SMARTSPECTRA: SMART MULTISPECTRAL CAMERA FOR INDUSTRIAL APPLICATIONS

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1. ABSTRACT

SmartSpectra is a project funded by the EU under the IST Programme that began in July 2002. The proposal is to build a platform to simplify the access to multispectral technologies at an affordable cost and effort. The idea is to build a camera, the software for the host computer, and to test it in 3 relevant applications. The camera will provide 6 bands, fully configurable from 400 to 1800nm and simulate 2 ordinary RGB Firewire cameras. Six partners will develop the platform and offer free or low cost access to the prototype to relevant third parties.

2. INTRODUCTION

In certain application fields where visual information processing is involved, the use of spectral information out of the VIS range is critical. SmartSpectra is a smart multispectral system at an affordable cost and enough robustness to make multispectral techniques accessible to industrial, environmental, and commercial applications.
SmartSpectra is a project supported by the European Commission under the Information Society Technologies Programme. The list of participants may be found in the aforementioned website: two universities, two institutes, and two companies. The SmartSpectra project started in July 2002 and will finish in July 2005.

2.1. Description of the SmartSpectra

Hyperspectral imagery has potential applications in many fields but presents a series of problems that prevents its use. Among these problems we highlight five: i) the high cost of the acquisition equipment (cameras or spectrometers), ii) the frequent tuning often required by these systems (calibrations, temperature drifts, illumination issues), iii) the large amount of data involved, iv) the many degrees of freedom (number of bands, bandwidths, etc.), and v) the lack of experience of the developers.

In order to make it easy for professionals to employ this technology, the proposed SmartSpectra project has three cornerstones (Fig 1):

1. The design and development of a robust cost-effective multispectral sensor for industrial applications.
2. The provision to customers of a developer toolkit that will simplify the use of the sensor.
3. Proof of the technology and methods developed in three real application areas.

The system can be divided into two main blocks, the sensor and the host computer. The sensor mainly involves optics and electronics. The host computer involves drivers for camera configuration and image acquisition, image processing software and the development of specific algorithms for the application fields of fruit quality assessment, agriculture, and environmental monitoring. The camera acquires 6 bands that may be located in the VIS and NIR spectra, and simulates two common Firewire RGB cameras.
The original point about the camera is that the 6 bands that form each image are fully configurable both in bandwidth and centre frequency from snapshot to snapshot. In addition, this camera is a hybrid between machine vision systems and spectrometers. It is not a spectrometer since the bands are usually neither as narrow (5-50 nm) nor as sharply defined. We do not want to compete in either increasing resolution or number of bands. SmartSpectra proposes a fusion between two close but different disciplines: machine vision and spectrometry.

