1-1-2007

HYPER-I-NET: European research network on hyperspectral imaging

Antonio Plaza
University of Extremadura

Andreas Mueller
German Remote Sensing Data Center

Rudolph Richter
German Remote Sensing Data Center

Torbjorn Skauli
Norwegian Defence Research Establishment

Zbynek Malenovsky
Institute of Systems Biology and Ecology, Czech Republic, zbynek@uow.edu.au

See next page for additional authors

Recommended Citation

Plaza, Antonio; Mueller, Andreas; Richter, Rudolph; Skauli, Torbjorn; Malenovsky, Zbynek; Bioucas, Jose; Hofer, Stefan; Chanussot, Jocelyn; Jutten, Christian; Carrere, Veronique; Baarstad, Ivar; Kaspersen, Peter; Nieke, Jens; Itten, Klaus; Hyvarinen, Timo; Gamba, Paolo; Dell'Acqua, Fabio; Benediktsson, Jon A.; Schaepman, Michael E.; Clevers, Jan G.; and Zagajewski, Bogdan, "HYPER-I-NET: European research network on hyperspectral imaging" (2007). *Faculty of Science, Medicine and Health - Papers: part A*. 2139.
https://ro.uow.edu.au/smhpapers/2139

HYPER-I-NET: European research network on hyperspectral imaging

Abstract

This paper addresses the main goals and objectives of the Hyperspectral Imaging Network (HYPER-I-NET), a recently started Marie Curie Research Training Network. The project is designed to build an interdisciplinary research community focusing on hyperspectral imaging activities. The core strategy of the network is to create a powerful interdisciplinary synergy between different domains of expertise closely related to hyperspectral imaging activities in Europe, ranging from sensor design and flight operation to data collection, processing, interpretation, and dissemination. Our main goals in this paper are to present the project to the Geoscience and Remote Sensing community and to provide an overview of the planned activities in each sub-activity covered by the network.

Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details

Plaza, A., Mueller, A., Richter, R., Skauli, T., Malenovsky, Z., Bioucas, J., Hofer, S., Chanussot, J., Jutten, C., Carrere, V., Baarstad, I., Kaspersen, P., Nieke, J., Itten, K., Hyvarinen, T., Gamba, P., Dell'Acqua, F., Benediktsson, J. A., Schaepman, M. E., Clevers, J. G. & Zagajewski, B. (2007). HYPER-I-NET: European research network on hyperspectral imaging. IEEE International Geoscience and Remote Sensing Symposium: IGARSS 2007 (pp. 4790-4793). USA: IEEE.

Authors

Antonio Plaza, Andreas Mueller, Rudolph Richter, Torbjorn Skauli, Zbynek Malenovsky, Jose Bioucas, Stefan Hofer, Jocelyn Chanussot, Christian Jutten, Veronique Carrere, Ivar Baarstad, Peter Kaspersen, Jens Nieke, Klaus Itten, Timo Hyvarinen, Paolo Gamba, Fabio Dell'Acqua, Jon A. Benediktsson, Michael E. Schaepman, Jan G. Clevers, and Bogdan Zagajewski

HYPER-I-NET: European Research Network on Hyperspectral Imaging

Antonio Plaza[1], Andreas Mueller[2], Rudolph Richter[2], Torbjørn Skauli[3], Zbynek Malenovský[4], José Bioucas[5], Stefan Hofer[6], Jocelyn Chanussot[7], Christian Jutten[7], Veronique Carrère[8], Ivar Baarstad[9], Peter Kaspersen[9], Jens Nieke[10], Klaus Itten[10], Timo Hyvarinen[11], Paolo Gamba[12], Fabio Dell'Acqua[12], Jon A. Benediktsson[13], Michael E. Schaepman[14], Jan G.P.W. Clevers[14] and Bogdan Zagajewski[15]

[1]University of Extremadura, Spain; [2]German Remote Sensing Data Center, Germany;
[3]Norwegian Defence Research Establishment; [4]Institute of Systems Biology and Ecology, Czech Republic;
[5]Instituto Superior Técnico, Portugal; [6]Kayser-Threde GmbH, Germany;
[7]GIPSA-Lab, Grenoble Institute of Technology, France; [8]Laboratoire Planetologie et Geodynamique, France;
[9]Norsk Elektro Optikk AS, Norway; [10]University of Zurich, Switzerland; [11]Spectral Imaging Oy Ltd., Finland;
[12]University of Pavia, Italy; [13]University of Iceland; [14]Wageningen University, The Netherlands;
[15]Warsaw University, Poland

