B7 Hyperspectral sensing systems

Introduction and basic concepts. *Imaging spectrometry*, or *hyperspectral imaging* as it is now called, has a long history of development. The impetus for the development of imaging spectrometry came in the 1970s from field spectral measurements in support of Landsat-1 data analysis. Advances required developments in electronics, computing, and software during the 1980s and into the 1990s before the technique was adopted by a larger portion of the earth observation community [4].

The *electromagnetic spectrum* is made up of electromagnetic waves at different frequencies or wavelengths. The spectrum can be broadly divided into radio waves, microwaves, infrared waves, visible light, ultraviolet radiation, X-rays and gamma rays. It is the visible part of the spectrum to the human eye that is referred to as light. This part is defined by a wavelength of 380 - 770 nm.

For *hyperspectral sensing*, the visible light and infrared bands are particularly important. The human eye is sensitive in the electromagnetic spectrum only to visible light, i.e., the wavelength range from 380 to 770 nm. In photopic vision, the eye is most sensitive to a wavelength of 555 nm, i.e., yellow-green. In scotopic vision, sensitivity peaks at 507 nm (blue green). [1], [2]

The hyperspectral nature of the data acquisition allows atmospheric correction factors to be generated from the data itself, which is important for each pixel because atmospheric transmission varies across the image due to altitude and water vapor differences.

Sensor sensing. An important element of cameras designed for imaging is the image sensor, which can detect incoming electromagnetic radiation at a range of spectral levels from X-rays to infrared. It always depends on its structure and the material that is sensitive to the desired wavelength. Silicon is used to capture conventional photography (visible light), which can capture light at the same wavelengths as the human eye and the beginning of infrared radiation.

For sensing, two types of sensors are commonly used, namely *Charge-Couple Device* (CCD) and *Complementary Metal-Oxid (CMOS).*

If the sensors are made of silicon, they are sensitive to wavelengths from 400 nm to 1000 nm, so they can capture some of the near-infrared radiation in addition to visible light. The CCD sensor acts as a shift register, the detected light intensity in the form of an electrical charge travels sequentially through the entire sensor to the output amplifier where the value is read and recorded. Unlike a CCD, a CMOS sensor has its own amplifier under each pixel and the value of the electrical charge or voltage is obtained from all pixels using a bus.

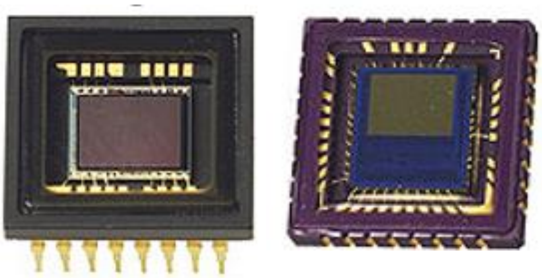

Figure 1: CCD and CMOS sensors. Source:https://netcam.cz/encyklopedie-ip-zabezpeceni/obrazove-snimace-ccd-cmos.php

Application of hyperspectral cameras in practice. Hyperspectral cameras have found applications in many industries and their use is expanding. The most common use, and one of their earliest applications, was in remote sensing (RS). Once imaged, it is possible to identify by reflectance objects on the ground, water quality, forest conditions and more. In crop production in particular, they are used, for example, to detect stressed plants or infested trees that have not yet become visually apparent. They are also used in food processing, waste sorting, forensic science, mineral recognition or in the military, for example to detect mines in enemy territory. The application possibilities are far from ending there, and other applications are constantly emerging, particularly in forestry and crop production. In crop production, the use of hyperspectral cameras is very extensive, with the camera often being placed on a specific

Unmanned Aerial Vehicle (UAV) drone. This drone then takes pictures from a certain height of the ground surface, where there may be, for example, a crop field or a forest. Hyperspectral sensing has already been used to detect rotten or mechanically damaged fruit and vegetables, to detect faecal contamination, to check cucumbers for cold damage, to measure the firmness of peaches, to measure the sugar content of apples, or to classify wheat seeds infected with fungi, for example, among many other applications.

For data processing, for example, the HyperCalib program developed in Matlab [5] can be used to analyse hyperspectral images and recognize samples based on the chosen spectral reflectance. The program can perform calibration, which is a key component after acquisition by hypercube imaging software. Furthermore, one can view the calibrated image at any wavelength, view the spectrum of a single image point with smoothing, or view the spectrum of a selected region directly on a graph in the user interface. An equally important part is to perform segmentation, which HyperCalib with the tool in Matlab also handles. Of course, exporting the variables for further work into the Matlab workspace.

The second part of HyperCalib allows you to select or upload endmembers (reference spectral reflectance) on the basis of which the analysis is performed according to three different algorithms. This determines where the material is located according to the spectral similarity. In the last part of the program, for example, the ink of a photograph can be analysed, and the type of ink and the printer used can be determined on the basis of the reflectance.

Analysing and working with hyperspectral data is also demanding on computer power, requiring tens of gigabytes of RAM and a powerful processor. A very powerful computer is therefore suitable for further development and fast data processing.

List of literature

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3) NAKAMURA, Junichi (ed.). Image Sensors and Signal Processing for Digital Still Cameras. 1st edition. Boca Raton, FL: CRC Press, 2005. isbn 978-0-8493-3545-7.

4) https://dspace.cvut.cz/bitstream/handle/10467/95287/F3-DP-2021-Ruzicka-Miroslav-Parametry_hyperspektralnich_snimacich_systemu.pdf?sequence=-1&isAllowed=y

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Key notes

Imaging spectrometry

hyperspectral imaging

electromagnetic spectrum

hyperspectral sensing

Charge-Couple Device

Complementary Metal-Oxid