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SPECTRAL IMAGING II

Half-day meeting: 13:15 am, 30th July, 2003
The Institute of Physics
76 Portland Place, London, W1B 1NT

Programme and Abstracts

Chair: Dr Andy Harvey
Heriot Watt University

13:15 Welcome

13:20 A new approach to anomaly detection in hyperspectral images
P Clare[a], M Bernhardt[b], W Oxford[a], S Murphy[a], P Godfreea and V Wilkinson[a]
[a]*Defence Science and Technology Laboratory*
[b]*Quantinuity Ltd*

13:40 Flight Experience of the Compact High Resolution Imaging Spectrometer (CHRIS)
M Cutter
Sira Electro-Optics Ltd

14:00 Biomedical and general applications of the SpectraCube® technology
M R Köhler
Applied Spectral Imaging GmbH, Germany

14:20 A Clinical Hyperspectral Fundus Imager
L J Otten, P Soliz, P Truitt, and P Fournier
Kestrel Corporation, Albuquerque NM, USA

14:40 Human Eye Fluorescence as an Optical Early Diagnostic for Diabetes Mellitus
BH Timmerman, C Beck, S Georgiannis and P J Bryanston-Cross
University of Warwick

15:00-15:30 TEA

Chair: Dr Mike Cutter
Sira Electro-optics Ltd

15:30 Application of spectral imaging to NRT (Novel Reclamation Techniques)
J Nothard and J Hargreaves
QinetiQ Farnborough

15:50 Species-Selective Imaging in Industrial Process Tomography
K B Ozanyan, F Hindle, S Carey, N R J Poolton, T L Yeo, C Garcia-Stewart, P Wright, and H McCann
Department of Electrical Engineering and Electronics, UMIST

16:10 Snapshot spectral imaging in two dimensions
D W Fletcher-Holmes and A R Harvey
Heriot Watt University

16:30 Pump-enhanced, continuous wave optical parametric oscillators: a broadly tunable, single frequency high power optical source for spectroscopic imaging
D J M. Stothard, C F Rae & M H Dunn.
University of St Andrews

16:50 Fourier-transform spectral imaging using a birefringent interferometer
D W Fletcher-Holmes and A R Harvey
Heriot Watt University

17:10 CLOSE

It is not necessary to register for the meeting

Lunch may be obtained from various outlets along Great Portland Street or *Royal Institute of British Architects*

Abstracts for this meeting will be available at
http://www.ece.eps.hw.ac.uk/~arharvey/IoP/SpectralImaging03 or
http://groups.iop.org/OP/programme.html

ORGANISER:

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SPECTRAL IMAGING II
ABSTRACTS

A NEW APPROACH TO ANOMALY DETECTION IN HYPERSPECTRAL IMAGES

P Clare[a], M Bernhardt[b], W Oxford[a*], S Murphy[a], P Godfreea, V Wilkinson[a]
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Anomaly detection is a powerful approach for detecting objects of interest because it does not require atmospheric compensation or signature libraries. Most existing methods require a parametric model of the background probability distribution to be estimated from the data. Most work has made use of the multivariate normal distribution. Also, the parameters must be estimated sufficiently accurately which can be problematic in high dimensional data. We present an alternative view starting from a minimal set of assumptions. We only require the background pixels to be samples from an independent and identically distributed process, but do not require the construction of a model for this distribution. The effectiveness of the algorithms is compared with a well-known algorithm from the literature on real data sets.

FLIGHT EXPERIENCE OF THE COMPACT HIGH RESOLUTION IMAGING SPECTROMETER (CHRIS)

M Cutter
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Tel:+44 0208 468 1785, Fax:+44 0208 468 1717, E-mail: Mike.Cutter@siraeo.co.uk
This paper will describe a Compact High Resolution Imaging Spectrometer (CHRIS) that has been developed at Sira Electro-Optics Ltd. The imaging spectrometer is flying on a small ESA agile satellite, which was launch in October 2001.
The spectral range covered is 400nm to 1050nm. The spatial sampling interval at apogee is approximately 17m. In this mode it is possible to readout 19 spectral bands. The location and width of the spectral bands are programmable. Selectable on-chip integration can increase the number of bands to 63 for a spatial sampling interval of 34m. The swath width imaged is 13km at perigee.

