RECENT ACTIVITIES IN THE HYPERSPECTRAL IMAGING NETWORK (HYPER-I-NET): A EUROPEAN CONSORTIUM FOSTERING IMAGING SPECTROSCOPY RESEARCH

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ABSTRACT

The Hyperspectral Imaging Network (HYPER-I-NET) is a four-year Marie Curie Research Training Network project designed to build an interdisciplinary European research community focusing on hyperspectral imaging activities. The network is currently formed by a multidisciplinary team composed of fifteen highly experienced European partner organizations. In this paper, we outline the activities that have been carried out in the four main areas covered by HYPER-I-NET: 1) hyperspectral sensor specification, 2) processing chain definition and implementation, 3) calibration, validation and definition of standardization mechanisms, and 4) science applications. Along with the description of the progress made in the four main areas listed above, this paper also describes some of the training and transfer of knowledge activities carried out during the first two years of the project.

***Index Terms*—** Hyperspectral imaging, education and training, sensor design, data processing, calibration/validation, science applications.

1. INTRODUCTION

Imaging spectroscopy [1, 2], also known as hyperspectral imaging, is concerned with the measurement, analysis, and interpretation of spectra acquired from a given scene (or specific object) at a short, medium or long distance by an airborne or satellite sensor. The Hyperspectral Imaging Network (HYPER-I-NET)[1] [3] is a four-year Marie Curie Research Training Network[2] designed to build an interdisciplinary European research community focusing on this technology, which has opened new perspectives in many Earth Observation related applications [4]. The network is currently formed by a multidisciplinary team composed of fifteen highly experienced European partner organizations, and the theme of the network 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 [5, 6] to advanced data processing [7], and science applications [8].

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 activities that have been carried out in the four main areas covered by HYPER-I-NET during the first two years of the project. Along with a detailed description of the progress made in the four main areas listed above, this paper also describes the training and transfer of knowledge activities. Being an educational project, HYPER-I-NET is particularly focused on the training of young researchers. In this regard, one of the main goals of the project is to provide young researchers involved in the network with the required background and expertise on the multiple disciplines involved in hyperspectral imaging.

2. SCIENTIFIC AREAS

In this section we provide an overview of the activities in the four main scientific areas covered by the network. This general overview serves as an introduction to the main activities in the different workpackages that are currently being addressed by network partners.

[1]http://www.hyperinet.eu
[2]http://cordis.europa.eu

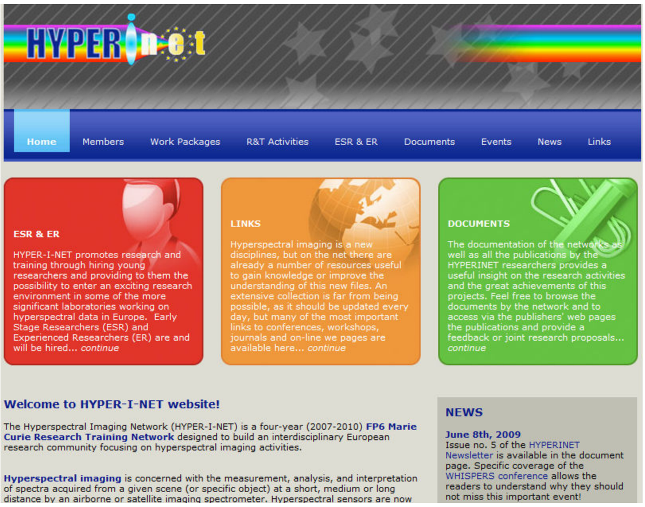

Fig. 1. Project website at http://www.hyperinet.eu

1. *Hyperspectral sensor specification*. The main goal of this activity is to investigate the sensor requirements for various applications and develop new sensor specifications. For this purpose, the tasks carried out comprise the analysis of application needs in terms of derived parameters and variables in different application fields such as agriculture, forestry, geology, phenology/limnology or urban management, with the ultimate goal of compiling spectral databases to determine the spectral response related to the individual variables and parameters and to translate the observed needs into performance requirements of new hyperspectral sensors by developing a dedicated hyperspectral instrument model (optical layout and transfer, noise, etc.)