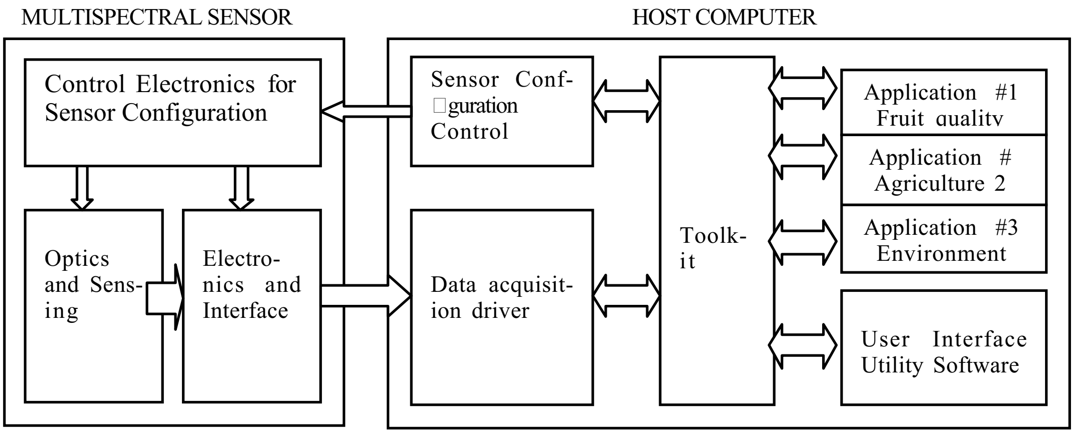

Figure 1. *The concept of SmartSpectra project in blocks*

The reason for this flexibility is that in many cases the users do not know 'a priori' the most appropriate bands for the problem, and, in addition these bands often change with the conditions (type of fruit, feature of interest, changing lighting conditions, etc.). So the proposed hardware platform will probably not be the cheapest option for a well-defined problem but will present the versatility to confront open tasks or those with changing conditions or demands. A first prototype with a reduced set of features to test the system is being developed by the partners.

2.1.1. SmartSpectra System

The first prototype of the SmartSpectra system will provide the following features:

- An array sensor to provide 2-D spectral images.
- Spatial-spectral information on 6 spectral bands in the range 400-1000 nm.
- VGA spatial resolution.
- Re-configuration: the possibility to choose the spectral bands provided.
- Progressive scanning
- Digital output compliant with the 1394 Trade Association's Digital Camera specification.
- Asynchronous reset.

2.1.2. Developer toolkit

The software tools developed in the project will include:

- A software driver to acquire multispectral images using standard IEEE-1394 bus-equipped PC. The driver will include the control of the features.
- A software package of methods and tools to perform visualization of multispectral data.
- A set of software methods and techniques to process and manipulate the multispectral images in order to extract and provide higher level information.
- Utility software with a graphical user interface to show application developers how to use the SmartSpectra system and to simplify tasks.

2.1.3. Test applications

At the end of the project the system will be tested in the following application fields:

- Quality assessment of some features in fruit sorting
- Rural monitoring: study of the effect of industrial and farming practices on wild plant life and biodiversity.
- Coastal water monitoring

3. STATE OF THE ART

The SmartSpectra camera uses state-of-the-art technologies in the fields of multispectral analysis, light sensing and smart imaging. We will now describe the current state of the art in these fields.

3.1. Multispectral techniques

The SmartSpectra camera is different from the rest of spectral systems on the market. The most similar devices available in the market are the spectrometers. Spectrometers can analyse a point, a line or a 2-D image.

Point spectrometers work on the spectral dispersion of a light beam using a reflection grating or prism. The spectrum is projected onto a linear array of sensors (CCD or photodiodes). Each element of the array is exposed to a single wavelength of the beam. The combination of the array elements response forms the spectrum of the beam.

Linear spectrometers analyse a linear image by dispersing the light into a rectangular area. One dimension of the area is the spatial axis while the other dimension represents the spectral axis. *Imspector* spectrograph from

Spectral Imaging Ltd. (Specim; www.specim.fi) is a good example. *PARISS spectrometer*, from LightForm Inc. is a complete linear spectrograph system designed to be used with a microscope. *ASPI Hyperspectral System*, has a linear spectrometer system with a spectral resolution up to 480 bands. It uses a holographic grating to disperse the spectrum and a CCD camera to capture the spectral information of the linear input image.

Finally, multiband systems can capture two-dimensional spectral images by the use of a filter in front of a CCD array. Commercial systems use fixed spectral bands, selected from a wheel of filters or from a Liquid Crystal Tunable Filter (LCTF).

Opto-knowledge Systems Inc. (OKSI) provides hyperspectral imaging systems in the VIS, NIR or SWIR ranges. The system is formed by a LCTF coupled to a standard C-mount camera, and the software to control and acquire the images. The range of the system is limited to less than 400nm in the VIS region and up to 600nm in the SWIR, with a nominal band pass of 5 to 50 nm. The camera runs in multiple-shots mode, not in real-time video mode. The control toolbox allows the user to define a multispectral acquisition formed by a list of exposure time and frequency sets. OKSI also provides a Toolbox that runs under ENVI software.

