HICOD2000 – INTEGRATED SYSTEM FOR CODING, PROTECTION AND TRADING OF EARTH OBSERVATION PRODUCTS IN JPEG2000

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ABSTRACT
This paper describes a system, called HICOD2000, derived from a project developed in collaboration between two Portuguese companies and the European Space Agency that exploited the possibilities offered by the emerging image encoding standard – JPEG2000 – and its applicability to Earth Observation Products.
The work described on this paper has been completed and it's currently being integrated with ESA own systems and EO products portal. Other important characteristic of the system consists in the usage of a Digital Rights Management platform to control the access and usage of EO products coded in JPEG2000 format.

KEY WORDS
Earth Observation, JPEG2000, Envisat, PDS, HDF, Security, DRM

1. Introduction

This paper describes the results of a project called HICOD2000 conducted with the European Space Agency (ESA) to study the applicability of the new image encoding standard – JPEG2000 - to Earth Observation (EO) products [1]. In this paper it is also described the system that was developed to ESA that allows, not only the encoding and decoding of EO products, but also describes the system that was developed to allow ESA to securely trade these products over the Internet on a specific portal.
The work performed was mostly based on EO data captured by the ENVISAT [7] and SPOT5 satellites. The ENVISAT satellite contains a payload of eight measuring instruments. Each instrument is tuned to a specific range in the electromagnetic spectrum, mostly in the infrared, the microwave and the visible spectrum. Some instruments are pointed directly at the Earth's surface while others point obliquely at the atmosphere. Some are intended to image the earth under different viewing conditions while others are intended to measure physical quantities or concentrations of chemical substances. The instruments store the measurement data in raw format, and send it back to ground stations at specific locations in their orbit path. This raw measurement data is afterwards combined to form different EO product levels.
Each of the ENVISAT instruments products [7] was examined during the project to determine it's suitability for JPEG2000 coding [1][10], and as a result several have been identified: MERIS [6], ASAR [4], GOMOS [5], ATTSR [3], RA2 [7] and SCIAMACHY [8][9]. Each of the products is currently coded in a ESA proprietary format called Payload Data Segment (PDS). This data format does not feature any compression and so can usually result in quite large product files, not very suitable for Internet transfer.
Each PDS coded product is further subdivided into some distinct parts mostly indicated as headers and datasets. The headers and the datasets in a PDS file store a large number of parameters with different data types. The parameters that are JPEG2000 compressible candidates are in the datasets of each PDS product, while the remaining components of a PDS product can be safely regarded as meta-data that does not need to be subject to JPEG2000 compression but that is still included in a JP2 file [2].
The SPOT5 satellite products, considered in the project, are about vegetation. The vegetation products are stored in the Hierarchical Data Format (HDF) [22]. This format consists in data structures organized in some kind of hierarchy. The structures suitable for JPEG2000 encoding are the Scientific Data Sets. Other structures are considered as meta-data and included in the JP2 file [2].
The advantages of coding PDS and HDF data with JPEG2000 come not only from achieving good compression ratios but also from using a standard coding format that is recognized worldwide and that has a number of interesting features for scalable coding of data with progressive quality improvement. JPEG2000 [10][11] has the option to perform lossless coding so that no loss of precision is involved in the trans-coding of PDS or HDF data to JPEG2000 data [11]. This represents one of the big results of the HICOD2000 project – the possibility to compress the ENVISAT and SPOT5 products to lossless JPEG2000 format, and the possibility to recover the original format without information loss.
One of the other major requirements of the HICOD2000 project consisted in the development of a new security

technology to protect the EO products. The usual process that ESA uses to deliver its EO products to its clients is outdated in terms of security, but is adequate for current business model. Currently the final user selects the EO product (or products) from the ESA portal and after payment the user can download the EO product from an FTP site [16] (authenticated by username and password), or the product is sent to the user in CD-ROM.

