

CHEMICAL COLOUR IMAGING

The next step in the evolution of machine vision

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Chemical Colour Imaging (CCI) makes complex hyperspectral data on a molecular level usable for machine vision. Hyperspectral imaging systems based on a generic, intuitive configurable data processing platform make the scientific methods of hyperspectral analysis accessible for everyone and open up new application areas.

1. Introduction

Machine vision technology has gone through a constant development process over the past decades. Starting with monochrome cameras, which use differences in contrast for defect detection, imaging technology has advanced to increasingly precise colour cameras revealing even the smallest colour deviation.

After colour imaging and the subsequent 3D imaging, Chemical Colour Imaging (CCI) takes this technological evolution to the next level. The software technology makes complex hyperspectral data on a molecular level usable for machine vision. The 'Perception' field of research includes a clearly understandable analysis and visualization of relevant information in large data volumes.

Hyperspectral imaging allows chemical properties of materials to be identified and thus differences in the materials to be analyzed. Objects leave a unique 'fingerprint' with their highly complex spectral information through chemical and molecular properties which can be identified.

However, hyperspectral camera technology has not yet been widely applied in the industrial environment. Standards for interfacing are missing, data needs to be analysed by scientific-motivated multivariate and chemometric data processing, elaborate correction methodology of cameras disorder has to be considered. Until now, the use of hyperspectral systems has only been accessible to a hand-full experts in spectroscopy and chemometry providing

their special purpose solutions to niche markets.

Machine vision is nowadays a standard technology in a lot of industries. Companies has focused on manifold applications, provide their customers special purpose solutions based on standardized machine vision technology and support based on their valued application know-how.

The spread of hyperspectral camera technology by the machine vision community were strongly restricted in the past because of the aforementioned hurdles.

2. CCI as a holistic approach

Chemical Colour Imaging (CCI) has closed this gap and allows - for the first time – the analysis of chemical properties by means of real-time image processing. The advantages of spectroscopy and the benefits of machine vision have been merged in a holistic approach.

The core element of CCI is the extraction of two-dimensional feature data - the chemical colour images - from complex, multi-dimensional hyperspectral data. Hyperspectral cube data are described by colour images holding spatial information together with spectroscopic information coded by colour. Doing so, the user deals with spectroscopic information and problems in a domain natural to him and even is able to learn by his cognitive intelligence. A set of CCI methods addresses standard problems by different approaches intuitive understandable by non-experts of the basing technologies. Encapsulated by the CCI methods, the mathematics in behind are based on well-selected combinations of well-approved statistical and chemometric methods primarily known from science work of last 20 years.

There are several approaches available which are useful to model an information of interest – the ap-

plication relevant information. Each approach results in a model.

A model is a simulation of a system to reproduce its behavior for a defined input range.

Once a model is designed, by applying it to new data (of same system) it results in a value used as scale of the behavior that was modeled.

For example: By applying a sugar-model onto one spectra, the sugar content represented by the spectra is measured - it results in 1 value, the sugar content.

By applying a sugar-model to hyperspectral data, a monochrome image is obtained describing the sugar content by its pixel values (gray values).

By applying a CCI-model to hyperspectral data, a color image (a perception) is obtained describing the scene by a combination of three orthogonal (independent) information – by its color channels. In the following three important approaches are summarized which are used frequently in industry [3].

Approach 'Extract': An unscrambling process is controlled by the maximum variance information of selected objects. The perception gained is composed of score values of calculated principle 'patterns' in the spectra. By assigning components to colour channels (which hold application relevant information), a perception is obtained based on principle components.

Approach 'Correlate': A spectra can be a mix of different spectra of pure components. By knowledge of 'all' pure components, a correlation value per component and pixel can be calculated. By assignment of component score images to colour channels, a perception is gained.

Approach 'Constrain': The user constrains expectations in form of colors to selected spectra from the scene. The modelling process calculates a model which tend to follow the user's expectation. By applying this model to the whole scene, a perception of the whole scene is obtained. In case the user's expectation is model able, the reached perception will be near to the user's expectation.

Figure 1 shows in its left image a hand holding 2 plastic plates.