Ducantech *DTI multispectral camera* is formed by three digital cameras. A colour-sorting prism separates the image into three spectral bands. Two of the cameras are B/W, and the other one can be RGB or B/W. In addition to the prism, trimmer filters (adjusted in factory) in front of each camera accommodate further control of spectral bands. The range of the CCD is 400-1100 nm.

3.2. Array sensors

The SmartSpectra camera uses commercial sensors. None of the existing technologies covers the range required by our system. Hence, it is necessary to use one sensor for the visible (VIS) part of the spectrum and another sensor for the near-infrared (NIR) region.

3.2.1. VIS image sensors

The first imaging technology used for the VIS region was that of the Charge-Coupled Devices (CCD). Currently, Complementary Metal-Oxide Semiconductor (CMOS) sensors compete with CCD in most features.

3.2.1.1 CCD

CCDs are composed of a matrix of photogates on which the light is collected [1]. The photons are converted into electrons (charge) and transferred to the output. At the output stage charge is converted to voltage. The bandwidth of the output limits the reading speed of the sensor. Conventional CCD sensors have a single output, but some CCD sensors have 2, 4 or even 32 outputs. A conventional CCD can read as much as 30 full images per second (in VGA format). A high-speed CCD with 32 outputs can read 300 full images per second (Sarnoff Corp. VCC1024H). Multiple outputs have a drawback in the uniformity of the image, which is decreased because of the differences between the output stages.

CCD characteristics greatly depend on the field of application [2]. Applications in astronomy demand the highest performance of CCD sensors. The reduction of the readout noise is achieved with long time exposure and low readout speed. To increase the responsivity, CCDs for astronomy are normally back-thinned. Alternatively, CCDs for science have a large full-well capacity. To exploit such a large dynamic range these cameras digitize the signal into 14-16 bit. The CCD for astronomy and science use mainly Full Frame architecture. We find astronomy CCDs ranging from 80x80 pixels to 2048x4096 pixels and data rates lower than 50kpixels/sec. Main manufacturers of astronomical CCDs are E2V Technologies, Scientific Imaging Technologies, Inc. (SiTe) and Fairchild Imaging.

By contrast, industrial applications demand lower resolutions but higher data rates. CCD sensors for machine vision need to be fast, with a resolution not higher than 10 bits. Spatial resolution is very dependent on the application and can be as low as VGA or as high as 2048x2048. Normally sensitivity is not an issue since lighting can be controlled. Dalsa, PerkinElmer, and Hamamatsu are some manufacturers of industrial CCDs.

3.2.1.2 CMOS

Complementary Metal-Oxide Semiconductor (CMOS) sensors are composed of a matrix of photodiodes with a charge-to-voltage converter in each. The readout speed can be much higher than in a CCD but the uniformity is much lower. CMOS sensors use the same manufacturing technology as other CMOS ICs and are therefore cheaper to produce than CCDs.

There are two main groups of CMOS sensors depending on the application. We can find low cost CMOS for cost-sensitive applications and high performance CMOS for high-speed imaging.

Examples of low-cost devices are Agilent ADCS-1120 and ADCS-2120, Omnivision OV76030 (color) and OV7130 (B/W) and National Semiconductor LM9617, LM9637 and LM9838. On the other hand, Kodak KAC-0311, Micron MI-MV13 (1.3 Mpixels at 500fps), Dalsa IA-G1-VGA (1300 fps at VGA resolution) and FillFactory IBIS5 are examples of high performance CCDs.

3.2.2. NIR

Silicon is not sensitive to IR light. In order to image infrared scenes other sensitive materials are required.

