry. The new RGB coordinates are linear combinations of the values obtained with the filters. The conversion coefficients are computed by measuring the response of the filters on standard colors with known RGB coordinates.

SENSORS

CCD tuning and calibration allows to correct most of the grey level distorsions generated by the whole acquisition system. The different stages of camera tuning are exposed in Pirard et all. (1999), in the case of microscopic imaging. An optimization of the grey level working range is achieved by tuning the gain, the offset and the exposure time of the camera. The goal is to obtain a maximal contrast in both darkest and brightest parts of the scene.

In macroscopic applications, the lighting is often less homogenous than in the field of a microscope. When adding others sources of spatial heterogeneity like CCD manufacturing defects, electronic noise (HOLST, 1998), and optical vignetting, it is frequent to observe a drift of more than 15 grey levels (6% of the dynamic) from the

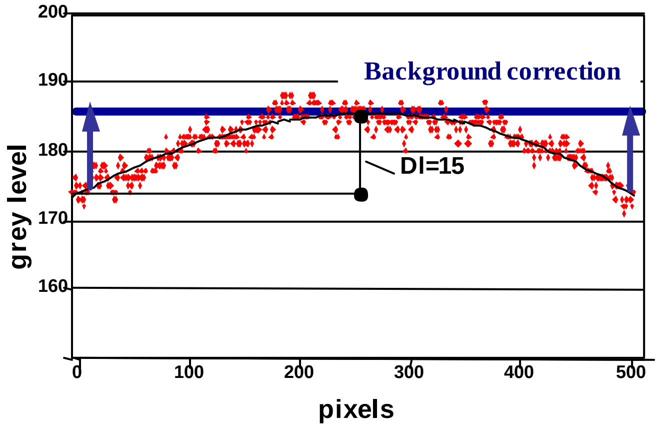


Fig. 4: Numerical gain and offset adjustment of individual pixels values

central part to the edges of an image (Fig 4). It is thus neccessary to numericaly adjust the gain and offset of each individual pixel. This background correction must take into account the additive black noise of the camera and the multiplicative spatial drift of photon intensities (Pirard et al., 1999). A paper by Chang and Reid (1996) describes a similar approach to ours for colour machine vision purposes.

IMAGING OF GEOLOGICAL OUTCROPS

In some paleoseismological studies, trenches are dug in order to observe sedimentological and recent tectonic structures. In order to archive the field data, it is essential to acquire, manage and store images of these temporary outcrops.

The first problem to solve is the design of an acquisition system isolated from natural light, without undesirable shadows and easy to use in the field. The system consists in an aluminium box (width: 1,56m, length: 1m, height: 1,36m) with a diffusing white coating on interior walls. An indirect illumination system composed by eight luminescent tubes and a black and white CCD camera with rotating R,G,B filters are fixed into the box. Images are stored in a portable computer system linked to the box. The structure stands on a trolley moving along two rails parallel to the trench walls (fig.5).

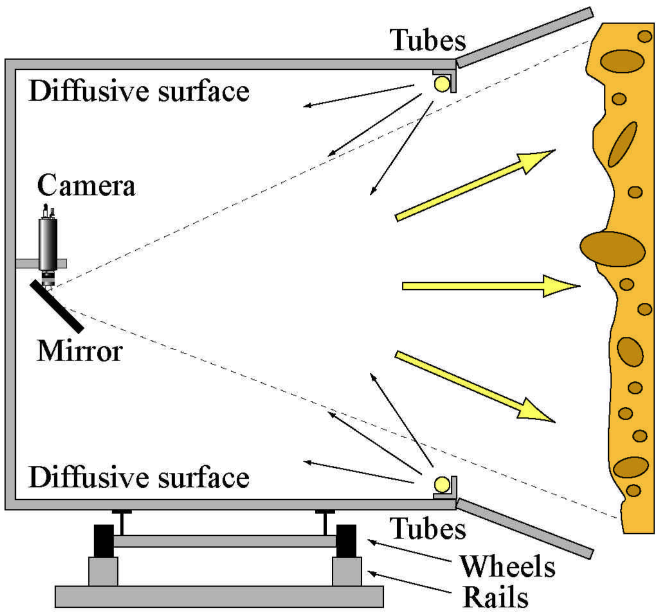


Fig. 5: Schematic drawing of the image acquisition system for outcrops imaging

This kind of acquisition system is totally controlled and calibrated but the box is quite heavy. It is thus a good tool to study a limited zone of the trench containing the most important information. For the remaining parts of the wall, a careful photographic acquisition can be sufficient. Reference white and black targets are placed within each acquired image, in order to enable later color calibration.

A geometrical correction is necessary to rectify the deformations due to the optical system or induced by a bad positioning of the ground control points (e.g. nails). After correction the images are ready to be mosaïcked.

In a second step, the images must be geographically referenced with respect to the ground coordinates (0,0) of the trench. As a result, each pixel of an image has got known dimension and spatial position, which is fundamental to import and manage the files within a GIS software.

Image information constitutes one layer of a multidata system containing also vectorial information (geological and textural zones drawn by the geologist in the field) and other alphanumeric data (chemical, radiometric,…).