***Abstract*— This paper addresses the main goals and objectives of the Hyperspectral Imaging Network (HYPER-I-NET), a recently started Marie Curie Research Training Network. The project is designed to build an interdisciplinary research community focusing on hyperspectral imaging activities. The core strategy of the network is to create a powerful interdisciplinary synergy between different domains of expertise closely related to hyperspectral imaging activities in Europe, ranging from sensor design and flight operation to data collection, processing, interpretation, and dissemination. Our main goals in this paper are to present the project to the Geoscience and Remote Sensing community and to provide an overview of the planned activities in each sub-activity covered by the network.**

I. Introduction

The Hyperspectral Imaging Network[1] (HYPER-I-NET) is a four-year Marie Curie Research Training Network[2] designed to build an interdisciplinary European research community focusing on hyperspectral imaging [1], a technology that has opened ground-breaking perspectives in many Earth Observation related applications [2]. The network is currently formed by a multidisciplinary team composed of fifteen highly experienced European partner organizations, although the network is widely open to collaborations with other international partners.

The theme of HYPER-I-NET is at the confluence of heterogeneous disciplines, such as sensor design including optics and electronics, aerospace engineering, remote sensing, geosciences, computer sciences including high performance computing, signal processing, and Earth Observation related products. In particular, activities in this network intend to cover all the different aspects that comprise the entire *hyperspectral data processing chain*, ranging from sensor design and calibration/validation [3], [4] to advanced data processing [5]–[8], and science applications [9], [10]. Although hyperspectral imaging has been a very active area recently, we believe that no sufficient attention has been given to research activities covering the entire data processing chain and, as a result, we feel that the abilities in this area are fragmented throughout various specialized research teams and companies, a fact that has largely resulted in the lack of data standardization and validation procedures.

In this regard, the proposed network aims at providing a timely and unique opportunity to bridge the gap between the operational procedures of hyperspectral imaging and the development of techniques for efficient data exploitation and management. As a result, our planned activities are specifically directed towards overcoming the boundaries between traditionally disjoint disciplines such as sensor design, data processing and application insight. Resulting from this effort, we expect to introduce new standardized frameworks for hyperspectral data processing and validation.

In this paper, we outline the main activities that will be carried out in the context of HYPER-I-NET, with the ultimate goal of introducing the project to the community and addressing its main strategic points. The paper is structured as follows. Section II lists the main objectives of HYPER-I-NET. Section III provides an overview of the planned research activities on hyperspectral imaging. Section IV outlines our planned training programme. Section VII details some of the scientific topics that will be covered by the network. Finally, Section VI summarizes our activity and provides hints at expected outcomes from the network project.

II. Objectives

The main overall objective of HYPER-I-NET is to provide high-level training in hyperspectral imaging to young researchers educated within the network. We also aim at introducing novel, standardized approaches and practices in this research area. In order to achieve the overall objectives

[1]http://www.hyperinet.eu
[2]http://cordis.europa.eu; Contract number MRTN-CT-2006-035927

1-4244-1212-9/07/$25.00 ©2007 IEEE.

above, several technical objectives (see below) will be pursued to:

1) bridge the gap between sensor design and hyperspectral data exploitation in remote sensing activities in Europe. This will be done by defining a standard hyperspectral processing chain;
2) develop standardized and innovative techniques/products for hyperspectral image analysis, taking into account specific requirements introduced by these data sets (collection, storage, processing and calibration);
3) establish standardized data processing and validation/quality control procedures in all the steps of the hyperspectral processing chain;
4) integrate knowledge from different disciplines (e.g., sensor design, data processing, scientific applications) and their contribution to the development, operation and exploitation of hyperspectral imaging systems;
5) improve the cooperation and transfer of knowledge, from research institutions and university groups to small-medium companies working on hyperspectral imaging;
6) create a powerful multidisciplinary synergy that will allow a more solid integration of technical and scientific issues, building a true interdisciplinary network relying on standardization and joint terminology.