3.2.2.1 Hybrid arrays

Hybrid arrays use chemical compounds or alloys, like HgCdTe, InSb, QWIP, and InGaAs [3]. These materials form detectors that implement the photon-to-electron

conversion. An independent integrated circuit is needed to read the output of the detector. To create an imaging system, lots of detectors are joined in an array called Focal Plane Array (FPA), and electrically connected to a Read-Out Integrated Circuit (ROIC). These circuits are very expensive and usually need cryogenic cooling. The fill factor is always 100% because the read-out transistors are placed below the detector array. Indigo Systems, Rockwell and Sensors Unlimited (USA), and Sofradir (France) are the main manufacturers of FPAs.
Indigo Systems offers the ISC9803 device, which presents a 640x512 pixels format with a dynamic range higher than 72dB and date rates of up to 107 fps. The detector array can be made with InSb, QWIP, InGaAs and MCT, depending on the spectral range.
Rockwell offers a range of ROICs from 640x480 pixels (TCM6600) to 2048x2048 (HAWAII2). These ROICs are hybridized with a HgCdTe detector array that is sensitive from 0.85 to 2.5µm.
Sensors Unlimited produces hybrid FPAs consisting of an InGaAs photodiode array operable in the 0.9 to 1.7 µm spectrum at room temperature. Their biggest available array is the SU320-1.7T1 (320 x 240 pixel).
Sofradir has designed a 320x256 ROIC with a HgCdTe FPA sensitive in the 1-2.5µm range. It can be operated at temperatures of 200K or above using thermoelectric coolers instead of cryogenic systems.

3.2.2.2 EBCCD

Electron-Bombarded CCD is a technique that improves the sensitive and spectral range of a CCD sensor. In this device the photons are detected by a photocathode placed in front of the sensor that generates electrons. The released electrons are accelerated across a gap and impact on the back of a back-thinned CCD. These energetic electrons generate multiple charges in the CCD resulting in a modest gain of a few hundred.
Intevac manufactures low light level EB imagers with a variety of high performance photocathodes. Depending upon the product application the EB imagers can be made with GaAsP (300 to 700 nm), GaAs (400 to 900 nm) or InGaAs/InP (950 to 1650 nm) photocathodes. A patented technology from *Intevac* allows NIR response (950 to 1650 nm) with thermally stable quantum efficiencies of greater than 20%. The same company also incorporates this technology in a Complementary Metal-Oxide-Semiconductor (CMOS) imager instead of a CCD chip [4]. This Electron Bombarded Active Pixel Sensor (EBAPS™) imager can be combined with different photocathodes to provide low light imaging capability.

4. DESCRIPTION OF THE SYSTEM

4.1. Block diagrams

The SmartSpectra system is divided into two main blocks, one sensitive in the VIS part of the spectrum and the other sensitive in the NIR region. The structure of the two blocks is very similar, with the only difference being the wavelengths they are sensitive to. When the light comes into the system, a beam splitter divides the light into two beams. One beam contains the VIS light and the other contains the NIR light. Each block of the system processes one beam.
Each block of the SmartSpectra system is similar to a monochrome camera with a bandpass filter in front of the sensor. The filter is electronically tunable in terms of frequency and bandwidth.
Figure 2 shows the block diagram of the first prototype of the system, which is sensitive in the range 400-1000nm. The final system will duplicate part of these blocks.
The optics transfers the object scene onto the sensor through the filter. The Acousto-Optic Tunable Filter (AOTF) selects a specific wavelength of light when an RF signal is applied to it. The frequency, power, and spectral distribution of the RF signal define the amplitude and bandwidth of the output light [5].

4.2. VIS sensor board

For the VIS sensor element of the system we will use a high performance CMOS sensor: the IBIS5 from Fill-Factory. The IBIS5 is a 1.3 megapixel imager with synchronous shutter and rolling shutter, on-chip 10 bits ADC and on-chip readout sequencer. It can achieve 30 fps at full resolution and up to 130 fps at VGA resolution.
Instead of the on-chip ADC we will use an Analog Front End (AFE) with 12-bit resolution and improved performance (AD9821 from Analog Devices Inc.). The sensor board also includes the circuitry needed to interface the sensor. This way the rest of the system is independent of the sensor and can work with different sensors. The inputs to this board are the clock signal to synchronize the sensor and the AFE and a control bus. The output of the board is a parallel bus containing the digital output of the AFE.

4.3. NIR sensor board

In the first prototype we will not include a NIR sensor. For later prototypes and the final system, we are evaluating the EBAPS sensor from Intevac. The NIR sensor will also fit in a board with all its interface circuitry.

