whispers

6th   Workshop on Hyperstectral Image and Signal Processing :
        Evolution in Remote Sensing

24-27 June 2014, Lausanne, Switzerland

www.ieee-whispers.com

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2014
Lausanne, Switzerland

1. Foreword

It is with great pleasure that we welcome you to Switzerland for this 6th edition of WHISPERS. Lausanne, city of Olympics, and the Ecole Polytechnique Fédérale de Lausanne are proud of hosting this workshop.

This year, we have received the highest number of paper submissions in the history of WHISPERS, with 205 papers submitted from every corner of the planet (well, except maybe Antarctica). We wish to thank Jocelyn Chanussot and Sebastian Lopez, the program chairs, for the incredible work done to gather all the reviews and to assemble an excellent technical program. We also would like to warmly thank all the reviewers, who dedicated their efforts and time to help improve contributions to WHISPERS!

Following the tradition at WHISPERS, we offer a wide technical program of interest to a large community: WHISPERS will begin with four tutorials on contemporary and rapidly evolving topics relevant to the hyperspectral community (radiative transfer models, kernel methods, image processing and high performance computing). We would like to particularly thank the workshop tutors for their support: J. Verrelst, J. Moreno, G. Camps-Valls, A. Plaza, M. Fauvel and M. Dalla Mura.
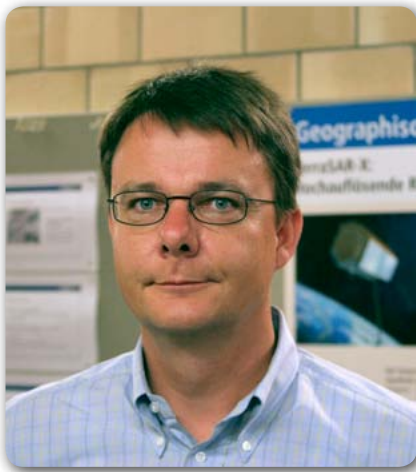
The tutorials will be followed by three days of technical sessions, which constitute the main body of the conference. Hydrology, fluorescence, planetary sciences and UAV: all these emerging topics join the more traditional technical sessions on unmixing, classification and modelling to provide a full experience for hyperspectral scientists and practitioners. Our gratitude also goes to the organizers of the special sessions: J. Theiler, A. Schaum, S. Amici, A. Lucieer, D. Odermatt, A. Wuest, H. Clenet, F. Tosi, M. Parente, R. Heylen, S. Delalieux, D. Messenger, D. Gillis, J. Mercier, R. Sundberg, J. Verrelst and J. Moreno. They have helped us expand the horizon of the workshop to new areas and have ensured the presence of key scientists in their respective areas.

And what would be hyperspectral imaging without an industrial component? This year we have a record number of sponsors, demonstrating a strong link between sensors, data providers and the scientific community. Do not forget to visit the expositors stands!

In between sessions and discussions, we hope you will find the time to enjoy the beauty of the city of Lausanne and everything it has to offer. We hope you will enjoy it as much as we do.

Welcome again to Lausanne and we wish you a rich and inspiring WHISPERS 2014!

Devis Tuia and Michael Schaepman

EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE
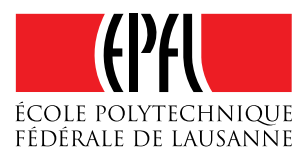
On behalf of the IEEE Geoscience and Remote Sensing Society, I am delighted to welcome you to WHISPERS 2014, the 6th Workshop on Hyperspectral Image and Spectral Processing: Evolution in Remote Sensing. WHISPERS has developed into a premier international workshop for our community, both because of the quality of the research in hyperspectral focused algorithms, and the bridge between analysis and broad based applications in spectroscopy. As President of the GRSS for 2014, I want to express our appreciation to the General Co-Chairs, Devis Tuia (EPFL) and Michael Schaepman (U of Zurich), for hosting WHISPERS 2014 in Lausanne, and to program co-chairs Sebastian Lopez (Universidad de las Palmas de Gran Canaria) and Jocelyn Chanussot (Grenoble Institute of Technology) and to Frank de Morsier and Francois Golay (EPFL), of the organizing committee, which is critical to the success of the workshop.

Interest in hyperspectral sensing and data analysis continues to grow in the international remote sensing community, as evidenced by both the submissions of papers to conferences and journals, and the increased interest in airborne and space-based hyperspectral sensing for a growing applications community. We anticipate the next generation of spaceborne missions, which will advance the international remote sensing spectral imaging community in many directions, and continue to be excited about opportunities for airborne sensing, including the rapidly growing interest in UAV technology. Parallel advances in spectral technology in food science, biomedical imaging, and environmental applications, to name a few, and methodology for analyzing hyperspectral data will also have a significant impact. These are great times to "think hyperspectral".

All the best from GRSS for a very successful WHISPERS 2014. I look forward to seeing you in Lausanne.

Melba Crawford

President, IEEE GRSS

2. Exhibitors

ReSe
Applications
Schläpfer

ReSe Applications Schläpfer is a small Swiss company focused on remote sensing data processing and imaging spectroscopy software. The company is focused in geometric and atmospheric modeling of radiation in optical remote sensing, as well as the geometric and radiometric preprocessing of optical remote sensing data. A development of ReSe is the PARGE® direct orthorectification software for airborne optical scanner systems. PARGE is used for both airborne imaging spectroscopy systems and for the rectification of UAV data.

For scientific analyses of the radiative transfer in remote sensing, ReSe developed the MODO software for the handling of Modtran® radiative transfer calculations. With this regards, ReSe holds a license for the redistribution of the Modtran®4 and Modtran®5 software components as part of its products.

ReSe successfully advances the development of the original ATCOR® atmospheric correction software packages in collaboration with Dr. R.Richter from DLR. ReSe holds exclusive rights for redistribution of the original implementation of the ATCOR software suite. ATCOR is suitable for standard satellite systems as well as for airborne scanner data. Recently, ReSe developed the BREFCOR BRDF correction module which is now included in ATCOR.

http://www.rese.ch

HySpex

HySpex, NEO's line of hyperspectral cameras, aims to offer compact, high performance and versatile instruments for a multitude of applications, ranging from airborne to laboratory and industrial use of imaging spectroscopy. Norsk Elektro Optikk AS (NEO) was established in 1985 as a privately owned research oriented company within the field of electro optics. NEO has grown to be the largest independent research and development organization in electro optics in Norway, and has in addition established itself as a manufacturer of advanced electro optical products for an international market.

http://www.hyspex.no

Headwall PHOTONICS

Headwall Photonics is the leading designer and manufacturer of hyperspectral imaging spectrometers and spectral instrumentation for remote sensing research, military/defense, and industrial applications and markets. Hyperspec™ imaging spectrometer solutions are available for satellite, airborne, handheld and process control deployment. With exceptional optical efficiency, Headwall's high performance spectrometers and spectral engines have been selected by OEM and end-user customers around the world for use in critical application environments. Headwall designs and manufactures patented aberration-corrected, spectral instrumentation that is customized for application-specific performance. Headwall Photonics was formed in 2003 as the result of a management buy-out from Agilent Technologies.

http://www.HeadwallPhotonics.com

A Company specialized in the sale, distribution and service of Analytical Instrumentation, throughout France, Spain, Portugal and Switzerland. ASD´s exclusive representative.

http://www.bonsaiadvanced.com/

ASD Inc., a PANalytical company, is the global leader in remote sensing and hyperspectral measurement solutions, providing unparalleled ground truthing results. Our rugged, portable FieldSpec® 4 line of spectroradiometers provides the freedom to rapidly collect high-quality spectra in the field. Trusted by top research experts at thousands of universities and research institutions, ASD's full-range spectrometers are used in more than 70 countries. For more information, please visit www.asdi.com.

http://www.asdi.com

 W. Ludolph

W. LUDOLPH founded in 1846 in Bremerhaven, Germany is a high standard manufacturer and approved service station for laboratory apparatus, navigation and scientific instruments. The company features different interrelated business divisions providing expertise in precision mechanics and special engineering. In cooperation with the German Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research AWI we are the manufacturer and distributer of **ManTIS**, a new field spectrogoniometer for ground based characterization of the surface. This is the appropriate tool for your spectro-directional observations and advanced use of hyperspectral sensors.

http://www.ludolph.de

Rikola Ltd.

Rikola Ltd. offers the world's smallest and the most lightweight hyperspectral camera for UAVs. This novel, innovative product is a frame-based spectral system providing true snapshot images for all the wavelength bands at a time. The frame based approach enables an easy image stitching for the mosaics with high resolution images. In addition, the approach doesn't need IMU for its operations, which makes the system low cost and low weight. The Rikola products have been tested with a wide variety of platforms including helicopters and fixed wing UAVs in several application areas like agriculture, forestry and water research. The camera system is very flexible, and it enables handheld use and use with computers in laboratory as well.

http://www.rikola.fi

SPECIM Spectral Imaging Ltd. is the world's leading manufacturer of hyperspectral imaging instruments and systems. In addition to airborne remote sensing systems, SPECIM provides ImSpector Imaging Spectrographs, Spectral Cameras and Hyperspectral Imaging Solutions to an increasing range of demanding industrial and science applications like colour measurement, process analytical technology (PAT), life sciences, chemical imaging and forensics.

http://www.specim.fi

SphereOptics

SphereOptics is a supplier of specialized equipment and services with a technical focus in the following areas of photonics: light measurement, remote sensing and manufacturing of reflectance standards for the remote sensing and vision market. SphereOptics offers a wide product portfolio for the remote sensing market which ranges from field spectrometers, hyperspectal cameras, thermal - FTIR spectrometers to reflectance standards & targets and uniform light sources for calibration of imaging cameras.

Since our formation in 2003, our goal has been to be much more than just a supplier of advanced equipment. Our mission is to SERVE BETTER. We do a few things really well, rather than try to do many things to a lesser standard. We serve our customers with expert advice and services. Our services include certified calibration of reflection standards, rent, lease and calibration of remote sensing spectrometers & cameras. Our sales and application engineers have a strong technical background in remote sensing, geochemistry, agriculture, etc. They are just experts in these fields and help our customers to get the most out of their investments.

http://www.sphereoptics.de

cubert
Real-Time Spectral Imaging

The Cubert GmbH – Real Time Imaging Spectroscopy – Made in Germany

Cubert is the first company in Europe, serving the market with a product that provides a real snapshot spectral imager. The technology was developed using no moving parts which makes it a very robust, high portable, lightweight camera. The imaging rate goes up to 20 hyperspectral cubes per second, which allows the user to create hyperspectral video sequences. As there is a system that provides special and spectral data at the same time, data acquisition in imaging spectroscopy becomes much easier.

In comparison to other imaging spectrometers, the Cubert system does not use a swivel head and a linear displacement unit, therefore it is possible to use the system mounted on very small portable devices without using additional technology, e.g.: gyroscopes.

The technology platform allows a high spectral, spatial and temporal variability, which brings up a variety of new unexplored areas of application. Therefore Cubert offers the possibility to create user adapted systems in addition to the standard products.

http://cubert-gmbh.de

3. Sponsors

sarmap SA, a Swiss company founded in 1998, is active since its establishment in the development of data processing algorithms and operational land applications – including modelling – using spaceborne and airborne Synthetic Aperture Radar (SAR) and, more recently, spaceborne and UAV multi-spectral data. Capacity building are primarily offered to extend the understanding in the processing and use of remote sensing data, but also, to demonstrate the technical advantages and economical benefits of this technology. sarmap's core activities are focused on the development of:

- SARscape® and OPTICALscape®, a set of modules, embedded in ENVI®, for the processing of SAR and optical multi-spectral data;

- Digital Elevation Model based on airborne and spaceborne SAR systems, and, more recently, on the synergetic use with stereo-optical data;

- Land displacements for the measurement of Earth movements up to mm level;

- Dedicated agricultural products targeted to food security, insurance, and precision farming applications at national scale;

- Countrywide customized forest products primarily dedicated to certification and management purposes.

http://www.sarmap.ch

SpecTIR, LLC Remote Sensing Experts

SpecTIR is a small business concern based in Reno, Nev., with offices in Manassas, VA, Easton, MD, and Los Angeles, CA. The company features three interrelated business divisions providing expertise in all aspects of remote sensing, from the design of sensors to the development of imagery and GIS products.

SpecTIR conducts a variety of large-scale geophysical and environmental studies. Projects include oil, gas, and mineral detection and exploration; point source pollution; water quality analysis and submerged aquatic vegetation mapping; forestry inventory and biomass evaluation and fire fuels modeling. With years of experience in remote sensing technology, SpecTIR's innovative professionals perform these studies using airborne hyperspectral imagery to collect, process and interpret data. This technology is based on the unique fingerprint or spectral signatures reflected by objects in the form of waves of energy across the electromagnetic spectrum. Using very sensitive detectors, high-speed computers and large data storage capacities, SpecTIR's professionals analyze this hyperspectral data to identify objects on the earth's terrestrial and water surfaces.

http://www.spectir.com

Raptor Photonics Limited is a global leader and manufacturer of high performance, industrial-grade and extremely rugged ultra low light digital & analogue cameras. Raptor specialises in complete cameras and core engine solutions using CCD, EMCCD, Scientific CMOS and SWIR sensor technology. The extreme low light capability of Raptor's cameras makes them ideal for day/night surveillance, homeland security, hyperspectral imaging and scientific markets. Raptor Photonics Ltd is a registered ISO 9001:2008 company and is headquartered in Larne, Northern Ireland.

http://www.raptorphotonics.com

TEL☉PS

Telops, located in Quebec City, Canada, specializes in the design and production of sophisticated opto-electronic systems for the defence & security, environmental and scientific research markets. Telops advanced optical systems allow the detection and identification of remote substances which are often invisible to the naked eye.

In addition to providing specialized opto-electronic engineering services, Telops has also developed the Hyper-Cam, an infrared hyperspectral imager which allows standoff chemical detection at a distance of up to five kilometers. This advanced instrument enables its user to measure different spectrum and then compare the measured spectrum with the signatures of known gases and solids. The constituents and properties of a target can then be easily identified. As well Telops has developed a high performance line of infrared cameras which includes unique cameras, custom designed for specific applications. This line includes the FAST-IR comprised of two different rapid frame rate infrared cameras, the HD-IR which includes high-definition infrared cameras, the MS-IR which offers unique, multispectral capabilities, the HDR-IR, a high dynamic range camera which allows users to resolve scenes up to 2500°C and finally the TS-IR, a versatile, easy to use infrared camera which comes in an IP67 sealed enclosure making it ideal for use in harsh environments.

Telops also offers R&D services for optical system technology development. Telops experts deliver significant expertise in the fields of opto-electronic systems engineering with full disciplinary specialist in optical, mechanical, electronics, thermal, software and system engineering. Telops works closely with its clients/scientists to develop customized optical solutions in the area of infrared remote sensing, spectrometry, cryogenic and ruggedized optical systems as well as dedicated imaging and calibration systems.

http://www.telops.com

perception park
color the invisible

Perception Park is your partner for high performance data processing of Hyperspectral data. Whether you want to process your data offline with highest efficiency or if you need a hard real time data processing solution, with the generic data processing products of Perception Park you are always perfectly equipped to implement your solutions.

Configurable real-time data processing:

The intuitive configurable real-time data processing unit Perception System is mainly used in rough industrial fields like food processing, recycling, mining as well as pharmaceutical industries. By using Chemical Color Imaging, the Perception System allows that chemical and molecular information become useable for industrial image processing and machine vision. Now, partners of Perception Park are able to provide new, highly innovative machinery to the market.

Critical application environments such as high g-forces or low-energy cases are enabled by the implementation of an FPGA-based Perception System.

First hyperspectral operating environment:

To deploy hyperspectral technology nowadays is tricky and time-consuming. Especially the cooperation of involved experts of different disciplines is limited due to a missing common basis. Therefore Perception Park decided to develop a layer between the operating system and the end application - the first operating environment for hyperspectral technology.

The included plug-in architecture provides a way to add or modify functionality. This results in an expandable and customizable mutual basis for hyperspectral technology. Such concepts are known from web browsers or mobile operating systems (App). The operating environment supports real-time processing as well as the integration of hardware and software by plug-ins. Users can easily add own plugins to do things we never even thought of. An operating environment including a plug-in framework is simple, clean and efficient.

http://www.perception-park.com

Spectral Sciences, Inc. (SSI) is a research and development company dedicated to producing technical solutions from concept to prototype to meet the needs of its customers. SSI develops cutting-edge technologies for its clients, including aerospace industry-standard computer models, simulation and data analysis software, and unique instrument prototypes. SSI scientists have expertise in radiative transfer, physical modeling, and the development of spectral data analysis tools.

- **Software for Remote Sensing, Spectroscopy and Imaging** SSI scientists are authors of widely recognized computer codes for modeling, simulating and processing atmospheric and space electro-optic radiation environments in three dimensions. MOD-TRAN®5 radiative transfer model, FLAASH and QUAC atmospheric correction software (sold together as the ENVI Atmospheric Correction Module), and MCScene and QUID spectral image scene simulation software are all SSI products.

- **Spectral Sensing & Imaging Instrumentation** SSI has developed a rugged, adaptable technology product line for ground-, aircraft-and space-based spectral imaging, control of aero-turbine combustion, and ambient gas and surface monitoring. Additional sensor systems employ optical gas correlation, tunable diode-lasers, and absorption monitoring.

- **Optical Phenomenology in Targets and Backgrounds** SSI scientists are leading experts in modeling optical signatures from aircraft, rockets, and non-equilibrium sources such as rocket plumes, vapor clouds, and chemical releases.

- **Advanced Imaging Techniques** SSI is applying tomographic reconstruction techniques adapted from radiotherapy to non-destructive testing, concealed object detection, and combustion monitoring concepts.

http://spectral.com

ITRES (1979) is an airborne hyperspectral remote sensing imager manufacturer and worldwide mapping survey provider.

Our performance-designed custom hyperspectral imagers are lidar-ready and feature unmatched precision, focus, and resolution. VNIR, SWIR, MWIR, & thermal IR spectral regions covered for infrastructure and environmental applications. Also offered: multiple sensor operation, remote control.

Recent product announcements: Wide-array thermal TABI-1800. Halve survey costs with a mapping swath twice as wide as the closest competitor. Applications include mapping heat loss, effluent, aquatic habitat, search and rescue, and thermal anomaly detection.

IPS (In-Flight Processing System): Rapid response mapping & data turnaround through in-flight geocorrection, mosaicking, target/thermal anomaly detection.

http://www.itres.com

DigitalGlobe is a leading provider of commercial high-resolution earth observation and advanced geospatial solutions that help decision makers better understand our changing planet in order to save lives, resources and time. Sourced from the world's leading constellation, our imagery solutions deliver unmatched coverage and capacity to meet our customers' most demanding mission requirements. Each day customers in defense and intelligence, public safety, civil agencies, map making and analysis, environmental monitoring, oil and gas exploration, infrastructure management, navigation technology, and providers of location-based services depend on DigitalGlobe data, information, technology and expertise to gain actionable insight.

DigitalGlobe is a registered trademark of DigitalGlobe.

http://www.digitalglobe.com

4. TECHNICAL SPONSORS

http://www.ieee.org

http://www.grss-ieee.org

http://www.epfl.ch

http://www.snf.ch

http://space.epfl.ch

http://www.vaud.ch

http://www.lausanne.ch

http://www.gipsa-lab.grenoble-inp.fr

5. COMMITTEES

General Chair
Devis Tuia, EPFL Lausanne, Switzerland
M. Schaepman, University of Zurich, Switzerland

Program Chairs
Jocelyn Chanussot, Grenoble Institute of Technology, France
Sebastian Lopez, Universidad de las Palmas de Gran Canaria, Spain

Organizing Committee
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Frank de Morsier, EPFL Lausanne, Switzerland
François Golay, EPFL Lausanne, Switzerland

Technical Committee
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Jose Bioucas Dias, Technical University of Lisbon, Portugal
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Nasser Nasrabadi, U.S. Army Research Laboratory, USA
Mario Parente, Brown University, USA
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Ils Reusen, VITO, Belgium
John Richards, The Australian National University, Australia
Stanley Rotman, Ben-Gurion University of the Negev, Israel
Alan Schaum, Naval Research Laboratory, Washington, D.C, USA
James Theiler, Los Alamos National Laboratory, USA
Jean-Yves Tourneret, IRIT Laboratory, Toulouse, France
Miguel Velez-Reyes, University of Texas at El Paso, USA
Alina Zare, University of Missouri, USA
Bing Zhang, Center for Earth Observation and Digital Earth, China

Webmaster & Graphic Designer
Vincent Couturier-Doux

6. Conference Information

Arrival to the Conference Venue -- EPFL:

- **By public transportation**
  The easiest way to reach the venue from the city is the Metro M1, leaving from "Flon" (see the metro lines map below). The Swiss Tech Convention convention Center is 50m from the metro stop "EPFL" (see the situation map below). More information on public transportation in Lausanne can be found at www.t-l.ch (download their Smartphones application for an online time table!).
  Hotels usually provide a free transportation card for the length of your stay.

- **By car**
  By car, on the motorway, follow direction "Lausanne-Sud" and then exit "EPFL".
  The parking "Quartier Nord" will be at your disposal on site at the rates that can be found here: http://quartier-nord.epfl.ch/parking.

- **Once there**
  Enter the TSTCC by the main entrance, descend one level to the ground floor and you're there.

Registration desk :

- Location: The Swiss Tech Convention Center, Ground level (see map of the Convention center below).

- Hours: Wednesday – Friday, 7h30 – 18h.

Internet :

- Option 1 (European academics): The network eduroam is available at EPFL. You can use your login as provided by your own university.

- Option 2 : Log-in instructions will be provided on-site.

Speaker Preparation:

- Software: Each lecture hall (Rooms 4 and 5, see map of the Convention center) is equipped with Office and Acrobat reader.

- File types: We accept .ppt, .pptx or .pdf formats.

- Loading your presentation: Please go to the appropriate lecture hall (Room 4 or Room 5) to upload your presentation BEFORE the start of your session. A Whisperer will be there to assist you as needed.

Poster sessions:

- Set-up : Please arrive each day before your session to set-up your poster. Whisperers will be there to assist you.

- Break-down : Please remove your poster at the end of the day, to free the spot for the next day's posters.

- Presentation : speaker should be alongside the poster during the poster session and the coffee breaks .

- Size : max posters size is A0 (841 × 1189 mm).

- The posters sessions will be held in the area in front of the conference room 5 (see map of the convention center)

Social Events:

Tuesday 24, from 19h30: Ice breaker @ Starling hotel.

The ice breaker will take place at the Starling Hotel, the four-stars hotel on EPFL campus (www.shlausanne.ch). Located on the EPFL campus and facing Lake Geneva, the starling hotel is the perfect place for starting WHISPERS in a modern and innovative atmosphere. The ice breaker will take place on the large terrace with a lovely view on the lake.

The participation to the ice breaker is included in the registration cost.

In order to reach the Starling hotel from the city, take the M1 metro line until the EPFL station and then follow the directions in the map below. Whisperers will be along the way to guide you.

Thursday 26, from 18h: Gala dinner @ Olympic museum

The gala dinner will take place a the Olympic Museum of the city of Lausanne (http://www.olympic.org/museum), situated on the shores of Lake of Geneva and surrounded by the Alps. The museum, re-opened in 2014 after two years of renovation, revisits all those memorable and thrilling moments of the Olympic Games through permanent and temporary expositions, a video library and many interactive activities.

The event will start with a visit of the museum, followed by an aperitif and dinner served within the museum.

The participation to the gala dinner is included in the registration cost.

In order to reach the Olympic museum from the conference center, take the metro M1 from the station "EPFL" until the last stop "Lausanne-Flon". From there, take the M2 line direction "Ouchy", until the last stop "Ouchy". Whisperers will be along the way to guide you.
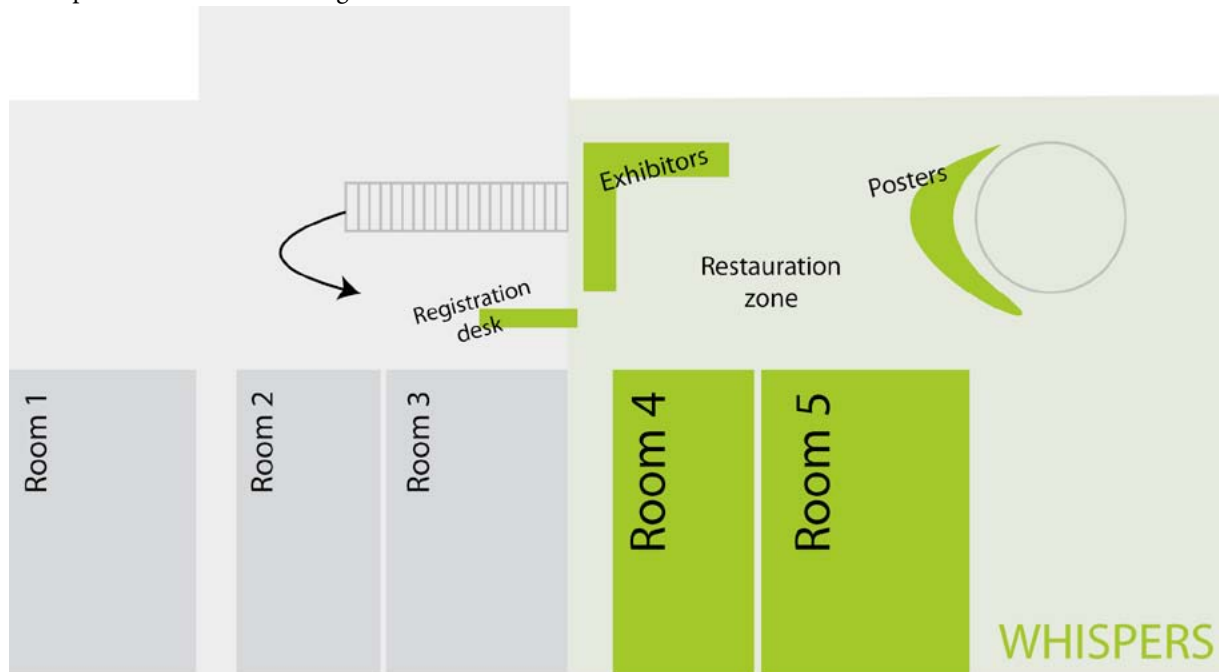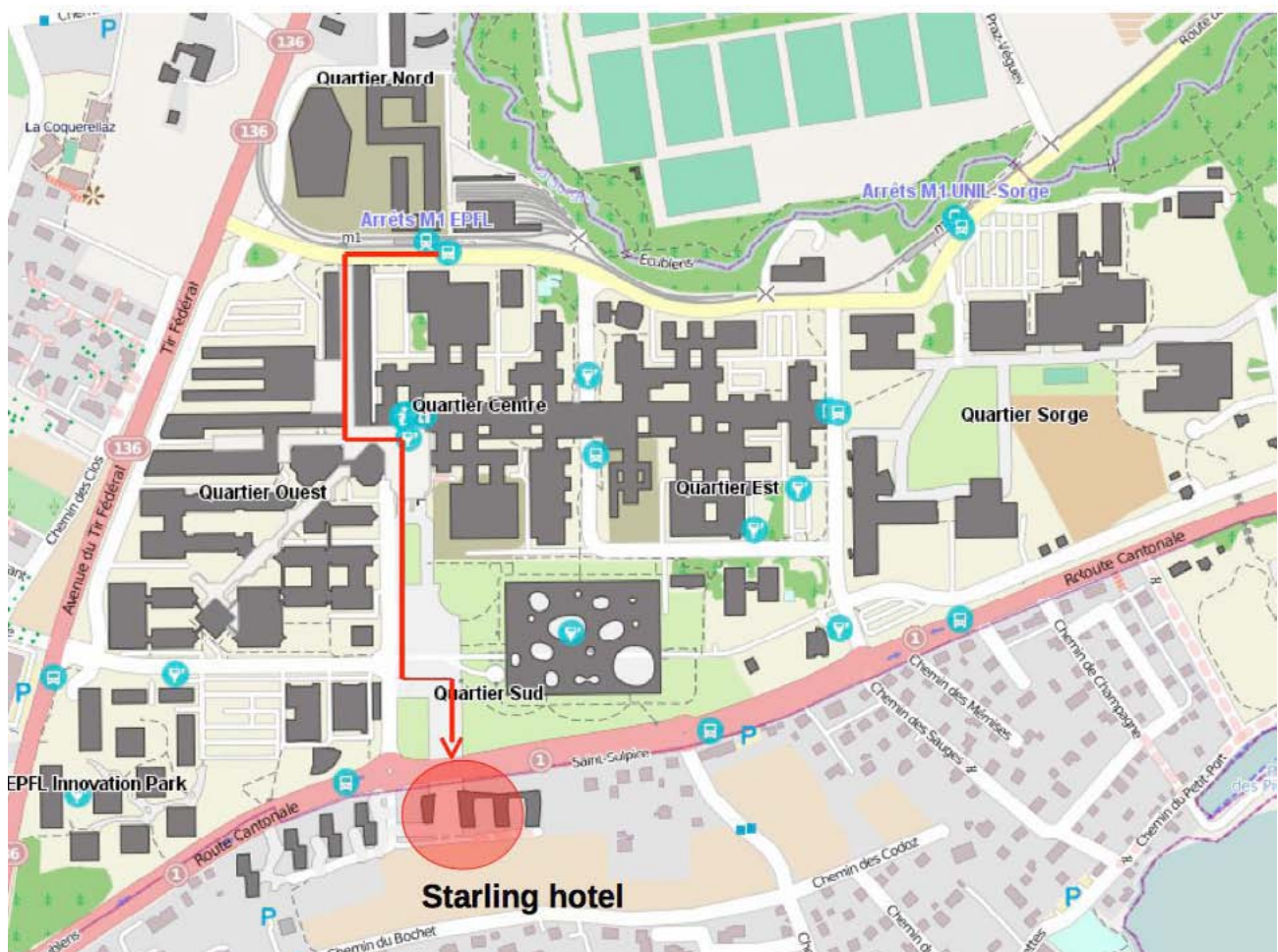
Map of metro network