MARBLE CHARACTERIZATION BY VISION

Like described above, the principal challenge when imaging polished surfaces is to separate diffuse component from specular one. In the study of marble, the two components are useful. Diffuse imagery leads to visual aspect characterization, texture analysis and colorimetry. Specular imagery gives a quantification of the polishing level. It is also a powerful tool to detect and characterize surface defects like scratches, cracks and stylolithes.

Diffuse imagery of marble tiles is based on the same principle as field imagery of trenches. The only additional problem is to minimize the specular component by creating a more diffuse lighting. The acquisition box is described in Fig. 1. When each step of the acquisition procedure is controlled and calibrated, the pixels of a CCD camera may be considered as micro-colorimeters. One can apply such a colorimetric approach to study the color changes due to climatic alteration of marble tiles. The method is illustrated in Fig. 6. The following procedure has to be followed:

1. acquire calibrated RGB images of marble tiles before alteration and convert it into L*a*b* system
2. place the tiles in an atmospheric simulation chamber
3. acquire calibrated RGB images of repositioned tiles after alteration
4. build a new image to express the color change: $(E)^2=?\ L^2+?\ a^2+?\ b^2$.

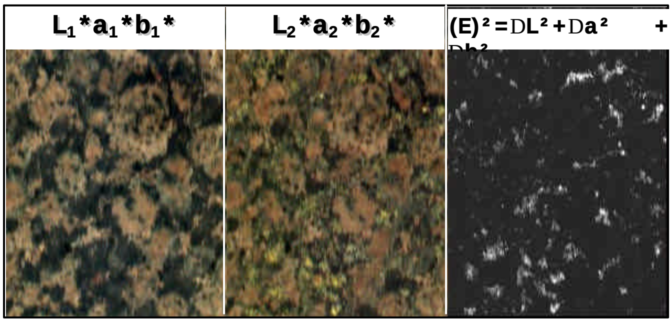


Fig. 6: Quantification of color change on a marble tile due to climatic alteration

An original acquisition system for specular imagery of marble tile is now patent pending. This machine opens new perspective in the field of quality control. Obtained images have appearance similar to those observed under reflected light microscopy. The detection of polishing defects is a straightforward application of specular imagery. Sulfides appear in light, fractures and polish defects in dark. One can apply the method both on large scale, in order to scan the entire tile in one picture, or on small scale to detect micro-defects invisible to the human eyes. Figure 7 presents the large-scale application on a Belgian "Petit Granit" sample. This limestone contains stylolithes remaining unpolished and appearing in black on the image.

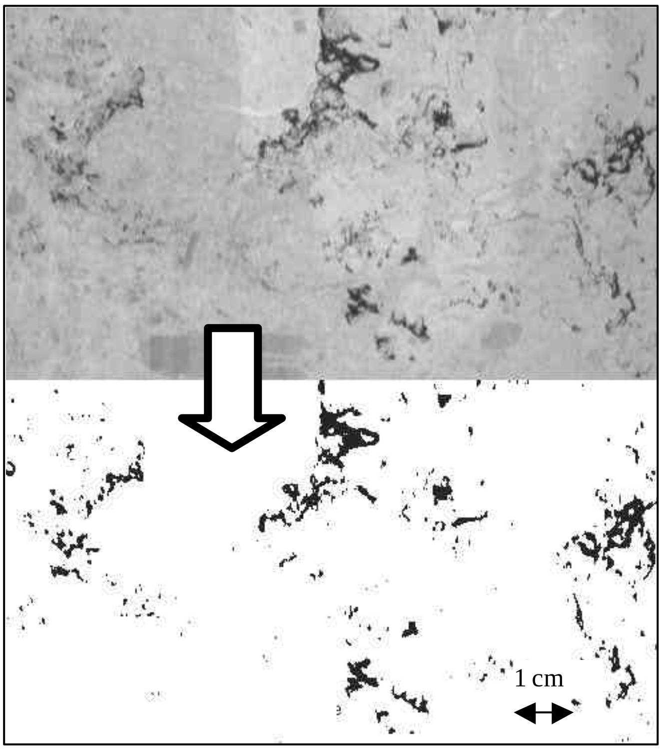


Fig. 7: Detection of millimetric polishing defects in a Belgian "Petit Granit" tile

FURTHER INVESTIGATIONS

In this paper, two applications of macroscopic image acquisition system are presented. Some important general guidelines are proposed that must be taken into consideration in most cases. Multispectral imaging and infrared imagery are now under investigation. New development in the acquisition system for marble inspection must be tested in the future. Finally, colorimetric calibration method must be improved and validated.

REFERENCES

CHANG Y.-C. AND REID J., 1996, RGB calibration for color image analysis in machine vision, IEEE Trans. Image Proc., V.5, n.10.

HOLST G. C., 1998, CCD Arrays, Cameras and Displays, SPIE Optical Engineering Press, Washington

PIRARD E., LEBRUN V. and NIVART J.-F. Optimal acquisition of video images in reflected light microscopy, Microscopy and Analysis (to be published in june)