4.4. AOTF driver board

The driver board generates an RF signal with the frequency, power and spectral shape required for the AOTF to filter the specified wavelength. With a pure sinusoidal RF signal the AOTF filters a single wavelength with a very narrow bandwidth (3-5nm). With a broadband noise signal the bandwidth of the filtered wavelength can be widened up to 50nm.

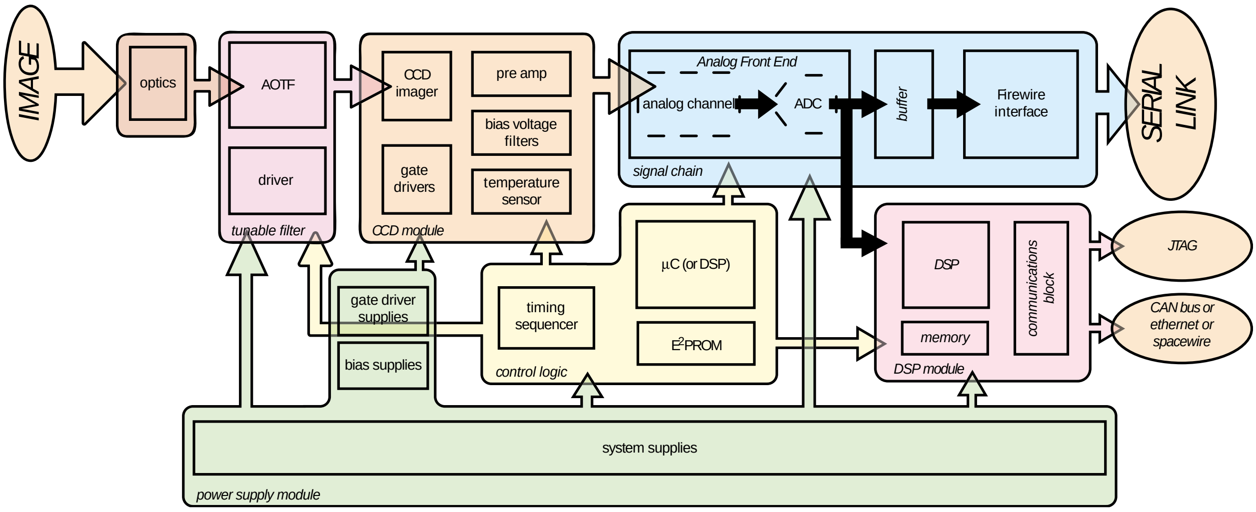

Figure 2: *Block diagram of the first prototype of the SmartSpectra camera*

The driver board will generate RF signals in the range from 100MHz to 200MHz with a bandwidth-selectable noise spectrum. The output signal has a maximum power of 2W (50Ω).
Due to the high output power in the RF range, this board is very prone to radiating noise that can affect other boards within the system. This is especially dangerous for the sensor board, which processes very weak analogue signals. Careful shielding and grounding of this board will avoid these harmful effects.

4.5. Control board

The control board manages the whole system. This board is isolated from the sensor and from the interface with the host. This means that the control is independent of either the sensor or the interface used, adding more flexibility to the system.
Apart from managing the sensor and the interface, this board controls the AOTF. The communication between the control board and the driver board is via the I2C bus.
The control board has a double task. First of all, it has to synchronize the output data stream from the sensor with the interface board. Furthermore, the board reads and executes the control commands from the host. These commands include the configuration of the sensor (exposure time, gain, fps, etc.) and the AOTF (central frequency, bandwidth).