Situation map of EPFL metro stop
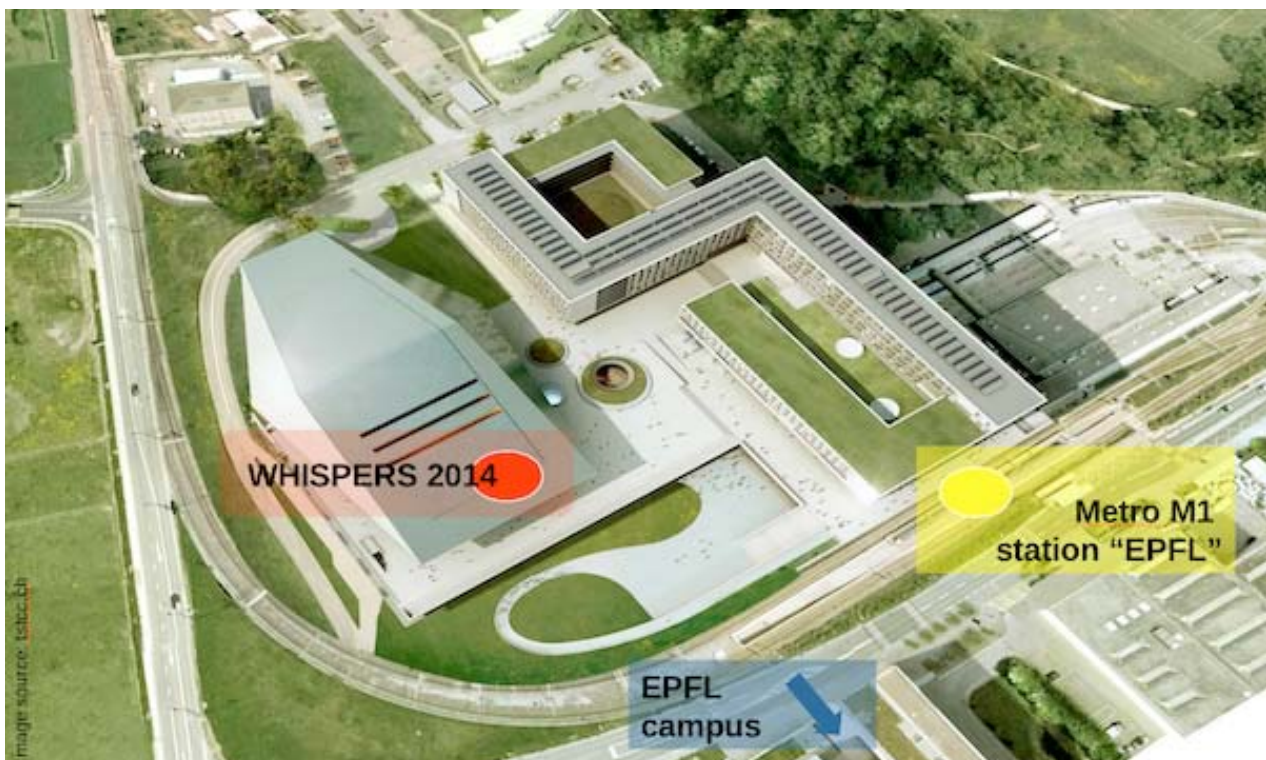
Map of the base floor of the ground level of the Center

Getting to the ice breaker

7. Technical Program

WHISPERS at a glance

Tuesday, 24

Time	
09:00	Tutorial 1 / Tutorial 2
12:30	
13:30	Tutorial 3 / Tutorial 4
17:00	
19:30	Icebreaker Starling Hotel

Wednesday, 25

Time	
8:00	Opening ceremony
8:30	Plenary 1
9:30	wed-p-(a,b & c) Spectral graph and manifold models / Planetary exploration / A diversity of applications
11:00	Posters & coffee break
11:00	Oral sessions — wed-o-1-a Imaging spectroscopy for UAVs / wed-o-1-b Spectral graph and manifold models
12:40	Lunch
14:00	Oral sessions — wed-o-2-a Detecting difficult targets / wed-o-2-b Planetary exploration
15:40	Coffee break
16:10	Oral sessions — wed-o-3-a Spectral unmixing (1) / wed-o-3-b Monitoring of the vegetation
17:50	
19:00	
23:00	

Thursday, 26

Time	
8:00	Plenary 2
9:00	thu-p-(a,b & c) Spectral unmixing / Feat. extraction, band select. and dim. reduction / Sensors, systems, missions
	Posters & coffee break
10:30	Oral sessions — thu-o-1-a Fluorescence data / thu-o-1-b Machine learning
12:10	Lunch
13:20	Oral sessions — thu-o-2-a Hyperspectral pan-sharpening and super-resolution / thu-o-2-b Forward modeling
15:00	Coffee break
15:30	Oral sessions — thu-o-3-a Spectral unmixing (2) / thu-o-3-b NIR/SWIR/THERMIC
17:10	
18:00	Banquet Olympic Museum of Lausanne
23:00	

Friday, 27

Time	
8:00	Plenary 3
9:00	fri-p-(a,b & c) Noise reduction / Classification / Advanced signal and image proc. techniques
	Posters & coffee break
10:30	Oral sessions — fri-o-1-a Spectroradiometric app. for optically complex waters / fri-o-1-b Sparsity in hyperspectral data processing
12:10	Lunch
13:20	Oral sessions — fri-o-2-a Advanced signal and image processing techniques / fri-o-2-b A diversity of applications
15:00	Coffee break
15:30	Oral sessions — fri-o-3-a Spectral unmixing (3) / fri-o-3-b Simulators and models
17:10	

Tuesday, 24, June

w h i s p e r s

09:00	**Tutorial 1** High Performance Computing for real-time hyperspectral image processing and compression Sebastian Lopez, Universidad de las Palmas de Gran Canaria, Spain Prof. Antonio J. Plaza, Department of Technology of Computers and Communications, University of Extremadura, Spain	**Tutorial 2** Image analysis of hyperspectral data using mathematical morphology Mauro Dalla Mura, Gipsa-Lab, France Mathieu Fauvel, INP ENSAT, France
12:30		

13:30	**Tutorial 3** Automating and optimizing vegetation properties mapping: The ARTMO toolbox Jochem Verrelst	**Tutorial 4** Kernel methods for hyperspectral image processing Gustavo Camps-Valls
17:00		

19:30	Icebreaker, Starling Hotel
21:00	

Wednesday, 25, June
Overview

| 8:00 | Opening of the conference |

8:30

Plenary 1
Albedo and Reflectance Anisotropy Products from MODIS, VIIRS, and Landsat
Crystal Schaaf, *University of Massachusetts Boston (MA), USA*
Session chair: Melba Crawford, *Purdue University, USA*

9:30

9:30 Posters / coffee break

Session wed-p-1-a
Analysis of hyperspectral imagery using spectral graph and manifold models
Session chairs :
David Messinger, *RIT, USA*
David Gillis, *Naval Research Laboratory, USA*

Session wed-p-1-b
Planetary exploration
Session chairs :
Harold Clenet, *EPFL, Switzerland*
Rachel Klima, *Johns Hopkins University Applied Physics Laboratory, USA*

Session wed-p-1-c
A diversity of applications
Session chairs :
Laurence Croizé-Guinet, *ONERA, Palaiseau, France*
Caroline Gevaert, *Lund University, Netherlands*

11:00

11:00

Session wed-o-1-a
Imaging spectroscopy for UAVs : innovation of sensors and applications
Session chairs :
Stefania Amici, *INGV, Italy*
Arko Lucieer, *University of Tasmania, Australia*

Session wed-o-1-b
Analysis of hyperspectral imagery using spectral graph and manifold models
Session chairs :
David Messinger, *RIT, USA*
David Gillis, *Naval Research Laboratory, USA*

12:40

12:40 Lunch

14:00

Session wed-o-2-a
Detecting difficult targets in hyperspectral imagery
Session chairs :
James Theiler, *Los Alamos National Laboratory, USA*
Al Schaum, *Naval Research Laboratory, USA*

Session wed-o-2-b
Planetary exploration
Session chairs :
Harold Clenet, *EPFL, Switzerland*
Federico Tosi, *INAF-IAPS, Italy*

15:40

15:40 Coffee

16:10

Session wed-o-3-a
Spectral unmixing (1)
Session chairs :
Mario Parente, *Univ. of Massachusetts, Amherst, USA*
Rob Heylen, *Univ. of Antwerp, Belgium*

Session wed-o-3-b
Monitoring of the vegetation
Session chairs :
Stéphanie Delalieux, *VITO, Belgium*
Frank Liebisch, *Institute of Agricultural Sciences, ETH Zürich*

17:50

Wednesday, 25, June

w h i s p e r s

8:00 Opening of the conference : opening ceremony

8:30

Plenary 1
Albedo and Reflectance Anisotropy Products from MODIS, VIIRS, and Landsat
Crystal Schaaf, *University of Massachusetts Boston (MA), USA*
Session chair: Melba Crawford, *Purdue University, USA*

9:30

9:30
Poster until 11:00

Posters / coffee break : 3 parallel sessions

Session wed-p-a
Analysis of hyperspectral imagery using spectral graph and manifold models
Session chairs :
David Messinger, *RIT, USA*
David Gillis, *Naval Research Laboratory, USA*

DIMENSIONALITY REDUCTION VIA REGRESSION ON HYPERSPECTRAL INFRARED SOUNDING DATA
Valero Laparra, Jesús Malo and Gustavo Camps-Valls

SEMI-SUPERVISED MANIFOLD LEARNING OF TIME-SERIES HYPERSPECTRAL FOREST IMAGES
Kuniaki Uto

MANIFOLD REPRESENTATIONS OF SINGLE AND MULTIPLE MATERIAL CLASSES IN HIGH RESOLUTION HSI
Amanda Ziemann and David Messinger

MODULARITY VERSUS LAPLACIAN EIGENMAPS FOR DIMENSIONALITY REDUCTION AND CLASSIFICATION OF HYPERSPECTRAL IMAGERY
Nathan Cahill, Benjamin Start and Selene Chew

IMPROVING HYPERSPECTRAL DATA CLASSIFICATION OF SATELLITE IMAGERY BY USING A SPARSE BASED NEW MODEL WITH LEARNING DICTIONARY
Chunmei Zhang, Xiaoting Hao, Jing Bai and Mo Dai

KERNELIZED SPARSE GRAPH-EMBEDDED DIMENSIONALITY REDUCTION FOR HYPERSPECTRAL IMAGE CLASSIFICATION
Zhaohui Xue, Peijun Du and Hongjun Su

Session wed-p-b
Planetary exploration
Session chairs :
Harold Clenet, *EPFL, Switzerland*
Rachel Klima, *Johns Hopkins University Applied Physics Laboratory, USA*

THE SPECTRAL IMAGING (SPIM) FACILITY IN SUPPORT OF HYPERSPECTRAL OBSERVATIONS OF SOLAR SYSTEM BODIES: PRELIMINARY CHARACTERIZATION
Eleonora Ammannito, Paolo Baldetti, Alessandro Bini, Angelo Boccaccini, Simone De Angelis, Maria Cristina De Sanctis, Tatiana Di Iorio, Fabrizio Liberati, Paola Manzari, Monica Olivieri, Carlo Pompei, Giampaolo Preti and Fabio Tarchi

SPECTROSCOPIC CLASSIFICATION OF ICY SATELLITES OF SATURN - IDENTIFICATION OF TERRAIN UNITS ON DIONE AND RHEA
Francesca Scipioni, Federico Tosi, Katrin Stephan, Gianrico Filacchione, Mauro Ciarniello, Fabrizio Capaccioni and Priscilla Cerroni

IRON MINERALOGY OF THE MARTIAN SURFACE WITH OMEGA SPECTROMETER
Filippo Giacomo Carrozzo, Francesca Altieri and Giancarlo Bellucci

THE ADAPTED MODIFIED GAUSSIAN MODEL: A TOOL TO CHARACTERIZE THE COMPOSITION OF MAGMATIC ROCKS ON TERRESTRIAL 'PLANETS'
Harold Clenet, Patrick Pinet, Cathy Quantin and Philippe Gillet

REVISITING THE PREPROCESSING PROCEDURES FOR ELEMENTAL CONCENTRATION ESTIMATION BASED ON CHEMCAM LIBS ON MARS ROVER
Wei Wang, Shuangjiang Li, Hairong Qi, Bulent Ayhan, Chiman Kwan and Steven Vance

DATA REDUCTION OF CRISM DATA TO HIGHLIGHT ALTERATION MINERALS
Benjamin Bultel, Cathy Quantin, Muriel Andréani and Harold Clénet

Poster until 11:00

MINERALOGICAL CHARACTERIZATION USING NEURAL NETWORKS: COMPOSITION OF MAFIC MINERALS IN MARTIAN METEORITES FROM THEIR SPECTRA
Antoine Rozel, Harold Clénet, Sylvain Douté and Cathy Quantin

Session wed-p-c
A diversity of applications
Session chairs :
Laurence Croizé-Guinet, *ONERA, Palaiseau, France*
Caroline Gevaert, *Lund University, Netherlands*

OPTICAL CLASSIFICATION OF OPTICALLY COMPLEX WATERS AROUND CHINA
Qian Shen, Li Ni, Xu Sun, Lianru Gao and Bing Zhang

INVERSING REFLECTANCE OF HIGHER RESOLUTION FROM HYPERSPECTRAL RADIANCE DATA BASED ON SPECTRAL SUPER-RESOLUTION
Guorui Jia, Huijie Zhao, Dongxing Tao and Kewang Deng

THE HAVEMANN-TAYLOR FAST RADIATIVE TRANSFER CODE: A LINE-BY-LINE SENSOR INDEPENDENT RADIATIVE TRANSFER CODE
Jean-Claude Thelen and Stephan Havemann

MULTI-ANGLE RECONSTRUCTION OF ENERGY DISPERSIVE X-RAY DIFFRACTION SPECTRA
Fanny Marticke, Caroline Paulus, Guillaume Montémont, Olivier Michel, Jérôme Mars and Loïck Verger

OPTIMIZING THE RANGE OF ATMOSPHERIC CONDITION PARAMETERS TO AVOID OVER AND UNDER-ESTIMATION OF UNCERTAINTY
Nitin Bhatia, Jan Biesemans, Valentyn Tolpekin, Ils Reusen, Sindy Sterckx and Alfred Stein

TARGET DETECTION OF MINE-RELATED FLOODED AREAS USING AISA-EAGLE DATA
Virginia Garcia Millan, Kian Pakzad and Ulrike Faude

LEMAN-BAIKAL: REMOTE SENSING OF LAKES USING AN ULTRALIGHT PLANE
Yosef Akhtman, Dragos Constantin, Martin Rehak, Vincent Nouchi and Galina Shinkareva

ASSESMENT OF OPTIMAL FLAT FIELD IN URBAN ENVIRONMENT FOR EO1-HYPERION SCENE
Shailesh Deshpande, Arun Inamdar and Harrick Vin

ON-LINE DETECTION OF OIL ON STEEL COILS AND THICKNESS MEASUREMENT USING HYPERSPECTRAL CAMERA
M. Ferté, C. Roquelet, D. Glijer, C. Carteret and G. Fricout

A NEURAL NETWORK APPROACH FOR SIMULTANEOUS RETRIEVAL OF VOLCANIC SO_2 AND PLUME HEIGHT USING HYPERSPECTRAL MEASUREMENTS
Alessandro Piscini, Elisa Carboni, Fabio Del Frate and Roy Gordon Grainger

SORTING OF CROP RESIDUES AND FOSSIL BONES FROM SOIL BY NIR HYPERSPECTRAL IMAGING
Damien Vincke, Damien Eylenbosch, Vincent Baeten, Bernard Bodson, Pierre Dardenne and Juan A. Fernández Pierna

MINERALOGY MAPPING OF THE RAMON CRATER IN ISRAEL USING HYPERSPECTRAL REMOTE SENSING DAY AND NIGHT LWIR IMAGES
Eyal Ben Dor and Gila Notesco

POSSIBILITIES FOR THE STUDY OF THE NLTE EFFECT ON ATMOSPHERIC CO_2 SPECTRAL SIGNATURES INDUCED BY A BLUE JET USING AN INFRARED SPECTRO-IMAGER EMBEDDED IN A STRATOSPHERIC BALLOON.
Laurence Croize, Sébastien Payan, Jérôme Bureau, Nathalie Huret and Fabrice Duruisseau

11:00

Wednesday, 25, June

w h i s p e r s

11:00 *Oral until* *12:40*	**Session wed-o-1-a** **Imaging spectroscopy for UAVs :** **innovation of sensors and applications** Session chairs : Stefania Amici, *INGV, Italy* Arko Lucieer, *University of Tasmania, Australia*	**Session wed-o-1-b** **Analysis of hyperspectral imagery using** **spectral graph and manifold models** Session chairs : David Messinger, *RIT, USA* David Gillis, *Naval Research Laboratory, USA*
11:00	DEVELOPMENT OF LIGHTWEIGHT HYPERSPEC- TRAL IMAGING SYSTEM FOR UAV OBSERVATION Kuniaki Uto, Haruyuki Seki, Genya Saito and Yukio Kosugi	AN INTRODUCTION TO SPECTRAL GRAPH TECH- NIQUES FOR THE ANALYSIS OF HYPERSPECTRAL IMAGE DATA David Gillis and David Messinger
11:20	LINEAR VARIABLE FILTERS – A CAMERA SYSTEM REQUIREMENT ANALYSIS FOR HYPERSPECTRAL IMAGING SENSORS ONBOARD SMALL REMOTELY PILOTED AIRCRAFT SYSTEMS Philippe Serruys, Aleksandra Sima, Stefan Livens, Bavo Delauré, Klaas Tack, Bert Geelen and Andy Lambrechts	SPATIAL CONTEXT DRIVEN MANIFOLD LEARNING FOR HYPERSPECTRAL IMAGE CLASSIFICATION Yuhang Zhang, Hsiuhan Lexie Yang, Dalton Lunga, Saurabh Prasad and Melba M. Crawford
11:40	COMBINING HYPERSPECTRAL UAV AND MUL- TISPECTRAL FORMOSAT-2 IMAGERY FOR PRECI- SION AGRICULTURE APPLICATIONS Caroline Gevaert, Jing Tang, F. Javier García-Haro, Juha Suomalainen and Lammert Kooistra	DIMENSIONALITY REDUCTION OF HYPERSPEC- TRAL IMAGERY WITH SPARSE AND COLLABORA- TIVE GRAPHS Nam Ly, Qian Du, James Fowler and Nicolas Younan
12:00	HIGH SPATIAL AND SPECTRAL REMOTE SENSING FOR DETAILED MAPPING OF POTATO PLANT PARAMETERS Stephanie Delalieux, Dries Raymaekers, Kris Nackaerts, Eija Honkavaara, Jussi Soukkamaki and Jacob Van Den Borne	CLASSIFICATION OF HYPERSPECTRAL IMAGERY ON EMBEDDED GRASSMANNIANS Sofya Chepushtanova and Michael Kirby
12:20 12:40	UAV: A MULTIDISCIPLINARY TOOL TO ACCESS EXTREME ENVIROMENTS Alessandro Iarocci, Giovanni Romeo, Adriano Mazzini, Giuseppe Di Stefano and Paolo Benedetti	MULTI-FEATURE BASED LABEL PROPAGATION FOR SEMI-SUPERVISED CLASSIFICATION OF HYPERSPECTRAL DATA Andong Ma and Li Ma
12:40 14:00	Lunch	
14:00 *Oral until* *15:40*	**Session wed-o-2-a** **Detecting difficult targets in hyperspectral imagery** Session chairs : James Theiler, *Los Alamos National Laboratory, USA* Al Schaum, *Naval Research Laboratory, USA*	**Session wed-o-2-b** **Planetary exploration** Session chairs : Harold Clenet, *EPFL, Switzerland* Federico Tosi, *INAF-IAPS, Italy*
14:00	PROGRESS IN DETECTOR FUSION Alan Schaum	TITAN'S SURFACE AND ATMOSPHERE AS SEEN BY THE VIMS HYPERSPECTRAL IMAGER ONBOARD CASSINI ONBOARD CASSINI Sebastien Rodriguez, Stéphane Le Mouélic, Christophe So- tin, Thomas Cornet, Jason W. Barnes and Robert H. Brown
14:20	A FAMILY OF KERNEL ANOMALY CHANGE DE- TECTORS Nathan Longbotham and Gustavo Camps-Valls	VISIBLE TO NEAR-INFRARED HYPERSPECTRAL MEASUREMENTS OF MERCURY: CHALLENGES FOR DECIPHERING SURFACE MINERALOGY Rachel Klima, Noam Izenberg, Gregory Holsclaw, Jörn Helbert, Mario D'Amore, William McClintock and Sean Solomon

Wednesday, 25, June

whispers

14:40	STATISTICAL MOMENTS BASED METHODS FOR DETECTING SUB-PIXEL TARGET TRACKS IN LARGE IMAGE SEQUENCES Christoph Borel, David Bunker and Lori Mahoney	SPECTRAL PROPERTIES OF ICY SATURNIAN SATELLITES DERIVED FROM CASSINI DATA Katrin Stephan, Ralf Jaumann, Roland Wagner, Roger Clark, Dale Cruikshank, Cristina Dalle Ore, Robert Brown, Bernd Giese, Thomas Roatsch, Dennis Matson, Kevin Baines, Gianrico Filiacchione, Fabrizio Cappacione, Bonnie Buratti and Phil Nicholson
15:00	ADVANTAGES AND LIMITATIONS OF SEGMENTATION FOR POINT TARGET DETECTION IN HYPERSPECTRAL IMAGERY Sapir Ben-Yakar, Stanley R. Rotman and Dan G. Blumberg	TESTING LINEAR SPECTRAL UNMIXING ON LABORATORY MIXTURES: APPLICATION TO VIR DATA FOR ASTEROID VESTA. Francesca Zambon, Federico Tosi, Maria Cristina De Sanctis, David Blewett, Eleonora Ammannito, Christofer Russell and Carol Raymond
15:20	HYPERSPECTRAL ANOMALY DETECTION BASED ON A NON-UNIFORM PARTITION OF THE PIXEL Edisanter Lo	A PRELIMINARY RESEARCH ON QUANTITATIVE RETRIEVAL OF HYDROUS MINERALS AROUND THE MARS SCIENCE LABORATORY LANDING SITE Tong Shuai and Xia Zhang
15:40		

15:40 16:10	coffee break

16:10 *Oral until* *17:50*	**Session wed-o-3-a** **Spectral unmixing (1)** Session chairs : Mario Parente, *Univ. of Massachusetts, Amherst, USA* Rob Heylen, *Univ. of Antwerp, Belgium*	**Session wed-o-3-b** **Monitoring of the vegetation** Session chairs : Stéphanie Delalieux, *VITO, Belgium* Frank Liebisch, *Institute of Agricultural Sciences, ETH Zürich*
16:10	NONLINEAR UNMIXING OF VEGETATED AREAS: A MODEL COMPARISON BASED ON SIMULATED AND REAL HYPERSPECTRAL DATA Nicolas Dobigeon, Laurent Tits, Ben Somers, Yoann Altmann and Pol Coppin	CHARACTERIZATION OF CROP VITALITY AND RESOURCE USE EFFICIENCY BY MEANS OF COMBINING IMAGING SPECTROSCOPY BASED PLANT TRAITS Frank Liebisch, Gabriela Küng, Alexander Damm and Achim Walter
16:30	RARE ENDMEMBERS ESTIMATION BY NMF METHODS USING MULTITEMPORAL HYPERSPECTRAL DATA AND CHANGE INFORMATIONS Godefroy Brisebarre, Mireille Guillaume and Christian Louis	ESTIMATING BIOMASS OF RICE IN FARMERS' FIELDS BY RED-EDGE INDICES Martin Leon Gnyp, Kang Yu, Yuxin Miao and Georg Bareth
16:50	SPECTRAL-SPATIAL JOINT SPARSITY UNMIXING OF HYPERSPECTRAL DATA USING OVERCOMPLETE DICTIONARIES Jakub Bieniarz, Esteban Aguilera, Xiaoxiang Zhu, Rupert Müller, Uta Heiden and Peter Reinartz	HYPERSPECTRAL TREE SPECIES CLASSIFICATION WITH AN AID OF LIDAR DATA Tomohiro Matsuki, Naoto Yokoya and Akira Iwasaki
17:10	A ROBUST SUBSPACE METHOD FOR SEMIBLIND DICTIONARY-AIDED HYPERSPECTRAL UNMIXING Xiao Fu, Wing-Kin Ma, Jose Bioucas-Dias and Tsung-Han Chan	SPECTRAL DISCRIMINATION OF TEA PLANT VARIETIES BY STATISTICAL, MACHINE LEARNING AND SPECTRAL SIMILARITY METHODS Rama Rao Nidamanuri
17:30	ESTIMATION OF NUMBER OF SIGNAL SUBSPACES IN HYPERSPECTRAL IMAGERY USING LOW-RANK SUBSPACE REPRESENTATION Alex Sumarsono and Qian Du	TOWARDS ROBUST VEGETATION INDICES: THE MULTI-CORRELATION MATRIX STRATEGY Helge Aasen, Martin Gnyp, Yuxin Miao and Georg Bareth
17:50		

Thursday, 26, June
Overview

w h i s p e r s

8:00	Opening of the conference

8:00

Plenary 2
By Definition Undefined: Adventures in Anomaly (and Anomalous Change) Detection
James Theiler, *Los Alamos National Laboratory, Los Alamos (NM), USA*
Session chair: Devis Tuia, *EPFL Lausanne, Switzerland*

9:00

9:00

Session thu-p-a
Spectral unmixing
Session chairs :
Anna Brook, *University of Haifa, Israel*
Laurent Tits, *KU Leuven, Belgium*

Session thu-p-b
Feature extraction, band selection and dimension reduction
Session chairs :
Loredana Pompilio, *D'Annunzio University, Italy*
Alp Etürk, *Kocaeli University, Turkey*

Session thu-p-c
Sensors, systems, missions
Session chairs :
Virginia Garcia Millán, *EFTAS Fernerkundung, Germany*
Kuniaki Uto, *Tokyo Institute of Technology, Japan*

10:30

10:30

Session thu-o-1-a
Fluorescence data
Session chairs :
Jochem Verrelst, *Universitat de Valencia, Spain*
Jose Moreno, *Universitat de Valencia, Spain*

Session thu-o-1-b
Machine learning
Session chairs :
Melba Crawford, *Purdue University, USA*
Jean-Yves Tourneret, *IRIT Laboratory, Toulouse, France*

12:10

12:10	Lunch

13:20

Session thu-o-2-a
Hyperspectral pansharpening and super-resolution
Session chairs :
Amanda Ziemann, *Rochester Institute of Technology, USA*
Akira Iwasaki, *University of Tokyo, Japan*

Session thu-o-2-b
Forward modeling
Session chairs :
Rob Sundberg, *Spectral Sciences, Inc., USA*
Jeffrey Mercier, *Sandia National Laboratories, USA*

15:00

15:00	Coffee

15:30

Session thu-o-3-a
Spectral unmixing (2)
Session chairs :
Mario Parente, *Univ. of Massachusetts, Amherst, USA*
Rob Heylen, *Univ. of Antwerp, Belgium*

Session thu-o-3-b
NIR/SWIR/THERMIC
Session chairs :
Christina Bogner, *University of Bayreuth, Germany*
Antonio Plaza, *University of Extremadura, Spain*

17:10

18:00	Banquet, Olympic Museum of Lausanne

23:00

Thursday, 26, June

8:00 Opening of the conference

8:00

Plenary 2
By Definition Undefined: Adventures in Anomaly (and Anomalous Change) Detection
James Theiler, *Los Alamos National Laboratory, Los Alamos (NM), USA*
Session chair: Devis Tuia, *EPFL Lausanne, Switzerland*

9:00

9:00
Poster until 10:30

Posters / coffee break : 3 parallel sessions

Session thu-p-a
Spectral unmixing
Session chairs :
Anna Brook, *University of Haifa, Israel*
Laurent Tits, *KU Leuven, Belgium*

GEOMETRIC MATCHED FILTER FOR HYPERSPEC-
TRAL PARTIAL UNMIXING
Muhammad Awais Akhter, Rob Heylen and Paul
Scheunders

A NEW MAXIMUM DISTANCE METHOD BASED
ON BARYCENTRIC COORDINATE FOR ENDMEM-
BER EXTRACTION
Luyan Ji, Xiurui Geng, Yongchao Zhao, Kang Sun and
Peng Gong

COMBINING MULTI-AGENT AND ANT COLONY
OPTIMIZATION FOR ENDMEMBER EXTRACTION
Lina Yang, Xu Sun, Qian Shen, Bing Zhang and Tianhe Chi

AN IMPROVED WEIGHT-CALCULATION NON-LOCAL
SPARSE UNMIXING FOR HYPERSPECTRAL IMAGERY
Ruyi Feng, Yanfei Zhong and Liangpei Zhang

STRUCTURED SPARSE BAYESIAN HYPERSPECTRAL
COMPRESSIVE SENSING USING SPECTRAL UNMIXING
Lei Zhang, Wei Wei, Yanning Zhang, Fei Li and Hangqi Yan

SPARSE UNMIXING VIA WM ALGORITHM FOR
HYPERSPECTRAL IMAGES
Ion Marqués and Manuel Graña

ENDMEMBER CONSTRAINED SEMI-SUPER-
VISED HYPERSPECTRAL UNMIXING
Jakob Sigurdsson, Magnus Ulfarsson and Johannes R. Sveinsson

VALIDATING NONLINEAR MIXING MODELS:
BENCHMARK DATASETS FROM VEGETATED
AREAS
Laurent Tits, Ben Somers, Jan Stuckens and Pol Coppin

RECURSIVE ORTHOGONAL VECTOR PROJECTION
ALGORITHM FOR LINEAR SPECTRAL UNMIXING
Meiping Song, Yao Li, Chein-I Chang and Lifu Zhang

MULTILAYER STRUCTURED NMF FOR SPECTRAL
UNMIXING OF HYPERSPECTRAL IMAGES
Roozbeh Rajabi and Hassan Ghassemian

ON THE USE OF RITZ VALUES FOR CALCU-
LATING THE NUMBER OF ENDMEMBERS IN
HYPERSPECTRAL IMAGES
Raúl Guerra, Sebastián López, Gustavo M. Callico, Jose F.
López and Roberto Sarmiento

BINARY PARTITION TREE-BASED LOCAL
SPECTRAL UNMIXING
Lucas Drumetz, Miguel Ángel Veganzones, Ruben Mar-
rero, Guillaume Tochon, Mauro Dalla Mura, Antonio
Plaza and Jocelyn Chanussot

A VARIATIONAL BAYES ALGORITHM FOR JOINT-
SPARSE ABUNDANCE ESTIMATION
Paris Giampouras, Konstantinos Themelis, Athanasios
Rontogiannis and Konstantinos Koutroumbas

Thursday, 26, June

w h i s p e r s

Session thu-p-b
Feature extraction, band selection and dimension reduction
Session chairs :
Loredana Pompilio, *D'Annunzio University, Italy*
Alp Etürk, *Kocaeli University, Turkey*

EVALUATION OF INTRINSIC DIMENSIONAL-
ITY METHODS USING RESIDUAL AND CHANGE-
POINT ANALYSES
Amin Alizadeh Naeini, Saeid Homayouni, Mo-
hammad Saadatseresht and Hossein Torabzadeh

A NEW ANT COLONY OPTIMIZATION ALGO-
RITHM BASED BAND SELECTION METHOD
Xu Sun, Lina Yang, Qian Shen, Li Ni and Bing Zhang

HYPERSPECTRAL BAND SELECTION USING FIRE-
FLY ALGORITHM
Hongjun Su, Qiannan Li and Peijun Du

FODSPO BASED FEATURE SELECTION FOR HY-
PERSPECTRAL REMOTE SENSING DATA
Pedram Ghamisi, Micael S. Couceiro and Jon Atli Bene-
diktsson

UNSUPERVISED DEEP FEATURE EXTRACTION OF
HYPERSPECTRAL IMAGES
Adriana Romero, Carlo Gatta and Gustavo Camps-Valls

USE INTERMEDIATE RESULTS OF WRAPPER BAND
SELECTION METHODS : A FIRST STEP TOWARD
THE OPTIMIZATION OF SPECTRAL CONFIGURA-
TION FOR LAND COVER CLASSIFICATIONS
Arnaud Le Bris, Nesrine Chehata, Xavier Briottet and
Nicolas Paparoditis

HYPERDIMENSIONAL DATA EXPLOITATION
THROUGH PARAMETRIC REDUCTION
Loredana Pompilio, Monica Pepe and Gabriele Candiani

