Smart Cameras for Colouring the Invisible

M. Burgstaller, M. Groinig

Jena, 15.12.2010
The Company

We develop and manufacture industrial sensors for the electronic detection and sorting of bulk materials with very high speed and high resolution.
The People

Employees: 29  (8/2010)
Technology & Sales:  19  (TU, FH & HTL)
Production:  5
Administration:  5
Turnover:  about 3 Mio €
## Customers and Technologies

### OEM and System Integrators

| Environment | Sorting of recyclable materials like glass, metal, plastic, paper, electronic waste, etc |
| Mining | Sorting of minerals like Brucite, Pegmatit, Marble, Dolomit, etc |
| Food Processing | Impurity detection, sorting upon the maturity level, etc |
| Pharma in preparation | Impurity detection, PAT |

### Sensor Technologies

| Colour Line Scan Sensor Systems EOS | UV-VIS, CCD, CMOS, LED continuous and flash-based illumination |
| Material-selective Metal Detection System ARGOS | Ferrous metal vs. non-ferrous metal vs. stainless steel. Non-ferrous vs. non-ferrous |
| Chemical Imaging Systems HELIOS | VISNIR (preparation), NIR (1.7), SWIR (2.5), Core, Class, Complete |

"visualize and classify bulk materials according to colour, form, size, material and structure"

... overall all Smart Camera Systems are based on FPGA and DSP Technology
Use of Chemical Imaging Systems

**Suitable if...**

- **Spectroscopic and spatial information necessary**
  The geometrically dimensions and position of interest. The distribution of ingredients are important. Evaluation of several spatial points to increase the signal-to-noise ratio.

- **Information is not “visible”**
  Cheap and high standardized image processing cameras are not suitable for the appropriate task. Information out of the visual region (Si).

- **Chemometric measurements**
  Spectroscopic processing allows the measurement of quantities e.g. to access a fruits state of maturity by measurement of the sugar quantity.

- **High quality colour measurement**
  Because of spectroscopic abilities, colour measurement can be with avoiding metamerism. Different colour calculation methods possible to achieve best results.

**Markets, Applications**

- **Recycling**
  Polymer and paper sorting (separation).

- **Minerals**
  Sorting minerals according the concentration of ingredient like Dolomite, Brucite, Talk, Magnesite, etc...

- **Food**
  Sugar content, detection of impurities, sorting according the state of maturity, etc...

- **Pharma, Agrar, textil, etc, etc, etc,**
  Pharma, if distributions are of interest. Agrar, deficiency symptoms of plants, textil, impurity detection, etc...
EC3 Example

Sorting of different minerals (Talc, Magnesite, Calcite)

Visible Information
All objects (stones) are showing nearly the same visible information – sorting by means of standard colour image processing not successful.

Ecologically Aspects
Minerals with good purity get seldom. Sorting out of minerals (stones) with high (or week enough) purity needed!

Industrial Inline Application
The sensor system must enable the sorting of tonnes of minerals per hour → high speed Inline processing of spectral information necessary

Spectroscopic differences
Each focused category has dedicated spectroscopic differences in the NIR-range – reported f.e. by Roger N. Clark / USGS, allmost in the range >2.0μm and also around 1.4μm.

Challenge
Finding an sensory that overcomes the demands of this industrial application. First test in the range 1.1-1.7μm (InGAs possible → “cheap” sensor) using EC3 technology.
Data Acquisition

The Measurement Process

**Measurement Setup**
Setup the illumination, the optical system (focal length, aperture), camera parameters (integr. time, scanrate, etc...), objects transport speed.

**Scanning**
During the scan-process all Chemical Images captured are stored in a buffer (PC). Image series describing the measurement object(s) are marked out for further processing.

**Organizing Measurement Series**
To get one data set that best describes all object categories, spatial regions of interest are marked out and different measurements are concatenated (along spatial or sample domain). Additional parameters used for reporting the measurement object(s) and process are attached to the data.

---

Some minerals under “industrial conditions“:

- **Object size**: >20mm
- **Lateral resolution**: ~3mm (240 spectra / line)
- **Scan rate**: 330 Chemical Images / s
- **Transport speed**: ~1.5m/s → 4mm resolution
- **Wavelength**: 1.1-1.7µm (316px, 2nm spectral resolution)

---

![Minerals](image)
Visualization – Questions / Possibilities...

What are the differences (spectral) ?

- **Measurement Errors**
  Calibration ok? Too week chemical information (specular reflection)? Dynamic range ok – systematic measurement error small enough?

- **Causality**
  Are there spectral informations strongly correlating with the desired chemical information?

- **Preprocessing**
  What kind of preprocessing might allow the best suitable spectra representation?

Where are the differences (spatial) ?

- **Correlation**
  Are spectra from an certain object showing a common spectral information – are the spectra correlated to each other?

