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Hsi Optical System by Conjugation of the Pupil with the Surface of a Refracting Mirror

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Abstract. In an optical imaging system with incoherent light, the study of spectral images is of great importance due to the large amount of information that can be obtained from an object in question. With the help of an object placed in the exit pupil, and following the theory of image formation, we show the design of an imaging system that allows to observe the optical spectrum of a test object, in this case a circular aperture and a filament of an incandescent lamp, through the conjugation of the pupil on a refracting mirror that, with a mechanical system to perform the scanning, we obtain a set of hyperspectral images.

Keywords: Spectral imaging, image processing, optical systems.

1 Introduction

The design of optical imaging systems has long seen a development in spectroscopic techniques as a non-invasive means of analysis and inspection, due to the possibility of obtaining information about the components of a sample based on the absorption of light [1-4]. With the support of visible/near infrared spectroscopic techniques and computer vision techniques, what is known as imaging spectroscopy has emerged [5-7]. Hyperspectral imaging is a map of light intensity that can be spread over one or more regions of the electromagnetic spectrum [8].

Hyperspectral images are a three-dimensional data set of an object or sample, these data contain spatial and spectral information. The three-dimensional data set is commonly referred to as a "hyperspectral cube". Data from a hyperspectral cube can reveal hidden information, such as the chemical or anatomical composition of an object [9]. Hyperspectral imaging is often used to detect physical and geometric features. Features such as color, size, shape, andtexture.

It can also be used to extract intrinsic chemical and molecular information (such as water, fats, proteins, and other constituents) from a product. Hyperspectral imaging systems, also called HSI, have the capability of imaging more than 100 spectral bands. The main elements of a spectral imaging system are the following [10]: Point source of light, lenses and filters, image sensor, scanning system, and image processing hardware and software.

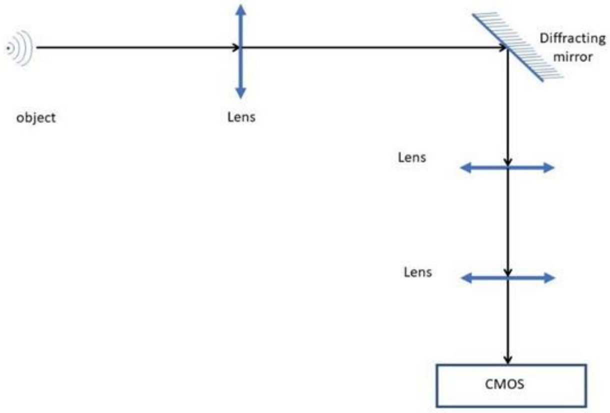

Fig. 1. Schematic of the imaging system.

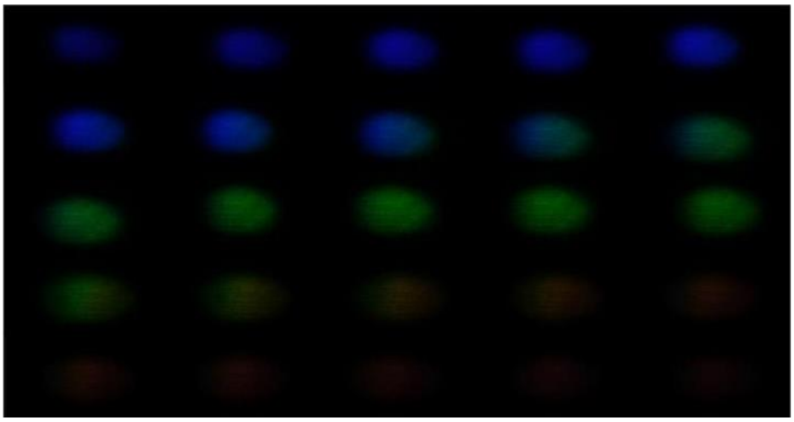

Fig. 2. Results of frequency segmentation of light emitted by LEDs.