SPATIAL-SPECTRAL FEATURE EXTRACTION ON
HYPERSPECTRAL IMAGERY
Jason Kaufman, Jeffrey Weinheimer and Mehmet Celenk

Session thu-p-c
Sensors, systems, missions
Session chairs :
Virginia Garcia Millán, *EFTAS Fernerkundung, Germany*
Kuniaki Uto, *Tokyo Institute of Technology, Japan*

SENSITIVITY OF SCOPE MODELLED GPP AND
FLUORESCENCE FOR DIFFERENT PLANT FUNC-
TIONAL TYPES
Christiaan van der Tol, Wout Verhoef, Jochem Verrelst, Fed-
erico Magnani, Gina Mohammed, Jose Moreno and Joe Berry

RESEARCH ON THE TECHNOLOGY OF HYPER-
SPECTRAL REMOTE SENSING OIL-GAS EXPLO-
RATION BASED ON VEGETATION REFLECTION
SPECTRUM ANOMALIES
Qianqian Li, Xiaomei Chen, Na Liu, Guoqiang Ni and Tian Lan

MAPPING ECOSYSTEM SERVICES USING IMAG-
ING SPECTROSCOPY DATA
Daniela Braun, Alexander Damm, Rogier de Jong and
Michael Schaepman

EVALUATION OF BREFCOR BRDF EFFECTS
CORRECTION FOR HYSPEX, CASI, AND APEX
IMAGING SPECTROSCOPY DATA
Daniel Schlaepfer and Rudolf Richter

MONITORING THE DIURNAL TIME COURSE OF
VEGETATION DYNAMICS WITH GEOSTATION-
ARY OBSERVATIONS : THE GFLEX PROJECT
Yves Goulas, Camill Rhoul, Fabrice Daumard, Abder-
rahmane Ounis, Maria-Llanos Lopez and Ismael Moya

A HYPERSPECTRAL IMAGING DEVICE FOR
MULTI-LABELLED FLUORESCENCE MICROSCOPY
Valentina Caricato, Marco Pisani, Andrea Egidi and
Massimo Zucco

THE USGS PRISM SYSTEM FOR SPECTRAL
ANALYSIS – AN ENVI/IDL-BASED SOFTWARE –
Raymond F. Kokaly and Thomas Bahr

PRELAUNCH ASSESSMENT OF WORLDVIEW-3
INFORMATION CONTENT
Nathan Longbotham, Fabio Pacifici, Bill Baugh and Gus-
tavo Camps-Valls

COMPARING CAMERA SENSITIVITY WITH
NOISE EQUIVALENT IRRADIANCE
Jean-Edouard Communal

10:30

Thursday, 26, June

10:30 *Oral until* *12:10*	**Session thu-o-1-a** **Fluorescence data** Session chairs : Jochem Verrelst, *Universitat de Valencia, Spain* Jose Moreno, *Universitat de Valencia, Spain*

10:30	AIRBORNE BASED SPECTROSCOPY TO MEASURE SUN-INDUCED CHLOROPHYLL FLUORESCENCE Alexander Damm, Micol Rossini, Roberto Colombo, Uwe Rascher and Michael E. Schaepman	
10:50	MEASUREMENT AND CORRECTION OF AT-MOSPHERIC EFFECTS IN O2-B AND O2-A AB-SORPTION BANDS IN THE CONTEXT OF SUN-INDUCED FLUORESCENCE REMOTE SENSING Fabrice Daumard, Yves Goulas, Abderrahmane Ounis, Roberto Pedros and Ismael Moya	
11:10	A FLUORESCENCE RETRIEVAL METHOD FOR THE FLEX SENTINEL-3 TANDEM MISSION Neus Sabater, Luis Alonso, Jorge Vicent, Sergio Cogliati, Jochem Verrelst and Jose Moreno	
11:30	REMOTE SENSING OF SUN-INDUCED CHLORO-PHYLL FLUORESCENCE AT DIFFERENT SCALES Roberto Colombo, Luis Alonso, Marco Celesti, Sergio Cogliati, Alexander Damm, Matthias Drusch, Luis Guanter, Tommaso Julitta, Panos Kokkalis, Stefan Kraft, Jose Moreno, Cinzia Panigada, Francisco Pinto, Uwe Rascher, Micol Rossini, Anke Schickling, Dirk Schüttemeyer, Wouter Verhoef and Frantisek Zemek	
11:50	GLOBAL SENSITIVITY ANALYSIS OF THE A-SCOPE MODEL IN SUPPORT OF FUTURE FLEX FLUORESCENCE RETRIEVALS Jochem Verrelst, Juan Pablo Rivera, Christiaan van der Tol, Federico Magnani, Gina Mohammed and Jose Moreno	
12:10		

Session thu-o-1-b
Machine learning
Session chairs :
Melba Crawford, *Purdue University, USA*
Jean-Yves Tourneret, *IRIT Laboratory, Toulouse, France*

HYPERSPECTRAL IMAGE REPRESENTATION USING LEARNED MULTISCALE DICTIONARIES
Qian Wu, Rong Zhang and Dawei Xu

WAVELET DOMAIN ACTIVE LEARNING FOR HYPERSPECTRAL IMAGE ANALYSIS
Xiong Zhou, Saurabh Prasad and Melba Crawford

COMBINING ACTIVE AND METRIC LEARNING FOR HYPERSPECTRAL IMAGE CLASSIFICATION
Edoardo Pasolli, Hsiuhan Lexie Yang and Melba M Crawford

HYPERSPECTRAL CLASSIFICATION USING STACKED AUTOENCODERS WITH DEEP LEARNING
Ekin Gedik, Okan Bilge Özdemir and Yasemin Yardımcı Çetin

HYPERSPECTRAL IMAGE CLASSIFICATION FROM MULTISCALE DESCRIPTION WITH CON-STRAINED CONNECTIVITY AND METRIC LEARNING
Sébastien Lefèvre, Laetitia Chapel and François Merciol

12:10 13:20	Lunch

13:20 *Oral until* *15:00*	**Session thu-o-2-a** **Hyperspectral pansharpening and** **super-resolution** Session chairs : Amanda Ziemann, *Rochester Institute of Technology, USA* Akira Iwasaki, *University of Tokyo, Japan*

Session thu-o-2-b
Forward modeling
 Session chairs :
Rob Sundberg, *Spectral Sciences, Inc., USA*
Jeffrey Mercier, *Sandia National Laboratories, USA*

13:20	EFFECT OF UNMIXING-BASED HYPERSPECTRAL SUPER-RESOLUTION ON TARGET DETECTION Naoto Yokoya and Akira Iwasaki

MODELING TRI-DIRECTIONAL REFLECTANCE DISTRIBUTION FUNTIONS (TRDF) WITH APPLI-CATION TO SUBPIXEL TARGET DETECTION
Joshua Zollweg and Prabal Nandy

Thursday, 26, June

whispers

13:40	HYPERSPECTRAL PAN-SHARPENING: A VARIATIONAL CONVEX CONSTRAINED FORMULATION TO IMPOSE PARALLEL LEVEL LINES, SOLVED WITH ADMM Alexis Huck, François de Vieilleville, Pierre Weiss and Manuel Grizonnet	HIGH-FIDELITY FORWARD MODEL FOR DETERMINING COMBUSTION EFFICIENCY OF INDUSTRIAL FLARES Raphael Panfili
14:00	THE J-SPARSEFI-HM HYPERSPECTRAL RESOLUTION ENHANCEMENT METHOD - NOW FULLY AUTOMATED Claas Grohnfeldt, Xiao Xiang Zhu and Richard Bamler	A NEW MODTRAN-BASED THERMAL MODEL FOR ACCELERATING PLUME TRACKER VOLCANIC EMISSION ANALYSIS Alexander Berk, Vincent Realmuto, Chona Guiang, Rosemary Kennett, Prabhat Acharya and J. Maxwell Riestenberg
14:20	HYPER-SHARPENING OF HYPERSPECTRAL DATA: A FIRST APPROACH Massimo Selva, Bruno Aiazzi, Francesco Butera, Leandro Chiarantini and Stefano Baronti	SPECTRAL MODELING OF THE DIFFUSE INTERSTELLAR BANDS Lawrence Bernstein, Frank Clark, Xiaofeng Tan and David Lynch
14:40 15:00	SUPER-RESOLUTION OF HYPERSPECTRAL IMAGES USING LOCAL SPECTRAL UNMIXING Giorgio Licciardi, Miguel Angel Veganzones, Miguel Simoes, Jose Bioucas Dias and Jocelyn Chanussot	MODTRAN®6: A MAJOR UPGRADE OF THE MODTRAN® RADIATIVE TRANSFER CODE Alexander Berk, Patrick Conforti and Rosemary Kennett

15:00 15:30	Coffee

15:30 *Oral until* *17:10*	**Session thu-o-3-a** **Spectral unmixing (2)** Session chairs : Mario Parente, *Univ. of Massachusetts, Amherst, USA* Rob Heylen, *Univ. of Antwerp, Belgium*	**Session thu-o-3-b** **NIR/SWIR/THERMIC** Session chairs : Christina Bogner, *University of Bayreuth, Germany* Antonio Plaza, *University of Extremadura, Spain*
15:30	GLUP: YET ANOTHER ALGORITHM FOR BLIND UNMIXING OF HYPERSPECTRAL DATA Rita Ammanouil, André Ferrari, Cédric Richard and David Mary	CLAY CONTENTS PREDICTED FROM HYPERSPECTRAL VNIR/SWIR IMAGERY, UNDER DIFFERENT ATMOSPHERIC CONDITIONS AND SPATIAL RESOLUTIONS Cecile Gomez, Rosa Oltra-Carrió, Sinan Bacha, Philippe Lagacherie and Xavier Briottet
15:50	NONLINEAR UNMIXING BY USING NON-EUCLIDEAN METRICS IN A LINEAR UNMIXING CHAIN Rob Heylen, Paul Scheunders, Anand Rangarajan and Paul Gader	PREDICTING WITH LIMITED DATA - INCREASING THE ACCURACY IN VIS-NIR DIFFUSE REFLECTANCE SPECTROSCOPY BY SMOTE Christina Bogner, Anna Kühnel and Bernd Huwe
16:10	UNMIXING MULTIPLE INTIMATE MIXTURES USING MANIFOLD CLUSTERING Arun Saranathan and Mario Parente	REMOTE SENSING OF SURFACE EMISSIVITY WITH THE TELOPS HYPER-CAM Steven Adler-Golden, Patrick Conforti, Marc-Andre Gagnon, Pierre Tremblay and Martin Chamberland
16:30	ROBUST UNMIXING USING CONSENSUS ANALYSIS Hamdi Jenzri and Hichem Frigui	SPECIES DISCRIMINATION USING EMISSIVE THERMAL INFRARED IMAGING SPECTROSCOPY Gilles Rock, Max Gerhards, Thomas Gattung, Chris Hecker, Thomas Udelhoven, Martin Schlerf and Willy Werner
16:50 17:10	CHARACTERIZATION OF HYPERSPECTRAL IMAGES PRIOR TO UNMIXING, BASED ON EIGENDECOMPOSITIONS AND SUM-TO-ONE CONDITION Yannick Deville, Charlotte Revel, Xavier Briottet and Veronique Achard	AIRBORNE THERMAL INFRARED HYPERSPECTRAL IMAGING OF GASES Marc-André Gagnon, Martin Chamberland, Simon Savary, Pierre Tremblay, Philippe Lagueux and Marc Duval

Friday, 27, June
Overview

8:00 Opening of the conference

8:00 **Plenary 3**
Recent Advances in Data Compression of Remote Sensed Hyperspectral Images
Prof. Raffaele Vitulli, *European Space Agency, ESTEC, The Netherlands*
Session chair: Sebastian Lopez, *Universidad de las Palmas de Gran Canaria, Spain*
9:00

9:00 Posters / coffee break

Session fri-p-a
Noise reduction
Session chairs :
Olga Duran, *Kingston University, UK*
Mathieu Fauvel, *INP ENSAT, France*

Session fri-p-b
Classification
Session chairs :
Azam Karami, *Vision Lab, University of Antwerp, Belgium*
Rob Heylen, *Vision Lab, University of Antwerp, Belgium*

Session fri-p-c
Advanced signal and image processing techniques
Session chairs :
Michele Volpi, *University of Edinburgh, UK*
Simon Henrot, *Gipsa-Lab, France*
10:30

10:30 **Session fri-o-1-a**
Spectroradiometric applications for optically complex waters
Session chairs :
Daniel Odermatt, *Brockmann Consult GmbH, Germany*
Alfred West, *Swiss Federal Institute of Aquatic Science and Technology, Switzerland*
12:10

Session fri-o-1-b
Sparsity in hyperspectral data processing
Session chairs :
Alina Zare, *University of Missouri, USA*
Wing-Kin Ma, *The Chinese University of Hong Kong*

12:10 lunch

13:20 **Session fri-o-2-a**
Advanced signal and image processing techniques
Session chairs :
Lori Bruce, *Mississippi State University, USA*
José Bioucas Dias, *Technical University of Lisbon, Portugal*
15:00

Session fri-o-2-b
A diversity of applications
Session chairs :
Qian Wu, *University of Science and Technology of China, China*
Lammert Kooistra, *Wageningen University, Netherlands*

15:00 coffee

15:30 **Session fri-o-3-a**
Spectral unmixing (3)
Session chairs :
Jenny Du, *Mississippi State University, USA*
Hichem Frigui, *University of Louisville, USA*
17:10

Session fri-o-3-b
Simulators and models
Session chairs :
Yasemin Yardımcı Cetin, *Middle East Technical University Informatics Institute Ankara, Turkey*
Xavier Briottet, *ONERA, Toulouse, France*

Friday, 27, June

8:00 Opening of the conference

Plenary 3
Recent Advances in Data Compression of Remote Sensed Hyperspectral Images
Prof. Raffaele Vitulli, *European Space Agency, ESTEC, The Netherlands*
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9:00

9:00
Poster until 10:30

Posters / coffee break : 3 parallel sessions

Session fri-p-a
Noise reduction
Session chairs :
Olga Duran, *Kingston University, UK*
Mathieu Fauvel, *INP ENSAT, France*

JOINT DENOISING AND UNMIXING FOR HYPERSPECTRAL IMAGE
Jingxiang Yang and Yongqiang Zhao

3-D WAVELETS-BASED DENOISING AND ENHANCEMENT OF HYPERSPECTRAL IMAGERY
Anna Brook

ESTIMATION OF CORRELATED NOISE IN HYPERSPECTRAL IMAGES
Asad Mahmood, Amandine Robin and Michael Sears

SINGULAR SPECTRUM ANALYSIS FOR EFFECTIVE NOISE REMOVAL AND IMPROVED DATA CLASSIFICATION IN HYPERSPECTRAL IMAGING
Jaime Zabalza, Jinchang Ren and Stephen Marshall

HYPERSPECTRAL IMAGE NOISE REDUCTION AND ITS EFFECT ON SPECTRAL UNMIXING
Azam Karami, Rob Heylen and Paul Scheunders

APPLICATION OF NON-LINEAR PRINCIPAL COMPONENT ANALYSIS TO HYPERSPECTRAL DATA FOR NOISE FILTERING USING ARTIFICIAL NEURAL NETWORKS
Alessandro Piscini and Giorgio Licciardi

Session fri-p-b
Classification
Session chairs :
Azam Karami, *Vision Lab, University of Antwerp, Belgium*
Rob Heylen, *Vision Lab, University of Antwerp, Belgium*

COLLABORATIVE REPRESENTATION BASED K-NEAREST NEIGHBOR CLASSIFIER FOR HYPERSPECTRAL IMAGERY
Wei Li, Qian Du, Fan Zhang and Wei Hu

A NOVEL SEMISUPERVISED TRANSDUCTIVE SVM WITH SPATIAL SIMILARITY FOR CLASSIFICATION OF HYPERSPECTRAL DATA
Lian-Zhi Huo, Li-Jun Zhao and Ping Tang

CONTRIBUTION OF BAND SELECTION AND FUSION FOR HYPERSPECTRAL CLASSIFICATION
Nesrine Chehata, Arnaud Le-Bris and Safa Najjar

CLASSIFICATION OF ENERGY TREE SPECIES USING SUPPORT VECTOR MACHINES
Peter Burai, Laszlo Beko, Csaba Lenart and Tamas Tomor

AN IMPROVED MARKER SELECTION METHOD FOR HYPERSPECTRAL IMAGE SEGMENTATION AND CLASSIFICATION
Davood Akbari, Saeid Homayouni, Abdolreza Safari, Safa Khazai and Hossein Torabzadeh

SUPPORT TENSOR MACHINE WITH LOCAL PIXEL NEIGHBORHOOD FOR HYPERSPECTRAL IMAGE CLASSIFICATION
Guo Xian, Huang Xin, Zhang Liangpei and Zhang Lefei

EDGE CONSTRAINED MRF METHOD FOR CLASSIFICATION OF HYPERSPECTRAL IMAGERY
Li Ni, Bing Zhang, Qian Shen, Lianru Gao, Xu Sun, Shanshan Li and Hua Wu

A NOVEL SPECTRAL SPATIAL FILTERING APPROACH FOR HYPERSPECTRAL IMAGE CLASSIFICATION
Kun Shang and Xia Zhang

Poster until 10:30	GAME THEORY MODELS FOR SPECTRAL BAND GROUPING AND CLASSIFIER ENSEMBLES FOR HYPERSPECTRAL IMAGE CLASSIFICATION Lori Bruce	NONLINEAR PARSIMONIOUS FEATURE SELECTION FOR THE CLASSIFICATION OF HYPERSPECTRAL IMAGES Mathieu Fauvel, Anthony Zullo and Frédéric Ferraty

SPECTROMETER-DRIVEN SPECTRAL PARTITIONING FOR HYPERSPECTRAL IMAGE CLASSIFICATION
Jun Li, Yi Liu, Antonio Plaza, Peijun Du and Mahdi Khodadadzadeh

Session fri-p-c
Advanced signal and image processing techniques
Session chairs :
Michele Volpi, *University of Edinburgh, UK*
Simon Henrot, *Gipsa-Lab, France*

SLOW FEATURE ANALYSIS FOR HYPERSPECTRAL CHANGE DETECTION Chen Wu, Bo Du and Liangpei Zhang	USE OF CLUSTERING WITH PARTIAL LEAST SQUARES REGRESSION FOR PREDICTIONS BASED ON HYPERSPECTRAL DATA Peter Bajorski, C. Kaźmierowski and J. Cierniewski
SIMULTANEOUS LEAST-SQUARES REGISTRATION OF SATELLITE TIME SERIES Luigi Barazzetti, Marco Gianinetto and Marco Scaioni	LOCAL DENSITY BASED BACKGROUND ESTIMATION Chen Lou and Huijie Zhao
SUBPIXEL TRACKING USING SPECTRAL DATA AND KALMAN FILTER Olga Duran	EXTENDED FUNCTIONS OF MULTIPLE INSTANCES FOR TARGET CHARACTERIZATION Alina Zare and Changzhe Jiao
HYPERSPECTRAL CHANGE DETECTION WITH STEREO DISPARITY INFORMATION ENHANCEMENT Ali Can Karaca, Davut Cesmeci, Alp Erturk, Mehmet Kemal Gullu and Sarp Erturk	EVALUATION OF ON-BOARD INTEGER WAVELET TRANSFORM BASED SPECTRAL DECORRELATION SCHEMES FOR LOSSLESS COMPRESSION OF HYPERSPECTRAL IMAGES Behcet Ugur Toreyin, Ozan Yilmaz and Yakup Murat Mert
GAS PLUME DETECTION AND TRACKING IN HYPERSPECTRAL VIDEO SEQUENCES USING BINARY PARTITION TREES G. Tochon, J. Chanussot, J. Gilles, M. Dalla Mura, J.-M. Chang, A. L. Bertozzi	MATCHED SUBSPACE DETECTOR BASED ON SPARSE REPRESENTATION FOR TARGET DETECTION IN HYPERSPECTRAL IMAGERY Yanfeng Gu, He Zheng and Guoming Gao

10:30

10:30 *Oral until* 12:10	**Session fri-o-1-a** **Spectroradiometric applications for optically complex waters** Session chairs : Daniel Odermatt, *Brockmann Consult GmbH, Germany* Alfred West, *Swiss Federal Institute of Aquatic Science and Technology, Switzerland*	**Session fri-o-1-b** **Sparsity in hyperspectral data processing** Session chairs : Alina Zare, *University of Missouri, USA* Wing-Kin Ma, *The Chinese University of Hong Kong*
10:30	OPERATIONAL NIR-RED ALGORITHMS FOR ESTIMATING CHLOROPHYLL-A CONCENTRATION FROM SATELLITE DATA IN INLAND AND COASTAL WATERS Wesley Moses, Anatoly Gitelson, Sergey Berdnikov, Jeffrey Bowles, Vasiliy Povazhnyi, Vladislav Saprygin, Ellen Wagner and Karen Patterson	JOINT SPARSE AND COLLABORATIVE REPRESENTATION FOR TARGET DETECTION IN HYPERSPECTRAL IMAGERY Wei Li and Qian Du

10:50	A CASE STUDY AT STARNBERGER SEE FOR HYPER-SPECTRAL BATHYMETRY MAPPING USING IN-VERSE MODELING Peter Gege	ANOMALY DETECTION AND IMPORTANT BAND SELECTION FOR HYPERSPECTRAL IMAGES VIA SPARSE PCA Santiago Velasco-Forero, Marcus Chen, Alvina Goh and Sze Kim Pam
11:10	HICO LEVEL-2 DATA PROCESSING TOOLBOX FOR THE ATMOSPHERIC CORRECTION AND THE RE-TRIEVAL OF WATER QUALITY PARAMETERS Jorge Vicent, Neus Sabater, Carolina Tenjo, Antonio Ruiz-Verdú, Jesús Delegido, Ramón Peña-Martínez and José Moreno	QUANTITATIVE DETECTION OF SETTLE DUST OVER GREEN CANOPY USING SPARSE UNMIX-ING OF AIRBORNE HYPERSPECTRAL DATA Anna Brook
11:30	MAPPING BENTHIC SUBSTRATE COVERAGE AND BATHYMETRY USING BIO-OPTICAL MODELLING - AN ENMAP CASE STUDY IN THE COASTAL WA-TERS OF HELGOLAND Katja Dörnhöfer and Natascha Oppelt	ON THE USE OF COLLABORATIVE SPARSE REGRES-SION IN HYPERSPECTRAL UNMIXING CHAINS Marian-Daniel Iordache, Akpona Okujeni, Sebastian van der Linden, Jose Bioucas-Dias, Antonio Plaza and Somers Ben
11:50 12:10	HYPERSPECTRAL OBSERVATIONS OF OPTICAL PROPERTIES IN LAKES IN PERSPECTIVE OF FUTURE SATELLITE SENSORS - A CASE STUDY IN ITALY Claudia Giardino, Mariano Bresciani, Erica Matta and Vittorio E Brando	HIERARCHICAL SPARSE REPRESENTATION FOR DICTIONARY-BASED CLASSIFICATION OF HYPER-SPECTRAL IMAGES Diego Marcos Gonzalez, Frank de Morsier, Giona Matasci, Devis Tuia and Jean-Philippe Thiran

12:10 Lunch 13:20	

13:20 *Oral until* *15:00*	**Session fri-o-2-a** **Advanced signal and image processing techniques** Session chairs : Lori Bruce, *Mississippi State University, USA* José Bioucas Dias, *Technical University of Lisbon, Portugal*	**Session fri-o-2-b** **A diversity of applications** Session chairs : Qian Wu, *University of Science and Technology of China, China* Lammert Kooistra, *Wageningen University, Netherlands*
13:20	COMPARATIVE STUDY ON MORPHOLOGICAL PRINCIPAL COMPONENT ANALYSIS OF HYPER-SPECTRAL IMAGES Gianni Franchi and Jesus Angulo	HYPERSPECTRAL CHARACTERIZATION OF MA-RINE PARTICLES BASED ON MIE-LORENTZ AND T-MATRIX CODES AND A GENETIC ALGORITHM Albert-Miquel Sánchez, Eloy Zafra and Jaume Piera
13:40	A COMPARATIVE ANALYSIS OF COVARIANCE MATRIX ESTIMATION. Santiago Velasco-Forero, Marcus Chen, Goh Alvina and Sze Kim Pam	OBJECT-BASED RANDOM FOREST CLASSIFICA-TION FOR MAPPING FLOODPLAIN VEGETATION STRUCTURE FROM NATION-WIDE CIR AND LI-DAR DATASETS Lammert Kooistra, Ernst Kuilder and Sander Mucher
14:00	ENHANCING PURE-PIXEL IDENTIFICATION PER-FORMANCE VIA PRECONDITIONING Nicolas Gillis and Wing-Kin Ma	A NON-LINEAR OPTIMAL ESTIMATOR FOR PLUME CONCENTRATION RETRIEVAL, USING AIRBORNE HYPERSPECTRAL MEASUREMENT Idoughi Ramzi, Foucher Pierre-Yves, Briottet Xavier, Pouti-er Laurent, Marc-André Gagnon and Véronique Achard
14:20	SUPERVISED HYPERSPECTRAL IMAGE SEGMEN-TATION: A CONVEX FORMULATION USING HID-DEN FIELDS Filipe Condessa, Jose Bioucas-Dias and Jelena Kovacevic	GLOBAL SENSITIVITY ANALYSIS OF WATER VAPOUR AND VISIBILITY FOR ATMOSPHERIC CORRECTION Nitin Bhatia, Jan Biesemans, Valentyn Tolpekin, Ils Reu-sen, Sindy Sterckx and Alfred Stein

| 14:40 | SPATIALLY AWARE SUPERVISED NONLINEAR DIMENSIONALITY REDUCTION FOR HYPERSPECTRAL DATA
Michele Volpi and Devis Tuia | CROSS VALIDATING HYPERSPECTRAL WITH ULTRASOUND-BASED SKIN THICKNESS ESTIMATION
Saurabh Vyas, Jon Meyerle and Philippe Burlina |
| 15:00 | | |

15:00 15:30	Coffee

15:30 *Oral until* *17:10*	**Session fri-o-3-a** **Spectral unmixing (3)** Session chairs : Jenny Du, *Mississippi State University, USA* Hichem Frigui, *University of Louisville, USA*	**Session fri-o-3-b** **Simulators and models** Session chairs : Yasemin Yardımcı Cetin, *Middle East Technical University Informatics Institute Ankara, Turkey* Xavier Briottet, *ONERA, Toulouse, France*
15:30	A NEW EXTENDED LINEAR MIXING MODEL TO ADDRESS SPECTRAL VARIABILITY Miguel A. Veganzones, Drumetz Lucas, Guillaume Tochon, Mauro Dalla Mura, Antonio Plaza, Jose M. Bioucas-Dias and Jocelyn Chanussot	AT-SENSOR RADIANCE SIMULATION FOR AIRBORNE IMAGING SPECTROSCOPY Fabian D. Schneider, Tiangang Yin, Jean-Philippe Gastellu-Etchegorry, Felix Morsdorf and Michael E. Schaepman
15:50	END-MEMBER EXTRACTION USING CONE NON-NEGATIVITY CONSTRAINTS John Gruninger and Hoang Dothe	REFLECTANCE RETRIEVAL IN THE PRESENCE OF OPTICALLY OPAQUE BROKEN CLOUDS Robert Sundberg and Steven Richtsmeier
16:10	INTEGRATING MULTIPLE NONLINEAR ESTIMATORS INTO HYPERSPECTRAL UNMIXING Andrea Marinoni, Javier Plaza, Antonio Plaza and Paolo Gamba	SYNTHETIC SCENE SIMULATOR FOR HYPERSPECTRAL SPACEBORNE PASSIVE OPTICAL SENSORS. APPLICATION TO ESA'S FLEX/SENTINEL-3 TANDEM MISSION Juan P. Rivera, Neus Sabater, Carolina Tenjo, Jorge Vicent, Luis Alonso and José Moreno
16:30	NON-LINEAR HYPERSPECTRAL UNMIXING BY POLYTOPE DECOMPOSITION Andrea Marinoni and Paolo Gamba	LOW-COST COMPUTATIONALLY HYPERESPECTRAL SIMULATOR FOR HIGHLY DYNAMIC MARINE ENVIRONMENTS Eloy Zafra, Albert-Miquel Sanchez Delgado, Elena Torrecilla Ribalta and Jaime Piera Fernandez
16:50	AN INTEGRATED GRAPH CUTS SEGMENTATION AND PIECE-WISE CONVEX UNMIXING APPROACH FOR HYPERSPECTRAL IMAGING Pegah Massoudifar, Anand Rangarajan, Paul Gader and Alina Zare	A COMPARISON OF MCSCENE AND CAMEOSIM SIMULATIONS OF A REAL SCENE Wellesley Pereira and Steven Richtsmeier
17:10		

8. Plenary speakers

PLENARY 1 (Wednesday, 25, June, 8:30)

ALBEDO AND REFLECTANCE ANISOTROPY PRODUCTS FROM MODIS, VIIRS, AND LANDSAT

Crystal Schaaf, *School for the Environment, University of Massachusetts Boston (MA), USA*

Abstract:

Surface albedo (and reflectance anisotropy) is recognized as an Essential Climate Variable (ECV) by the international Global Climate Observing System (GCOS), the Global Terrestrial Observing System (GTOS), the Committee on Earth Observing Satellites (CEOS) and the World Meteorological Organization (WMO). As such, global satellite-derived products are in demand by climate, biogeochemical, hydrological, and numerical weather prediction modelers. In order to describe the surface anisotropy, the MODerate Resolution Imaging Spectroradiometer (MODIS) Albedo product retrieves a Bidirectional Reflectance Distribution Function (BRDF) from high quality, clear sky, multi-date, multi-spectral surface reflectances.

This global product, which is available from the year 2000, uses data from both the Terra and Aqua platforms to provide intrinsic measures of surface albedo, BRDF, and Nadir BRDF-Adjusted Reflectance (NBAR) at a 500m resolution on a daily timestep. Albedo, BRDF and NBAR products from 2012 onward can also be prepared from the spectrally similar Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi National Polar-orbiting Partnership (NPP). And further efforts are underway to couple the spectacular near-nadir imagery from Landsat 8, launched in Feb 2013, with MODIS and VIIRS BRDF information to provide 30m measures of albedo. An overview of these products and the ongoing efforts to evaluate them under the auspices of the CEOS/Working Group on Cal/Val (WGCV)/Land Product Validation (LPV) program will be presented.

Biography :

Crystal Barker Schaaf is working on the development and use of operational products from NASA's MODerate Resolution Imaging Spectrometer (MODIS) to monitor the Earth's environments from the Terra and Aqua polar orbiting space platforms. She is a science team member for both MODIS and the VIIRS (Visible Infrared Imaging Radiometer Suite) sensor on board the Suomi National Polar-orbiting Partnership platform (NPP is the precursor to the next generation of national meteorological satellites).

Prof. Schaaf's current interests include modeling reflectance anisotropy and albedo and using remote sensing data to reconstruct and monitor the reflectance characteristics of various land surfaces, including vegetation phenology and land surface change. More recently she has also been involved in the development and use of ground-based Lidar systems to characterize biomass and vegetation structure.

http://www.umb.edu/academics/csm/faculty_staff/crystal_schaaf

PLENARY 2 (Thursday, 26, June, 8:00)

BY DEFINITION UNDEFINED: ADVENTURES IN ANOMALY (AND ANOMALOUS CHANGE) DETECTION

James Theiler, *Los Alamos National Laboratory, Los Alamos (NM), USA*

Abstract:

This talk will survey anomaly detection and anomalous change detection algorithms for hyperspectral imagery, with an emphasis on characterizing background clutter. An anomaly, roughly speaking, is a deviation from what is typical or expected. In general, the detection of anomalies is complicated by the fact that anomalies are rare and that anomalies tend to defy any kind of precise specification. One might even say of anomalies that they are by definition undefined.