4.6. Interface board

The interface between the system and the host computer will be digital through the IEEE 1394 bus (also known as Firewire). This is a serial bus with a transmission rate of 400 Mbps. At this rate, our system will be able to transmit more than 160 fps (nearly 30 images per second, with each image composed of 6 different wavelength frames). The SmartSpectra camera will follow the D-Cam specification of the Camera Working Group of the 1394 Trade Association. This specification is used in machine vision systems, and defines the streaming formats and control commands for an IEEE-1394 based video camera. The SmartSpectra camera will appear to the host as two standard D-Cam cameras in RGB mode (8 bits/colour) with VGA resolution. Each of the colour bands will represent the information from one selected wavelength of the image. Therefore, any D-Cam host will be able to use the SmartSpectra camera, with the only limitation being a fixed wavelength selection. A function in the host driver of the SmartSpectra camera uses an open feature of the D-Cam specification to transmit to the camera information about the wavelength selection.

4.7. DSP board

This is an additional block that can be skipped in basic camera configurations. It contains a Digital Signal Processor with enough resources to carry out certain processing and turn the camera into an intelligent system.
When the camera works in ‘standard mode’, this block may perform basic operations typically performed with LUT’s and simple pre-processing tasks, such as point operations, correlations, linear filtering (3x3), pixel labelling, area counting, blob counting, etc.
When in ‘smart mode’ (stand-alone) this block may carry out higher-level tasks such as image enhancement, feature selection, basic pattern recognition, scene analysis, compression, motion compensation, etc. This block may carry out high-level tasks that permit the camera to work without any PC or human supervision. It will include

one or several industrial bus connections: CAN or Ethernet.
The *SmartSpectra* project does not include the development of preprocessing or high-level algorithms for the DSP board. The idea is to provide computing resources in order to make it possible to carry out these tasks. These will be developed by future customers or by the company distributing the camera specifically for certain applications. SmartSpectra's purpose is to provide a simple means to access this hardware in a virtually transparent mode.
This video processing block is conceived as an additional mezzanine board including a fixed-point Blackfin DSP (from ADI), memory banks, and minimum hardware.
This block will include a RTOS in order to manage basic resources and simplify final user programming and downloading tasks, while assuring camera performance.

5. HOST SOFTWARE

There are three main software blocks in the host computer. The first is the driver that controls the camera and manages data acquisition. The second is the toolkit that provides the hyperspectral possibilities of the system to the user. Last of all is the User Utility software.
Let us describe all of them in detail.

5.1. Driver for sensor control and acquisition

The driver for sensor control and acquisition must provide an API that will be used in the Windows environment by high level software. The tool we will use to develop the driver is Microsoft's Driver Development Kit (DDK) that is included in the MSDN subscription download from this manufacturer.
The driver for sensor control of the SmartSpectra camera is a set of low level functions that allows the toolkit in the host computer to communicate with the sensor configuration port and set up all its functionalities.
The driver of the camera is divided in two parts:

- The part of the driver dedicated to set the parameters of acquisition.
- The part of the driver dedicated to acquire the images.

Due to the selection of the IEEE 1394 (Firewire) as the transmitting medium to access the sensor, we are developing an interface between the toolkit application and the Firewire standard.
The driver for the sensor must have the ability to be used with PC commercial cards that comply with the IEEE 1394 specification.
The SmartSpectra camera driver for sensor control and acquisition will adhere to the 1394-based Digital Camera specification (D-Cam specification) suggested by the Camera Working Group of the 1394 Trade Association [6]. The purpose of this is to guarantee interoperability for this class of devices. The driver will make use of the two data-transfer modes defined by the IEEE 1394:

- Isochronous mode will be used to transmit the acquired image with a guaranteed bandwidth.
- Asynchronous mode will be used in the control and adjustment of the acquisition in both directions.

The D-Cam specification defines a set of registers, fields within those registers, video formats, modes of operation, and controls for each one.
The driver for sensor control will make the interface between the host computer running the toolkit and a SmartSpectra camera simulating a digital camera device. Due to the amount of bands the SmartSpectra camera is allowed to send to the host (a maximum of 6 bands), it will simulate 2 colour cameras in a logical sense. Both cameras will share the same control parameter values, although the values of wavelength and bandwidth of each band used by the filters will be different.
All the parameter set in the specification will be implemented but some settings have no real effect on the acquisition of data.
The SmartSpectra software will be developed to run under the most recent Microsoft Operating Systems. Microsoft supplies a set of bus drivers that may be utilized within a driver stack to control the device. This driver stack is implemented according to a set of recommendations referred to as the "Windows Driver Model". The Device Driver will be the main task/function to be provided.