Figure 1: Hand and plastic plates

The image in the middle shows the gained chemical color image describing the chemical scene: The plastic plates and hand came along with distinct (orthogonal) color information while an overlap of objects results in a mix of chemical and therefore in a mix of color information. From the image to the right, all possible material combinations are circumscribed. The perception shown was reached by applying the 'Correlate' method. The two plastic plates as well as the hand were assumed to be pure components. So the image show the correlation of this components expressed as color information.

The extraction of application relevant information is referred to as offline work, provided by the Perception Studio user interface program.

3. CCI compliant hyperspectral cameras – the product Perception System

By adapting a hyperspectral camera with a real-time processing core, Chemical Colour Imaging turns the camera system into an easy-to-understand and intuitive configurable 'chemical colour camera'. The chemical colours reflect the molecular properties of the scanned objects.

Perception Park has developed such a hardware adapter called Perception System. Beside its main use case, the streaming of molecular information, the hardware fully abstracts the interfaced camera and makes it accessible through standard interfaces like GigEVision or CameraLink. By means of a calibration package per camera, individual electrically and optically disorders gets corrected. By an abstraction layer, each camera, regardless of the type, gets abstracted and standardized by the Perception System. This opens up the selection of camera technology independently from the provider and enables standardized integration and application by CCI.



Figure 2: CCI logo denoting CCI compliant hardware devices

After configuration of the Perception System by the Perception Studio user interface program, the hardware adapter switches into streaming modus, transforms camera row data into application relevant molecular information and outputs this information to an interfaced machine vision application.

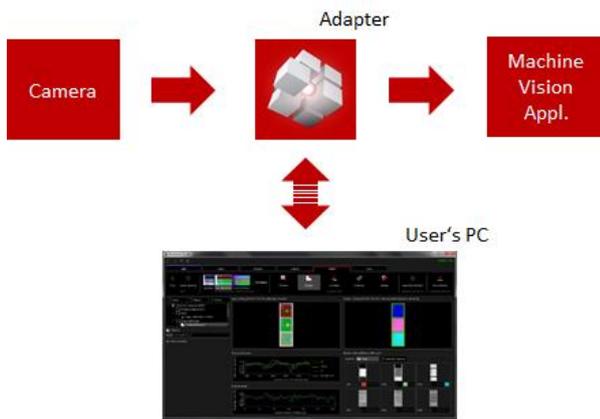


Figure 3: Integration

Therefore, CCI compliant hyperspectral cameras get integrated like conventional machine vision cameras and interfaced by standard machine vision tools (see Figure 3).

4. Special purpose devices based on CCI

Thanks to an underlying plugin framework, the processing core (Perception System) as well as the user interface program (Perception Studio) is extendable and customizable to specific needs.

By providing the processing core for different processing platforms, like GPU-based, CPU-based or even DSP-based, special purpose devices like handhelds, or more generally, embedded devices get feasible. Machine vision tools runnable in parallel enable device manufacturers to bring in their core competence and to profit from all advantages mentioned above. This results in hyperspectral imaging based special purpose devices provided by established players in their markets.

Telemedicine devices or cell-phone based inspection tools for the consumer market are consequently a possible next step. Thanks to the underlying framework solution, device manufacturers are enabled to focus on their core competence and to provide future devices by adding on their value.

5. The current state of technology

5.1. Hyperspectral Imaging

Hyperspectral imaging, like other spectral imaging, collects and processes information from across the electromagnetic spectrum. Much as the human eye sees visible light in three bands (red, green, and blue), spectral imaging divides the spectrum into many more bands. This technique of dividing images into bands can be extended beyond the visible.

Hyperspectral sensors look at objects using a vast

portion of the electromagnetic spectrum. Certain objects leave unique 'fingerprints' across the electromagnetic spectrum. These 'fingerprints' are known as spectral signatures and enable identification of the materials that make up a scanned object. For example, a spectral signature for oil helps mineralogists find new oil fields [1].

Up to now, industrial hyperspectral imaging was a discipline primarily applicable for scientific oriented companies and institutions with a strong competence in big data processing and a focus on application engineering. Such a complex camera technology typically needs special treatments to overcome electrical and optical disorders and special piecewise calibration effort to ensure consistently and repeatable quality of output data.