Despite this lack of specification, or perhaps because of it, a bewildering variety of algorithms have been proposed, developed, and implemented for the purpose of detecting anomalies. And, like anomalies themselves, the full range of these algorithms tends to defy any kind of regular taxonomy. But one emphasis that at least most of these algorithms share, explicitly or implicitly, is the characterization of the non-anomalous background.

If anomalies are deviations from what is normal, then a sensible first step is to figure out what's normal. So the bulk of this talk will be on modeling background clutter. For hyperspectral imagery this is a challenge because there are so many channels (the hyperspectral part) and because there is so much spatial structure (the imagery part). Even when the background is modeled as a single global Gaussian distribution, there is still the challenge of estimating mean and covariance. But real hyperspectral imagery has much more structure than that, and that structure translates into opportunity: the more structure there is in the background that can be modeled, the more effectively targets and anomalies can be distinguished from that background. A wide range of models have been proposed for characterizing hyperspectral clutter: global and local models, Gaussian and non-Gaussian models, full-rank and subspace models, parametric and nonparametric models. In discussing how these models relate to each other, an important theme will be characterizing the quality of a model in the absence of ground truth.

Biography :

James Theiler received a Ph.D. in physics from Caltech in 1987, and subsequently held appointments at UCSD, MIT Lincoln Laboratory, Los Alamos National Laboratory, and the Santa Fe Institute. He joined the technical staff at Los Alamos in 1994, and was named a Laboratory Fellow in 2005. His professional interests include statistical modeling, machine learning, image processing, and remote sensing.

http://public.lanl.gov/jt/

PLENARY 3 (Friday, 27, June, 8:00)

RECENT ADVANCES IN DATA COMPRESSION OF REMOTE SENSED HYPERSPECTRAL IMAGES

Prof. Raffaele Vitulli, *On-Board Payload Data Processing Section, European Space Agency, ESTEC, The Netherlands*

Abstract:

Image compression is becoming more and more important, as new multispectral and hyperspectral instruments are going to generate very high data rates due to the increased spatial and spectral resolutions. Transmitting all the acquired data to the ground segment is becoming a serious bottleneck, and compression techniques are a feasible solution to this problem. Whenever lossless compression is not able to provide a sufficient degree of data volume reduction to meet the bandwidth requirements of the downlink channel, a lossy approach is then the only possible solution. The CCSDS (Consultative Committee for Space Data Systems) Multispectral/Hyperspectral Working Group is working actively in this area in order to standardise algorithms for lossless and lossy compression of remote sensed images. In this talk, the recent advances in this field and the work performed in the CCSDS Working Group will be described. Experimental results will be presented as well, employing the CCSDS reference dataset for multispectral and hyperspectral image compression. ESA activities in the field of data compression, future scenarios and evolutions will also be addressed.

Biography :

Raffaele Vitulli received his M.S degree in Electronic Engineering in 1991, from Politecnico of Bari, Italy. He is currently staff member of the European Space Agency, and he is working for the On-Board Payload Data Processing Section, located in ESTEC (NL). He is acting as main contact point for all the activities related to Satellite Data Compression in the Agency, and his interests are in the field of Synthetic Aperture Radar, image and data compression, data handling, data processing, GPU and HW acceleration.

Recently he is also involved in the field of GNSS reflectometry, for the development of the Correlator and Control Unit for the PARIS concept. He is participating to the work of the Consultative Committee for Space Data System, as a member of the Multispectral/Hyperspectral Data Compression Working Group. The mandate of the Working Group is the production of standards in the field of satellite data compression. He contributed to publish the CCSDS 122 Image Data Compression standard and the CCSDS 123 Hyperspectral Lossless Compression standard.

He is Chairman and Organizer of the On-Board Payload Data Compression Workshop. The Workshop aims to bring together all the professionals working in the field of satellite data compression, to share the latest ideas and developments and to pave the way for the future technological challenges.

9. SESSION MENU

10. Contents

DIMENSIONALITY REDUCTION VIA REGRESSION ON HYPERSPECTRAL INFRARED SOUNDING DATA

Valero Laparra, Jesús Malo and Gustavo Camps-Valls, *Image Processing Laboratory (IPL), Universitat de València, Spain*

Abstract : This paper introduces a new method for dimensionality reduction via regression (DRR). The method generalizes Principal Component Analysis (PCA) in such a way that reduces the variance of the PCA scores. In order to do so, DRR relies on a deflationary process in which a non-linear regression reduces the redundancy between the PC scores. Unlike other nonlinear dimensionality reduction methods, DRR is easy to apply, it has out-of-sample extension, it is invertible, and the learned transformation is volume-preserving. These properties make the method useful for a wide range of applications, especially in very high dimensional data in general, and for hyperspectral image processing in particular. We illustrate the performance of the algorithm in reducing the dimensionality of IASI hyperspectral image sounding data. We compare DRR with related and invertible methods such as linear PCA and Principal Polynomial Analysis (PPA) in terms of reconstruction error, and expressive power of the extracted features to estimate atmospheric variables.

SEMI-SUPERVISED MANIFOLD LEARNING OF TIME-SERIES HYPERSPECTRAL FOREST IMAGES

Kuniaki Uto, *Tokyo Institute of Technology, Japan*

Abstract : The accuracy of regression based on hyperspectral data is degraded by a restricted number of labeled data and the curse of dimensionality inherent in the high-dimensional feature space. In this paper, we propose two types of semi-supervised manifold learning methods for regression by a combination of supervised learning based on a small number of labeled data and unsupervised learning based on abundant unlabeled feature data. The regression and nonlinear manifold learning are realized by a kernelization of generalized eigenvalue problems. The proposed methods are applied to synthetic manifold learning problems and time-series hyperspectral leaf-scale images of oak trees.

MANIFOLD REPRESENTATIONS OF SINGLE AND MULTIPLE MATERIAL CLASSES IN HIGH RESOLUTION HSI

Amanda K. Ziemann and David W. Messinger, *Chester F. Carlson Center for Imaging Science Rochester Institute of Technology, USA*

Abstract : Hyperspectral image data are traditionally analyzed using statistical models. However, as the spatial and spectral resolutions of the images improve as a result of advances in sensor technology, the data no longer maintain a Gaussian distribution; this is due to increased material diversity in the scene, i.e., clutter. This causes many statistical assumptions about the data – and subsequently, the algorithms based on those assumptions – to be flawed. In high dimensional data, manifold learning seeks to recover the embedded non-linear, lower-dimensional manifold upon which the data inherently lie. By recovering the lower-dimensional manifold, intrinsic structures and relationships within the data may be identified and exploited. Here, we consider the impacts of increasing material spectral clutter on the low dimensional manifolds recovered from high spatial resolution hyperspectral scenes for both single and multiple material classes. The Locally Linear Embedding manifold learning method is modified to use an adaptive graph, and is used to extract low dimensional manifolds from hyperspectral image data collected during the SHARE 2012 campaign.

MODULARITY VERSUS LAPLACIAN EIGENMAPS FOR DIMENSIONALITY REDUCTION AND CLASSIFICATION OF HYPERSPECTRAL IMAGERY

Nathan D. Cahill, D. Benjamin Start and Selene E. Chew,
Center for Applied and Computational Mathematics, School of Mathematical Sciences Rochester Institute of Technology, Rochester, USA

Abstract : Since hyperspectral imagery typically contains information from hundreds of spectral bands, dimensionality reduction is often used as a pre-processing step in algorithms for classifying pixels/regions. A popular algorithm for dimensionality reduction is Laplacian Eigenmaps (LE), which uses a graph- based model of the hyperspectral data and constructs a basis for the reduced-dimensional space from a few generalized eigenvectors of the graph Laplacian matrix. A related matrix that can be constructed from the same graph-based model is the modularity matrix, which has been used in complex network problems to detect "community" structures in graphs. In this paper, we use the modularity matrix to construct a basis for dimensionality reduction, yielding an algorithm called Modularity Eigenmaps (ME). We then assess the performance of ME versus LE on the subsequent classification of publicly available hyperspectral imagery with known ground truth labels, illustrating a tradeoff between accuracy/precision measures and computational speed.

IMPROVING HYPERSPECTRAL DATA CLASSIFICATION OF SATELLITE IMAGERY BY USING A SPARSE BASED NEW MODEL WITH LEARNING DICTIONARY

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Abstract : Statistic classification of hyperspectral data is a great challenge because of its large number of spectral channels, especially when the labeled training samples are relatively few. Most of the classification methods require using a large number of training samples, but in remote sensing situations, identifying and labeling samples are extremely difficult and expensive. A sparse representation classification approach (SR) has proven that it can perform quite well with only a few labeled samples. In this paper we propose an improved classification model by using dictionary learning of sparse representation (DLSR). We tested the proposed approach with 75%, 50% 10% and 5% amount of training samples and compared the classification accuracy of hyperspectral data with the state-of-the-art SVM, HSVM and the classical sparse representation methods. We performed experiments using real hyperspectral dataset of the NASA AVIRIS spectrometer acquired data over the KSC, Florida on March 23, 1996. Results show that our improved approach offers more classification accuracy and more efficiency than the three above methods.

KERNELIZED SPARSE GRAPH-EMBEDDED DIMENSIONALITY REDUCTION FOR HYPERSPECTRAL IMAGE CLASSIFICATION

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Abstract : Visible and near infrared optical constants are required to quantitatively determining mineral abundances from remote sensing data. Preliminary optical constants of a synthetic potassium jarosite, an important sulfate mineral on both Earth and Mars, are determined using a new MatLab encoded minimization routine based on Hapke's treatment of radiative transfer theory. The steps for determining these optical constants are delineated theoretically and programmatically in an attempt to assist the expansion of the library of optical data.

II.   Session wed-p-1-b : Planetary exploration

THE SPECTRAL IMAGING (SPIM) FACILITY IN SUPPORT OF HYPERSPECTRAL OBSERVATIONS OF SOLAR SYSTEM BODIES: PRELIMINARY CHARACTERIZATION

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Abstract : The SPectral IMaging (SPIM) facility is a laboratory imaging VIS-IR spectrometer, operative in the INAF/IAPS laboratory in Rome. The facility is used as a laboratory support for the DAWN mission (to the asteroids Vesta and Ceres) and for the 2018 ExoMars mission (to Mars). This imaging spectrometer, which is the spare of the VIR spectrometer on-board the DAWN spacecraft, is operative in the 0.22–5.05 μm spectral range. It is characterized by high spatial (38 μm) and spectral (2 nm in the VIS channel, 12 nm in the IR channel) resolution. The high spectral performances, combined with the high spatial resolution imaging capability of this instrument allow a very accurate laboratory investigation and characterization of numerous types of mineral and rock samples, both in powder and in slab form, and also of extra-terrestrial samples, down to a few tens of micrometers in size.

SPECTROSCOPIC CLASSIFICATION OF ICY SATELLITES OF SATURN - IDENTIFICATION OF TERRAIN UNITS ON DIONE AND RHEA

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Abstract : The surfaces of the major Saturnian moons are composed primarily by water ice, with a minor percentage of non-water ice materials whose composition is still debated and whose distribution is not uniform across the satellites' surface. The differences in contaminants' composition, water ice abundance and regolith grain size are revealed by variations in spectral profiles, which may be due both to exogenic and endogenic processes. One way to discern between them and to understand how each satellite evolved is to investigate the distribution of contaminants and water ice on the moons' surfaces. Here we present an automatic classification scheme for the icy surfaces of the Saturnian satellites Dione and Rhea based on the analysis of variations in their infrared spectra and the research of a correlation between the surface morphology and the variations in grain size, water ice abundance and contaminants distribution.

IRON MINERALOGY OF THE MARTIAN SURFACE WITH OMEGA SPECTROMETER

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Abstract : Goal of this paper is mapping the 1 μm from the OMEGA spectra in order to study the Martian iron mineralogy. This study is based on the results of Carrozzo et al.. Goal of this paper is to map the 1 μm absorption signature in OMEGA spectra, in order to study the Martian mineralogy. In particular, we search for new spectral indices around the 1-μm absorption and the correlations between them. Due to the misalignment of the OMEGA VNIR and SWIR channels, spectral indices related to the 1-μm absorption have been usually computed by using the left or right shoulders of the absorption, without considering he band as a whole. In this work we report on a method we used to co-register the VNIR and SWIR channels of the OMEGA instrument to properly compute the 1 μm band area, search for new spectral indices and possible correlations between them.

THE ADAPTED MODIFIED GAUSSIAN MODEL: A TOOL TO CHARACTERIZE THE COMPOSITION OF MAGMATIC ROCKS ON TERRESTRIAL 'PLANETS'

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Abstract : Here we present an adapted version of the Modified Gaussian Model (MGM), a tool developed to detect and characterize both simple and complex mineralogies in magmatic rocks, and we review the results we obtained over the last years on four different planetary bodies.

We first describe the working principle of the adapted MGM technique, with the differences compared to the original version, and the validation process using various laboratory and natural spectra. We then describe the results obtained on the Oman ophiolite (Earth), taken as a planetary spectral analog for magmatic terrains. We finally present spectroscopy-based mineralogical maps and some petrologic implications for key regions of Mars, the Moon and asteroid Vesta.

REVISITING THE PREPROCESSING PROCEDURES FOR ELEMENTAL CONCENTRATION ESTIMATION BASED ON CHEMCAM LIBS ON MARS ROVER

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Abstract : The ChemCam instrument package on the Mars rover, "Curiosity", is the first planetary instrument that employs laser- induced breakdown spectroscopy (LIBS) to determine the compositions of geological samples on another planet. However, the sampled spectra are often corrupted by various sources of interferences that would largely affect the accuracy of elemental concentration estimation. Therefore, pre- processing is essential to improve the quality of the spectra. This paper revisits the conventional preprocessing procedures where denoising is followed by continuum removal. Through comprehensive performance evaluation, we propose a new procedure that would lead to much improved estimation accuracy. First, we show that the denoising process should be conducted *after* continuum removal. Second, a state-of-the- art image denoising technique is adapted to the 1D domain to boost the performance of denoising. Third, an additional preprocessing step is added that effectively select the most informative spectral bands. All these approaches have largely improved the accuracy of concentration estimation with band selection being the most effective.

DATA REDUCTION OF CRISM DATA TO HIGHLIGHT ALTERATION MINERALS

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Abstract : CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) hyperspectral data have a spatial resolution ranging from 12 to 36m/pixel allowing the high resolution mapping of minerals at the surface of Mars. However, the signal-to-noise ratio (SNR) makes challenging the discrimination of minerals spectrally close such as certain phyllosilicates and carbonates. Here, we discuss different processing of data reduction used to improve the signal-to-noise ratio and to highlight the alteration minerals at the surface of Mars and their limit. We show that our tool allows to understand trends in global mineralogy present in hyperspectral data cube.

MINERALOGICAL CHARACTERIZATION USING NEURAL NETWORKS: COMPOSITION OF MAFIC MINERALS IN MARTIAN METEORITES FROM THEIR SPECTRA

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Abstract : In this study, we test the ability of neural networks to determine the composition of magmatic rocks from their laboratory spectra. We first describe the structure and behaviour of the multilayer perceptron that we implement and train for quantitative characterization. For that purpose, reference laboratory spectra of mafic minerals from both natural and synthetic samples are used. As their composition in terms of the three mafic minerals, olivine (OL), orthopyroxene (OPX) and clinopyroxene (CPX) are known, those spectra are given as inputs during the learning phase of the neural network. In the analysis phase, we use the neural network to process spectra acquired on SNCs (Shergottites, Nakhlites, Chassignites) meteorite samples that are considered to be representative of Mars surface. The network outputs mineralogical compositions very quickly, performing only explicit operations. Our preliminary results show that neural networks are able to quantify mafic minerals, especially in the case of complex mixtures, with much improved computer efficiency and comparable accuracy compared to usual methods. This is very promising regarding future analysis of huge datasets.

III.   SESSION WED-P-C : A DIVERSITY OF APPLICATIONS

OPTICAL CLASSIFICATION OF OPTICALLY COMPLEX WATERS AROUND CHINA

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Abstract : For optically complex waters, the optical classification was suggested to be a good solution to improve the retrieval of biogeochemical products, and more appropriate for large-scale complex waters than classical regional waters. Around China there are turbid lakes, complex rivers and highly contrasted coastal regions, so the study provided an applicable classification strategy for characterizing the optical variability of the optically complex waters of Chaohu Lake, Three Gorges, Dianchi Lake, Taihu Lake, and Huanghe estuary waters. An improved K-means algorithm based on spectral angle distance was used to cluster an in situ data set of remote sensing reflectance spectra (447 stations) into five optical classes. The combination of the characteristic wavelengths, a set of features of spectra to distinguish the waters into five optical types was provided. This work provides an effective set of features of spectra to divide the optically complex waters around China and the potential of class-specific inversion methods for deriving bio-optical products by the satellite images in optically complex waters.

ASSESSMENT OF OPTIMAL FLAT FIELD IN URBAN ENVIRONMENT FOR EO1- HYPERION SCENE

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Abstract : In this paper, we suggest optimal flat fields for calibration of hyperspectral data (EO1) - predominantly of urban nature. We compare the suitability of various flat field candidates by performing vegetation, soil, and impervious surface (VIS) classification. Flat Field methods provide 90% average overall accuracy (with best 100% and 77% worst accuracies) over number of conducted experiments. Flat fields show marginal improvement over IAR. Most common urban land covers such as play grounds, concrete parking lots, and especially industrial roof covers have been found adequate for the image calibration.

INVERSING REFLECTANCE OF HIGHER RESOLUTION FROM HYPERSPECTRAL RADIANCE DATA BASED ON SPECTRAL SUPER-RESOLUTION

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Abstract : To promote cross-calibration or information extraction involving hyperspectral reflectance data from different sources, a method for restoring reflectance of a higher spectral resolution from hyperspectral radiance data is proposed. It involves three steps: spectral super-resolution of radiance data, transformation to the higher resolution of interest, and radiative-transfer-model-based atmospheric correction. The spectral resolution of the super-resolved radiance and the spectral response model of the restored reflectance were analyzed. The restored reflectance matches the library spectrum better than the directly inversed and the interpolated reflectance spectra in the validation experiment based on HyMap data and USGS spectral library. This method is theoretically applicable to get reflectance of a relative lower spectral resolution as well.

ON-LINE DETECTION OF OIL ON STEEL COILS AND THICKNESS MEASUREMENT USING HYPERSPECTRAL CAMERA

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Abstract : The control of thickness homogeneity is a major concern in steel industry for quality issues. In the case of oil, an inhomogeneous coating on whole strip surface can create oxidation and lubrication trouble during coiling. Nowadays, different commercial solutions exist on the market (Light induced fluorescence, infrared gauges) but mainly for punctual measurements. The ability of new devices to characterize thin oil layers have been studied in this paper. This poster is focused on the study of spatial homogeneity for oil layer detection on steel surface for potential new online solution. The results presented in this paper confirm the interest of devices working in 3-5 μm spectral range to potentially answer to industrial needs.

THE HAVEMANN-TAYLOR FAST RADIATIVE TRANSFER CODE: A LINE-BY-LINE SENSOR INDEPENDENT RADIATIVE TRANSFER CODE.

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Abstract : The Havemann-Taylor Fast Radiative Transfer Code (HT- FRTC) is based on Principal Components (PCs) and allows fast and exact radiance and/or transmittance calculations. It is ideally suited for the simulation of hyperspectral sensors with hundreds or thousands of channels. The HT-FRTC can simulate a full instrument spectrum for any atmosphere and surface within a few milliseconds. It works for satellite- based, airborne and ground-based sensors. The code has been applied in any part of the spectrum from the short-wave to the long-wave (i.e. infrared plus microwave). It includes the solar and the lunar source and can account for the spherical Earth. The HT-FRTC has been incorporated into a one- dimensional variational (1D-Var) retrieval system that also works solely in PC space. This keeps the dimensions of the matrices involved small. The solution of the full non-linear problem is achieved by an iterative Levenberg-Marquardt minimization procedure. The retrieval state vector includes the vertical profiles of atmospheric temperature, water vapour and ozone, and possibly other trace gases as well as the surface temperature and surface emissivity / reflectivity (the latter being represented by a set of PCs). For a scattering atmosphere, cloud parameters and aerosol parameters have been added to the state vector. The cloud part of the state vector for cirrus cloud includes cloud-top pressure, ice water content, cloud fraction and cloud geometrical thickness. For water cloud there is also an effective droplet size.

A NEURAL NETWORK APPROACH FOR SIMULTANEOUS RETRIEVAL OF VOLCANIC SO_2 AND PLUME HEIGHT USING HYPERSPECTRAL MEASUREMENTS.

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Abstract : In this study two neural networks were implemented in order to emulate a retrieval model and to estimate the sulphur dioxide (SO_2) columnar content and plume height from volcanic eruption. ANNs were trained using all IASI channels in TIR as inputs, and the corresponding values of SO_2 content and height of plume obtained using the Oxford SO_2 retrievals as target outputs. The retrieval is demonstrated for the eruption of the Eyjafjallajökull volcano (Iceland) occured in 2010 and to three IASI images of the Grímsvötn volcanic eruption that occurred in May 2011, in order to evaluate the networks for a different eruption. The results of validation, both for Eyjafjallajökull and Grímsvötn independent datasets, provided RMSE values between neural network outputs and targets lower than 20 DU for SO_2 total column and 200 mb for plume height, therefore demonstrating the feasibility to estimate SO_2 values using a neural network approach, and its importance in near real time monitoring activities, owing to its fast application. Concerning the validation carried out with neural networks on images from the Grímsvötn eruption, the RMSE of the outputs remained lower than the Standard Deviation (STD) of targets, and the neural network underestimated retrieval only where target outputs showed different statistics than those used during the training phase.

MULTI-ANGLE RECONSTRUCTION OF ENERGY DISPERSIVE X-RAY DIFFRACTION SPECTRA

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Abstract : X-ray diffraction is a powerful technique to provide information on the molecular structure of samples. Energy dispersive X-ray diffraction (EDXRD) spectra are classically measured at one single fixed scattering angle using a polychromatic X- ray source and a spectroscopic detector. In order to remove system blurring and restore material proper information, inversion of the EDXRD spectra is required. This paper proposes to combine EDXRD spectra at different scattering angles to improve reconstruction results. To quantify the improvements, detective quantum efficiency (DQE) calculations are used, which allow to compare the performance of mono- and multi-angle systems, are used. We present a reconstruction method based on multi-angle EDXRD spectra. The algorithm was tested on simulated salt ($NaCl$) spectra. Finally, advantages of multi-angle over mono-angle spectra are discussed.

SORTING OF CROP RESIDUES AND FOSSIL BONES FROM SOIL BY NIR HYPERSPECTRAL IMAGING

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Abstract : The scope of this paper is to present two applications using Near Infrared Hyperspectral Imaging (NIR-HSI) combined with chemometrics to sort constituents of soil and assess their qualitative parameters. In the first application, the feasibility of using NIR-HSI to sort crop residues such as roots and straws in soil has been demonstrated. In the second application the potential of such instrumentation and method to assess the level of collagen preservation in fossil bones has been proved.

OPTIMIZING THE RANGE OF ATMOSPHERIC CONDITION PARAMETERS TO AVOID OVER AND UNDER-ESTIMATION OF UNCERTAINTY

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Abstract : The physical basis of rock identification is spectral feature. In order to remove the rock spectrum noise, the discrete wavelet transform (DWT) was used to deal with the spectra of 13 rock samples of metamorphic rocks collected in mineral reservation region. The Biorthogonal 4.4 wavelet of the scale of decomposition was selected was selected as the mother wavelet to smooth the spectra and highlight features of absorption. By correspondence analyzing (CA) spectra normalized by DWT, we find that the rock spectra were classified into three clusters through analyzing two-dimensional image of CA. The first cluster has higher reflectivity than other two clusters, because the compound of light-colored minerals, the key to high reflectivity, of the first cluster is greater than that that of other two clusters. The second cluster has obvious iron alteration. The third cluster has obvious clay alteration. The results of classification, verified by cluster analysis, are better corresponding. The paper provides a physical basis for Metamorphic rocks classification and identification by using remote sensing technology.

MINERALOGY MAPPING OF THE RAMON CRATER IN ISRAEL USING HYPERSPECTRAL REMOTE SENSING DAY AND NIGHT LWIR IMAGES

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Abstract : The hyperspectral remote sensing in the thermal infrared region is being acknowledged as an innovative tool for Earth environmental studies and is complimentary to the optical range. The current study focuses on surface mineral content mapping using day and night airborne data in the LWIR spectral range over a well known mineralogical site in Israel. The data was acquired with the AisaOWL hyperspectral sensor over Ramon crater in the Negev desert in southern Israel. The identification of major minerals was enabled by locating similarities in day and night at-sensor radiance spectra. The analysis resulted with the classification of quartz, carbonates, gypsum, kaolinite and other silicates according to their observed spectral features in both day and night data.

TARGET DETECTION OF MINE-RELATED FLOODED AREAS USING AISA-EAGLE DATA

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Abstract : The present research is developed in the frame of the R&D project GMES4Mining, which aims to support particular tasks within the different phases of a mining life cycle [1]. During the exploitation and after the closure of the mine, environmental and civil impacts may happen, due to changes in the compacting properties of the soil related to mining activities. In this paper, we focus in the emergence of flooded areas, due to a subsidence of the ground surface. Above-ground vegetation is affected by changes in groundwater's dynamics; at first trees suffer defoliation and senescence, and after some time, they die. Several methods have been tested, to detect changes in spectral response of forests in a mine area, which are related to imminent flooding. ENVI's Target Detection Tool has been used to estimate the reflectance proportion at pixel level of four targets of interest in AISA-Eagle's data, which are present in flooded areas: water, dead trunks, senescent trees and green stands within water. Five target detection's methods have been tested: Constrained Energy Minimization (CEM), Adaptative Coherence Estimator (ACE), Spectral Angle Mapper (SAM), Target-Constrained Interference- Minimized Filter (TCIMF) and Mixture Tuned Matched Filtering (MTMF).

POSSIBILITIES FOR THE STUDY OF THE NLTE EFFECT ON ATMOSPHERIC CO2 SPECTRAL SIGNATURES INDUCED BY A BLUE JET USING AN INFRARED SPECTRO- IMAGER EMBEDDED IN A STRATOSPHERIC BALLOON.

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F. Duruisseau, N. Huret, *Laboratoire de Physique et Chimie de l'Environnement, CNRS and Université d'Orléans, Orléans, France*

Abstract : HALESIS (High Altitude Luminous Events Studied by Infrared Spectro-imagery) is an innovative project based on hyperspectral imagery. The purpose of this experience is to measure the atmospheric perturbation in the minutes following the occurrence of Transient Luminous Events (TLEs) from a stratospheric balloon in the altitude range of 20 to 40 km. The first part of the study has been dedicated to establish the project feasibility. To do that, we have simulated spectral perturbations induced by an isolated blue jet. Simulations have been performed using the line by line radiative transfer model LBLRM taking into account the Non Local Thermodynamic Equilibrium. The case of the estimation of the CO_2 infrared signature that could be the result of a single blue jet occurrence is presented.

Then, the estimated spectral signatures have been confronted with the technical capabilities of different kinds of hyperspectral imagers. The study has demonstrated the feasibility of the project, but it has also pointed to the challenges to build perfectly adapted instrument.

LEMAN-BAIKAL: REMOTE SENSING OF LAKES USING AN ULTRALIGHT PLANE

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D. Bouffard and N. Pasche, *École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*
S. Chalov, *Lomonosov Moscow State University, Moscow, Russian Federation*
U. Lemmin and B. Merminod, *École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*
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Abstract : The Leman-Baikal project constitutes an international Swiss- Russian collaborative research initiative in the field of physical limnology. The three-year framework involves the development and deployment of a novel multispectral and hyperspectral remote sensing platform optimised for the sensing of land and water surfaces from an ultralight aircraft. In this paper we discuss the developed remote sensing methodology and the initial obtained results.

IV.   Session wed-o-1-a : Imaging spectroscopy for UAVs : innovation of sensors and applications

DEVELOPMENT OF LIGHTWEIGHT HYPERSPECTRAL IMAGING SYSTEM FOR UAV OBSERVATION

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Abstract : To acquire accurate, real-time hyperspectral images with high spatial resolution, we develop two types of low-cost, lightweight Whisk broom hyperspectral sensors that can be loaded onto lightweight unmanned autonomous vehicle (UAV) platforms. A system is composed of two Mini- Spectrometers, a polygon mirror, references for sensor calibration, a GPS sensor, a data logger and a power supply. The acquisition of images with high spatial resolution is realized by a ground scanning along a direction perpendicular to the flight direction based on the polygon mirror. To cope with the unstable illumination condition caused by the low-altitude observation, skylight radiation and dark current are acquired in real-time by the scanning structure. Another system is composed of 2D optical fiber array connected to eight Mini- Spectrometers and a telephoto lens, a convex lens, a micro mirror, a GPS sensor, a data logger and a power supply. The acquisition of images is realized by a ground scanning based on the rotation of the micro mirror.

LINEAR VARIABLE FILTERS – A CAMERA SYSTEM REQUIREMENT ANALYSIS FOR HYPERSPECTRAL IMAGING SENSORS ONBOARD SMALL REMOTELY PILOTED AIRCRAFT SYSTEMS

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Abstract : Improving the spectral detail of earth observation imaging from Remotely Piloted Aircraft Systems (RPAS) can greatly expand its potential for use in vegetation monitoring and specifically in precision agriculture. Spatially variable interference filters which can be placed very close to the image sensor offer an excellent opportunity for reducing the size, mass and complexity of hyperspectral imagers, allowing them to be mounted onboard small RPAS. Recent advances in filter deposition techniques allow to directly deposit interference filters on an image sensor. The monolithic integration of optical hyperspectral filters on top of a standard CMOS image sensor has been demonstrated by IMEC. Compared to the more conventional deposition of filters onto an external glass substrate, this new approach offers advantages in terms of cost, alignment accuracy, straylight , etc..

A hyperspectral camera prototype compatible with small RPAS has been developed by VITO to demonstrate the potential of LVF-based compact spectral camera's. Whereas application of the filter technology offers major advantages for RPAS systems, it still faces some important challenges. The prototype system specifications need to fit a fixed wing RPAS platform that is able to cover several km2 in a single flight with hyperspectral geo-information. It remains challenging to make a sufficiently compact camera system, achieve precise spectral band registration, handle the amount of data to be processed and cope with limited integration times possible during acquisition.