5.2. Toolkit Specifications

The Toolkit is the high level software layer to be used by the system integrators for accessing and programming the sensor for each particular application. The main purpose of this software layer is to provide basic data structures and processing of the multispectral images to extract information useful for applications.
This software is intended to be the basis for any specific program developed for any specific application. It has to provide high level information in the sense of making the sensor and the data provided from the sensor accessible using some high level abstraction concepts to hide the low level structure and specific implementation of sensor functions and control.
The rationale of the approach is that system integrators and developers only need the basic tools to interface the low level layer of the system. Extensive and too specific procedures usually become useless and lack flexibility. Complex toolkits tend to be underused by integrators.
Therefore, the main objective of this is to provide adequate programming tools to achieve the above-mentioned connection of the system with the application integrator, focusing most of the attention to the specific functionalities related with the features of the system.
The main requirements for the toolkit are:

- To allow programming in a common and widely used language for application development in image

analysis and machine vision. In this case, an object oriented approach is adopted.
- To be extendable. The user may easily extend the set of functions and abstract data types from those present in the toolkit to others that the user can develop. The object oriented programming is a suitable paradigm to accomplish this requirement.
- Work on PC-based architectures under the most common OS, at least Windows and Linux.
- Explore the possibility of working with real time operating systems, in order to assess the possibility to use the toolkit in real time applications, with real time versions of Windows 2000 and RT-Linux.

Apart from tools for sensor configuration, acquisition, storage and basic functionality, the toolkit will provide specific tools for:
- Filtering and segmentation techniques for multispectral images using several bands.
- Statistical analysis of multispectral data, automatic band selection using feature selection techniques and dimensionality reduction of data representation.
- Invariance image representation of multispectral data. Other multispectral image representation for application purposes.

The toolkit also includes the possibility of interfacing to well-known commercial software for multispectral images like ENVI or IDL programming, in order to simplify access to system developers and integrators to higher level and more specific toolkits.

5.3. User Utility software

The User Utility Software (UUS) is a software application that provides potential users with an insight into the technical features of the SmartSpectra camera in an easy and effective way.

This software application will use graphical components to display all the information extracted from acquired images (using the SmartSpectra camera), stored images (using the most known graphic file formats) or the result of processing images using generic algorithms.

Users will be able to test the capabilities of the system in a generic way before developing their own applications or buying more specific libraries and tools.

Therefore, the tasks of supplying the UUS must include features that allow:
- Inquiries to find the number of SmartSpectra cameras present on the IEEE 1394 bus and select one of them for use.
- Display and configuration of the SmartSpectra sensor configuration.
- Set frame rate acquisition and acquisition format.
- Display of acquired, stored or grabbed images. These images will be the result of a single band acquisition or a three band acquisition. This feature will be able to use the most common non-compressed graphical formats to store the results and load images; this capability can be achieved by the used of graphical format converters.
- Allow the display of the result of applying generic digital processing algorithms provided by the toolkit..

The SmartSpectra UUS will have to be able to run in any Windows environment from Windows XP on and Linux. The capabilities of the SmartSpectra UUS do not require real time processing characteristics. The feasibility of these features are based on real time operating systems and, in general, they are a more specific approach to a non-generic solution.

6. APPLICATIONS OF SMARTSPECTRA

Although potential applications of the SmartSpectra camera are numerous, three examples have been identified in order to show the usefulness of the system and make clear its use. They have been chosen considering three features:
- Relevance (industrial/scientific impact)
- Broad coverage of conditions (high/low speed, controlled/natural lighting)
- Solid background of the researchers in the application.

More applications may be considered if qualified third parties are interested in applying the SmartSpectra platform to their areas of interest.