BIOMEDICAL AND GENERAL APPLICATIONS OF THE SPECTRACUBE® TECHNOLOGY

M R Köhler
Applied Spectral Imaging GmbH, Technologiezentrum (TGZ), Weinheimer Straße 62, D-68309 Mannheim
Tel.: +49-(0)6203-923800 Fax: +49-(0)6203-923826, Email: Michael.Koehler@spectral-imaging.com
The basic principle of the SpectraCube® technology is the use of interference spectroscopy in combination with CCD imaging for simultaneously detecting the spectrum for each point of an image. The acquired spectral data about light's unique qualities can then be used to distinguish between different materials even if they look identical to the eye (i.e. by unmixing a complex image to its unique spectral components). By this means it is possible to simultaneously display morphologic information of a specimen together with it's spectral characteristics thus obtaining hitherto unknown insights into the molecular composition and/or metabolic state of the sample.
The ability of the award-winning SpectraCube® to measure fluorescence, absorption, and reflectance spectra allows for various applications in Biomedicine such as cytogenetics (Spectral Karyotyping, SKY™), pathology (SpectraView),

cell biology, ophthalmology, neuro surgery, photodynamic therapy, bacteriology, and others. It also opens ways into non-biomedical areas like remote-sensing, forensic applications, art restoration, mineralogy, etc.

A CLINICAL HYPERSPECTRAL FUNDUS IMAGER

L J Otten, P Soliz, P Truitt, and P Fournier
Kestrel Corporation, Albuquerque NM, USA
e-mail ljotten@kestrelcorp.com
Hyperspectral imaging has become a routine remote sensing tool for many environmental and military applications. Recently these same technologies have started to be introduced into the biomedical fields. One of the more promising biomedical uses in non invasive imaging of the retina where hyperspectral imaging, in which the spectral properties of each spatially resolved point in the image or scene are measured, can enable the study of individual spectral characteristics of retinal tissues. This paper will discuss a 87 cm^{-1} spectral resolution, 28 micron spatial resolution, 27 degree field of view hyperspectral retinal imager based on a common path Fourier Transform technique. The presentation will include a discussion on the optical design and its adaptation to a commercial fundus imager, characterization results, and samples of hyperspectral images of the human retina.

HUMAN EYE FLUORESCENCE AS AN OPTICAL EARLY DIAGNOSTIC FOR DIABETES MELLITUS

B H Timmerman, C Beck, S Georgiannis, P J Bryanston-Cross
Optical Engineering Laboratory, University of Warwick, Coventry CV4 7AL
The effect of diabetes on human eyes has been investigated as part of a DTI Smart Award. In the case of diabetes, there is an accelerated build-up of Advanced Glycation End (AGE) products in the eye lens, compared to the AGE accumulation in healthy eye lenses, which occurs with increasing age. The AGE products are observed as a green fluorescence when illuminated by blue lght. Investigations are presented into the properties and distribution of the fluorescence in healthy versus diabetic eye lenses. Understanding the processes that are involved potentially allows the development of a technique for early diagnostics of diabetes.

APPLICATION OF SPECTRAL IMAGING TO NRT (NOVEL RECLAMATION TECHNIQUES)

J Nothard and J Hargreaves
QinetiQ, Farnborough
QinetiQ have extensive experience in the definition, use, processing and analysis of hyperspectral equipment and data, principally in the military environment. This expertise has been applied to the problem of identifying in real time the types of material which would travel on a conveyor belt prior to being sorted for recycling. The study has addressed the problems of operating parameters, instrument requirements, data requirements, and integration of the sub-system into a complete working package.
The presentation will outline the problems and challenges associated with the project.

SPECIES-SELECTIVE IMAGING IN INDUSTRIAL PROCESS TOMOGRAPHY

K B Ozanyan , F Hindle, S Carey, N R J Poolton, T L Yeo, C Garcia-Stewart, P Wright, and H McCann
The Maurice Beck Laboratory for Industrial Process Tomography, Department of Electrical Engineering and Electronics, UMIST, P.O.Box 88, Manchester M60 1QD, UK
This contribution reviews the achievements of the UMIST group in the research and development of portable all-optoelectronic instrumentation systems for tomographic imaging of chemical species in industrial plant. Images are generated from a multiple projection set of spectrally selective optical measurement data, using tomographic reconstruction algorithms or direct concentration mapping.
A Near-IR Absorption Tomography (NIRAT) system has been demonstrated for applications demanding fast frame rates, e.g. in-cylinder fuel imaging in internal combustion engines. Utilising the 1.7?m overtone of the optical resonance of the C-H bond, imaging temporal resolution of the order of 1K frames/s has been achieved, at temperature up to 180°C and pressure varying from 1 to 10 bar.