COMBINING HYPERSPECTRAL UAV AND MULTISPECTRAL FORMOSAT-2 IMAGERY FOR PRECISION AGRICULTURE APPLICATIONS

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Abstract : Remote sensing is a key tool for precision agriculture applications as it is capable of capturing spatial and temporal variations in crop status. However, satellites often have an inadequate spatial resolution for precision agriculture applications. High-resolution Unmanned Aerial Vehicles (UAV) imagery can be obtained at flexible dates, but operational costs may limit the collection frequency. The current study utilizes data fusion to create a dataset which benefits from the temporal resolution of Formosat-2 imagery and the spatial resolution of UAV imagery with the purpose of monitoring crop growth in a potato field. The correlation of the Weighted Difference Vegetation Index (WDVI) from fused imagery to measured crop indicators at field level and added value of the enhanced spatial and temporal resolution are discussed. The results of the STARFM method were restrained by the requirement of same-day base imagery. However, the unmixing-based method provided a high correlation to the field data and accurately captured the WDVI temporal variation at field level (r=0.969).

HIGH SPATIAL AND SPECTRAL REMOTE SENSING FOR DETAILED MAPPING OF POTATO PLANT PARAMETERS

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E. Honkavaara,   *Finnish Geodetic Institute, Finland*
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Abstract : This preliminary study shows the potential of highly flexible drones and hyperspectral technology to make detailed chlorophyll maps of an experimental potato field. A novel, innovative hyperspectral frame camera (Rikola Ltd) was employed to gather the spectral information (24 bands) at 5 cm spatial resolution. A first challenge therefore was to set- up a dedicated preprocessing chain for the images coming from this novel sensor. Coregistration of the images was successful resulting in an image displacement of only 1-2 pixels. The chlorophyll map created from the Rikola data corresponded well to the field measurements. R2 values of 0.70 were found for a linear relation between the averaged field chlorophyll measurements and the mean of the (R780- R550)/(R780+R550) index calculated for all vegetated Rikola pixels within an experimental potato cultivar plot. These chlorophyll maps which are directly linked to the vegetation status of the crops can be used by the farmer for better management decision making.

UAV: A MULTIDISCIPLINARY TOOL TO ACCESS EXTREME ENVIROMENTS

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Adriano Mazzini, *University of Oslo*
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Abstract : In the recent years UAV have become an important tool for monitoring and sampling activities in a wide range of applications. Last December an UAV was used for the first time to survey the Lusi volcano (Indonesia). The aim was to take mud and gas samples, aerial photographs, videos and contact temperature measurements.

Two different prototypes of remote controlled gas containers were available; in particular one prototype is a real-time telemetry and gas sampling system that returns to the ground station sensors and positioning data and receives and executes commands for the gas sampling.

Another important application consists to equip the UA V   with   hyperspectral   cameras   and   develop appropriate electronics in order to permit the ground station to have also a preview of the hyperspectral images during the survey.

V.   Session wed-o-1-b : Analysis of hyperspectral imagery using spectral graph and manifold models

AN INTRODUCTION TO SPECTRAL GRAPH TECHNIQUES FOR THE ANALYSIS OF HYPERSPECTRAL IMAGE DATA

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Abstract : Two of the biggest challenges in analyzing HyperSpectral Image (HSI) data are that, first, the data is very high- dimensional, and secondly, by its very nature, HSI contains both spatial and spectral information. In order to make full use of this information, models and algorithms should incorporate both aspects of the data; unfortunately, this is a decidedly non-trivial problem. In recent years, spectral graph theory (including manifold learning) has proven to be a very successful technique for analyzing high-dimensional data sets. Given the highly abstract nature of graphs, many of these techniques are easily applied to HSI data; moreover, by carefully choosing how the graph is constructed, both the spatial and spectral nature of the data can be included in the model. In this note, we present a general background overview of spectral graph theory, with an emphasis on how it can be used to analyze HSI data (in particular, to perform nonlinear dimensionality reduction as well as segmentation and classification). We include examples from real-world data, and also point out some of the issues (such as computational complexity and storage requirements) that need to be addressed.

SPATIAL CONTEXT DRIVEN MANIFOLD LEARNING FOR HYPERSPECTRAL IMAGE

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D. Lunga, *Meraka Institute, Council for Scientific and Industrial Research, South Africa*
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Abstract : Manifold learning techniques have been demonstrated to be successful in representing spectral signatures in hyperspectral images, which consist of spectral features with very subtle differences and often spatially induced disjoint classes whose neighborhood relations are difficult to capture using traditional graph based embedding techniques. Robust parameter estimation is a challenge in traditional kernel functions that compute neighborhood graphs *e.g finding the optimal number of nearest neighbors*. We address these challenges by proposing spatial context driven manifold learning methods. Empirically, the study reveals that use of spatial contextual information has a bearing on the structure of the graph Laplacian that in turn links image pixel observations to their manifold spaces. Further experimental results demonstrate an improvement in the classification performance compared to traditional manifold learning methods.

DIMENSIONALITY REDUCTION OF HYPERSPECTRAL IMAGERY WITH SPARSE AND COLLABORATIVE GRAPHS

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Abstract : Hyperspectral image dimensionality reduction with graph-based approaches is considered. With available labeled samples, a graph can be formed with these samples by constructing an affinity matrix through their sparse or collaborative representations. In addition, sparse or collaborative representation can be done using within-class samples, resulting in block-sparse representation, although within each block the representation can be either sparse or non-sparse (collaborative). The experimental results show that the block-sparse plus within-block-collaborative representation can yield the best performance.

CLASSIFICATION OF HYPERSPECTRAL IMAGERY ON EMBEDDED GRASSMANNIANS

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Abstract : We propose an approach for capturing the signal variability in hyperspectral imagery using the framework of the Grassmann manifold. Labeled points from each class are sampled and used to form abstract points on the Grassmannian. The resulting points on the Grassmannian have representations as orthonormal matrices and as such do not reside in Euclidean space in the usual sense. There are a variety of metrics which allow us to determine a distance matrices that can be used to realize the Grassmannian as an embedding in Euclidean space. We illustrate that we can achieve an approximately isometric embedding of the Grassmann manifold using the chordal metric while this is not the case with geodesic distances. However, non-isometric embeddings generated by using a pseudometric on the Grassmannian lead to the best classification results. We observe that as the dimension of the Grassmannian grows, the accuracy of the classification grows to 100% on two illustrative examples. We also observe a decrease in classification rates if the dimension of the points on the Grassmannian is too large for the dimension of the Euclidean space. We use sparse support vector machines to perform additional model reduction. The resulting classifier selects a subset of dimensions of the embedding without loss in classification performance.

MULTI-FEATURE BASED LABEL PROPAGATION FOR SEMI-SUPERVISED CLASSIFICATION OF HYPERSPECTRAL DATA

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Abstract : For hyperspectral remote sensing, some spatial features e.g., texture and morphological feature, have been successfully employed for classification task. In this paper, we investigate the utilization of multiple features in label propagation (LP) classifier, attempting to improve the classification accuracy with small size samples. The graph of LP classifier is constructed by using multiple features, where each feature calculates a similarity matrix and a composite similarity matrix is obtained via linear combination. To weight the importance of each feature in the combination, leave-one- out strategy is applied to obtain a suitable weight for each feature. Experimental results on two high resolution hyperspectral data show that the proposed approach obtained better classification performance than LP classifier with single spectral feature and LP with equal weighted multi-feature.

VI.   SESSION WED-O-2-A : DETECTING DIFFICULT TARGETS IN HYPERSPECTRAL IMAGERY

PROGRESS IN DETECTOR FUSION

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Abstract : Introduced to the hyperspectral imaging community in the WHISPERS 2010 Reykjavik meeting, the "clairvoyant fusion" methodology for creating detection algorithms has since been applied to a variety of binary decision problems. These are summarized here. For any detection problem amenable to a fusion approach, an infinity of "flavors" can be devised. This paper describes what problems have been formulated in ways that insure closed form solutions. Such solutions are necessary in all applications that fuse a continuum of tests, because otherwise an infinity of logical operations would need to be implemented. The applications have featured a variety of subspace detection problems of varying dimensionality, along with several types of elliptically contoured distributions. Model subtleties not recognized by classical methods are discussed, along with a recent theoretical extension enabling the design of unbeatable methods.

A FAMILY OF KERNEL ANOMALY CHANGE DETECTORS

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Abstract : This paper introduces the nonlinear extension of the anomaly change detection algorithms in based on the theory of reproducing kernels. The presented methods generalize their linear counterparts, under both the Gaussian and elliptically-contoured assumptions, and produce both improved detection accuracies and reduced false alarm rates. We study the Gaussianity of the data in Hilbert spaces with kernel dependence estimates, provide low-rank kernel versions to cope with the high computational cost of the methods, and give prescriptions about the selection of the kernel functions and their parameters. We illustrate the performance of the introduced kernel methods in both pervasive and anomalous change detection problems involving both real and simulated changes in multi- and hyperspectral imagery. Excellent performance is achieved in terms of detection accuracy, especially when few training examples are available. Results also reveal that the elliptically-contoured assumption may be still valid in Hilbert spaces, particularly when high pervasive distortions mask anomalous targets.

TATISTICAL MOMENTS BASED METHODS FOR DETECTING SUB-PIXEL TARGET TRACKS IN LARGE IMAGE SEQUENCES

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Abstract : This paper reviews and compares the performance of several methods to detect target tracks in image sequences. The targets are assumed to be sub-pixel or not resolved by the imaging system, and moving over a static background. To process the resulting large amount of data requires simple, fast and robust processing methods to quickly find and display tracks of moving targets in a single image. An object moving through a pixel in a scene will momentarily perturb the pixel intensity signal, introducing a change of both skewness and kurtosis in the intensity histogram relative to an undisturbed pixel. Numerical experiments show that for Gaussian and Poisson distributed system noise higher order moments (>2) perform better than second order detectors.

ADVANTAGES AND LIMITATIONS OF SEGMENTATION FOR POINT TARGET DETECTION IN HYPERSPECTRAL IMAGERY

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Abstract : Segmentation appears to be an attractive preprocessing state when performing point target detection in hyperspectral data. Nevertheless, the literature contains examples of both successful and unsuccessful segmentation. Using simulations and several new analytical tools, we propose to derive guidelines when segmentation would be useful and when it would be superfluous. A real dataset with parameters when segmentation is worthwhile and when not is given.

HYPERSPECTRAL ANOMALY DETECTION BASED ON A NON-UNIFORM PARTITION OF THE PIXEL

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Abstract : Detection of anomalous objects is an important application of hyperspectral imaging in remote sensing. Current anomaly detection algorithms for a subspace target are based on partialling out the main background from each spectral component of a pixel. This paper proposes an anomaly detection algorithm that partials out the main background from each subset of a pixel that has been partitioned using non-uniform subsets. The anomaly detector is defined as the Mahalanobis distance of the resulting residual. Experimental results show that the anomaly detector has a substantial improvement in detection over the conventional anomaly detectors.

VII.   SESSION WED-O-2-B : PLANETARY EXPLORATION

TITAN'S SURFACE AND ATMOSPHERE AS SEEN BY THE VIMS HYPERSPECTRAL IMAGER ONBOARD CASSINI

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Robert H. Brown, *Lunar and Planetary Lab., University of Arizona, Tucson, AZ, USA*

Abstract : The surface of Titan, the largest icy moon of Saturn, is veiled by a very thick and hazy atmosphere. The Visual and Infrared Mapping Spectrometer onboard the Cassini spacecraft, in orbit around Saturn since July 2004, conducts an intensive survey of Titan with the objective to understand the complex nature of the atmosphere and surface of this mysterious moon, and the way they interact. We review in this paper our long-term monitoring of Titan's surface and atmosphere with the VIMS instrument. We focus on the global mapping of Titan cloud cover and geological units, and discuss the challenging problem of the decorrelation between atmospheric and surface components.

VISIBLE TO NEAR-INFRARED HYPERSPECTRAL MEASUREMENTS OF MERCURY: CHALLENGES FOR DECIPHERING SURFACE MINERALOGY

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Abstract : The surface of Mercury has long been known to be low in ferrous iron. Spectral reflectance data from the MESSENGER spacecraft do not show a ferrous absorption band near 1 μm, complicating mineralogical analysis of Mercury's surface. With careful calibration, however, these data can yield new constraints on the maximum amount of ferrous iron that can be present in the silicates.

SPECTRAL PROPERTIES OF ICY SATURNIAN SATELLITES DERIVED FROM CASSINI DATA

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G. Filiacchione and F. Cappacione, *INAF-IASF, Rome, Italy*
B.J. Buratti, *JPL, Pasadena, USA*
P.D. Nicholson, *Cornell Univ., Ithaca, USA*

Abstract : Cassini's Visual and Infrared Mapping Spectrometer (VIMS) offers the first spatially resolved hyperspectral data of the Saturnian satellites allowing a detailed comparison of their spectral properties including their spatial distribution across the satellite's surface. Additionally, images acquired by the Cassini ISS cameras offer the opportunity to study any relationships between the spectral variations to geological and morphological surface features. This is essential to understand the origin of the major and especially minor surface compounds and/or their physical properties. Either, the derived spectral variations are closely related to the surface geology of the specific satellite, or they can be explained by the interaction of the surface material and the space environment (including the planets magnetosphere). Thus, the analysis of the icy satellites spectral properties not only further our understanding of the icy satellites evolution but also complete our view about the whole planetary system.

TESTING LINEAR SPECTRAL UNMIXING ON LABORATORY MIXTURES: APPLICATION TO VIR DATA FOR ASTEROID VESTA.

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D.T. Blewett, *The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD, USA*
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C.A. Raymond, *NASA/Jet Propulsion Laboratory and California Institute of Technology, Pasadena, CA, USA*

Abstract : At 525 km in mean diameter, Vesta is the second largest object of the main asteroid belt. The Visible and InfraRed (VIR) spectrometer onboard Dawn provided more than 20 millions spectra at variable spatial resolution, allowing one to discriminate the different lithologies on Vesta. In this work, we tested linear spectral unmixing on three different mixtures, to verify the applicability of linear unmixing to VIR data of Vesta, and to determine the accuracy of the detection of the amount of the different minerals. We studied the following mixtures: two pyroxenes, pyroxene and olivine, and pyroxene and plagioclase. We next applied linear spectral unmixing to VIR spectra for localized features and larger areas, with the goal of deriving the composition and abundance of the minerals present.

A PRELIMINARY RESEARCH ON QUANTITATIVE RETRIEVAL OF HYDROUS MINERALS AROUND THE MARS SCIENCE LABORATORY LANDING SITE

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Abstract : The detection of hydrous minerals is of great importance in revealing the early water environment and even biotic activities on Mars. However, few studies focus on quantitatively retrieving hydrous minerals due to some problems. In this paper, the area around the Mars Science Laboratory (MSL) landing site is studied for quantitatively retrieving hydrous minerals. Firstly, the distribution of hydrous minerals is extracted using water absorption features. Then, sparse unmixing is employed with CRISM spectral library to retrieve the abundance of hydrous minerals in the hydrous region. The results show that seven hydrous minerals are quantitatively retrieved, e.g. actinolite, montmorillonite, saponite, jarosite and so forth, and the total concentration of all hydrous minerals can reach up to 40% near the lower reaches of Mount Sharp.

VIII.   Session wed-o-3-a : Spectral unmixing (1)

NONLINEAR UNMIXING OF VEGETATED AREAS: A MODEL COMPARISON BASED ON SIMULATED AND REAL HYPERSPECTRAL DATA

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Laurent Tits, *Department of Biosystems, KU Leuven, Belgium*
Ben Somers, *Division Forest, Nature and Landscape, KU Leuven, Belgium*
Yoann Altmann, *University of Toulouse, IRIT/INP-ENSEEIHT/TéSA, Toulouse, France*
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Pol Coppin, *Department of Biosystems, KU Leuven, Belgium*

Abstract : When analyzing remote sensing hyperspectral images, numerous works dealing with spectral unmixing assume the pixels result from linear combinations of the endmember signatures. However, this assumption cannot be fulfilled, in particular when considering images acquired over vegetated areas. As a consequence, several nonlinear mixing models have been recently derived to take various nonlinear effects into account when unmixing hyperspectral data. Unfortunately, these models have been empirically proposed and without thorough validation. This paper attempts to fill this gap by taking advantage of two sets of real and physical-based simulated data. The accuracy of various linear and nonlinear models and the corresponding unmixing algorithms is evaluated with respect to their ability of fitting the sensed pixels and of providing accurate estimates of the abundances.

RARE ENDMEMBERS ESTIMATION BY NMF METHODS USING MULTITEMPORAL HYPERSPECTRAL DATA AND CHANGE INFORMATIONS

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M. Guillaume, *Aix-Marseille Université, CNRS, Centrale Marseille, Institut Fresnel, France*
C. Louis, *THALES Communications & Security, France*

Abstract : Rare endmembers estimation is a very interesting and difficult issue in the unmixing field. We focus on the case of a rare endmember which appear as a change between two images of a same scene. We use both the information of the image where the new endmember is missing and change detection results to estimate the appearing endmember. We base the proposed approach on spectral unmixing with non negative matrix factorization (NMF), adding appropriate constraints on changed or non-changed pixels. We choose to test and discuss the alternate projected gradient optimization scheme. We compare the results to those of the estimation of appearing endmember through classical NMF unmixing on simulated data.

SPECTRAL-SPATIAL JOINT SPARSITY UNMIXING OF HYPERSPECTRAL DATA USING OVERCOMPLETE DICTIONARIES

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Abstract : Sparse spectral unmixing can be modeled as a linear combination of endmembers contained in an overcomplete dictionary weighted by the corresponding sparse abundance vector. This method exploits the fact that there is only a small number of endmembers inside a pixel compared to the overcomplete endmember spectral dictionary. Since the information contained in hyperspectral pixels is often spatially correlated, in this work we propose to jointly estimate the sparse abundance vectors of neighboring hyperspectral pixels within a local window exploiting joint sparsity with common and noncommon endmembers. To demonstrate the efficiency of our framework, we perform experiments using both simulated and real hyperspectral data.

A ROBUST SUBSPACE METHOD FOR SEMIBLIND DICTIONARY-AIDED HYPERSPECTRAL UNMIXING

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José M. Bioucas-Dias, *Instituto de Telecomunicações and Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal*
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Abstract : Recent development in semiblind dictionary-aided hyperspectral unmixing (HU) shows that a classical method in sensor array processing, namely, multiple signal classification (MUSIC), provides an effective way for endmember identification. However, MUSIC (and in fact, other dictionary-based sparse regression algorithms) assumes that there are no mismatches between the true endmember signatures and the dictionary spectral signatures, which may be violated in practice owing to reasons such as endmember variability and calibration errors. This paper presents a robust MUSIC method, wherein spectral signature mismatches are incorporated in the original MUSIC formulation to make the resulting algorithm robust. A computationally simple method is derived for the implementation of robust MUSIC. Simulation results show that robust MUSIC provides improved robustness against spectral signature mismatches than the original MUSIC.

ESTIMATION OF NUMBER OF SIGNAL SUBSPACES IN HYPERSPECTRAL IMAGERY USING LOW-RANK SUBSPACE REPRESENTATION

Alex Sumarsono and Qian Du, *Department of Electrical and Computer Engineering, Mississippi State University, USA*

Abstract : In this paper, we address the problem of hyperspectral subspace estimation based on low-rank representation. It is often assumed that major signal sources occupy a low-rank subspace. Due to the mixed nature of hyperspectral data, the underlying data structure may include multiple subspaces instead of a single subspace. Therefore, in this paper, we propose the use of low-rank subspace representation to estimate the number of subspaces. In particular, we develop simple estimation approaches without user-defined parameters. Real data experiments demonstrate excellent performance of the proposed approaches.

IX.   Session wed-o-3-b : Monitoring of the vegetation

CHARACTERIZATION OF CROP VITALITY AND RESOURCE USE EFFICIENCY BY MEANS OF COMBINING IMAGING SPECTROSCOPY BASED PLANT TRAITS

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Abstract : In this contribution measurements of the Airborne Prism Experiment (APEX) imaging spectrometer were used to derive products related to plant traits, e.g., leaf chlorophyll, carotenoid, anthocyanin, and water content, leaf greenness, biomass, and leaf area index. The Apex products were highly correlated to the related ground truth measurements in major crops under experimental and field situations. The relationship of APEX derived NDVI ($NDVI_{APEX}$) with ground measured NDVI and canopy cover is shown in detail. Additionally, interrelations between the aerial detected traits are discussed. The combination of the presented remotely measured plant traits can potentially give crop specific indications of their growth status and vitality. Such tools could help to improve resource use efficiency in agricultural systems and are needed for applications in precision agriculture and mapping of land use and land cover for scientific purposes or decision making.

ESTIMATING BIOMASS OF RICE IN FARMERS' FIELDS BY RED-EDGE INDICES

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Abstract : Biomass is an important parameter that has a decisive influence on the final yield. Destructive measurements of biomass are time-consuming and labor-intensive. Proximal sensing methods using field spectrometers offer indirect observation and estimation of biomass. For this purpose, farmers' fields were investigated in a two-year growing season of rice and canopy reflectance was measured by spectrometers. Several vegetation indices (VIs) and multiple linear regression (MLR) models based on bands around the red-edge domain (680-760 nm) were tested. Published red- edge VIs were generally prone to saturation, whereas MLR models and the Ratio of Reflectance Difference Index in the red-edge (RRDIre) were less influenced by saturation. The linearly tested MLR (based on VIs) and the RRDIre models provided the best performance for biomass estimation in model validation using an independent dataset.

HYPERSPECTRAL TREE SPECIES CLASSIFICATION WITH AN AID OF LIDAR DATA

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Abstract : Classification of tree species is one of the most important applications in remote sensing. A methodology to classify tree species using hyperspectral and LiDAR data is proposed. The data processing consists of shadow correction, individual tree crown delineation, classification by support vector machine (SVM) and postprocessing by a smoothing filter. The authors applied this procedure to the data taken over Tama Forest Science Garden in Tokyo, Japan and classified it into 16 classes of tree species. As a result, the authors achieved classification accuracy of 79 % with 10 % training data, which is 17 % higher than what is obtained by using hyperspectral data only. Shadow correction and morphological processing derived from LiDAR data increase the accuracy by 3 % and 14 %, respectively.

SPECTRAL DISCRIMINATION OF TEA PLANT VARIETIES BY STATISTICAL, MACHINE LEARNING AND SPECTRAL SIMILARITY METHODS

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Abstract : **R**emote discrimination and mapping of tea plantations is a valuable tool for efficient management of inventory and optimization of resources. Apart from the planting multiple tea varieties, growth of natural vegetation species is common scenario in plantations. The objective of this research was spectral discrimination of nine important tea varieties in the presence of six natural vegetation species in Munnar, Western Ghat highlands of south India. Discrimination models using six methods: k-nearest neighborhood classifier (k-NN), linear discriminant analysis (LDA), support vector machines (SVM), normalized spectral similarity score (NS³), maximum likelihood classifier (MLC) and artificial neural networks (ANNs) were applied on the hyperspectral reflectance measurements collected at canopy level. The existence and statistical significance of spectral differences of the tea and natural vegetation species were assessed by MANOVA. Results indicate that six out of 9 tea varieties could be discriminated with best accuracies 75 to 80%. While a closer spectral similarity is observed in few tea varieties, the presence of natural vegetation species has decreased inter species variability for few tea varieties while enhancing the same for few other tea varieties at the cost of reducing spectral separability among the vegetation species.

TOWARDS ROBUST VEGETATION INDICES: THE MULTI-CORRELATION MATRIX STRATEGY

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Abstract : This paper presents a new fusion approach producing unobservable fused remote sensing data with high spatial and spectral resolutions. This approach, related to linear spectral unmixing (LSU) techniques, introduces joint nonnegative matrix factorization (JNMF) for combining observable low spatial resolution hyperspectral and high spatial resolution multispectral data. JNMF is applied to synthetic but realistic data generated from real airborne hyperspectral data. Spectral and spatial qualities of fused data are evaluated by frequently used criteria. Experimental results show the low computational cost of the proposed approach, and the good spectral and spatial fidelities of the fused data. Our method also outperforms the recently proposed coupled nonnegative matrix factorization (CNMF) method.

X.   SESSION THU-P-A : SPECTRAL UNMIXING

GEOMETRIC MATCHED FILTER FOR HYPERSPECTRAL PARTIAL UNMIXING

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Abstract : In this paper, a new geometric matched filter is presented by combining the standard matched filtering with concepts of convex geometry. The purpose of the method is partial unmixing of a hyperspectral image, where an estimate is given for the relative contribution of each pixel to a specific target spectrum. In standard matched filtering, the filter is designed based on the background statistics of the entire image, which works fine when the target is contained in a limited number of pixels, but fails when the target is abundantly present throughout the whole image. The presented method calculates the filter based on the statistics of pixels that do not contain the target spectrum. These background pixels are identified based on the simplex formed by the target and other relevant endmembers of the dataset. In the experiments, the presented method is shown to outperform standard matched filtering for partial unmixing.

A NEW MAXIMUM DISTANCE METHOD BASED ON BARYCENTRIC COORDINATE FOR ENDMEMBER EXTRACTION

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Abstract : In this paper, we present a new maximum distance method (MDM) by applying the simplex barycentric coordinate for endmember extraction, named BC-MDM. Under linear mixing model and pure-pixel assumption, the MDM, which is proposed by Geng in 2005, is based on the fact that a pixel is an endmember if it has the maximum distance to the sub-simplex with vertices being endmembers already extracted. Calculating the distance of a pixel to the sub-simplex is quite time-consuming. To overcome this problem, we introduce the idea of barycentric coordinate to MDM, which transforms the problem of distance calculation into spectral unmixing with abundance sum-to-one constraint. As a result, BC-MDM has greatly reduced the computational complexity of original MDM. The experimental results with real hyperspectral image demonstrate that compared to the simplex growing algorithm (SGA), the proposed method can provide the same performance with a computational complexity between one and two orders magnitude lower, and compared to vertex component analysis (VCA), our method can provide consistent result while requires less computing time.

COMBINING MULTI-AGENT AND ANT COLONY OPTIMIZATION FOR ENDMEMBER EXTRACTION

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Abstract : Ant colony optimization (ACO) is an effective algorithm to extracting endmembers in the field of hyperspectral remote sensing. However, its speed is relatively low, and the increasing data size will cause its decreasing computing efficiency. Based on Agent-Oriented Programming paradigm to build a distributed Multi-Agent System (MAS) of ACO to extract endmembers is an efficient way of reducing computing time. By designing a distributed architecture that consists of a manager agent and multiple ant agents, and assigning agents different behaviors and communication contents, this paper proposes and realizes an ACO and MAS combined method to make ants execute endmember extraction tasks in parallel. Moreover, three comparative experiments using an AVIRIS image have been done to test the method, which proves that using multiple hosts to build MAS can greatly improve the efficiency of intelligent computing.

AN IMPROVED WEIGHT-CALCULATION NON-LOCAL SPARSE UNMIXING FOR HYPERSPECTRAL IMAGERY

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Abstract : Spatial sparse unmixing techniques have been known as a series of effective way in improving the unmixing accuracy with the integration of spatial correlations of imagery. To better utilize the non-local spatial information, spatial sparse unmixing methods based on non-local means such as non- local sparse unmixing (NLSU) have been proposed. However, the non-local spatial correlations in NLSU represented by weights between similar windows in the estimated abundances are always changing and not so reliable during the process of optimization. To obtain more precise and fixed spatial relationships, the improved weight- calculation non-local sparse unmixing algorithm is proposed in this paper by replacing the weight acquisition source from the variable estimated abundances to original hyperspectral imagery. The experimental results using two groups of simulated hyperspectral datasets indicate that the IW-NLSU outperforms the previous spatial sparse unmixing methods.

STRUCTURED SPARSE BAYESIAN HYPERSPECTRAL COMPRESSIVE SENSING USING SPECTRAL UNMIXING

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Abstract : To reduce huge consumption of processing hyperspectral images(HSI), a novel Bayesian unmixing compressive sensing framework is proposed to compress and reconstruct HSI effectively, called structured sparse Bayesian umixing compressive sensing(SSBUCS). SSBUCS unites compressive sensing and hyperspectral linear mixed model in Bayesian framework. An HSI is decomposed as a linear combination of endmembers and abundance matrix. The abundance matrix is transformed to a structured sparse signal in the wavelet domain. Then, compressive sensing is employed on this sparse signal to produce a more compact result. To recover the HSI, a Markov chain Monte Carlo(MCMC) method based on Gibbs sampling is proposed, imposing structured sparse prior on abundance matrix. Experimental results verify the superiority of the proposed method over several state-of-art methods.

SPARSE UNMIXING VIA WM ALGORITHM FOR HYPERSPECTRAL IMAGES

Ion Marques *Student Member, IEEE*, and Manuel Graña *Member, IEEE*

Abstract : Spectral unmixing aims to estimate the fractional abundances of spectral signatures in each pixel. The Linear Mixing Model (LMM) of hyperspectral images assumes that pixel spectra are affine combinations of fundamental spectral signatures called endmembers. Endmember induction algorithms (EIA) extract the endmembers from the hyperspectral data. The WM algorithm assumes that a set of Affine Independent vectors can be extracted from the rows and columns of dual Lattice Autoassociative Memories (LAAM) built on the image spectra. Indeed, the set of endmembers induced by this algorithm defines a convex polytope covering the hyperspectral image data. However, the number of endmembers extracted can be huge. This calls for additional endmember selection steps, and to approaching the unmixing problem with linear sparse regression techniques. In this paper, we combine WM algorithm with clustering techniques and Conjugate Gradient Pursuit (CGP) for endmember induction. Our experiments are conducted using hyperspectral imaging obtained by the Airborne Visible/Infrared Imaging Spectometer of the NASA Jet Propulsion Laboratory.

ENDMEMBER CONSTRAINED SEMI-SUPERVISED HYPERSPECTRAL UNMIXING

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Abstract : In this paper an endmember constrained semi-supervised hyperspectral unmixing method is proposed. The linear model is used to represent the hyperspectral data. A priori information about the endmembers is incorporated into the objective function with soft regularization. This information can be acquired from a spectral library or from the data itself. Quantitative evaluation of the method is done using simulated data and it is shown the soft regularization can yield better results than hard regularization. The method is also applied on a real hyperspectral data set and the estimated abundance maps improve when a priori information is used to aid the unmixing.

VALIDATING NONLINEAR MIXING MODELS: BENCHMARK DATASETS FROM VEGETATED AREAS

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Abstract : Our understanding of nonlinear mixing events in vegetated areas is currently hampered by a pertinent lack of well-validated datasets. Most quantification and modeling efforts are based on theoretical assumptions or indirect empirical observations. In this study, a physically based ray tracer was used to create simulated hyperspectral datasets of vegetative systems. This model incorporates multiple scattering effects, and nonlinear mixing behavior can be observed in the rendered data. The main benefit of the ray-tracer is that we were able to demonstrate with in situ measurements that both the nature and the intensity of the nonlinear mixing events are realistically modeled. Different ray-tracer datasets will be made available to the wider scientific community as a benchmark dataset to test and validate new and existing unmixing methodologies. In this contribution, we would like to present the structure of these datasets, and show how they can be used to evaluate nonlinear mixing models. In addition, and maybe even more important, we would like to draw the attention to the limitations of the data, as well point out the assumptions made in the construction of the data.

RECURSIVE ORTHOGONAL VECTOR PROJECTION ALGORITHM FOR LINEAR SPECTRAL UNMIXING

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Abstract : Orthogonal vector projection (OVP) is recently developed as a versatile technique which can used in various application in hyperspectral imaging such as subpixel detection, linear spectral unmixing and endmember finding. A great advantage of OVP is that only calculations of vector products are required with no need of matrix multiplications and inverse calculations. Furthermore, this paper develops a recursive version of OVP, to be called recursive OVP (ROVP) so that OVP can be performed vector by vector recursively without using previously processed vectors. As a result, the computational complexity of ROVP is much lower than other algorithms. Furthermore, the ROVP is much easier to be applied to hardware such as FPGA or GPU in the future.