2. *Processing chain definition and implementation*. The main goal of this activity is to settle the basis for the generalization of a well-defined hyperspectral data collection and processing chain that might serve as a standardized procedure for processing this type of data in Europe. For this purpose, the tasks carried out comprise the definition of a processing chain able to address needs from scientific applications and constraints imposed by sensor design, and the preliminary implementation of the processing chain steps. The expected outcome of this activity is a series of standardized hardware/software processing techniques able to deal with the intrinsic complexity of the data, along with processing chain definition and implementation reports.

3. *Calibration, validation and definition of standardization mechanisms*. This activity is focused on the calibration/validation of hyperspectral sensors and the results 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. For this purpose, the tasks carried out comprise an inventory of existing calibration equipment and methodologies as well as an inventory of methods and processors for onboard, laboratory and vicarious calibration and assimilation, interaction with scientists and researchers.

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. The main task carried out in this activity comprise the definition of an algorithm theoretical baseline document (ATBD) listing methods used for selected applications, complemented partly by available models and source code.

It is important to emphasize that the parts of these work-packages which have been approved for public distribution by the consortium are available online from the HYPER-I-NET project website (see Fig. 1). The fact that several of the deliverables resulting from the main scientific activities of the project are publicly available in the form of technical reports[3] allows a rapid dissemination of such activities in the wide remote sensing community. The dissemination is supported by the network newsletter[4], which provides a forum for presenting the main research and transfer of knowledge activities carried out by the different partners in the consortium.

3. TRAINING AND TRANSFER OF KNOWLEDGE

Being an educational project, one of the main objectives of HYPER-I-NET during the first two years of the project has been to provide high-level training in hyperspectral imaging to young researchers, with the ultimate goal of introducing novel, standardized approaches and practices for this emerging research area in Europe. In this regard, the key elements of the proposed research methodology have been focused on the development of research and training activities on hyperspectral imaging, with the ultimate goal of training young researchers in this area and to allow our appointed young researchers to have significant competitive advantages and the potential to find better jobs in science and commercial environments.

Among other training events, the network has organized two summer schools in its first two years. The First Hyper-I-Net School on Hyperspectral Imaging[5] was held in Caceres, Spain, in October 2007, with attendance of more than 100 international researchers. The school included in-depth tutorials and state-of-the-art presentations from leading experts in the field. The Second Hyper-I-Net School on Earth Science and Applications Using Imaging Spectroscopy[6] was held in

[3]http://www.hyperinet.eu/publication4.htm
[4]http://www.hyperinet.eu/publication5.htm
[5]http://www.hyperinet.eu/event1.htm
[6]http://www.hyperinet.eu/event3.htm

Fig. 2. Summerschool in Wageningen, The Netherlands.

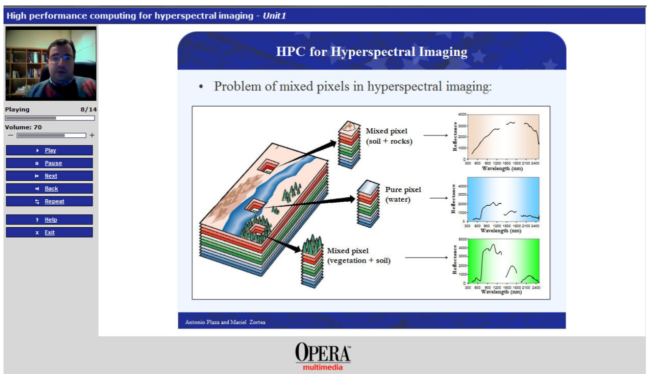

Fig. 3. Multimedia course in the e-learning platform.

Wageningen, The Netherlands, in September 2008, with attendance of more than 80 international researchers (see Fig. 2). During the two summer schools, young researchers had the opportunity to interact with more experienced ones and receive training on specialized instruments and equipment. These activities served as a basis for providing young researchers with specialized training through their operation of equipment facilitated by networks partners, including hyperspectral cameras, field spectrometers and other instruments that could be easily shared by young researchers. In addition to this, hands-on practice sessions were organized, including tutorials on hyperspectral data processing and calibration, data collection, ground campaigns, etc.