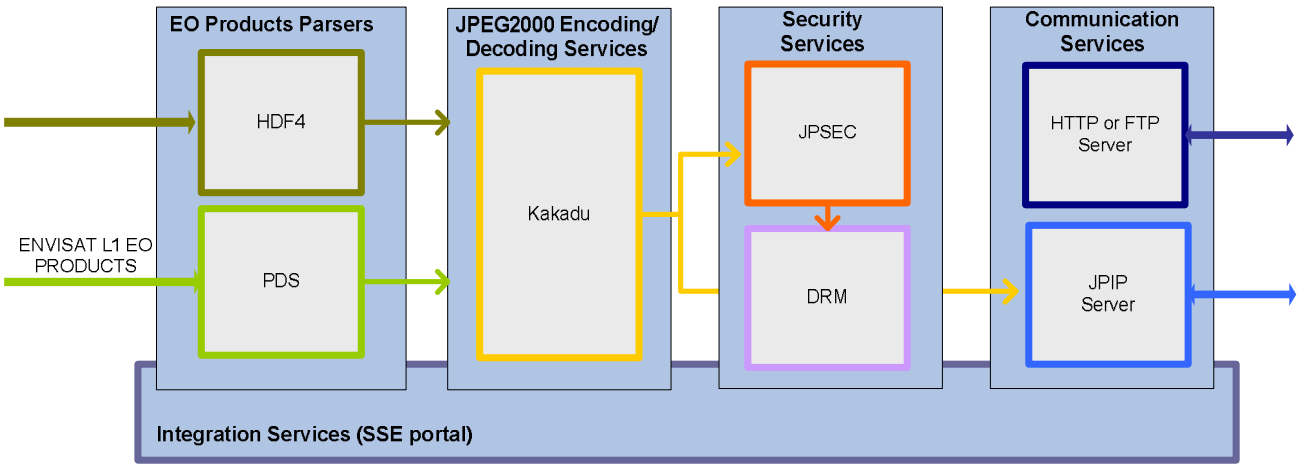

Figure 1 - Architecture of the HICOD2000 black-box (H2KBB)

HICOD2000 studied the possibility to integrate a better security model and at the same time empower ESA, or ESA EO product retailers, to develop new business models based on this new paradigm. HICOD2000 designed the solution based on one of the parts of JPEG2000 standard, called JPSEC [2][14], which deals with code-stream protection. Therefore we developed a method for ciphering the EO product according to its resolution levels, integrating a DRM solution [13] to control the user access granularity to each of the EO product resolutions. Using this solution ESA could profit in terms of flexibility of its traditional business model, and allow the price differentiation of its own EO products according to the resolution level selected by the client [13]. The paying and registered client can use a viewer developed for the purpose to visualize the JPEG2000 EO products and that can allow the final user to access the image resolutions that he have paid for and also to recover the original product format (PDS or HDF4).

The final part of this paper describes the integration of the developed system with the existing ESA Ground Segment systems specifically the Services Support Environment (SSE) [21]. The SSE service directory offers access to a continuously expanding set of basic and complex Earth observation and Geographical Information Systems (GIS) services. An interested client can request a quotation for each of the services or order them via an online form. The SSE portal [21] provides access to a large variety of services from a diverse set of contributors such as: space agencies, data processing centres, data providers, educational establishments, private companies and research centres. HICOD2000 service is one of the services integrated in this SSE portal [21]. This paper also describes the final integration architecture and the JPEG2000 EO product data process request from the SSE portal using the HICOD2000 service running at the service provider premises.

2. JPEG2000 EO products coding and decoding

The HICOD2000 system creates an environment for seamlessly converting between EO native file formats (PDS and HDF) to JPEG2000 and to perform the reverse conversion. The system defines a self-contained set of components that will interact with each other to provide the conversion functionalities, as well as a set of additional functionalities:

- Security and Access Control;
- Integration Mechanisms;
- Access Interactivity.

This set of components, integrated, will form what is called the HICOD2000 black-box (H2KBB). The H2KBB (Figure 1) can be used either in stand-alone operation or integrated with other ESA services or applications, since it provides a SSE-compliant interface and an API that allows it to be invoked from the outside.

Two of the H2KBB core sub-systems are the EO products parsing and JPEG2000 encoding [15]. In a very generic way, the functionality of the EO products parser consists in extracting from the original products format the JPEG2000 data and metadata that can be encoded, as well as some additional information to be used in the original product reconstruction. The EO products parser is used to parse PDS and HDF [18]. The function of each of the parsers is similar: the parser extracts raw data into separate files and meta-information from the EO product. During this operation a couple of files are also created with information related with the compress/decompress operation to follow. One of the files is immediately used

in the compression process; the other is stored inside the JPEG2000 product in a jp2 file format XML box [1]. In this way all the necessary data to recover the original product is stored together. The inverse process is accomplished invoking the JPEG200 decoder to extract the raw files, as well as meta-data, and hand them to the parser which will use the information to rebuilding the original file.

The encoding/decoding sub-system is based on one of the most well known JPEG2000 encoders, called Kakadu [17]. This encoder receives the output of the EO products parsers and produces an EO product JPEG2000 image. The encoding parameters are specified on a file that was created by the EO products parsers – the compression is performed in a lossless manner to avoid loosing any information on the original products and to be able to recover them afterwards (Table 1). Like the EO products parser this compression sub-system is reversible, allowing that from the JPEG2000 generated product the original file format could be recovered.

Product Type	MERIS	MERIS	ASAR
Name	MER_RR__1PNPDK20020803_092852_000002702008_00165_02223_3798	MER_RR__1PNPDK20020802_184536_000002702008_00156_02214_3739	ASA_APG_1PXPDE20020819_093043_000000152008_00394_02452_0000
Original Filesize (bytes)	55772805	55772805	403179920
Parsing	0:16	0:19	4:12
Encoding	0:28	0:26	3:47
Compressed Filesize (bytes)	37403433	32366619	158367114
Ratio	0,67	0,58	0,39

Table 1 - EO products compression ratios

3. JPEG2000 EO products protection

One of the requirements of the HICOD2000 system consisted in the capability of offering granular protection to JPEG2000 EO products – the capability to offer strong protection [12] to the global EO product as well as the capability to protect just some parts of the product while others remained in clear.