MULTILAYER STRUCTURED NMF FOR SPECTRAL UNMIXING OF HYPERSPECTRAL IMAGES

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Abstract : One of the challenges in hyperspectral data analysis is the presence of mixed pixels. Mixed pixels are the result of low spatial resolution of hyperspectral sensors. Spectral unmixing methods decompose a mixed pixel into a set of endmembers and abundance fractions. Due to nonnegativity constraint on abundance fraction values, NMF based methods are well suited to this problem. In this paper multilayer NMF has been used to improve the results of NMF methods for spectral unmixing of hyperspectral data under the linear mixing framework. Sparseness constraint on both spectral signatures and abundance fractions matrices are used in this paper. Evaluation of the proposed algorithm is done using synthetic and real datasets in terms of spectral angle and abundance angle distances. Results show that the proposed algorithm outperforms other previously proposed methods.

ON THE USE OF RITZ VALUES FOR CALCULATING THE NUMBER OF ENDMEMBERS IN HYPERSPECTRAL IMAGES

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Abstract : Signal subspace identification is a crucial step in many hyperspectral processing algorithms such as target detection, change detection, classification, and unmixing. This is due to the fact that a correct dimensionality reduction improves algorithm performances and reduces their complexity and data requirements.

This paper introduces a new method for this task which is based on the Ritz values obtained in methods such as the restarted Arnoldi method or the Lanczos method for calculating the eigenvalues and eigenvectors of a given matrix. In particular, it first calculates a high number of eigenvalues and eigenvectors, and a Ritz value per eigenvalue calculated and then, it estimates the dimension of the signal subspace according to the Ritz values obtained. The results obtained with the proposed method for synthetic and real hyperspectral images verify the performance of the introduced methodology to estimate the number of endmembers in different types of hyperspectral images. Moreover, these results are better than the ones obtained, for the same images, with the most popular algorithm for this task in the state of the art, i.e. the HySIME and the Virtual Dimensionality algorithms.

BINARY PARTITION TREE-BASED LOCAL SPECTRAL UNMIXING

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Abstract : The linear mixing model (LMM) is a widely used methodology for the spectral unmixing (SU) of hyperspectral data. In this model, hyperspectral data is formed as a linear combination of spectral signatures corresponding to macroscopically pure materials (endmembers), weighted by their fractional abundances. Some of the drawbacks of the LMM are the presence of multiple mixtures and the spectral variability of the endmembers due to illumination and atmospheric effects. These issues appear as variations of the spectral conditions of the image along its spatial domain. However, these effects are not so severe locally and could be at least mitigated by working in smaller regions of the image. The proposed local SU works over a partition of the image, performing the spectral unmixing locally in each region of the partition. In this work, we first introduce the general local SU methodology, then we propose an implementation of the local SU based on a binary partition tree representation of the hyperspectral image and finally we give an experimental validation of the approach using real data.

A VARIATIONAL BAYES ALGORITHM FOR JOINT-SPARSE ABUNDANCE ESTIMATION

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Abstract : This paper presents a variational Bayesian scheme for semi-supervised unmixing on hyperspectral images that exploits the inherent spatial correlation between neighboring pixels. More specifically, a hierarchical Bayesian model that promotes a joint-sparse profile on the abundance vectors of adjacent pixels is developed and a computationally efficient variational Bayes algorithm is incorporated to perform Bayesian inference. The benefits of the proposed joint-sparse model are demonstrated via simulations on both synthetic and real data.

XI.   Session thu-p-b : Feature extraction, band selection and dimension reduction

EVALUATION OF INTRINSIC DIMENSIONALITY METHODS USING RESIDUAL AND CHANGE-POINT ANALYSES

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Abstract : The number of endmembers (NOE) in hyperspectral imagery plays an important role in image analysis applications such as classification, clustering and unmixing. Over the last years, different algorithms have been proposed to estimate the NOE. Nonetheless, each method depends on its own parameters' values, and as a result, leads to different values for intrinsic dimensionality (ID). In this study a statistical-based method is proposed to evaluate different results of ID algorithms. In this method, the reasonable candidates of ID are selected using both residual analysis (RA) and Change-Point analysis (CPA). Different values for ID are then compared with these candidates. If these values are equal or close to these candidates they may be considered as the ID. Although the proposed method can be used for every ID method, here, the results of two new methods, namely, SML, and O-GENE-AH algorithms have been investigated on Pavia Center hyperspectral dataset.

A NEW ANT COLONY OPTIMIZATION ALGORITHM BASED BAND SELECTION METHOD

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Abstract : For hyperspectral image processing, dimensionality reduction is an important step, which has direct impact on hyperspectral image classification accuracy. Unsupervised band selection is an important means of data dimensionality reduction. This paper presents an ant colony optimization (ACO) algorithm based hyperspectral image band selection method (ACO-BS). First, four kinds of distance are used to measure the difference between the bands so to turn the band selection problem into a cumulative distance optimization problem. In order to solve the band selection problem, an ant colony optimization algorithm procedure is given, including the path search criteria (transition probability) and exchange rules (pheromone update). Experiments show that regardless of the Maximum Likelihood (ML) or Support Vector Machine (SVM), the ACO-BS selected band can get higher classification accuracy, cosine distance has obvious advantages among the four kinds of distance, followed by mutual information.

HYPERSPECTRAL BAND SELECTION USING FIREFLY ALGORITHM

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Abstract : A novel band selection algorithm for hyperspectral dimensionality reduction by improving the firefly algorithm is put forward. Specifically, the framework which using bio-inspired algorithm for hyperspectral band selection is described; the between-class separability criteria such as Jeffreys-Matusita (JM) distance, transformation divergence (TD) are used for objective function. A HYDICE Washington DC Mall data was used in the experiments, and the results have proved the promising ability of the proposed method for hyperspectral band selection.

FODSPO BASED FEATURE SELECTION FOR HYPERSPECTRAL REMOTE SENSING DATA

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Abstract : A new feature selection technique is proposed to address the main difficulty of hyperspectral data processing, which is related to high redundancy of data and the curse of dimensionality. The new approach is based on a new binary optimization method named Binary Fractional Order Darwinian Particle Swarm Optimization (BFODPSO) and Support Vector Machine (SVM). Then, an application of the proposed feature selection approach is taken into account in order to solve the main shortcomings of using attribute profile for extracting spatial information from the input data. Results confirm the capability of the new method for handling very high dimensional data.

UNSUPERVISED DEEP FEATURE EXTRACTION OF HYPERSPECTRAL IMAGES

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Abstract : This paper presents an effective unsupervised sparse feature learning algorithm to train deep convolutional networks on hyperspectral images. Deep convolutional hierarchical representations are learned and then used for pixel classification. Features in lower layers present less abstract representations of data, while higher layers represent more abstract and complex characteristics. We successfully illustrate the performance of the extracted representations in a challenging AVIRIS hyperspectral image classification problem, compared to standard dimensionality reduction methods like principal component analysis (PCA) and its kernel counterpart (kPCA). The proposed method largely outperforms the previous state-of-the-art results on the same experimental setting. Results show that single layer networks can extract powerful discriminative features only when the receptive field accounts for neighboring pixels. Regarding the deep architecture, we can conclude that: additional layers in a deep architecture significantly improve the performance w.r.t. single layer variants; the max-pooling step in each layer is mandatory to achieve satisfactory results; and the performance gain w.r.t. the number of layers is upper bounded, since the spatial resolution is reduced at each pooling, resulting in too spatially coarse output features.

USE INTERMEDIATE RESULTS OF WRAPPER BAND SELECTION METHODS: A FIRST STEP TOWARD THE OPTIMIZATION OF SPECTRAL CONFIGURATION FOR LAND COVER CLASSIFICATIONS

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Abstract : Intermediate results of two state-of-the-art wrapper feature selection approaches (GA and SFFS) associated to a classifier (linear SVM) applied to hyperspectral data sets were used to derive information about band importance for specific land cover classification problems. The impact of the number of selected bands on classification accuracy was obtained thanks to SFFS, while a band importance measure was derived from intermediate sets of bands tested by GA. Such results are a first step toward the identification of the most suitable spectral bands to design superspectral camera systems dedicated to specific applications (e.g. classification of urban land cover and material maps).

HYPERDIMENSIONAL DATA EXPLOITATION THROUGH PARAMETRIC REDUCTION

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Abstract : Feature reduction of hyperspectral data is a big challenge, particularly because the reduced dimensions must preserve the separability properties and key information content. Nevertheless, various techniques have been developed so far and are well documented in the literature. Here we characterize a novel technique of feature reduction, with main emphasis on the ability of enhancing the informative content of the reduced dataset, for data exploitation purposes. The parametric reduction of hyperspaces using the Exponential Gaussian Optimization (EGO) approach allows the analyst to quickly explore the dataset in terms of the occurrence and properties of the diagnostic features and the local albedo, as well. As a consequence, this technique is able to provide new insights into the accomplishment of the delicate task of hyperspectral classification.

SPATIAL-SPECTRAL FEATURE EXTRACTION ON HYPERSPECTRAL IMAGERY

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Abstract : In this work we extend several spatial feature extraction techniques to operate on hyperspectral imagery (HSI), which has several image bands. The HSI image bands provide a high dimensionality spectral image space, which is then compounded by the addition of several spatial features per pixel. We investigate enhancing the spatial resolution of Airborne Real-time Cueing Hyperspectral Enhanced Reconnaissance (ARCHER) HSI imagery with coincident high spatial resolution panchromatic imagery and compare feature extraction performance when both the spatial and spectral attributes are considered simultaneously as opposed to individually. Our experimental results show that spatial-spectral features of pansharpened HSI imagery improve the separability of different target classes, particularly when targets move between looks.

XII.   SESSION THU-P-C : SENSORS, SYSTEMS, MISSIONS

SENSITIVITY OF SCOPE MODELLED GPP AND FLUORESCENCE FOR DIFFERENT PLANT FUNCTIONAL TYPES

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Gina Mohammed, *P&M Technologies, Sault Ste Marie, Ontario, Canada*
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Abstract : This study addresses the question which factors are responsible for reported positive correlations between solar induced fluorescence (SIF) and gross primary production (GPP). A sensitivity analysis of the model SCOPE, which simulates photosynthesis, fluorescence emission and radiative transfer in canopies, has been carried out for four different plant functional types (PFT): tropical rainforest, C4 crops, C3 crops, and tundra, located in distinct climate zones: tropical everwet (Af), tropical with seasonal drought (savannah, Aw), temperate (Cf), and continental tundra (Dfd). Literature values for structural and physiological parameters and climate reanalysis data were used as input. The effect of main driving variables points towards a positive relation between GPP and SIF. For all four climates, the partial derivative of SIF to GPP is higher when irradiance varies than when any other parameter varies. Climate and PFT specific differences occurred, including a hot-spot effect on SIF in the tropics, relatively strong sensitivity of SIF and GPP to carboxylation capacity in the tropics, and a temperature and humidity effect in the tropical seasonal climate.

RESEARCH ON THE TECHNOLOGY OF HYPERSPECTRAL REMOTE SENSING OIL-GAS EXPLORATION BASED ON VEGETATION REFLECTION SPECTRUM ANOMALIES

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Abstract : Seepage of underground oil-gas reservoirs will bring stress effects for poisoning of roots of vegetation in the environment, which will be reflected in vegetation canopy reflectance spectra. In order to explore how to extract anomalous vegetation resulting from natural oil-gas microseepage by hyperspectral remote sensing images, this paper presents a data processing flow for effectively extracting wild anomalous vegetation resulting from oil-gas microseepage. Sparse vegetation covered area in Yulin, China was taken as an experimental zone, the CASI images were used as test data, wild vegetation anomaly spectrum information resulting from oil-gas microseepage was extracted according to the flow, and the oil-gas anomaly zone is hereby delineated. Locations of small gas wells known in the research zone and the resulting anomaly zone are highly conforming, which verifies the effectiveness of the data processing flow, and can provide some reference and basis for oil-gas exploration in other cover type areas.

MAPPING ECOSYSTEM SERVICES USING IMAGING SPECTROSCOPY DATA

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Abstract : Ecosystem services (ES) generate benefits to human well-being but quality and amount of their provisioning is threatened by environmental change. Remote sensing techniques allow assessments of ES at critical scales using combinations of remotely measurable ecosystem properties. In this contribution, we use an ES assessement approach suggested by Homolová et al. and extend it to estimate ES supply continuously for a heterogenous landscape across different Earth spheres using data of the Airborne Prism Experiment (APEX) imaging spectrometer. We further suggest a conceptional framework to combine ES maps to match the needs of different stakeholders. Our results show the heterogenuous supply of agronomic ES, carbon sequestration and cultural ES within the landscape and and its different ecosystems. Our proposed ES mapping approach and the conceptual framework developed for combining ES according to stakeholder requests, provide spatially explicit information on ES across heterogeneous landscapes and can therefore improve decision-making of stakeholders.

EVALUATION OF BREFCOR BRDF EFFECTS CORRECTION FOR HYSPEX, CASI, AND APEX IMAGING SPECTROSCOPY DATA

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Abstract : The correction of BRDF effects for airborne wide FOV imaging spectroscopy data is of interest for a consistent data processing and products generation. Recently, a new BRDF effects correction method (BREFCOR) has been implemented as additional processing step after the well-known atmospheric compensation workflow. This paper shows validation results of the method for sample data sets of HYSPEX, CASI, and APEX data. It can be shown that the method is able to deal with a broad variety of sensors and surface characteristics. The quality of the spectral albedo data products is substantially increased in terms of consistency for all data sets. Future potential improvements and additions for a better operational usability and for the processing of complete spectra are finally summarized.

MONITORING THE DIURNAL TIME COURSE OF VEGETATION DYNAMICS WITH GEOSTATIONARY OBSERVATIONS : THE GFLEX PROJECT

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Abstract : Given the present state of the art, remote sensing of vegetation fluorescence from space can be considered as feasible on a technical point of view. However, many unresolved questions remain about its interpretation and its use as a physiological indicator. Low sun- synchronous orbiting satellites are not adapted to capture the highly dynamical variations of vegetation fluorescence under environmental constraints because of their long repeat cycles. However, high frequency observations can be reached by geostationary platforms. We present and discuss here the GFLEX project. Its objective is the use of a multispectral imaging system to assess photosynthesis dynamics as a function of irradiation by observing chlorophyll fluorescence and the photochemical reflectance index from a geostationary orbit. The possibility to merge GFLEX and OCAPI, an ocean colour geostationary project for marine applications is also discussed.

A HYPERSPECTRAL IMAGING DEVICE FOR MULTI-LABELLED FLUORESCENCE MICROSCOPY

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Abstract : In this work we present a hyperspectral imaging device (HSI) developed at INRIM and integrated in an inverted microscope for application in multi labeled fluorescence microscopy. The HSI device is realized with a scanning Fabry-Perot interferometer and a fast CMOS camera integrated in an optical microscope. The HSI camera alone has been tested for some fluorescent molecules in multi-well samples to unambiguously discriminate them by analyzing the spectral fingerprints. Compared with other techniques the "multi label fluorescence microscope" has the advantage to acquire spectra of different dyes simultaneously without the use of multiple filters set or dispersive means. In the present work we use the microscope to observe various fluorescent dyes commonly used in biology and demonstrate the capability to discriminate between them by observing their spectral shapes.

THE USGS PRISM SYSTEM FOR SPECTRAL ANALYSIS – AN ENVI/IDL-BASED SOFTWARE –

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Abstract : The identification of materials by measuring and analyzing their reflectance spectra has been an important method used in the physical sciences for well over a century. Modern airborne and space-based imaging spectrometers give scientists the opportunity to detect materials and map their distributions across the landscape. With new satellite-borne sensors planned for the future, for example, EnMap (Environmental Mapping and Analysis Program) and HyspIRI (Hyperspectral InfraRed Imager), robust methods are needed to fully exploit the information content in hyperspectral remote sensing data. In this paper, a software package written in Interactive Data Language (IDL) called PRISM (Processing Routines in IDL for Spectroscopic Measurements) is described. The core functions of PRISM are algorithms for spectral feature analysis and spectral feature comparison, permitting identification of and mapping of materials in hyperspectral remote sensing data.

PRELAUNCH ASSESSMENT OF WORLDVIEW-3 INFORMATION CONTENT

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Abstract : The upcoming WorldView-3 satellite is designed to collect unique data by combining very-high spatial resolution (VHR) with observation bands in the short wave infrared (SWIR) in addition to the visible and near-infrared (VNIR) multispectral and panchromatic bands currently available on the VHR WorldView-2 system. These SWIR bands were specifically selected in order to target unique reflectance and absorption features presented by various surface materials and should, therefore, significantly improve the platforms information content for many image mining applications. This presentation explores the information content available to the WorldView-3 platform in two ways. First, second-order statistics and mutual information estimates are utilized to measure the spectral content of simulated WorldView-3, WorldView-2, and QuickBird data relative to AVIRIS hyperspectral imagery. Then, WorldView-3 supervised classification performance is explored relative to that of hyperspectral imagery for both urban and agricultural data sets. Results suggest that the additional spectral content of the WorldView-3 platform provides a competitive information source to that of hyperspectral for broad applications in agricultural, mineral exploration, or urban monitoring.

COMPARING CAMERA SENSITIVITY WITH NOISE EQUIVALENT IRRADIANCE

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Abstract : It can be difficult to compare the merits of cameras using different sensor technologies using only the specifications typically provided by the manufacturers. The Noise Equivalent Irradiance (NEI) provides a normalized and unique parameter allowing a direct comparison. It is also fairly simple to calculate from the commercial specifications for a given wavelength and exposure time of interest. We compare the merits between typical CCD, EMCCD, CMOS and InGaAs FPA cameras.

XIII.   Session thu-o-1-a : Fluorescence data

AIRBORNE BASED SPECTROSCOPY TO MEASURE SUN-INDUCED CHLOROPHYLL FLUORESCENCE

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Uwe Rascher, *Institute of Bio- and Geosciences, IBG-2: Plant Sciences, Forschungszentrum Jülich GmbH, Germany*
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Abstract : Sun-induced chlorophyll fluorescence (Fs) is a remote sensing (RS) observable to be linked to plant photosynthesis. Variations of measured canopy Fs are, however, related to several effects in addition to a physiological response of plants. The impact of atmospheric scattering and absorption processes were identified as most critical if Fs retrievals are based on atmospheric O2- absorption bands. In this contribution, we aim to demonstrate the feasibility of airborne based Fs retrievals using the O2-A absorption band. We applied two airborne spectroscopy experiments including a non-imaging repeat- track approach with changing flight altitudes and a multi- temporal imaging approach using the new HyPlant spectrometer. Our results demonstrate that atmospheric effects can be compensated and accurate airborne based Fs measurements can be obtained using atmospheric absorption features. Our results are particularly important in view of ESA's potential Earth Explorer "Fluorescence Explorer" (FLEX) mission that intents to provide high resolution global maps of Fs using atmospheric oxygen absorption features.

MEASUREMENT AND CORRECTION OF ATMOSPHERIC EFFECTS IN O_2-B AND O_2-A ABSORPTION BANDS IN THE CONTEXT OF SUN-INDUCED FLUORESCENCE REMOTE SENSING

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Abstract : Under sun-light illumination, the shape of the atmospheric oxygen bands (O_2-B, 687 nm and O_2-A, 760 nm) of the vegetation radiance is modified by chlorophyll fluorescence. However for far- range measurements, atmospheric effects also modify this shape. In this study, measurements in O_2-A and O_2-B absorption bands have been performed at different altitudes up to 3123 m over bare soil and wheat fields. It is observed that bands depth increase significantly with altitude. In O_2-B band, the total magnitude of variation is of the same order of magnitude as the change induced by vegetation fluorescence, while it is much greater in O_2-A band. We used MODTRAN 4 to correct measurements from these atmospheric effects and to retrieve ground level band depths. It is found that the variation of corrected band depth with altitude is greatly reduced. These results show that MODTRAN 4 can be used to account for atmospheric effects. We also showed that an accurate evaluation of the contribution of environment is needed to correct band depth from atmospheric effects, especially in the O_2-B band.

A FLUORESCENCE RETRIEVAL METHOD FOR THE FLEX SENTINEL-3 TANDEM MISSION

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Abstract : A new fluorescence retrieval method is proposed to support ESA's 8th Earth Explorer Fluorescence EXplorer (FLEX) candidate mission. Most hyperspectral fluorescence retrieval algorithms available in the literature are very sensitive to true reflectance modelization and/or they assume the atmospheric status as known. The proposed algorithm delivers the retrieval of full fluorescence spectrum at canopy level by using only Top Of Atmosphere (TOA) radiances as input. The proposed method starts with the atmospheric correction of TOA radiances, characterizing the state of the atmosphere without assuming any a-priori classification on aerosols models, performing a first estimation of fluorescence values in main oxygen absorption bands without any approximation of true reflectance spectrum, and using this fluorescence estimation to initialize a Spectral Fitting Method (SFM) to finally retrieve a full fluorescence spectrum. All these aspects make the proposed fluorescence retrieval method robust and independent of external auxiliary data.

REMOTE SENSING OF SUN-INDUCED CHLOROPHYLL FLUORESCENCE AT DIFFERENT SCALES

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Abstract : In this contribution we present activities and selected results obtained in recent studies and campaigns conducted in the context of the FLuorescence EXplorer (FLEX) mission. FLEX is a candidate mission for the ESA 8th Earth Explorer and large efforts are currently dedicated to the development of an implementation scheme for an accurate mapping of fluorescence from the selected spaceborne sensor and mission configuration. Field and airborne data collected in different experimental campaigns, together with simulated data, have been used to demonstrate the feasibility of fluorescence retrievals and the potential of exploiting high spatial resolution fluorescence maps for a better understanding of the environment from space.

GLOBAL SENSITIVITY ANALYSIS OF THE A-SCOPE MODEL IN SUPPORT OF FUTURE FLEX FLUORESCENCE RETRIEVALS

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Christiaan van der Tol, *University of Twente, Netherlands*
Federico Magnani, *University of Bologna, Italy*
Gina Mohammed, *P&M Technologies, Sault Ste Marie, Ontario, Canada*
Jose Moreno, *Image processing Laboratory (IPL), University of Valencia, Spain*

Abstract : In support of ESA's Earth Explorer 8 candidate mission FLEX (FLuorescence EXplorer), a Photosynthesis Study has been initiated to quantitatively link fluorescence to photosynthesis. This led to the development of A-SCOPE, a graphical user interface software package that integrates multiple biochemical models into the soil-vegetation- atmosphere-transfer model SCOPE. Its latest version (v1.53) has been successfully verified and was subsequently evaluated through a global sensitivity analysis. By using the method of Saltelli, the relative importance of each input variable to model outputs was quantified through first order and total effect sensitivity indices. Variations in leaf area index (LAI) and chlorophyll content are mostly impacting the reflectance and fluorescence signal. Non-driving variables that can be safely set to default values have been identified and will facilitate consolidating SCOPE into an operational and invertible model.

XIV.   Session thu-o-1-b : Machine learning

HYPERSPECTRAL IMAGE REPRESENTATION USING LEARNED MULTISCALE DICTIONARIES

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Abstract : The different reflection or absorption characteristics of ground targets at different wavelength lead to diverse energy distribution among band images of hyperspectral images (HSIs). In this paper, we propose a sparse representation of HSIs using learned multi-scale dictionaries with the help of the distinctive physical characteristics. First, each band is cut into patches of different size using quadtree decomposition, meanwhile original bands are divided into two groups, key band and less-key bands. Then, multi-scale patches from the key bands are sparsely coded using greedy algorithm. Finally, those image patches from less-key bands are approximated using pseudo inverse. Experiments reveal that our proposal outperform 3D-DWT and that using single scale dictionary. Some applications like HISs compression will be benefit from our approach.

WAVELET DOMAIN MULTI-VIEW ACTIVE LEARNING FOR HYPERSPECTRAL IMAGE ANALYSIS

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Melba Crawford, *Schools of Civil Engineering and Electrical and Computer Engineering, Purdue University*

Abstract : This paper introduces a new wavelet based active learning approach for hyperspectral image (HSI) analysis. Specifically, it uses a redundant wavelet transform (RDWT) to construct a multi-view active learning framework for hyperspectral classification. We show that a wavelet decomposition provides a unique multi-view framework that results in improved active learning and classification, and apply the proposed method to a benchmark hyperspectral dataset. Experimental results demonstrate the efficacy of the proposed method compared to traditional learning methods, including random sampling, margin sampling, and multi-view active learning based on correlated subsets of contiguous bands.

COMBINING ACTIVE AND METRIC LEARNING FOR HYPERSPECTRAL IMAGE CLASSIFICATION

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Abstract : Classification of hyperspectral remote sensing images is affected by two main problems: high dimensionality of the acquired signatures and scarce availability of labeled samples. Learning a low dimensional manifold and active learning represent two approaches that have been investigated in the literature to mitigate these effects. However they are usually applied independently from each other. In this paper we propose a method in which feature extraction and active learning are combined. In particular, a new reduced feature space is learned by large margin nearest neighbor (LMNN), a metric learning strategy that takes advantage of labeled information. The method is applied in conjunction with k-nearest neighbor (k-NN) classification, for which a new sample selection strategy is proposed. Experiments on a real hyperspectral dataset confirm the effectiveness of the proposed method.

HYPERSPECTRAL CLASSIFICATION USING STACKED AUTOENCODERS WITH DEEP LEARNING

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Abstract : In this study, stacked autoencoders which are widely utilized in deep learning research are applied to remote sensing domain for hyperspectral classification. High dimensional hyperspectral data is an excellent candidate for deep learning methods. However, there are no works in literature that focuses on such deep learning approaches for hyperspectral imagery. This study aims to fill this gap by utilizing stacked autoencoders. Experiments are conducted on the Pavia University scene. Using stacked autoencoders, intrinsic representations of the data are learned in an unsupervised way. Using labeled data, these representations are fine tuned. Then, using a soft-max activation function, hyperspectral classification is done. Parameter optimization of Stacked Autoencoders (SAE) is done with extensive experiments. Results are competitive with the state-of-the-art techniques.

HYPERSPECTRAL IMAGE CLASSIFICATION FROM MULTISCALE DESCRIPTION WITH CONSTRAINED CONNECTIVITY AND METRIC LEARNING

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Abstract : Mapping of remote sensing data is usually done through image classification. For hyperspectral images, the classification process often relies only on the spectral signature of each single pixel. Nevertheless, combining spatial and spectral features has been a promising way for accuracy improvement. We address here this problem by computing spectral features from spatially identified regions, sampled from a hierarchical image representation, namely α-tree, built with prior knowledge. The sampling of the tree nodes (i.e., regions) is based on the paradigm of constrained connectivity and the global range criterion. In this paper, we extend this criterion to hyperspectral data and apply it to our knowledge-based α-tree. Our results show an improvement of pixelwise classification accuracy over spectral features only.

XV.   Session thu-o-2-a : Hyperspectral pansharpening and super-resolution

EFFECT OF UNMIXING-BASED HYPERSPECTRAL SUPER-RESOLUTION ON TARGET DETECTION

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Abstract : We present an airborne experiment on unmixing- based hyperspectral super-resolution using RGB imagery to examine the restoration of pure spectra comparing with ground-measured spectra and demonstrate its impact on target detection. An extended version of *coupled nonnegative matrix factorization* (CNMF) is used for hyperspectral super-resolution to deal with a challenging problem setting. Our experiment showed that the extended CNMF can restore pure spectra, which contribute to accurate target detection.

HYPERSPECTRAL PAN-SHARPENING: A VARIATIONAL CONVEX CONSTRAINED FORMULATION TO IMPOSE PARALLEL LEVEL LINES, SOLVED WITH ADMM

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Pierre Weiss, *ITAV-USR3505, université de Toulouse, France*
Manuel Grizonnet, *CNES, Toulouse, France*

Abstract : In this paper, we address the issue of hyperspectral *pansharpening*, which consists in fusing a (low spatial resolution) hyperspectral image HX and a (high spatial resolution) panchromatic image P to obtain a high spatial resolution hyperspectral image. The problem is addressed under a variational convex constrained formulation. The objective favors high resolution spectral bands with level lines parallel to those of the panchromatic image. This term is balanced with a total variation term as regularizer. Fit-to-P data and fit-to-HX data constraints are effectively considered as mathematical constraints, which depend on the statistics of the data noise measurements. The developed Alternate Direction Method of Multipliers (ADMM) optimization scheme enables us to solve this problem efficiently despite the non differentiabilities and the huge number of unknowns.

THE J-SPARSEFI-HM HYPERSPECTRAL RESOLUTION ENHANCEMENT METHOD – NOW FULLY AUTOMATED

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Technische Universität München, Department of Remote Sensing Technology (LMF), Germany

Abstract : This paper introduces the new scheme of the previously proposed Joinly Sparse Fusion of Hyperspectral and Multispectral Imagery (J-SparseFI-HM) fusion method. This extended, now fully automated and parallelized version of J-SparseFI-HM jointly estimates bundles of an adjustable number of high resolution hyperspectral bands by fusing corresponding low resolution bands with possibly multiple high resolution multispectral ones. Which multispectral bands are individually used is decided via a decision matrix that is calculated from the spectral response functions of the multispectral sensor. Tests are performed on the SuperMUC petascale system. Recently acquired 0.75 airborne VNIR HySpex data is used to synthesize a WorldView-2 image as well as low resolution hyperspectral data with a down-sampling factor of 10. The fusion results are compared to those produced by three state- of-the-are hyperspectral resolution enhancement methods.

HYPER-SHARPENING OF HYPERSPECTRAL DATA: A FIRST APPROACH

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Abstract : This paper enriches the hyperspectral pansharpening field following the development of new instruments. The updated version of SIM-GA imager, designed by Selex ES, is now composed by a panchromatic camera and two spectrometers in the VNIR and SWIR spectral ranges, respectively. Due to the different resolution factors among Panchromatic, VNIR and SWIR, various pansharpening approaches are possible. This paper is a first contribution on this subject, exploring the different ways to fuse the SWIR data to VNIR resolution. It is showed that the new proposed method outperforms the previous solutions reported in literature.

SUPER-RESOLUTION OF HYPERSPECTRAL IMAGES USING LOCAL SPECTRAL UNMIXING

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Abstract : For many remote sensing applications it is preferable to have images with both high spectral and spatial resolutions. On this regards, hyperspectral and multispectral images have complementary characteristics in terms of spectral and spatial resolutions. In this paper we propose an approach for the fusion of low spatial resolution hyperspectral images with high spatial resolution multispectral images in order to obtain super- resolution (spatial and spectral) hyperspectral images. The proposed approach is based on the assumption that, since both hyperspectral and multispectral images acquired on the same scene, the corresponding endmembers should be the same. On a first step the hyperspectral image is spectrally down- sampled in order to match the multispectral one. Then an endmember extraction algorithm is performed on the down- sampled hyperspectral image and the successive abundance estimation is performed on the multispectral one. Finally, the extracted endmembers are up-sampled back to the original hyperspectral space and then used to reconstruct the super- resolution hyperspectral image according to the abundances obtained from the multispectral image.