4. DISTRIBUTED E-LEARNING PLATFORM

A distributed e-learning platform (see Fig. 3) offering a comprehensive learning environment to young researchers and external partners has been developed by HYPER-I-NET partners, supported by Opera Multimedia[7]. This platform is used to provide multimedia courses and resources on different topic areas related with the project. The platform is available via login/password from the main project website. Most partners offer a multimedia course (audio and video) broken down into several units. Each unit is treated as a separate learning object which can be accessed independently so that users can decide which unit to access and in which order (flexible training path). Each course is accompanied by a pre-assessment and post-assessment in which the fellows can self-assess their progress. A total of 13 multimedia courses (summarized below) have been designed by HYPER-I-NET partners and are currently available in the e-learning platform:

- *Urban Remote Sensing*. This course provides a first introduction of urban remote sensing and data fusion related to urban area analysis using remotely sensed data. A more specific analysis is then dedicated to hyperspectral data and their processing challenges.
- *Remote Sensing Measurements of Vegetation*. This course addresses the relevant topic of how to characterize vegetation parameters using remotely sensed hyperspectral image data.
- *Retrievals of the ecosystem variables from the remotely sensed (hyper)spectral data*. This e-learning course provides insight into the quantitative remote sensing of vegetation of terrestrial ecosystems.
- *Quantitative remote sensing*. This course introduces the use of (hyperspectral) remote sensing for deriving quantitative information on biophysical and biochemical properties of vegetation. The course highlights current developments and challenges in quantitative remote sensing of vegetation.
- *GIS Module*. This module provides the theoretical background that remote sensing specialists will require when working with geographic information systems.
- *Calibration and characterization of hyperspectral cameras*. This course provides an overview of methods for calibrating and characterizing hyperspectral cameras of the "pushbroom" type. In includes theory as well as practical examples.
- *High performance computing for hyperspectral imaging*. This course focuses on the development and efficient implementation of algorithms for hyperspectral imaging, with emphasis on endmember extraction and spectral unmixing.
- *Hyperspectral Imaging Techniques*. This course starts with a short hyperspectral history and then gives an introduction into the physical basics, necessary to understand hyperspectral sensor principles. It then provides insight into instrument development and design aspects. The course closes with an overview of existing and future sensors.
- *Campaign Planning and Operations*. In this course, the fundamental processes for the preparation and the realization of an airborne hyperspectral survey are presented. This includes planning of a whole airborne hyperspectral survey as well as single data acquisitions,

[7] http://www.operamultimedia.com

planning of a field campaign and introduction on field methods for remote sensing, general campaign management, calibration and operation of a sensor.

- *Hyperspectral Unmixing*. This course addresses the hyperspectral unmixing inverse problem, which, given a set of hyperspectral vectors, is the inference of the number of reference substances, also called endmembers, their spectral signatures, and their abundance fractions.
- *Hyperspectral camera technology*. This course gives a basic introduction to the technology of hyperspectral imagers. Emphasis is given to the topics of imaging optics and photodetectors. Examples are used to illustrate the effect of camera parameters on the outcome of hyperspectral image processing.
- *Applications of hyperspectral imaging to geologic and coastal environments*. This course presents some examples on how imaging spectrometer data can be used to map information relevant to geologic and coastal environments.
- *Source separation with Independent Component Analysis*. This course focuses on the adaptation of source separation techniques to the analysis of hyperspectral data, with particular emphasis on the characterization of mixed pixels and the estimation of fractional abundances.

5. SUMMARY AND FUTURE EVENTS

We have described recent activities 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. Our focus has been on providing an overview of the scientific aspects that are being covered by the project, as well as on describing the main training and transfer of knowledge events carried out during the first two years of the project. In addition, we have described the project e-learning platform comprising a set of multimedia courses used to provide multimedia courses and resources on different topic areas related with the project. These activities, along with the research work carried out by the 12 early-stage researchers and 5 experienced researchers appointed in the project, is expected 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.

In the future, the network will continue pursuing the research and training/transfer of knowledge activities described in the scientific workplan. The increasing impact and relevance of the research work carried out by HYPER-I-NET fellows[8] allows us to anticipate that the young researchers trained within the network will have the potential to lead the future expansion in the use of this technology.

6. ACKNOWLEDGEMENT

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[8] http://www.hyperinet.eu/publication3.htm