III. Research Activities

Research activities within HYPER-I-NET will be mainly directed towards the improvement of hyperspectral sensor and mission design by taking advantage of the significant feedback obtained from application algorithm developers and end-users. These activities will also contribute to the development of new processing algorithms, able to fully exploit the very high spectral and spatial resolution of current and planned hyperspectral sensors, defining a standard data processing chain suitable to address many different devices and applications. Four main sub-activities have been identified:

1) *Hyperspectral sensor specification*. This activity will investigate the sensor requirements for various applications and develop new sensor specifications. The complementary expertise of several partners on design of hardware and electronics will be integrated, and the outcomes of this research element will be specifications for the design of new hyperspectral sensor instruments (sensor modeling programme) and a collection of simulated data sets of potential new sensors based on ground spectral databases.
2) *Processing chain definition and implementation*. The main goal of this activity will be to settle the basis for the generalization of a well-defined hyperspectral data collection and processing chain that will serve as a standardized procedure for processing this type of data in Europe. Complementary expertise of partners in image processing, pattern recognition and high-performance computing will be used to define a suitable chain. The outcomes of this element will be a series of standardized hardware/software processing techniques able to deal with the intrinsic complexity of the data, along with a detailed processing chain definition/implementation/optimization/validation report. The new methods and techniques resulting from this activity will be validated using both simulated and real data experiments in the framework of the following sub-activities (i.e., laboratory calibration/validation and evaluation in the context of realistic scientific applications).
3) *Calibration, validation and definition of standardization mechanisms*. This activity will focus on the calibration/validation of hyperspectral sensors and the result from various processing steps of the processing chain described above. This is a crucial step to reduce the overall uncertainties introduced by hyperspectral imaging instruments. The outcomes of this research element will be an inventory of existing calibration equipment and methodologies (along with methods and processors for onboard, laboratory and vicarious calibration), and the development of a set of round-robin, inter-calibration experiments of available ground equipment (in-laboratory, and during field campaigns that will be connected to summer schools and camps).
4) *Science applications*. This activity is aimed at compiling relevant applications and methods applied using imaging spectrometer data, and creating a product catalogue of both. Complementary expertise of partners in environmental applications (including monitoring of urban, vegetation and semi-arid areas) will be integrated. The main outcomes of this activity will be the development of an algorithm theoretical baseline document (ATBD) listing methods used for selection applications. In addition, an application library will also be obtained, composed of documents, code and results in terms of specific applications.

IV. Training Activities

Being an educational project, HYPER-I-NET will particularly focus on the training of young researchers in all the research areas that comprise the entire hyperspectral processing chain, from sensor design and flight operation to data collection, processing, management and application development. Specifically, it is our goal to provide young researchers involved in the network with the required background and expertise on the multiple disciplines involved in hyperspectral imaging. For that purpose, we have made provision for several training-oriented activities such as:

1) *Definition and implementation of local training programmes*. These will be mainly directed to young researchers and will comprise basic/specialized courses and other formative activities.
2) *Network-wide training*. In addition to local training activities, network-wide events such as summer schools and camps, technical seminars, workshops and other training events will also take place, including close interaction with industrial partners.

3) *Distributed learning*. A distributed e-learning platform will be developed in order to provide online courses and other training materials, thus allowing a highly interdisciplinary e-learning system taking advantage of the possibilities offered by online-based formative environments to disseminate training skills in relevant areas.

V. Scientific Topics

In this section, we provide a detailed description of some of the scientific topics that will be covered by the network. Each of the topics will be pursued by a young researcher working towards his/her PhD in the specified areas listed below:

- *Hyperspectral instrument design*. This topic offers an opportunity to become familiar with the technology behind hyperspectral imaging. Possible subtopics include conducting a survey of existing technologies and relative assessment of new sensor concepts, detailed instrument modeling and quantitative comparison with existing instruments, automated camera calibration, including design of an onboard calibration device, modeling of a novel instrument design, experimental feasibility study and application-specific instrument optimization.
- *Improved hyperspectral sensor design*. To address this topic, a modular sensor simulation tool shall be designed and implemented. The tool will allow spectral, radiometric, and geometric instrument characterization using a modular software design with the following components: optics, dispersing elements (grating, prism, spectral filters), detector focal plane, different detector types, micro-vibrations, front-end-electronics, noise sources, signal to noise ratio, co-registration offsets between different spectrometer units of an instrument. The toolbox shall be flexible enough to support the simulation/assessment of future multi/hyperspectral instruments. Synthetic scenes shall be simulated using spectral reflectance/emissivity databases for different applications (e.g., agriculture, forestry, mineralogy), using results of radiative transfer calculations in atmospheric databases.
- *Advanced calibration and validation of hyperspectral instruments*. This topic will be oriented towards the definition and implementation of advanced hyperspectral calibration and validation techniques. First, an inventory of existing calibration equipment and methodologies will be conducted, and an inventory of methods and processors for onboard, laboratory and vicarious calibration and assimilation will be performed. Then, new generation scene-based calibration and assimilation methods and procedures will be developed, and inter-calibration experiments of ground equipment (in laboratory, during field campaigns) will be performed. Finally, new generation scene-based calibration and assimilation methods will be tested and validated.
- *Efficient endmember extraction and source separation algorithms*. This topic will be oriented towards the definition and implementation of advanced algorithms for endmember extraction and source separation in hyperspectral imagery. A main goal will be to perform endmember extraction (i.e., to estimate the respective proportions of different materials included within one pixel) using statistical methods such as the independent component analysis (ICA) or Bayesian approaches. Compared with the canonical source separation scenario, the sources in hyperspectral unmixing (i.e., the materials present in the scene) are statistically dependent and may combine in nonlinear fashion. These characteristics, together with the high dimensionality of hyperspectral pixel vectors, place the unmixing of hyperspectral mixtures beyond the reach of most source separation algorithms, thus fostering active research in this area. To address this topic, different strategies (spectral versus hybrid spatial/spectral approaches) will be explored for endmember extraction. Physical considerations about how to model the mixture of elements at the pixel resolution will also be incorporated in order to achieve a better source separation (e.g., linear versus non-linear mixture models).
- *Vegetation monitoring using hyperspectral data and advanced processing techniques*. This topic will address vegetation monitoring using hyperspectral airborne or spaceborne data in both mountainous and urban areas. The research will require the definition and the implementation of a full processing chain able to start with radiometrically calibrated data and ending with maps of vegetated species and tree status in various environments. Testing of known algorithms and development of innovative and advanced ones for each step of the defined chain will also be required, with particular emphasis on geometric and atmospheric corrections and classification procedures based on known spectral of vegetated species. Joint spectral and spatial analyses will be also considered to implement the final mapping chain. Validation and accuracy assessment will be performed by means of both *in situ* spectral measurements and visual inspection.
- *Using coupled radiative transfer models to bridge scaling gaps in boreal forest*. Recent advances in assessing the pigment and non-pigment systems of plants using high spectral and spatial resolution imaging spectroscopy reveal that improved understanding of an ecosystem can be obtained by modeling the interaction of light with vegetation at leaf (needle), shoot, branch and tree levels. Current challenges in assessing the pigment system and the non-pigment system in boreal forests include proper estimates of the clumping of the vegetation at various scale levels, the proper separation of understorey and overstorey vegetation, as well as the separation of the canopy in photosynthetic and non-photosynthetic (litter, stems, branches, etc.) components. In order to properly fill the scaling gaps at the above-mentioned levels, a model suite based on radiative transfer theory will be used in combination with advanced experimental field methods (e.g., transmission measurements at needle level, shoot level experiments, etc.) to simulate and validate imaging spectrometer data.

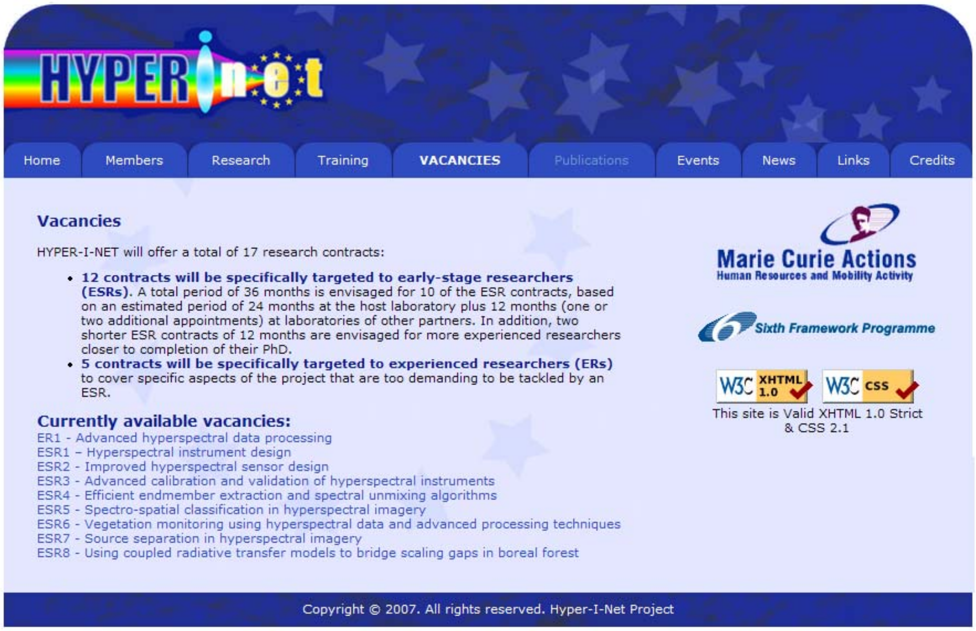

Fig. 1. The HYPER-I-NET website at http://www.hyperinet.eu.