XVI.   SESSION THU-O-2-B : FORWARD MODELING

MODELING TRI-DIRECTIONAL REFLECTANCE DISTRIBUTION FUNTIONS (TRDF) WITH APPLICATION TO SUBPIXEL TARGET DETECTION

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Abstract : Spatially unresolved targets, such as vehicles, reflect a radiance spectrum that is more complicated than the simple linear mixing of target and background material spectra. Although different materials in the target and background classes have Bi-Directional Reflectance Function (BRDF) dependent spectra, the unique geometry and orientation of a target object, in addition to the solar illumination and observation angles, define a more complex Tri-Directional Reflectance Function (TRDF) in which glints and shadows are important spectral contributors. For different observation scenarios, the apparent spectra of an unresolved target may vary significantly. However, since solar and observation angles are often known to operators of remote sensing instruments, well characterized TRDFs for specific targets allow for refinement in the estimation of the expected spectra of different unresolved targets. More accurately defined target classes may lead to improved performance in established subpixel target detection algorithms for remote sensing.

HIGH-FIDELITY FORWARD MODEL FOR DETERMINING COMBUSTION EFFICIENCY OF INDUSTRIAL FLARES

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Abstract : The petroleum refining process utilizes hydrocarbon combustion by industrial flares to dispose of waste gas streams. These flares emit substantial quantities of greenhouse gases into the atmosphere. As a result, there is an ongoing need for monitoring and control technology to minimize the products of incomplete combustion, including ozone-forming highly-reactive volatile organic compounds (HR-VOCs) and human carcinogens. Remote sensing of emission products using a combination of a hyperspectral infrared imager and a high-performance retrieval algorithm can provide a robust, low-cost solution. Here, we outline the construction of a high-fidelity forward model to be used by our retrieval algorithm. This model takes user-supplied layer temperatures and molecular concentrations and provides the retrieval algorithm with bandpass-specific spectral radiances (for least-squares fitting against measured data) and derivatives with respect to the dependent variables (to adjust the next iterative step).

A NEW MODTRAN-BASED THERMAL MODEL FOR ACCELERATING PLUME TRACKER VOLCANIC EMISSION ANALYSIS

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Abstract : Plume Tracker (PT), formerly MAP_SO2, is robust, extensively validated, analyst driven software for retrieving gaseous emissions from volcanic releases. While Plume Tracker provides very accurate results, analyzing multi- spectral imagery typically takes several days of analyst time. The major bottleneck in the PT processing is the relatively slow but accurate FORTRAN-based MODTRAN gas plume and atmospheric radiative transfer (RT) model. This paper describes physics/algorithm based approaches to accelerate the Thermal Infrared (TIR) data analysis of PT analysis by in excess of 100-fold. In particular, we demonstrate that thermal radiance predictions for varying spectral emissivities and surface temperature can be determined from a single MODTRAN run.

SPECTRAL MODELING OF THE DIFFUSE INTERSTELLAR BANDS

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Abstract : We consider spectral modeling of the diffuse interstellar bands (DIBs). We focus on two aspects of DIB spectral modeling that are often overlooked, but significantly impact the interpretation of a spectral fit in terms of a potential molecular carrier. The first concerns ambiguities in the retrieved spectral parameters. Very different combinations of rotational temperature, transition symmetry, and spectroscopic parameters can yield nearly identical spectral fits. The second concerns the probability and effects of overlapping DIBs on spectral modeling. The high DIB spectral density, ~28 DIBs/Å, results in a significant overlap probability, ~30%. To exemplify these concerns, we model the spectral profile of the DIB λ6614. We use Gaussian fitting of λ6614 in order to show that it can be de-composed into two overlapping DIBs, λ6613.6, and λ6614.2. The spectral profiles of these DIBs can be fit more accurately than the fit obtained by treating λ6614 as a single DIB.

MODTRAN®6:A MAJOR UPGRADE OF THE MODTRAN® RADIATIVE TRANSFERCODE

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Abstract : The MODTRAN6 radiative transfer (RT) code is a major advancement over earlier versions of the MOD-TRAN atmospheric transmittance and radiance model. This version of the code incorporates modern software architecture including an application programming interface, enhanced physics features including a line-by-line algorithm, a supplementary physics toolkit, and new documentation. The application programming interface has been developed for ease of integration into user applications. The MODTRAN code has been restructured towards a modular, object-oriented architecture to simplify upgrades as well as facilitate integration with other developers' codes. MODTRAN now includes a line-by-line algorithm for high resolution RT calculations as well as coupling to optical scattering codes for easy implementation of custom aerosols and clouds.

XVII.   Session thu-o-3-a : Spectral unmixing (2)

GLUP: YET ANOTHER ALGORITHM FOR BLIND UNMIXING OF HYPERSPECTRAL DATA

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Abstract : This paper addresses the problem of blind fully-constrained linear unmixing of hyperspectral images. The endmembers and their cardinality are assumed unknown, but the endmember spectra are supposed to be present in the scene. Group Lasso regularization is used to extract the endmembers. The estimation problem is convex, and solved with the Alternating Direction Method of Multipliers. Comparisons with state-of-the-art methods on synthetic and real data sets show the efficiency of our approach.

NONLINEAR UNMIXING BY USING NON-EUCLIDEAN METRICS IN A LINEAR UNMIXING CHAIN

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Abstract : In the linear mixing model, many techniques for endmember extraction are based on the assumption that pure pixels exist in the data, and form the extremes of a simplex embedded in the data cloud. These endmembers can then be obtained by geometrical approaches, such as looking for the largest simplex, or by maximal orthogonal subspace projections. Also obtaining the abundances of each pixel with respect to these endmembers can be completely written in geometrical terms. While these geometrical algorithms assume Euclidean geometry, it has been shown that using different metrics can offer certain benefits, such as dealing with nonlinear mixing effects by using geodesic or kernel distances, or dealing with correlations and colored noise by using Mahalanobis metrics. In this paper, we demonstrate how a linear unmixing chain based on maximal orthogonal subspace projections and simplex projection can be written in terms of distance geometry, so that other metrics can be easily employed. This yields a very flexible processing chain: by using other metrics, the same unmixing methodology can be used to deal with a wide range of unmixing models and scenarios. As an example, metrics are provided for dealing with intimate mixtures, nonlinear dimensionality reduction, and colored noise.

UNMIXING MULTIPLE INTIMATE MIXTURES USING MANIFOLD CLUSTERING

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Abstract : In this paper, we will show that the Hapke model, a well known radiative transfer scattering model for intimate mixtures, when considered as a nonlinear function of endmember grain sizes, abundances, illumination and viewing angles, can be represented geometrically as a low dimensional manifold with a gentle curvature. In this scenario, we can represent the data cloud of a scene composed by several intimate mixtures with shared endmembers as a set of intersecting manifolds. We propose a manifold-clustering based method to identify the different intimate mixtures by learning the optimal geometrical separation of a linear approximation of the corresponding manifolds. Unmixing is then performed separately in each discovered cluster by a modification of the ISOMAP embedding that takes into account that the Hapke model produces data clouds exhibiting an increasing density gradient from bright to dark endmembers. Given the lack of availability of ground truth and datasets of known intimate mixture measurements, we test the algorithm on several simulated datasets generated using a version of the Hapke model.

ROBUST UNMIXING USING CONSENSUS ANALYSIS

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Abstract : Spectral unmixing is a challenging, ill-posed, inverse problem. Many algorithms have been proposed for robust, stable, and accurate unmixing solutions. Different algorithms have different modes of operation and usually yield different results. Moreover, most of them require specifying the number of endmembers to be extracted before hand. We propose using consensus analysis on multiple unmixing results to find the "optimal" endmembers in the data. We run multiple unmixing algorithms, using different numbers of endmembers, and combine the results using consensus analysis. The claim is that actual endmembers will have a consensus among all runs. Using simulated and real hyperspectral data, we show that the proposed approach identifies robust endmembers.

CHARACTERIZATION OF HYPERSPECTRAL IMAGES PRIOR TO UNMIXING, BASED ON EIGENDECOMPOSITIONS AND SUM-TO-ONE CONDITION

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Abstract : When performing blind unmixing of hyperspectral images, the mixing model properties determine which unmixing methods are adequate and how their parameters should be set. One should therefore derive these properties before unmixing, directly from the observed mixed data. We show how to deduce such properties from the eigenvalues of the correlation and covariance matrices of observed hyperspectral images, separately considered as spectral and spatial functions. Our methods first determine if the sum of all coefficients is the same for all pixels. They thus distinguish between (i) the usual mixing model: linear combinations of "monospectra" (i.e. standard spectra), with sum-to-one condition for coefficients and (ii) the linear-quadratic model: linear combinations of monospectra and "bispectra" (i.e. products of two monospectra), with non-constant sum of coefficients. Moreover, we show how to estimate the total number of monospectra and bispectra, if any, mixed in observations. Performance is validated for synthetic mixtures of real pure spectra.

XVIII. Session thu-o-3-b : NIR/SWIR/THERMIC

CLAY CONTENTS PREDICTED FROM HYPERSPECTRAL VNIR/SWIR IMAGERY, UNDER DIFFERENT ATMOSPHERIC CONDITIONS AND SPATIAL RESOLUTIONS

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Abstract : Visible, Near-Infrared and Short Wave Infrared hyperspectral satellite imaging is one of the most promising tools for soil property mapping. The objective of this study was to test the sensitivity of soil property prediction results to atmospheric effects and to degradation in image spatial resolutions, to offer a first analysis of the potential of future hyperspectral satellite sensors for Soil applications (HYPXIM, PRISMA, Shalom, ENMAP and HyspIRI). Our results showed that regression methods have robust performances from images from 5 to 30m and are inaccurate from images at 60 and 90m; when a correct compensation of the atmosphere effects is done, no differences are detected between the soil property maps retrieved from airborne imagery and the ones from spaceborne imagery; the spatial aggregation of the images induces a loss of the variance of the soil property prediction from 15 m of spatial resolution and a loss of information on soil spatial structures from 30 m of spatial resolution.

PREDICTING WITH LIMITED DATA – INCREASING THE ACCURACY IN VIS-NIR DIFFUSE REFLECTANCE SPECTROSCOPY BY SMOTE

Christina Bogner, *Ecological Modelling BayCEER, University of Bayreuth, Bayreuth, Germany*
Anna Kühnel and Bernd Huwe, *Soil Physics Group BayCEER, University of Bayreuth, Bayreuth, Germany*

Abstract : Diffuse reflectance spectroscopy is a powerful technique to predict soil properties. It can be used in situ to provide data inexpensively and rapidly compared to the standard laboratory measurements. Because most spectral data bases contain air-dried samples scanned in the laboratory, field spectra acquired in situ are either absent or rare in calibration data sets. However, when models are calibrated on air-dried spectra, prediction using field spectra are often inaccurate. We propose a framework to calibrate partial least squares models when field spectra are rare using synthetic minority oversampling technique (SMOTE). We calibrated a model to predict soil organic carbon content using air-dried spectra spiked with synthetic field spectra. The root mean-squared error of prediction decreased from 6.18 to 2.12 mg g−1 and R2 increased from −0.53 to 0.82 compared to the model calibrated on air-dried spectra only.

REMOTE SENSING OF SURFACE EMISSIVITY WITH THE TELOPS HYPER-CAM

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Abstract : Processing long-wave infrared (LWIR) hyperspectral imagery to surface spectral emissivity or reflectance units via atmospheric compensation and temperature-emissivity separation (TES) affords the opportunity to remotely classify and identify surface materials with minimal interference from atmospheric effects. This paper describes an automated atmospheric compensation and TES method, called FLAASH-IR (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes – Infrared), and its application to airborne imagery taken with the Telops Inc. Hyper-Cam interferometric hyperspectral imager. The results demonstrate good suppression of the atmospheric features due to water vapor and ozone, resulting in quantitative surface spectra, even with highly reflective (low emissivity) objects such as bare metal.

SPECIES DISCRIMINATION USING EMISSIVE THERMAL INFRARED IMAGING SPECTROSCOPY

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M. Gerhards, *Département Environnement et Agro-biotechnologies, Centre de Recherche Public – Gabriel Lippmann, Luxembourg*
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C. Hecker, *Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, the Netherlands*
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M. Schlerf, *Département Environnement et Agro-biotechnologies, Centre de Recherche Public – Gabriel Lippmann, Luxembourg*
W. Werner, *Department of Geobotany, University of Trier, Trier, Germany*

Abstract : A plant species discrimination experiment was carried out using emissive thermal infrared imaging spectroscopy. This was a first application of the Telops HyperCam-LW for vegetation analysis. The Telops HyperCam-LW is a Fourier-transform imaging spectrometer designed for airborne, field and laboratory application. Compared to laboratory spectrometers, this spectrometer allows fast measurements at high spectral resolution in the 8 – 12 μm spectral range. This paper shows that this spectrometer – in a field measurement setup – is capable of capturing high quality spectral information, comparable to laboratory instruments. We used this spectrometer to capture leaf spectra, generally considered as spectrally flat surfaces. Using the Telops HyperCam-LW, it was possible to capture the subtle signatures and perform species discrimination analysis with very good results. Further, the potential of a hyperspectral airborne or spaceborne study focusing on vegetation analysis is discussed.

AIRBORNE THERMAL INFRARED HYPERSPECTRAL IMAGING OF GASES

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Abstract : Characterization of gas clouds are challenging situations to address due to the uneven distribution of these large entities as a function of time. Whether gas characterization is carried out for gas leaks surveys or environmental monitoring purposes, explosives and/or toxic chemicals are often involved. In such situations, airborne measurements present distinct advantages over ground based-technics since large areas can be covered efficiently from a safe distance. Most gases are infrared-active and can be probed using infrared imaging. Airborne thermal infrared hyperspectral imaging was carried out above smokestacks and a ground-based gas release experiment in order to illustrate the benefits of this technique to characterize gas clouds. Quantitative airborne chemical images of carbon monoxide (CO) and ethylene (C_2H_4) were obtained from measurements carried out using a midwave (3-5 μm) and a longwave (8-12 μm) airborne infrared hyperspectral sensor respectively. Airborne measurements were carried out using both mapping and targeting acquisition modes. The later provides unique time- dependent information such as the gas cloud direction and velocity.

XIX.   SESSION FRI-P-A : NOISE REDUCTION

JOINT DENOISING AND UNMIXING FOR HYPERSPECTRAL IMAGE

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Abstract : Denoising and spectral unmixing are two separate steps traditionally, unmixing algorithm is implemented to hyperspectral image after denoising. The performance of unmixing will be promoted if noise in hyperspectral image is removed efficiently. But the result of unmixing can not be used to improve the result of denoising. In this paper we propose a joint denoising and unmixing algorithm for hyperspectral image. In this algorithm, denoising and unmixing result can be obtained simultaneously and they can improve the performance of each other. Noise is removed in sparse representation framework, abundance information is used as spectral constraint to enhance the denoising performance. The unmixing would perform better when noise is suppressed and would be more robust to noise. The obtained endmember and abundance information will further enhance the result of denoising. The experiment proves that our algorithm can provide denoising and unmixing result that both of them are competitive to the state-of-the-art methods in their respective fields.

SINGULAR SPECTRUM ANALYSIS FOR EFFECTIVE NOISE REMOVAL AND IMPROVED DATA CLASSIFICATION IN HYPERSPECTRAL IMAGING

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Abstract : Based on the well-known Singular Value Decomposition (SVD), Singular Spectrum Analysis (SSA) has been widely employed for time series analysis and forecasting in decomposing the original series into a sum of components. As such, each 1-D signal can be represented with varying trend, oscillations and noise for easy enhancement of the signal. Taking each spectral signature in Hyperspectral Imaging (HSI) as a 1-D signal, SSA has been successfully applied for signal decomposition and noise removal whilst preserving the discriminating power of the spectral profile. Two well-known remote sensing datasets for land cover analysis, AVIRIS 92AV3C and Salinas C, are used for performance assessment. Experimental results using Support Vector Machine (SVM) in pixel based classification have indicated that SSA has suppressed the noise in significantly improving the classification accuracy.

3-D WAVELETS-BASED DENOISING AND ENHANCEMENT OF HYPERSPECTRAL IMAGERY

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Abstract : In this paper, an original three-dimensional denoising approach and coding scheme are proposed. The suggested denoising algorithm is taking full advantage of the supplied volumetric data by decomposing the original hyperspectral imagery into individual subspaces applying orthogonal isotropic three-dimensional divergence-free wavelet transformation. The delineated capability of hierarchically structured wavelet coefficients improves the efficiency of the suggested denoising algorithm and effectively preserves the finest details and the relevant image features. The reported results are based on a real data set, presenting four different airborne hyperspectral systems: AVIRIS, AisaDUAL, AHS and APEX. Several qualitative and quantitative evaluation measures are applied to validate the ability of the suggested method for noise level reduction and for image quality enhancement. Experimental results demonstrate that the proposed denoising algorithm achieves better performance when applied on the suggested wavelet transformation compared to other examined transformation techniques.

HYPERSPECTRAL IMAGE NOISE REDUCTION AND ITS EFFECT ON SPECTRAL UNMIXING

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Abstract : In hyperspectral images (HSI), many of the spectral bands have low noise levels (LN bands) while some have high noise levels (junk bands). If a noise reduction algorithm is globally applied to the whole dataset, it usually affects the LN bands adversely. Therefore, we consider different criteria for denoising LN and junk bands. First, we discriminate between LN and junk bands using the spectral correlation between adjacent bands. After that, the mirror- extended curvelet transform is applied to all spectral bands. Next, each LN band is denoised using a soft thresholding technique, while a local noise reduction method is used for the junk bands, where the curvelet coefficients of adjacent LN bands are used to recover the junk bands. This targeted approach is prone to reduce spectral distortions during denoising compared to global denoising methods. This is shown in simulations where the proposed method is compared to a wavelet and a 3-dimensional Wiener filtering denoising algorithm. The proposed method outperforms the global methods in terms of PSNR. To assess the effect of spectral distortion, spectral unmixing is applied to the denoised results and reconstruction errors are compared, again showing the benefit of the proposed approach.

ESTIMATION OF CORRELATED NOISE IN HYPERSPECTRAL IMAGES

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Abstract : Many hyperspectral image processing algorithms (e.g detection, classification, endmember extraction etc.) are generally designed with the assumption of no spectral or spatial correlation in noise. However, studies have shown the presence of non-negligible correlation between the noise samples in different spectral bands, especially between noise of adjacent bands. It was also shown recently that many well- known endmember extraction algorithms e.g. give poor estimates for the number of endmembers in the presence of correlated noise. This asks for a precise estimation of noise for cases where noise is spectrally correlated. We show in this paper that the commonly employed hyperspectral noise estimation algorithm based on regression residuals is very affected by spectrally correlated noise and we suggest a modified approach that proves to be very robust to noise correlation. Simulation results show that the estimation error is reduced at times by a factor of 5 when there is high spectral correlation in the noise.

APPLICATION OF NON-LINEAR PRINCIPAL COMPONENT ANALYSIS TO HYPERSPECTRAL DATA FOR NOISE FILTERING USING ARTIFICIAL NEURAL NETWORKS

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Abstract : This work describes results of noise filtering techniques based on a Non-Linear Principal Component Analysis (NLPCA), applied to Hyperspectral CASI remote sensed data. NLPCA was carried out using Artificial Neural Networks (ANN) which are capable of modeling data non-linearity. NLPCA operated feature extraction on which original data were reconstructed, filtering the noise which affects first VNIR bands. Such a technique cleans VNIR bands, but does not affect the signal of other bands (SWIR). In order to appreciate improvements in classification due to noise filtering a supervised classification algorithm, based on Support Vector Machines (SVM), was applied to both original, noise filtered data, and NLPCA components (NLPCs). Results show that classification obtained using NLPCA-derived data is more accurate. Finally, SVM classification was also applied to fused images adding LiDAR Digital Surface Model (DSM) to the NLPCs and the original image in order to evaluate further improvements introduced by the dimensionality reduction offered by the NLPCA. Results show that the proposed method is able to improve the classification both by reducing dimensionality and suppressing the noise.

XX.   SESSION FRI-P-B : CLASSIFICATION

COLLABORATIVE REPRESENTATION BASED K-NEAREST NEIGHBOR CLASSIFIER FOR HYPERSPECTRAL IMAGERY

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Qian Du, *Department of Electrical and Computer Engineering, Mississippi State University*
Fan Zhang and Wei Hu, *College of Information Science & Technology, Beijing University of Chemical Technology*

Abstract : We propose a novel collaborative representation based k- nearest neighbors algorithm for hyperspectral image classification. The proposed method is based on a collaborative representation computed by an l_2-norm minimization with a Tikhonov regularization matrix. More specific, the testing sample is represented as a linear combination of all the training samples, and the weights for representation are estimated by an l_2-norm minimization derived closed-form solution. The label of the testing sample is determined by the majority vote of those with k largest representation weights. The experimental results show that the proposed algorithm achieves better performance than several previous algorithms, such as the original k-nearest neighbor classifier and local mean based nearest neighbor classifier.

AN IMPROVED MARKER SELECTION METHOD FOR HYPERSPECTRAL IMAGE SEGMENTATION AND CLASSIFICATION

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Abdolreza Safari, *Dept. of Surveying and Geomatics Eng., College of Engineering, University of Tehran, Tehran, Iran*
Safa Khazai, *Dept. of Civil Eng., College of Engineering, Imam Hussein Comprehensive University, Tehran, Iran*
Hossein Torabzadeh, *Remote Sensing Laboratories, University of Zurich, Zurich, Switzerland*

Abstract : Recently, a new approach for spectral-spatial classification of hyperspectral images has been proposed by Tarabalka et al. This approach is based on the Minimum Spanning Forest (MSF) grown from automatically selected markers by using the Support Vector Machines (SVM) classification. This paper aims at improving this approach by means of a new method for the selection of markers. This method is a combination of SVM and multi-layer perceptron (MLP) neural network classifiers. In the proposed method, the most reliable pixels, i.e. markers, are extracted from the classification maps and used to build the MSF. Three scenarios are evaluated for the first stage of marker selection: SVM, MPL and combination of SVM and MPL. Experimental results on two benchmark hyperspectral datasets demonstrate that the proposed method significantly improves the classification accuracies compared to the approach based on the SVM classification.

A NOVEL SEMISUPERVISED TRANSDUCTIVE SVM WITH SPATIAL SIMILARITY FOR CLASSIFICATION OF HYPERSPECTRAL DATA

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Abstract : In this paper, a novel semisupervised algorithm is proposed with spatial similarity for classification of hyperspectral data based on the transductive support vector machines algorithm. The proposed method exploits the characteristic of the hyperspectral data, in which spatially nearby points are likely to belong to the same class. To utilize this assumption, a novel transductive support vector machines algorithm is proposed. Experimental tests are performed on two hyperspectral data sets. The results show that the proposed algorithm obtains

SUPPORT TENSOR MACHINE WITH LOCAL PIXEL NEIGHBORHOOD FOR HYPERSPECTRAL IMAGE CLASSIFICATION

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Abstract : A multiclass support tensor machine (STM) for the classification of remotely-sensed imagery is investigated in this study aiming at simultaneously exploiting the spectral and spatial information for accurate image interpretation. Spatial relationship of neighboring pixels has been taken into consideration by a local pixel neighborhood (LPN), which processes the local imagery patch as a cube, and is capable of separating land classes in both spectral and spatial domains. To deal with the tensor data and keep the data structure in high-order feature space, support vector machine has been extended to support tensor machine by the multilinear algebra. Experiments conducted on AVIRIS hyperspectral image revealed that the STM achieved much better results than the standard SVM classifier.

CONTRIBUTION OF BAND SELECTION AND FUSION FOR HYPERSPECTRAL CLASSIFICATION

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Abstract : For some specific land cover classification problems, it may be interesting to design superspectral camera systems with reduced numbers of bands (~20) and optimized band widths. This paper assesses the contribution of band selection and band fusion processes separately and jointly for dimensionality reduction. The proposed approach is fully automatic and based on a wrapper feature selection using Random forest classifier and a similarity-based fusion process. While combining both processes, selection before fusion gave the best results, reducing by almost 91% the number of bands while keeping satisfying accuracies. Results are presented on Indian Pines, Salinas and Pavia Centre hyperspectral datasets.

EDGE CONSTRAINED MRF METHOD FOR CLASSIFICATION OF HYPERSPECTRAL IMAGERY

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Hua Wu, *Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China*

Abstract : This paper proposes an edge constrained Markov random field (MRF) method for accurate classification of hyperspectral imagery. The characteristic of the proposed method is using an alterable spatial weighting coefficient, which is acquired based on the edge information, instead of a traditional fixed coefficient. In this way, the spatial contributions in MRF model are different for pixels inside objects or on the boundaries. Therefore, the "salt and pepper" inside object can be removed and the "overcorrection" can be resolved. Experimental results of the synthetic hyperspectral data and the real hyperspectral image demonstrate that the proposed method works better on both homogeneous regions and class boundaries with improved classification accuracies.

CLASSIFICATION OF ENERGY TREE SPECIES USING SUPPORT VECTOR MACHINES

Peter Burai, Laszlo Beko, Csaba Lenart and Tamas Tomor,
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Abstract : This paper investigates whether the combination of airborne hyperspectral imagery (Aisa EAGLE II) and image classification methods (MLC,SVM) using feature extraction can discriminate among species and clones of energy trees. The trees examined have similar morphological traits due to limitation of detection. The image classification was applied on a spectrally selected and transformed (PCA, MNF) dataset. A binary tree SVM classifier was developed in accordance with the principle of SVM, based on the Jeffries-Matusita (JM) separability measure of selected classes. The adaptive binary tree SVM on MNF-transformed dataset provided more accurate results than applied MLC and multiclass SVM methods. The primary outcome of this study was a comparison of support vector machines (SVM) classification methods to evaluate species or clones of energy plants. In this paper, an adaptive binary tree SVM classifier (ABTSVM) is proposed to increase the accuracy of subspecies level.

A NOVEL SPECTRAL SPATIAL FILTERING APPROACH FOR HYPERSPECTRAL IMAGE CLASSIFICATION

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Abstract : In this paper, we proposed a spectral spatial filtering (SSF) method by employing the spectral angle distance between central pixel and its neighboring pixels in the window. And its performance was verified using different classifiers of hyperspectral images. Classification results show that SSF method is able to smooth the image effectively while keep detailed information at the same time. SSF can significantly improve the classification accuracy for these classifiers, in which the SSF-Maximum Likelihood achieves the best result with the highest overall accuracy and kappa coefficient. It shows great performance in distinguishing some classes, which are difficult for other classifiers. We also test the adaptability of SSF to classification of small sample by using Support Vector Machine classifier, and reach to some encouraging results as expected.

GAME THEORY MODELS FOR SPECTRAL BAND GROUPING AND CLASSIFIER ENSEMBLES FOR HYPERSPECTRAL IMAGE CLASSIFICATION

Lori Mann Bruce, *Professor and Dean of the Graduate School, Mississippi State University, U.S.A*

Abstract : This paper investigates the utilization of game theory models for automated analysis of hyperspectral imagery. The author proposes three approaches to using strategic, competitive game theory models for groundcover classification using hyperspectral imagery, including the application of game theory models to (i) hyperspectral band grouping and (ii) pixel classification in a classifier ensemble system. Proposed model uses conflict data filtering based on mutual entropy along with the Nash equilibrium as the means to find a steady state solution. Proposed model (ii) utilizes a strategic coalition game, specifically the weighted majority game (WMG). Both a models are implemented under the assumption that all players are rational. The author incorporates each of the proposed approaches, (i) and (ii), into a multi-classifier decision fusion (MCDF) system for automated ground cover classification with hyperspectral imagery. The paper provides experimental results demonstrating the efficacy of the proposed game theoretic approaches, presenting significant improvements over existing methods.

NONLINEAR PARSIMONIOUS FEATURE SELECTION FOR THE CLASSIFICATION OF HYPERSPECTRAL IMAGES

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Institut de Mathématiques de Toulouse - UMR 5219 & Université de Toulouse, France
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Abstract : A nonlinear parsimonious feature selection algorithm is presented in this paper. It is based on a Gaussian mixture model (GMM). GMM are used for classifying hyperspectral images. The algorithm selects iteratively spectral features that maximizes an estimate of the correct classification rate. In order to perform fast in terms of computing time, an efficient implementation is proposed. First, the GMM can be updated when the estimation of the correct classification rate is computed, rather re-estimate the full model. Secondly, using marginalization of the GMM, sub models can be directly obtain from the full model learns with all the spectral features. Experimental results for three hyperspectral data sets show that the method performs very well and is able to extract very few spectral channels.

SPECTROMETER-DRIVEN SPECTRAL PARTITIONING FOR HYPERSPECTRAL IMAGE CLASSIFICATION

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Abstract : Classification is an important and widely used technique for remotely sensed hyperspectral data interpretation. Although most techniques developed for classification assume that the spectral signatures provided by an imaging spectrometer can be interpreted as a unique and continuous signal, in practice this signal may be obtained after the combined individual responses from several different spectrometers. For instance, the Airborne Visible Infra-Red Imaging Spectrometer (AVIRIS) system is in fact formed by four different spectrometers, covering the nominal spectral ranges of 400-700 nm, 700-1300 nm, 1300-1900 nm, and 1900–2500 nm, respectively. In this work, we propose a new classification strategy which takes into account the physical design of the imaging spectrometer system for partitioning the spectral bands collected by each spectrometer, and resampling them into different groups or partitions. The final classification result is obtained as a combination of the results obtained from each individual partition. This concept is illustrated in this work using AVIRIS data, and our experimental results indicate that the proposed strategy provides advantages in terms of classification accuracy, in particular, when very limited training samples are available.

XXI.   Session fri-p-c : Advanced signal and image processing techniques

SLOW FEATURE ANALYSIS FOR HYPERSPECTRAL CHANGE DETECTION

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Bo Du, *School of Computer, Wuhan University, Wuhan, P.R. China*
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Abstract : Hyperspectral image can provide more abundant information on spectral changes. Because of its high dimension, it is hard to directly apply change detection algorithm on hyperspectral images. Slow feature analysis is a novel change detection theory for multi-temporal remote sensing image. In this paper, we propose a new method to employ SFA for hyperspectral change detection. A Multi-temporal PCA method is proposed to reduce the dimension of hyperspectral dataset. Then SFA can be used on the low-dimension dataset to separate changes and non-changes. The experiment proved that our proposed method is effective to detect changed areas.

USE OF CLUSTERING WITH PARTIAL LEAST SQUARES REGRESSION FOR PREDICTIONS BASED ON HYPERSPECTRAL DATA

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Abstract : This paper presents a new technique able to register satellite time series made up of several images within a global Least Squares adjustment. The method improves traditional 'master-to-slave' registration approaches and extends the pairwise registration concept towards block adjustment. Its main advantage concerns the combined analysis of multiple images, avoiding standard matching between one 'master' and several 'slave' images. This results in a better control of errors and a more robust and reliable Least Squares solution with full error propagation. Application to Landsat TM images is reported to show the performance of the simultaneous Least Squares registration.

LOCAL DENSITY BASED BACKGROUND ESTIMATION

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Abstract : Background statistics estimation is the key point for the statistics model based detectors. The background statistics obtained globally from the whole image may be inaccurate due to target contamination of the background information. To solve this problem, this paper proposed a local density based background estimation algorithm (LDBE) based on the definition of local density based anomaly score (LDAS). LDAS is a new metric that utilizes the distance between spectral to calculate each pixel's probability of background. LDBE uses LDAS as a criterion to determine whether a pixel is part of the background or not. By applying this algorithm, the background statistics can be estimated more accurately with the non-background pixels eliminated. The experimental results on real hyperspectral datasets suggest that the proposed background estimation algorithm can greatly improve the performance of statistical model based target detectors.