2 Image Formation Theory

An optical imaging system with modification in pupil function has been a widely used method to encode the wavefront, phased objects are commonly used to widen the field and inhibit optical aberrations, shadow objects to apodize and increase the resolution of images [11].

Particularly here we use this method to separate spectral images of a test object. Based on the theory of image formation, and applying the mathematical treatment for the case with incoherent light, it can be described mathematically by obeying the following equation:

$$g\,(x, y) = h\,(x, y) \times O_i\,(x, y), \quad (1)$$

where g(x,y) corresponds to the image, h(x,y) to the optical system and O(x, y) tothe object's intensity.

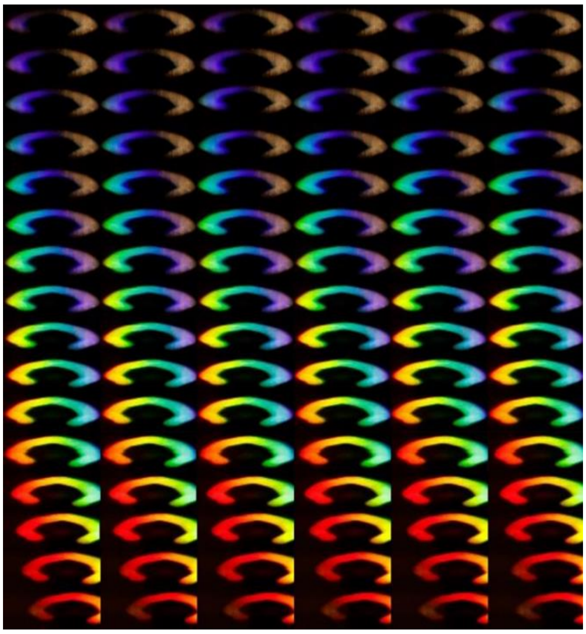

Fig. 3. Frequency segmentation of the incandescent filament.

3 Experiment Design and Results

3.1 Experiment Design

With the aid of a test object, placed in the exit pupil of the optical system, an imaging system is assembled to observe the optical spectrum of the object. For this work, a mirror containing a grating on its surface was used, which gives rise to a conjugation of planes to obtain the image formation, this method is known as pupil conjugation.

The arrangement in Figure 1 was tested using a circular aperture in the plane of the object to simulate a quasi-point source. A lens was placed behind the pupil to collimate the light rays coming from it and then a concave diffracting mirror was placed with the collimated light beam. Finally, with the reflection of the diffracted light, a telescopic lens system is mounted, and the image is formed on the CMOS detector.

A mechanical system performed the scanning in the image plane, the number of images obtained belong to hyperspectral images.

3.2 Results

The first experiment was performed with a white LED, which was placed in front of a pupil so that it could simulate a quasi-punctual source, from this test we obtained a set of images where the transition of the frequencies of the optical spectrum in which the LED emits can be clearly seen as in the cooler areas of the spectrum emits more intensely, but in the area of the red spectrum, it is appreciated to a lesser extent. They were captured with a Canon T6 camera.

In experiment two an incandescent bulb is used, which contains a wider range of frequencies of the spectrum and when capturing them is visually appreciated with better contrast and more intensity in its filament, which allowed us to corroborate how the system is capable of obtaining a large number of images throughout the entire optical spectrum emitted by an object. We obtained 212 images in a 300 nm range, from 350 nm to 650 nm.

It is observed that there was a shift in the hyperspectral images obtained and it seems that all images are identical, however, due to the large amount of information only 96 of the 212 images are shown.

4 Conclusions

With an imaging system and the modification of the pupil, in this case conjugating the pupil planes with the mirror surface, it is possible to have a large number of images in the width of the visible light spectrum, as can be observed in the filament of the incandescent bulb, even the configuration would not change much if you want to measure near infrared or UV.

This technique allows spectral image analysis containing a large amount of information in areas such as the study of biological or chemical samples, in order to know their condition, defects or even if they are contaminated with any external agent because we can obtain spectral resolutions of 1.4 nm.

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