The analysis of hyperspectral data was the field solely of experts of the disciplines multivariate and chemometric data processing as well as spectroscopy.

5.2. Machine Vision

Machine vision (MV) is the technology and methods used to provide imaging-based automatic inspection and analysis for such applications as automatic inspection, process control, and robot guidance in industry. The scope and industrial spread of MV is very broad – nowadays the technology is well established over the whole world [2].

5.3. Enabling the Machine Vision community to profit from Hyperspectral technology

The main idea and the driving thought behind Chemical Color Imaging was to enable the existing Machine Vision community to profit from the valuable hyperspectral Imaging technology known from science.

CCI based systems are used since 2014 primarily by machine builders for sorting applications. Since 2015 hyperspectral camera suppliers deliver their cameras together with CCI technology (Perception System and Perception Studio). Since 2016, STEM-MER IMAGING enables the machine vision community in Europe and Asia to profit from their hyperspectral systems based on CCI [4].

5.4. CCI in today's industry

Chemical Colour Imaging today is applied to industrial purposes by solution providers such as me-

chemical engineers with machine vision competence. Since CCI enables configuration instead of programming, the development effort per application can be reduced dramatically. This has particular advantages for the food processing industry, where the sorted products can quickly change, (for example due to maturation) thanks to shorter development and modification cycles. Figure 4 shows the distinction of potatoes from stones and soil by means of molecular information accessible by CCI.

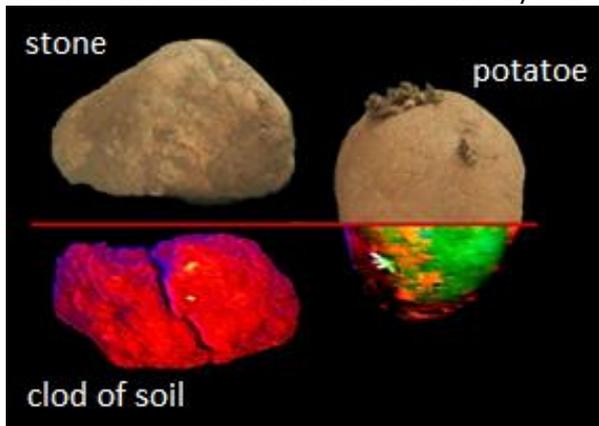


Figure 4: Sorting potatoes

In addition to the food industry Chemical Colour Imaging systems are especially suited for recycling, mining and the pharmaceutical industry. A specific application in the recycling industry is the automated separation of plastics (see Figure 1). Investigation into pills show the potential for contact-less measurement of active pharmaceutical ingredients. Figure 5 highlights the distribution of Aspirin in a commercial pill.

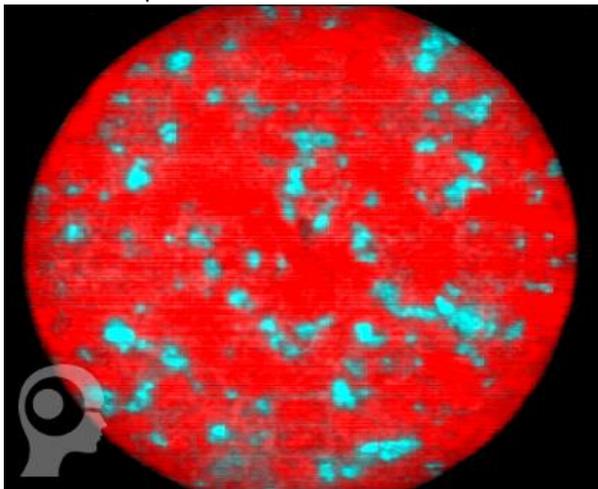


Figure 5: Distribution of Aspirin in a pill

Chemical colour information as well as monochrome information can be processed by the user's vision system. Thus, a hyperspectral camera may be integrated into already existent solutions like sorting machines. Even in the medical field there are initial tests using CCI technology to visualize the blood

vessels inside a human hand shown in Figure 6.