- **Separation**
  Does object A and B showing spectral differences – are the differences repeatable (systematic)?

- **Border Effects?**
  Are there measurement errors at the spatial border of objects – spectra mixing?
Visualization by means of Chemical Colours

First Impression – Standard Transformation

Chemical-Colour-Image representation of minerals, categories: talc (top row), magnesite (middle row), calcite (bottom row), EC3-method: Transformation to VIS (jet), measurement system: HELIOS Class NIR (1.1-1.7µm)
Smart Cameras for Colouring the Invisible

**EC3 – EVK Chemical Colour Camera**

- **Data Processing**: Inline processing of spectra by means of multivariate and image processing methods. 240 spectra per frame, 330 frames per second.
- **Output**: RGB line containing chemical information of objects.
- **Configuration**: Development of industrial solutions by means of an intuitional configuration tool (designed for image processors).
- **Wavelength regions**: Different wavelength regions → wide pallet of possible applications.

**Acts like a colour linescan camera...**

**Link from Spectroscopy to Image Processing**

**EC3 → “easy-three“**
- Easy Access
- Easy Handling
- Easy Development

**Scanrate & Resultion**

**Complexity of problems**

**Spectroscopy**

**Color-Imaging**

**EC3**

www.chemical-imaging.com - www.evk.biz
**EC3 Methods**

**Analysis I (PCA-Nipals)**

Chemical-Colour-Image representation and referenced spectra of minerals, categories: talc (top row), magnesite (middle row), calcite (bottom row).

Preprocessing: Normalization

Talk: blue markers and spectra

Magnesite: green markers and spectra
Calcite: red markers and spectra

Score Images of principle component analysis (Nipals). Used for EC3-configuration: Red: PC1, Green: PC2, Blue: PC4

EC3 output image and HSV representation of referenced spectra.

Talk: blue circles
Magnesite: green circles
Calcite: red circles
EC3 Methods

Contrain Colours (PLS)

Chemical-Colour-Image representation and referenced spectra of minerals, categories: talc (top row), magnesite (middle row), calcite (bottom row).

Preprocessing: Normalization
Talk: blue markers and spectra
Magnesite: green markers and spectra
Calcite: red markers and spectra

Constrain-Colour-dialog and Score Images.
left bar on the right: given colours
right bar on the right: predicted colours

EC3 output image and HSV representation of referenced spectra.
Talk: redish colour and circles
Magnesite: greenish colour and circles
Calcite: bluish colour and circles
EC3 Methods and Further Processing

Additional Methods

**Analysis II**
Principle component analysis (PCA) based on singular value decomposition (SVD)

**Quantity**
Calculation of the quantity of constituents (spectra of pure “material”) - each constituent a colour channel.

**Transformation to VIS**
Transformation of spectral information to colour by predefined filter curves (models)

**Apply Model**
Applying models calculated by chemometric software packages like The Unscrambler

Further Processing

**Elimination of “Border-Spectra”**
Border spectra are spectra of different spatial origin and mixed spectral information. These chemical information in the spectra are different → different colour. By applying image processing algorithms like “opening functions”, the objects border can be eliminated.

**Classification**
Classification of the chemical information is done by classifying its chemical colour representation (HSV).
# Summary

## EC3 Example on Sorting Minerals (Talc, Magnesite, Calcite)

<table>
<thead>
<tr>
<th><strong>“Invisible” Information</strong></th>
<th>A separation criteria for those materials can be found in the NIR range (characteristic absorbance bands). No systematic information in the visible range.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Repeatability</strong></td>
<td>Spectra “in” an object are similar to each other → chemical information is similar → Similar colour.</td>
</tr>
<tr>
<td><strong>Separation</strong></td>
<td>Spectra of different categories are systematically different → chemical information is different → systematically different colours</td>
</tr>
<tr>
<td><strong>Separation Foreground / Background</strong></td>
<td>Necessary to get the focus on the objects to be sorted. Done by combination the additional feature „Baseline Offset“. Combination of additional features is mostly valuable when solving industrial applications.</td>
</tr>
<tr>
<td><strong>Industrial suitability</strong></td>
<td>Measurement setup and HSI data acquisition was similar to industrial conditions. Spectra quality quite „good enough“ → Repeatability, Separation Next work: Implementation in field.</td>
</tr>
<tr>
<td><strong>Configuration / Validation</strong></td>
<td>Figuring out the first “meaningful” chemical images were done in few minutes. The complete configuration and validation with masses of materials were done in few hours.</td>
</tr>
<tr>
<td><strong>Additional Cognitions</strong></td>
<td>Objects detected that are different to objects of the same group (category) → different colour. Special treatment possible / necessary? Are their other informations detectable that can gain an additional benefit?</td>
</tr>
</tbody>
</table>
Chemical-Imaging Systems
Thank you for your attention!

See also:

Inline quality control for potatoes