Selective imaging of longer-chain hydrocarbon constituents of fuel is possible by Optical Fluorescence Auto-Projection Tomography (OFAPT), implemented with a fibre-based fluorescence probe, powered by a 404nm commercial laser diode. An important variant of this work has been pursued in the area of compact fluorimeter systems. Determination of gasoline provenance and lubricant oil ageing has been demonstrated by analyses of spectral data acquired by the probe in the range 400-700nm.

SNAPSHOT SPECTRAL IMAGING IN TWO DIMENSIONS

D W Fletcher-Holmes, A R Harvey*
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Nearly all spectral imagers proposed to date tackle the fundamental problem of assembling a 3D spectral data cube from 2D images by recording data time sequentially. The third dimension is obtained either by spatial scanning of a one-dimensional spectral image or by wavelength scanning a two-dimensional image (or path-length scanning for a Fourier-transform instrument.) These techniques are not well suited to recording spectral images where there is irregular motion between the scene and the imager (such as for spectral imaging of the ground from an airborne platform, of for imaging of a retina) or of transient phenomena (such as combustion or biological phenomena).
We will report two new types of spectral imager, which enable record 3D spectral data cubes to be recorded in a snapshot. The first is based on a generalisation of the traditional Lyot filter in which birefringent interferometry combined with polarising beam splitters enables multiple spectral images to be recorded simultaneously on a single detector with '100%' optical efficiency. This technique is suitable for modest spectral resolutions and field of view. The second technique implements a hyperspectral fovea embedded within a panchromatic periphery. As in the evolution of a fovea in the human visual system, this technique addresses the fundamental problem of the data throughput bottlenecks of the imaging detector and the information processing system.

PUMP-ENHANCED, CONTINUOUS WAVE OPTICAL PARAMETRIC OSCILLATORS: A BROADLY TUNABLE, SINGLE FREQUENCY HIGH POWER OPTICAL SOURCE FOR SPECTROSCOPIC IMAGING.

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**Tel 01334 463103, Fax: 01334 467313, e-mail djms1@st-and.ac.uk*
We describe the operation of a continuous wave, high power all solid state optical parametric oscillator based upon both periodically poled $LiNbO_3$ (PPLN) and $RbTiOAsO_4$ (PPRTA), using a pump-enhanced configuration. Tuning was achieved, on a single mode, between 3.15 and 3.70?m at power levels exceeding 150mW. The tunable, single frequency, high power nature of the device output in the mid-infrared spectral region makes this system particularly suited to spectroscopic imaging applications. With the use of a simple polygonal imaging system, we have demonstrated spectroscopic imaging of methane at 3.27?m (3057.7cm^{-1}) at concentration depths as low as 50ppm.m^{-1}. We anticipate image processing techniques will improve minimum detectability limits.

FOURIER-TRANSFORM SPECTRAL IMAGING USING A BIREFRINGENT INTERFEROMETER

D W Fletcher-Holmes, A R Harvey*
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Fourier transform imaging spectrometers can offer important advantages over other hyperspectral imaging techniques, including high spectral resolution, high optical throughput and a wide spectral range. Unfortunately, the inherent vibration sensitivity and precision mechanics required in the conventional traditional scanning-mirror FT spectrometer has tended to restrict their application to the controlled environment of the research laboratory.
We describe a new type of FT imaging spectrometer, employing a scanning birefringent interferometer. This technique retains the accepted advantages of traditional FT devices, but because it employs common-path interferometry and because path differences are introduced within solid optical elements, the system is inherently very robust. Furthermore, the required precision of the scanning mechanism can be typically two orders of magnitude lower than for

a traditional interferometer, resulting in a much simpler, lower cost instrument. This opens the possibility of employing Fourier transform imaging spectrometers in harsh environments for the first time.