We emphasize that the list of topics above is not exhaustive since several new topics are currently being defined by network partners. A detailed description of the full list of topics covered by the network will be periodically updated at the project website (see Fig. 1).

VI. Summary and Expected Outcomes

We have described the main strategic aspects and scientific topics in HYPER-I-NET, a recently funded Marie Curie Research Training Network which focuses both on educational aspects and on the scientific goals which are achieved through training in all the research areas that comprise the entire hyperspectral processing chain, from sensor design and flight operation to data collection, processing, management and interpretation. The network aims at overcoming fragmentation and advancing a step further than the state-of-the-art in this area by introducing techniques for standardization and validation of hyperspectral methods and products. We expect that the network will serve as a framework to introduce new methods for hyperspectral data collection, processing, validation and exploitation, thus creating an impact on the design of future and on-going remote sensing and exploration missions. Further, we expect that the young researchers trained within the network will have the potential to lead the future expansion in the use of this technology.

VII. Acknowledgement

This work has been supported by the European Community's Marie Curie Research Training Networks Programme under contract MRTN-CT-2006-035927, Hyperspectral Imaging Network (HYPER-I-NET).

References

[1] A. F. H. Goetz, G. Vane, J. E. Solomon and B. N. Rock, "Imaging spectrometry for Earth remote sensing," *Science*, vol. 228, pp. 1147-1153, 1985.

[2] R. O. Green et al., "Imaging spectroscopy and the airborne visible/infrared imaging spectrometer (AVIRIS)," *Remote Sensing of Environment*, vol. 65, pp. 227-248, 1998.

[3] R. Richter, A. Mueller, M. Habermeyer, S. Dech, K. Segl and H. Kaufmann, "Spectral and radiometric requirements for the airborne thermal imaging spectrometer ARES," *International Journal of Remote Sensing*, vol. 26, pp. 3149, 2005.

[4] J. Nieke, J. W. Kaiser, D. Schläpfer, J. Brazile, K. I. Itten, P. Strobl, M. E. Schaepman and G. Ulbrich, "Advanced calibration methodology of the Airborne Dispersive Pushbroom Imaging Spectrometer (APEX)," In: *Proceedings of SPIE*, vol. 5570, 2004.

[5] A. Plaza, J.A. Benediktsson, J. Boardman, J. Brazile, L. Bruzzone, G. Camps-Valls, J. Chanussot, M. Fauvel, P. Gamba, J.A. Gualtieri, J.C. Tilton and G. Trianni, "Advanced processing of hyperspectral images," In: *Proceedings IEEE International Geoscience and and Remote Sensing Symposium*, pp. 1974-1978, Denver, CO, 2006.

[6] J. A. Benediktsson, J. A. Palmason and J. R. Sveinsson, "Classification of hyperspectral data from urban areas based on extended morphological profiles," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 43, pp. 480-491, 2005.

[7] P. Gamba, F. Dell'Acqua, A. Ferrari, J. A. Palmason, J. A. Benediktsson and K. Arnasson, "Exploiting spectral and spatial information in hyperspectral urban data with high resolution," *IEEE Geoscience and Remote Sensing Letters*, vol. 1, no. 4, pp. 322-326, 2004.

[8] S. Hosseini and C. Jutten, "On the separability of nonlinear mixtures of temporally correlated sources," *IEEE Signal Processing Letters*, vol. 10, pp. 43-46, 2003.

[9] G. Strub, M. E. Schaepman, Y. Knyazikhin and K. I. Itten, "Evaluation of spectrodirectional alfalfa canopy data acquired during Daisex'99," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 41, pp. 1034-1042, 2003.

[10] M. E. Schaepman, B. Koetz, G. Schaepman-Strub and K. I. Itten, "Spectrodirectional remote sensing for the improved estimation of biophysical and chemical variables: two case studies," *International Journal of Applied Earth Observation and Geoinformation*, vol. 6, pp. 271-282, 2005.