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Mhysti

Demystifying multi and hyper spectral Imaging for industrial applications

In this two-year tetra research project, we will study emerging affordable multi- and hyperspectral imaging sensors and testing, examine the necessary data processing, and apply these techniques in use cases in machine vision, surveillance and close-range remote sensing.

Classical cameras in vision applications, in imitation of the human eye, are limited to three spectral bands. This sensitivity curve containing only red, green and blue color bands gives a realistically looking image. But if we can observe more color bands, as in multispectral (up to 10 color bands) and hyperspectral imaging (over 100 color bands), then there is a lot more possible. Indeed, with the full spectrum of an object we can distinguish things that look identical to the human eye. With proper calibration, we can even recognize the material from which the object is made.

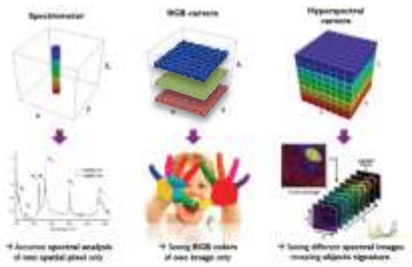


Figure 1: Illustration of spectrometry, RGB imaging and hyperspectral imaging

Checking these high expectations of hyperspectral imaging is the core of this research project. For many vision applications in industry it would be very useful to be able to distinguish objects of different materials from each other, even if they look identical to the naked eye.

There are, however, a number of obstacles that pop up when applying hyper/multispectral imaging in an industrial context, such as the expensive sensors, the large data streams and the complex mathematics necessary to achieve a good result. In this project, we will eliminate these impediments while working out a number of relevant industrial case studies, using modern affordable sensors and understandable performant software.

Hyperspectral sensors can be extremely expensive, but nowadays there are some affordable alternatives that are perfect for industrial applications:
- A spectrograph is an optical component which can be mounted on a conventional camera, and which, like a prism, spreads out the incident light gradually in the various spectral components, like a rainbow. The result is a line scanner, which can be deployed as a pushbroom sensor
- Also tunable filters are now affordable and achieve the necessary switching speeds for a real-time application. Besides the classic color wheel, especially electronically controlled liquid crystal tunable filters, acousto-optical tunable filters and Fabry-Perot filters seem worth a study.
- IMEC has recently developed a number of promising HSI-sensors, wherein the spectral filters are applied directly on the CMOS sensor, both in the form of a line sensor as well as a 2D Bayer pattern.
- Instead of making the camera sensitive for specific spectral components, the spectral resolution can also be inserted through the illumination. A very low-cost solution is to measure the reflection of a few specific wavelengths by illuminating with a set of different narrow-band LEDs.

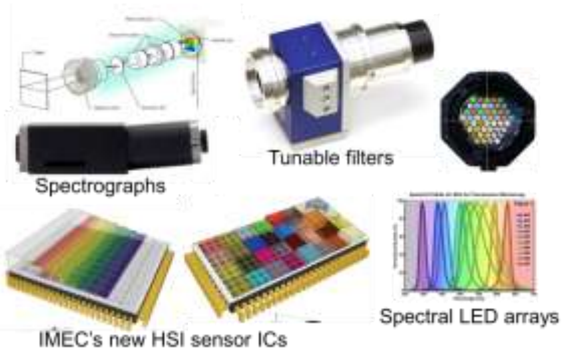
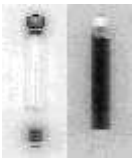


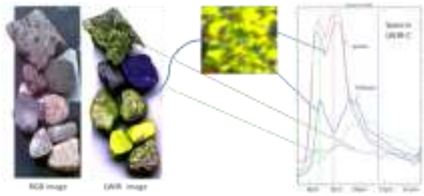
Figure 2: different affordable multi-and hyperspectral sensors

These multi- and hyperspectral sensors, which are limited to the VNIR region, are very promising and available at affordable prices. In this project, we thoroughly test these sensors and compare over different industrial case studies, proposed by companies. We limit this project to applications in three domains: machine vision, surveillance and close-range remote sensing.

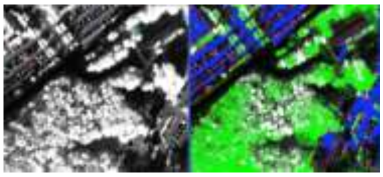
Example applications in machine vision include:
- product mix-up detection for drugs
- inspection of tricolore lettuce plants, just before they are planted




- Material characterization for battery recycling
- Fruit and vegetables quality inspection
- Controlling a fruit picking robot
- Quality control of the output of a wheat threshing machine
- Grading orchids
- Quality control of pharmaceutical products in vials
- Counting mites in microscope images



In remote sensing, we think of:
- Road maintenance, measuring the aging status of asphalt
- Mapping asbestos roofing materials
- Roofing material classification to interpret thermal images
- Field inspection for precision agriculture
- Combination of 3D photogrammetry and hyperspectral material characterization for city modeling
- Biodiversity mapping of natural habitats
- Detection of archaeological remains in croplands (crop marks)



For these remote sensing applications, we can make use of existing satellite and aerial images. Yet another possibility is to mount the above proposed sensors on a UAV to gather very high resolution imagery.

Besides acquiring multi- and hyperspectral images the data visualization and processing is obviously a challenge. Therefore we will test and compare the available software packages (Spectronon, Gerbil, ENVI / IDL, MultiSpec (Purdue), MATLAB Hyperspectral Toolbox, Opticks (Ball Aerospace)), and integrate these in commonly used frameworks such as Halcon, Cognex VisionPro, OpenCV and Matlab. To ensure that the companies of the target group can pick up this technology, we organize interactive workshops and publish tutorials. It is important to provide insight in an accessible way in the sometimes complex mathematical methods for hyperspectral classification, which are based on multivariate analytical techniques such as principal component analysis (PCA), partial least squares (PLS), linear discriminant analysis (LDA), Fisher discriminant analysis (FDA), multi-linear regression (MLR) and artificial neural networks (ANN).

Besides the main objective of this project, enabling companies to adopt multi-and hyperspectral imaging and processing through a number of case studies, we will also study a few innovative new features in this area:
- The integration of multiple spectral components in a state-of-the-art object detection algorithm as Dollar's Integral Channel Features detector [Integral Channel Features, P. Dollar, Z. Tu, P. Perona, and S. Belongie, BMVC 2009] (which we studied in our previous project "TOBCAT"), towards a well-founded way to combine spectral classification and shape recognition to detect objects.
- Installation of a greyscale camera and a hyperspectral line scanner on a UAV to extend hyperspectral data 3D photogrammetry (studied by us in our previous project "3D4SURE"). This yields a three-dimensional hyperspectral model of the scene, in which very interesting analysis can be done.
- Looking into the possibility to see through fog or smoke using hyperspectral images by registering the wavelengths that are not blocked by fog or smoke. In theory, this might be accomplished when the spectral absorption spectrum of the medium is known.

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