The applications being explored are:

6.1. Fruit Quality Assessment

Most of the processes involved in fruit quality assessment involve visual inspection. Extensive research work in fruit quality assessment has been carried out using spectral information, either in the VIS or NIR spectrum. NIR energy is absorbed by certain chemical groups and not by others, allowing for detection and quantification of certain substances, like chlorophyll, soluble solids, and proteins. Presence and quantity of many of these compounds determine the fruit quality parameters.

Therefore, NIR analysis is a non-invasive and fast way to measure fruit quality [7]. Two key parameters for the ripeness of a fruit are the total soluble solids and the skin chlorophyll, and both are measurable using NIR spectrometry. UV spectrum is also used to detect and measure substances related to some fruit diseases, like fungus infections and bruises.

The aim of this application software is to develop processes and techniques to detect and quantify a given set of fruit quality parameters using multispectral images.

We can distinguish two types of fruit quality parameters:
- External parameters, mostly related to fruit appearance (colour, shape, etc) and different types of defects on the fruit surface, mainly due to some pathological (fungus, insects, insect bites, etc) or physical effects

(scratches, injuries, blemishes, depositions of insects).

- Internal parameters, related to chemical contents of the fruit pulp, like sugar or acid content, internal blemishes or other physical properties, like number and size of the seeds and peel thickness.

6.2. Outdoor Vegetation Assessment for Rural Monitoring

Although the primary requirement for agriculture is the production of food, the public now expects it to be carried out in a way that is sustainable both in terms of production and its effects on the environment. This requires efficient and effective production practices coupled with a need to monitor the effects of agriculture on the environment. The concept of "precision agriculture" has been developed in which sensing and control systems are used to apply chemicals only where needed. This has been taken further in the concept of "plant scale husbandry" [8] where detailed machine vision sensing is done from a moving platform for on-line treatment. It may also be possible to use some of these techniques to manage the natural environment, for example to assess bio-diversity or to control noxious weeds.

This application example seeks to assess how multiband imaging and subsequent analysis could be used in the applications of rural monitoring mentioned above. The main objectives are: i) to select a sensing situation (e.g. type of crop, weed etc) that will set a challenging problem to the multiband system in terms of differentiation between components in the images and making measurements on them; ii) to determine a methodology of selecting appropriate wave bands; iii) to analyse images, making use of their multiband properties, to differentiate components; iv) to develop techniques that are tolerant to conditions that apply especially to this application, i.e. those caused by natural illumination.

6.3. Coastal Water Monitoring

The main target of this application is to demonstrate the capabilities of the developed multispectral sensor in remote sensing applications, i.e. with non controlled conditions (especially lighting). The selected application is coastal water monitoring.

Water quality is an important indicator of the health of an environmental system. Traditionally, water quality analysis has involved direct sampling in selected areas. This method is difficult, if not impractical, for large areas or when data needs to be frequently taken. Remote sensing offers the possibility of covering a large spatial area with a high temporal frequency. It also provides a spatial distribution of the constituents that cannot be accomplished with direct sampling at a sensible cost. Spatial distributions provide deeper insight into many of the hydrologic and biological processes that are directly affected by the concentrations of water constituent

Some water quality constituents of interest that are detectable via remote sensing are the water itself, chlorophyll, total suspended solids, and colored dissolved organic matter. Total suspended solids consist of suspended minerals and other inorganic matter [9].

7. CONCLUSIONS

The SmartSpectra project proposes a new concept for multispectral imaging. It is a hybrid of common colour cameras (R, G and B bands) and spectrometers (very narrow bands). Bandwidths and center frequencies for each band are configurable from snapshot to snapshot. Stress is placed on robustness, flexibility, and affordable cost in order to make it accessible to final users. A software platform is built to simplify the use of this camera. Its application to three very different and relevant areas will be analyzed and developed.

We have developed (at conference time) the hardware for the first prototype covering a restricted range from 400 to 1000nm so we are able to debug the software for the host platform. A second prototype with no practical cost restriction and full range coverage will be available by December 2004. Some third parties have been identified in order to provide images for or access to the platform in 2004. Developers of applications of multispectral imagery eager to access the SmartSpectra system are welcome.

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