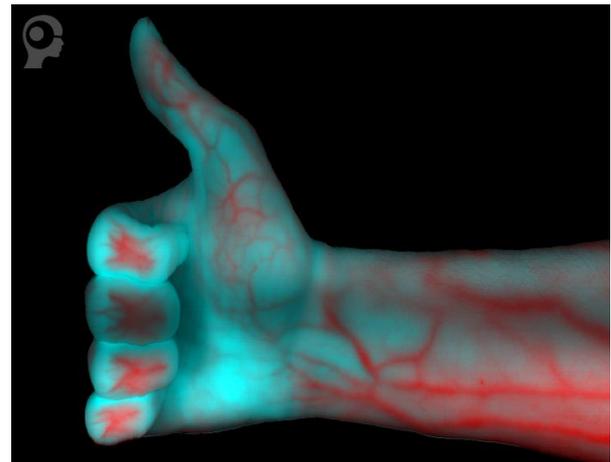


Figure 6: Blood vessels inside a human hand

6. Relevance for the machine vision community

CCI enables machine vision related companies to benefit from new application fields which require spectroscopic information to be accessible. Since CCI is not limited to a specific spectral range or spectroscopic technology, all advantages known from science are accessible now by the machine vision community. For example: Near-infrared spectroscopy is well-established for material characterization based on investigating molecular vibrations. Spectroscopy in the visual domain allows to get precise measurements on the objects color property. Interferometry can be applied to quantify thickness information of coatings. Gas detection get feasible by means of mid- and longwave-infrared spectroscopy. Genes are shown already to get addressable by means of UV spectroscopy. It seem this list can be continued endless thanks to all the work investigated from researchers in past decades.

6.1. Value for the machine vision community

- CCI makes molecular object properties accessible to the machine vision community by means of standardized interfaces.
- Machine vision related experts are enabled to develop hyperspectral applications on their own without necessarily being experts for the basing technologies.
- Industrial real-time hyperspectral imaging application get possible by the extension of a hyperspectral camera by the Perception System hardware adapter.

- Since any hyperspectral camera gets abstracted and standardized by a Perception System, no more bounding relationship between application suppliers and camera supplier.
- Thanks to standardized interfacing by GigEVision or CameraLink, all existent machine vision tools are compatible to interface CCI based hyperspectral cameras.
- Due to the generic, configurable data processing framework of Perception Park, new applications are configured instead of programmed from scratch. This allows a reduction in development of about 95% per application.
- By means of the application driven user interface program Perception Studio, machine vision users gets enabled to configure 'the camera' to output application relevant molecular information. This is enabled through a set of intuitive understandable CCI methods.
- CCI based products are available not only from Perception Park but in addition from camera suppliers and distributors of machine vision components. This allows machine vision related organization to cooperate with their established and well-known network.
- Application related machine vision experts are enabled to extent their product portfolio and to gain unique selling propositions (USP's). This furthers their distinction to competitors.
- Special purpose device suppliers gets enabled to build up future vision devices. Because of the extensible framework solution, customization is provided through development of e.g. application specific plug-ins.
- Perception Park acts as a technology provider with a passion for hyperspectral imaging. Their licensed software products and additional services enable 3rd parties to provide hyperspectral technology on their own. This circumstance enables the development of new products and new business models by the community.

6.2. Value for the end customer

Sorting:

- More consistent and higher quality of goods. More precise measurement of the color property or measurements of chemical parameters – like the state of maturity of fruits.

- Detection of injuring or nauseating components. Like the detection of PVC plastics before waste combustion or detection of bugs in a fruit stream before mixing up with dairy products.

Process Control:

- Important feedback values to achieve a more efficient and more ecologically production. Like controlling the temperature of a fryer as function of the water content in goods like potatoes.
- Improved product quality, reduced product variance. New key parameter are available. Like the spatial resolved inline measurement of moisture during paper production.

Quality inspection:

- Improved consistency of products by inline measurement of spectrally deviation: Like the qualification of the color of LED-controls assembled in a cockpit (automotive).
- 100% quality control of pills in pharmaceutical processes.

Monitoring:

- New parameters to improve security. Like the measurement of cellulose content in air in a wood processing environments (to reduce the risk for self-ignition).

Early diagnosis:

- Monitoring of the healing process of woods by inspection of the origination of tissue.
- Cancer detection by investigating into tissue types.

And many, many more...

7. References

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