SUBPIXEL TRACKING USING SPECTRAL DATA AND KALMAN FILTER

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Abstract : This paper proposes a tracking method for multispectral and hyperspectral sequences. Tracking small objects in spectral scenes is often difficult with the assumption of coarse pixels due to sensor resolution and often requires the use of sub-pixel detection algorithms. The approach presented in this paper combines the linear spectral mixing model with Kalman- Filter (KF) for tracking. We introduce the dimension of time to the problem of spectral unmixing to identify and track sub- pixel size targets. Results are provided and compared with previously proposed methods for tracking targets in spectral data.

EXTENDED FUNCTIONS OF MULTIPLE INSTANCES FOR TARGET CHARACTERIZATION

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Abstract : An extension of the Function of Multiple Instances (FUMI) algorithm for target characterization is presented. FUMI is a generalization of Multiple Instance Learning (MIL). However, FUMI differs significantly from standard MIL and supervised learning approaches because only data points which are functions of class concepts are available. For applicability to hyperspectral data, this paper addresses the problem in which data points are convex combinations of target and non-target concepts. The presented method, eFUMI, extends previous methods to allow for further unspecificity in training labels while estimating target and non-target concepts, the number of non-target concepts, and the weight associating each concept to each data point. For eFUMI, training data need only binary labels indicating whether a spatial area in an input image contains or does not contain some proportion of target material; the specific locations or target proportions for training data are not needed. After learning the target concept, target detection can be performed on test data. Results showing sub-pixel target detection on simulated and real Hyperspectral data are provided.

HYPERSPECTRAL CHANGE DETECTION WITH STEREO DISPARITY INFORMATION ENHANCEMENT

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Abstract : A hyperspectral change detection method with stereo depth information enhancement is proposed in this paper. The method operates on the hyperspectral data acquired by the ground-based hyperspectral stereo imaging system. The imaging system combines the properties of panoramic and stereo imaging with the high spectral resolution of hyperspectral cameras, and is of use especially for surveillance applications. Stereo and spectral information provided by the system are fused in the proposed method for enhanced change detection. Experimental results are evaluated on two hyperspectral datasets acquired by the system. Preliminary results show the improved performance of the system and the proposed method.

EVALUATION OF ON-BOARD INTEGER WAVELET TRANSFORM BASED SPECTRAL DECORRELATION SCHEMES FOR LOSSLESS COMPRESSION OF HYPERSPECTRAL IMAGES

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Ozan Yilmaz and Yakup Murat Mert, *Tübitak Uza*

Abstract : Integer-coefficient Discrete Wavelet Transformation (DWT) filters widely used in the literature are implemented and investigated as spectral decorrelator for on-board lossless hyperspectral image compression. As the performance of spectral decorrelation step has direct impact on the compression ratio (CR), it is important to employ the most convenient spectral decorrelator in terms of low computational complexity and high CR. Extensive tests using AVIRIS image data set are carried out and CRs corresponding to various subband decomposition levels are presented within a lossless hyperspectral compression framework. Results suggest that Cohen-Daubechies- Feauveau (CDF) 9/7 integer-coefficient wavelet transform with five levels of spectral subband decomposition would be an efficient spectral decorrelator for on-board lossless hyperspectral image compression.

GAS PLUME DETECTION AND TRACKING IN HYPERSPECTRAL VIDEO SEQUENCES USING BINARY PARTITION TREES

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Abstract : Thanks to the fast development of sensors, it is now possible to acquire sequences of hyperspectral images. Those hyperspectral video sequences are particularly suited for the detection and tracking of chemical gas plumes. However, the processing of this new type of video sequences with the additional spectral diversity, is challenging and requires the design of advanced image processing algorithms. In this paper, we present a novel method for the segmentation and tracking of a chemical gas plume diffusing in the atmosphere, recorded in a hyperspectral video sequence. In the proposed framework, the position of the plume is first estimated, using the temporal redundancy of two consecutive frames. Second, a Binary Partition Tree is built and pruned according to the previous estimate, in order to retrieve the real location and extent of the plume in the frame. The proposed method is validated on a real hyperspectral video sequence and compared with a state-of-the-art method.

MATCHED SUBSPACE DETECTOR BASED ON SPARSE REPRESENTATION FOR TARGET DETECTION IN HYPERSPECTRAL IMAGERY

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Abstract : In this paper, we propose a new sparsity-based matched subspace detector (SMSD) algorithm for target detection in hyperspectral imagery (HSI). This algorithm, based on the concept that a pixel in HSI lies in a low-dimensional subspace and thus can be represented as a sparse linear combination of the training samples, explores the linear mixing model to both specify the desired target and characterizes the interfering background. In the algorithm, the linear subspace mixture model for the MSD is first reformulated and then the corresponding expression for the generalized likelihood ratio test (GLRT) is obtained for this model and at last we use the sparse representation to modify the MSD model. The proposed algorithm is compared with the sparsity-based algorithm. Simulation results show that our algorithm outperforms the sparsity-based target detection algorithm.

XXII.   SESSION FRI-O-1-A : SPECTRORADIOMETRIC APPLICATIONS FOR OPTICALLY COMPLEX WATERS

OPERATIONAL NIR-RED ALGORITHMS FOR ESTIMATING CHLOROPHYLL-A CONCENTRATION FROM SATELLITE DATA IN INLAND AND COASTAL WATERS

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Abstract : We present here results that strongly support the use of NIR- red algorithms, developed based on the spectral channels of MERIS, as standard tools for estimating chlorophyll-a (chl- a) concentration in turbid productive waters. We used an extensive set of MERIS imagery and in situ data collected between 2008 and 2010 in the Azov Sea and the Taganrog Bay, Russia. The overall estimation errors were only 5.5% of the total range of chl-a concentrations measured, illustrating the high accuracy of the MERIS-based NIR-red algorithms without the need for case-specific re- parameterization. The NIR-red algorithms were also applied to a series of images acquired by HICO over the same region in 2012-13, after the demise of MERIS. The results demonstrated the strong potential of HICO as a reliable tool for determining coastal water quality.

A CASE STUDY AT STARNBERGER SEE FOR HYPERSPECTRAL BATHYMETRY MAPPING USING INVERSE MODELING

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Abstract : In coastal regions, hyperspectral remote sensing is becoming an established method to map water depth. For inland waters however, only few studies based on empirical methods have been published so far. This paper presents a study for the German lake Starnberger See using a physically based approach. Hyperspectral data were acquired from airplane using a HySpex VNIR-1600 sensor. They were processed by inverse modeling using a radiative-transfer based analytical model. In situ measurements were taken to decide which model parameters to fit and which to keep constant during data analysis, and they were used to initialize the parameters. Bottom reflectance was determined from the image itself. An echo sounding survey was undertaken for validation. For the studied area, bathymetry could be mapped up to a depth of 8 m with a rms error of 37 cm. Accuracies of 10-25 cm from 0-4 m and 35-65 cm from 4-8 m seem possible if the remaining systematic errors can be further reduced, e.g. by accounting for changes of bottom reflectance.

HICO LEVEL-2 DATA PROCESSING TOOLBOX FOR THE ATMOSPHERIC CORRECTION AND THE RETRIEVAL OF WATER QUALITY PARAMETERS

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Abstract : The Hyperspectral Imager for the Coastal Ocean (HICO) is an imaging spectrometer specifically designed to monitor the coastal ocean. The processing of Top-Of-Atmosphere (TOA) radiance data down to surface reflectance is fundamental for the retrieval of water quality products. However, the current HICO processing chain does not provide atmospheric corrected data nor higher-level water quality products. This work describes a toolbox for the atmospheric correction of HICO data and the retrieval of water quality products. The HICO toolbox, consisting on three main modules (image pre-processing, atmospheric correction and retrieval of water quality products), has been used over a set of HICO images showing a good linear correlation (R2 = 0.95) between in- situ measured and retrieved Chl-a over a water body. The presented toolbox will ease the processing of HICO data down to surface reflectance that will allow to derive water quality parameters.

MAPPING BENTHIC SUBSTRATE COVERAGE AND BATHYMETRY USING BIO-OPTICAL MODELLING - AN EN-MAP CASE STUDY IN THE COASTAL WATERS OF HELGOLAND

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Abstract : Kelp forests, which are dense stands of brown seaweeds of the taxonomic order Laminariales, often are used as indicator species for assessing the environmental state of coastal waters. To this end, large scale monitoring approaches are required apart from traditional labor-intensive point sampling techniques. Bio-optical modelling with hyperspectral remote sensing data provides the possibility to take on the task. Yet, hyperspectral imagery mainly originates from airborne data. Within in the scope of the EnMAP Preparatory Program the bio-optical model WASI-2D was tested to the coastal area of Helgoland. A simulated EnMAP scene was spectrally unmixed for the two substrate types Laminariales and sediment. Inverse modelling yielded plausible patterns and gradients of substrate coverages and bathymetry. Comparisons with in situ data revealed results tended to overestimate sediment and to underestimate Laminariales coverage and bathymetry. WASI- 2D, however, was able to resolve the complex bottom and bathymetric structure at the rocky coast of Helgoland.

HYPERSPECTRAL OBSERVATIONS OF OPTICAL PROPERTIES IN LAKES IN PERSPECTIVE OF FUTURE SATELLITE SENSORS - A CASE STUDY IN ITALY

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Abstract : HICO, Hyperion and MERIS have already demonstrated the capabilities of hyperspectral sensors to gather information on optical properties in inland waters. With the advent of Sentinel-2, Sentinel-3, EnMap, PRISMA and HyspIRI we expect that application of remote sensing techniques for inland water quality assessment will progress even more. Some clear advantages rely on: 1) improved spatial resolution (so that even medium/small lakes are imaged), 2) increased frequency of over-passes (so that environmental processes are detected in time) and 3) enhanced sensor characteristics (which allow, for instance, the secondary phytoplankton pigments to be retrieved). In this study we present how these improvements will permit to deliver improved products for inland water quality addressing better the end-user demands.

XXIII. Session fri-o-1-b : Sparsity in hyperspectral data processing

JOINT SPARSE AND COLLABORATIVE REPRESENTATION FOR TARGET DETECTION IN HYPERSPECTRAL IMAGERY

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Abstract : In this paper, we propose a joint sparse and collaborative representation-based algorithm for target detection in hyperspectral imagery. The proposed target detection is achieved by the representation of the test samples using a target library and a background library. The sparse representation of given target samples is solved by an l_1-norm minimization of the representation weight vector, and the collaborative representation of background samples is estimated by an l_2-norm minimization. The detection output of the test sample is determined by the difference between sparse reconstruction and collaborative reconstruction. Experimental results show that this algorithm outperforms the existing hyperspectral target detection algorithms, such as adaptive coherence estimator and pure sparse representation-based detector.

ANOMALY DETECTION AND IMPORTANT BANDS SELECTION FOR HYPERSPECTRAL IMAGES VIA SPARSE PCA

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Marcus Chen, Alvina Goh and Sze Kim Pang, *DSO National Laboratories*

Abstract : We propose a regularised version of the classical singular value decomposition for simultaneous outliers and associated important bands selection. The contributions are twofold: First, we exploit sequential optimisation techniques in L_0 formulation to obtain sparse solution of classical principal component analysis. Second, we have develop new formulation for the anomaly detection problem where the simultaneous identification of important bands can be performed. Experiments in real and simulated data are included to validate the proposed method.

ON THE USE OF COLLABORATIVE SPARSE REGRESSION IN HYPERSPECTRAL UNMIXING CHAINS

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Abstract : Hyperspectral unmixing is a complex process in which several steps are consecutively executed to derive the desired results: the image endmembers and their corresponding fractional abundance maps. Each of these unmixing stages benefits nowadays from a plethora of algorithms, continuously developed and improved. In this paper, we analyze three of the general unmixing steps: band selection (data dimensionality reduction), endmember extraction and fractional abundance inference (inversion) from a multi-measurement vector problem point of view. We show that these particular steps can be expressed as a convex optimization problem in which the concept of data collaborativity is exploited and one single algorithm can be efficiently used to solve them. Our experimental results obtained in an urban dataset acquired over Berlin, Germany, show the potential of this approach in remote sensing applications.

HIERARCHICAL SPARSE REPRESENTATION FOR DICTIONARY-BASED CLASSIFICATION OF HYPERSPECTRAL IMAGES

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Abstract : The recent advances in sparse coding and dictionary learning have shown extremely good performances and robustness in high-dimensional classification problems. Most often, dictionary-based methods rely either on the reconstruction power of the dictionary or on the structure of the sparse representation. In this paper we jointly exploit the discrimination power of both approaches by combining the reconstruction error with the hierarchical information of the sparse codes collected during the learning stage. The proposed method performs similarly to state-of-the-art classifiers and outper- forms them sharply in small sample situations, where the number of patterns used to learn the dictionaries is much smaller than the number of dimensions.

QUANTITATIVE DETECTION OF SETTLE DUST OVER GREEN CANOPY USING SPARSE UNMIXING OF AIRBORNE HYPERSPECTRAL DATA

Anna Brook, *Remote Sensing Laboratory, Center for Spatial Analysis Research, Department of Geography University of Haifa, Israel*

Abstract : The main task of environmental and geosciences applications are efficient and accurate quantitative classification of earth surfaces and spatial phenomena. Recently, the ground-truth and laboratory measured spectral signatures promoted by advanced algorithms are proposed as a new path toward solving the unmixing problem of hyperspectral remote sensing (HRS) imagery in semi- supervised fashion. In this paper, the sensitivity of sparse non-linear unmixing techniques to extract and identify a small amount of settle dust over green vegetation canopy using HRS airborne imagery data is proposed. Among the available techniques, this study present results of two selected algorithms: 1) $L_{1/2}$ sparsity-constrained nonnegative matrix factorization ($L_{1/2}$–NMF) and 2) orthogonal matching pursuit (OMP). The performance is evaluated on real HRS imagery data via detailed experimental assessment. The first dataset including a conducted study area in Hadera, Israel and the second dataset is APEX Open Science Data Set (OSDS) in Baden, Switzerland. The results compared with performances of selected conventional unmixing techniques.

XXIV. SESSION FRI-O-2-A : ADVANCED SIGNAL AND IMAGE PROCESSING TECHNIQUES

COMPARATIVE STUDY ON MORPHOLOGICAL PRINCIPAL COMPONENT ANALYSIS OF HYPERSPECTRAL IMAGES

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Abstract : This paper deals with a problem of dimensionality reduction for hyperspectral images using principal component analysis. Hyperspectral image reduction is improved by adding structural/spatial information to the spectral information, by means of mathematical morphology tools. It can be then useful for instance in supervised classification. The key element of the approach is the computation of a covariance matrix which integrates simultaneously both spatial and spectral information.

A COMPARATIVE ANALYSIS OF COVARIANCE MATRIX ESTIMATION IN ANOMALY DETECTION

Santiago Velasco-Forero, *National University of Singapore*
Marcus Chen, Alvina Goh and Kim Pang Sze, *DSO National Laboratories*

Abstract : Different methods of covariance matrix estimation are analysed in the context of anomaly detection in hyperspectral images. Regularised and robust covariance matrix estimators as well as sparse matrix transform are quantitatively compared in Dirichlet simulations and real HS images.

ENHANCING PURE-PIXEL IDENTIFICATION PERFORMANCE VIA PRECONDITIONING

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Abstract : In the scenario where pure pixels exist, pure-pixel search is well known to be a simple and effective approach for hyperspectral unmixing. However, in the noisy case, the performance of a pure-pixel search algorithm usually depends on the conditioning of the endmember matrix. This paper describes several data preconditioning methods for mitigating the aforementioned issue, including a newly proposed heuristic approach. The development is based on a pure-pixel search algorithm called successive projection algorithm (SPA). Simulations based on synthetic data sets show that preconditioning makes SPA much more robust against noise.

SUPERVISED HYPERSPECTRAL IMAGE SEGMENTATION: A CONVEX FORMULATION USING HIDDEN FIELDS

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Abstract : Image segmentation is fundamentally a discrete problem. It consists of finding a partition of the image domain such that the pixels in each element of the partition exhibit some kind of similarity. The optimization is obtained via integer optimization which is NP-hard, apart from few exceptions. We sidestep from the discrete nature of image segmentation by formulating the problem in the Bayesian framework and introducing a hidden set of real-valued random fields determining the probability of a given partition. Armed with this model, the original discrete optimization is converted into a convex program. To infer the hidden fields, we introduce the Segmentation via the Constrained Split Augmented Lagrangian Shrinkage Algorithm (SegSALSA). The effectiveness of the proposed methodology is illustrated with hyperspectral image segmentation.

SPATIALLY AWARE SUPERVISED NONLINEAR DIMENSIONALITY REDUCTION FOR HYPERSPECTRAL DATA

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Abstract : In this paper we study the effect of injecting spatial information of image patches directly in the process of supervised dimensionality reduction. In particular, we adopt an approach derived from the mean map kernel framework to map image patches of variable size into a reproducing kernel Hilbert space. In that space, the orthonormalized partial least squares performs supervised dimensionality reduction to a discriminant subspace. Advantages of the proposed approach are discussed by studying two well known hyperspectral image benchmarks and by comparing it to composite-kernel feature extraction framework.

XXV.   SESSION FRI-O-2-B : A DIVERSITY OF APPLICATIONS

HYPERSPECTRAL CHARACTERIZATION OF MARINE PARTICLES BASED ON MIE-LORENTZ AND T-MATRIX CODES AND A GENETIC ALGORITHM

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Abstract : Particle modeling is usually exploited, along with measured data, to infer the water content. However, the particle properties must be accurately known. In this paper, a methodology to estimate the hyperspectral complex-refractive-index signatures of marine particles is presented. It is is based on the Mie-Lorentz and T-matrix characterizations to obtain the particle inherent optical properties and uses a genetic algorithm for search optimization. This methodology is tested by accurately estimating the hyperspectral complex refractive indexes on two different examples, including monodisperse and polydisperse particle size distributions of spherical and non-spherical particles.

OBJECT-BASED RANDOM FOREST CLASSIFICATION FOR MAPPING FLOODPLAIN VEGETATION STRUCTURE FROM NATION-WIDE CIR AND LIDAR DATASETS

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Abstract : Very high resolution aerial images and LiDAR (AHN2) datasets with a national coverage provide opportunities to produce vegetation maps automatically. As such the entire area of the river floodplains in the Netherlands may be mapped with high accuracy and regular updates, capturing the dynamic state of the vegetation. In this study, these fused datasets are used to map the vegetation of 936 ha of the floodplain on the north-side of the river Nederrijn near Wageningen into ten vegetation structure classes. The method follows object-based image analysis principles. Objects are defined in segmentation and subsequently labeled using the ensemble-tree classifier random forest. The mapping scale is controlled by selecting segmentation parameters from quantified discrepancies between reference polygons and segmented objects. Effects on the mapping scale of different reference polygons and different segmentation data is investigated. The results show that it is important to be able to select the right segmentation parameters to control the mapping scale. A discrepancy measure with reference polygons is a suitable method to do this objectively. The use of random forest classification on the objects resulted in an estimated classification accuracy of 86% on the basis of the built-in cross-validation estimate of random forest. Variable importance measures of random forest showed that the AHN2 lidar dataset is a valuable addition to the spectral information contained in the aerial images in the classification.

A NON-LINEAR OPTIMAL ESTIMATOR FOR PLUME CONCENTRATION RETRIEVAL, USING AIRBORNE HYPER-SPECTRAL MEASUREMENT

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Marc-André Gagnon, *TELOPS Inc., Quebec, Canada*
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Abstract : Anthropogenic sources, especially industrial, emit into the atmosphere gases and aerosols, which play an important role in atmospheric exchanges. The use of new hyperspectral airborne sensors in the infrared range at high spatial resolution opens the way for further improvements in the characterization of industrial plumes. Existing methods, based on linear or Bayesian approach, present two major limitations: the heterogeneous environment impact on retrievals and the spatial and vertical extents of the plume are not considered. In this paper, a new method for plume characterization is presented to overcome such limitations. This method uses an accurate non linear formalism of cloud gas radiative impact. It includes furthermore a ground classification of the scene, in order to take into account the soil heterogeneity and spectral behaviour. This strategy will be validated using synthetic scenes of industrial area, and real data from Telops HyperCam airborne platform.

GLOBAL SENSITIVITY ANALYSIS OF WATER VAPOUR AND VISIBILITY FOR ATMOSPHERIC CORRECTION

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Alfred Stein, *ITC, Faculty of Geo-Information Science and Earth Observation of the University of Twente, The Netherlands*

Abstract : This study aims to quantify sensitivity of two atmospheric condition parameters: water vapour concentration (wv) and visibility in atmospheric correction processes in an operational processing chain. wv and visibility are important atmospheric condition parameters when retrieving surface reflectance from at-sensor radiance. To save cost, these parameters are often estimated using an image-based method. Their values are therefore uncertain, which in turn propagates to the surface reflectance in the atmospheric correction process. This study proposes an e-FAST based methodology that quantifies sensitivity of the two parameters in order to calculate their relative importance. The methodology is demonstrated with HyMap data. The results show that the two parameters have high sensitivity indices (> 0.8) and are dependent on the wavelength. This indicates that both parameters are important. The uncertainty in the parameters can possibly be further reduced by improving the estimation method.

CROSS VALIDATING HYPERSPECTRAL WITH ULTRASOUND-BASED SKIN THICKNESS ESTIMATION

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Abstract : Our work is focused on the development of non-invasive methods to estimate skin constitutive elements. Such methods can play an important clinical and scientific role in detecting the early onset of skin tumors. Given current statistics by the American Academy of Dermatology suggesting that more than 10 people die each hour worldwide due to skin related conditions, this has potentially high impact on the delivery of skin cancer diagnostics, and patient mortality and morbidity. It can also serve as a valuable tool for research in cosmetology and pharmaceuticals in general. We combine a physics-based model of human skin with machine learning and hyperspectral imaging to non-invasively estimate physiological skin parameters, including melanosomes, collagen, oxygen saturation, blood volume, and skin thickness. While some prior work has been done in this regard, no validation against ground truth has occurred whatsoever. In this specific study we develop a protocol to validate our methodology for estimating one of these skin parameters, skin thickness, using a dataset of 48 hyperspectral signatures obtained in vivo, and cross-validate our depth estimates with a gold standard obtained via Ultrasound. Relative to this gold standard, we find promising mean absolute errors of less than 0.1 mm for skin thickness estimation.

XXVI. Session fri-o-3-a : Spectral unmixing (3)

A NEW EXTENDED LINEAR MIXING MODEL TO ADDRESS SPECTRAL VARIABILITY

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Abstract : Spectral variability is a phenomenon due, to a grand extend, to variations in the illumination and atmospheric conditions within a hyperspectral image, causing the spectral signature of a material to vary within a image. Data spectral fluctuation due to spectral variability compromises the linear mixing model (LMM) sum-to-one constraint, and is an important source of error in hyperspectral image analysis. Recently, spectral variability has raised more attention and some techniques have been proposed to address this issue, i.e. spectral bundles. Here, we propose the definition of an extended LMM (ELMM) to model spectral variability and we show that the use of spectral bundles models the ELMM implicitly. We also show that the constrained least squares (CLS) is an explicit modelling of the ELMM when the spectral variability is due to scaling effects. We give experimental validation that spectral bundles (and sparsity) and CLS are complementary techniques addressing spectral variability. We finally discuss on future research avenues to fully exploit the proposed ELMM.

END-MEMBER EXTRACTION USING CONE NON-NEGATIVITY CONSTRAINTS

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Abstract : This paper presents a new factorization approach for hyperspectral data based on non-negativity constraints. The method does not assume a one to one correspondence between the pseudo-rank of the data matrix and the number of unique components present. Rather it assumes that the number of unique components is related to the number of extreme points of the cone formed by the data matrix. The cone is represented by singular vectors and a set of linear homogeneous inequality constraints. The extraction of extremes is based on the identification of non-redundant inequalities. The approach is illustrated in an application to an AVIRIS spectral image of the Cuprite mining site.

INTEGRATING MULTIPLE NONLINEAR ESTIMATORS INTO HYPERSPECTRAL UNMIXING

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Javier Plaza and Antonio Plaza, *Hyperspectral Computing Laboratory, University of Extremadura, Cáceres, Spain*
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Abstract : Linear spectral unmixing has been widely used for hyperspectral data interpretation. However, there is a need for nonlinear unmixing methods that can model more complex geometries without the need to resort to prior knowledge about the objects in the scene. In this paper, we present a novel strategy for nonlinear spectral unmixing which combines polytope decomposition (POD) with artificial neural network (ANN)-based learning. Even if no ground-truth information is available, the ANN can still efficiently estimate the order of the nonlinearity involved in the problem and enhance the capacity of the POD method to deliver unmixing performance for a wider range of nonlinearities. The proposed method has been evaluated using both simulated and real scenes, providing promising results.

NON-LINEAR HYPERSPECTRAL UNMIXING BY POLYTOPE DECOMPOSITION

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Abstract : This work provides a novel approach to non-linear unmixing of hyperspectral images assuming a polynomial postnonlinear mixing model. The new model exploits polytope decomposition to compute abundances under a polynomial approximation which is computed on a pixel by pixel basis in a very efficient way, with no requirements for a global optimization for the whole scene. The approach is validated with artificial and actual scenes and shows improvements over similar state of the art techniques.

AN INTEGRATED GRAPH CUTS SEGMENTATION AND PIECE-WISE CONVEX UNMIXING APPROACH FOR HYPERSPECTRAL IMAGING

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Abstract : Context-based unmixing has been studied by several researchers. Recent techniques, such as piece-wise convex unmixing using fuzzy and possibilistic clustering or Bayesian methods proposed in [11] attempt to form contexts via clustering. It is assumed that the linear mixing model applies to each cluster (context) and endmembers and abundances are found for each cluster. As the clusters are spatially coherent, hyperspectral image segmentation can significantly aid unmixing approaches that perform cluster specific estimation of endmembers. In this work, we integrate a graph-cuts segmentation algorithm with piece-wise convex unmixing. This is compared to fuzzy clustering (FCM) with results obtained on two datasets. The results demonstrate that the integrated approach achieves better segmentation and more precise endmember identification (in terms of comparisons with known ground truth).

XXVII. SESSION FRI-O-3-B : SIMULATORS AND MODELS

AT-SENSOR RADIANCE SIMULATION FOR AIRBORNE IMAGING SPECTROSCOPY

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Abstract : Physically-based radiative transfer modeling is the key to remote sensing of forest ecosystems. To scale spectral information from the leaf to the sensor level, the canopy architecture of a forest, illumination conditions and the viewing geometry have to be taken into account. Therefore, a new airborne image simulation approach is being developed for the 3D radiative transfer model DART to model individual viewing angles for each pixel of a scene. A first comparison to actual imaging spectrometer data showed promising results, mainly because the atmosphere simulation could be improved compared to previous versions of the DART model.

REFLECTANCE RETRIEVAL IN THE PRESENCE OF OPTICALLY OPAQUE BROKEN CLOUDS

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Abstract : This paper will discuss the effects of broken cloud fields on solar illumination reaching the ground. Broken cloud fields pose a problem for many atmospheric compensation algorithms which retrieve reflectance and/or aerosol properties from measured spectral imagery. In the reflective domain (visible to the SWIR), the application of atmospheric compensation algorithms in the vicinity of broken clouds leads to inaccuracies because of the enhanced number of photons scattered from the clouds into the clear sunlit areas. These illumination effects are simulated for simple slab clouds and complex broken cloud fields using the MCScene code, a high fidelity model for full optical spectrum (UV through LWIR) hyperspectral image simulation. MCScene provides an accurate, robust, and efficient means to generate spectral scenes for algorithm validation. MCScene utilizes a Direct Simulation Monte Carlo approach for modeling 3D atmospheric radiative transfer including full treatment of molecular absorption and Rayleigh scattering, aerosol absorption and scattering, and multiple scattering and adjacency effects, as well as scattering from spatially inhomogeneous surfaces. The model includes treatment of land and ocean surfaces, 3D terrain, 3D surface objects, and effects of finite clouds with surface shadowing.

SYNTHETIC SCENE SIMULATOR FOR HYPERSPECTRAL SPACEBORNE PASSIVE OPTICAL SENSORS. APPLICATION TO ESA'S FLEX/SENTINEL-3 TANDEM MISSION

J.P. Rivera, N. Sabater, C. Tenjo, J. Vicent, L. Alonso and J. Moreno, *Image Processing Laboratory, University of Valencia (Spain)*

Abstract : The simulation of synthetic images serve scientists and engineers to study the instrument configuration as well as to develop image processing and retrieval strategies for a sensor in development. Despite synthetic scene simulators have been developed in the past in the frame of satellite missions, their functionality and flexibility to create a user-defined scene is limited by their architecture, design and implementation. This paper introduces the design of a generic scene simulator with the flexibility to generate realistic synthetic scenes by configuration of the surface and atmosphere. Following this generic design, a scene simulator is being developed for the ESA's Earth Explorer 8th candidate mission FLEX in order to reproduce the high spectral resolution signal acquired by its hyperspectral instrument. The proposed design and architecture can be adapted to any other passive optical space and airborne instruments.

LOW-COST COMPUTATIONALLY HYPERSPECTRAL SIMULATOR FOR HIGHLY DYNAMIC MARINE ENVIRONMENTS

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Abstract : Hyperspectral optical observations and the development of new processing strategies are key for a better understanding of complex marine ecosystems and space-time distribution of ecological parameters. In this paper, the methodologies to implement a simulator of hyperspectral-resolved optical data corresponding to highly dynamic marine environments are presented. The simulator is based on a coupled radiative transfer and Lagrangian hydrodynamic model, which is organized in four basic blocks: a hydrodynamic model, a particle tracking model, a transformation function and a radiative transfer model. The transformation function is needed to adapt the output of the tracking model (given in number of particles per unit volume) to mass concentration, suitable for the radiative transfer model. The transformation function has been derived considering an allometric relationship between both magnitudes, since it is found in nature. The simulator is finally tested by considering the Alfacs Bay (NW Mediterranean Sea), as a case study site.

A COMPARISON OF MCSCENE AND CAMEOSIM SIMULATIONS OF A REAL SCENE

Wellesley Pereira, *U.S. Air Force Research Laboratory, Space Vehicles Directorate, Kirtland AFB, NM*
Steven Richtsmeier, *Spectral Sciences, Inc., 4 Fourth Ave., Burlington, MA*
Stephen Carr, Sergey Kharabash and Andrew Brady, *Australia Defence Science & Technology Organisation, Edinburgh, South Australia*

Abstract : Under an International Cooperative Research and Development agreement, the U.S. Air Force Research Laboratory (AFRL) and Spectral Sciences, Inc. (SSI) are collaborating with the Australian Defence Science and Technology Organisation (DSTO) to use their respective scene simulation codes in order to generate synthetic imagery as viewed from space and covering visible through long wave infrared wavelengths. AFRL uses MCScene, which is SSI's hyperspectral scene simulation code incorporating first-principles 3-D radiative transport (RT) through a world that includes measured terrain and atmosphere/cloud data into the simulations. DSTO uses the code CameoSim to generate hyperspectral imagery over a similar wavelength regime. This joint effort will share and evaluate results from the two codes simulated for a common scene with available ground truth data, with an overall goal of enhancing the scene modeling capabilities of all three organizations. This paper shows preliminary results from each method.

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