The emerging JPEG2000 – Part 8 [2], called JPSEC [14], aimed at the development of a protection scheme for JPEG2000 code-streams was the selected technology to protect the EO products. The HICOD2000 project specified the protection granularity of the EO products at the resolution level, up to a maximum of 6 different resolution levels [13].

Each of the JPEG2000-encoded EO product resolution level was ciphered with a different key using the AES (OFB mode) algorithm [20]. The JPEG2000 code-stream was properly signalled so that even the ciphered code-stream could maintain its integrity to be readable by any JPEG2000-compliant viewer [14].

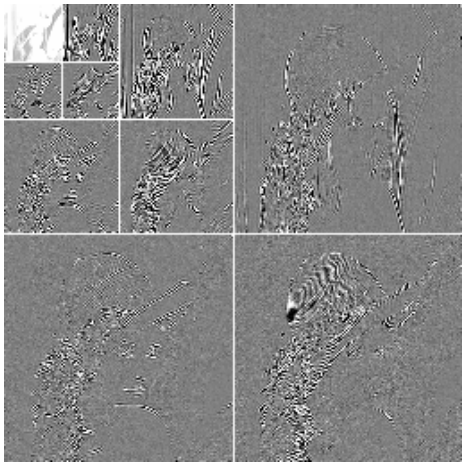

Figure 2 - JPEG2000 image ciphered at different levels

Another interesting feature, that was not yet present on any similar system, was the capability to control and enforce the user and content access control to protected EO products using a DRM system [12]. This DRM system, called OpenSDRM [13], was developed on a previous European project, taken in mind that it could be adapted for use with several business models and different types of content, aiming at enabling business involving multimedia content to function, by enforcing licensing agreements for content use and offering business opportunities to the content rights owner and content provider. OpenSDRM defines a distributed architecture in which every component can be separated [13]. This allows the possibility to the architecture to be flexible to the addition of new components or the substitution of same components with new ones supporting different functionalities, or the integration of the DRM platform with third party networked systems and services, such as the case of the HICOD2000 system described on this paper.

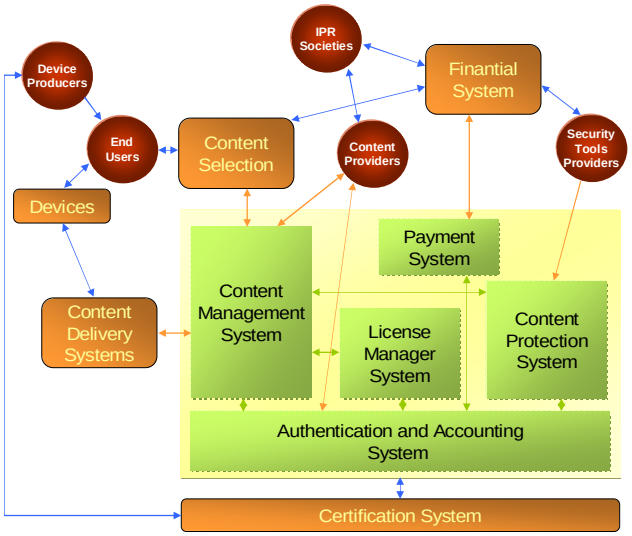

Figure 3 - OpenSDRM service-oriented architecture

The H2KBB was integrated with OpenSDRM using the publicly available WSDL interfaces [13], to provide DRM functionalities such as: user authentication, content registration, content encryption keys registration and license management.
Therefore when H2KBB is converting an EO product to JPEG2000 format a parallel DRM process is also triggered: the OpenSDRM registers the EO product, assigning a unique identifies that is inserted inside the JPEG2000 EO product. This identifier can be used after to establish the connection between two elements that allow the download of the necessary content keys to access the clear product – the user and the EO product [13].
During the H2KBB EO products protection, the content encryption keys are established and registered on the DRM platform – a logical connection between the EO product unique identifier and the content keys.
Whenever a final user selects a product from the EO portal, and upon the payment is made, the DRM platform generates a license establishing specific usage conditions and containing the content keys needed to access to the contracted EO product resolution. At the client-side, using specific purpose software, the license rights are uphold on the content and the keys are applied allowing the user to browse the acquired product.

The DRM platform is not only responsible for managing the content and the rights, but at the same time is also controlling the user access to content itself.

4. Integration with ESA SSE portal

One of the major objectives of ESA was the possibility to integrate the HICOD2000 system at two levels: on the service provider side and also at the final user side.
At the final user side, on the requirements imposed by ESA was the possibility that the original file format of the EO products could be recovered entirely without any losses. This requirement rose from the fact that ESA already had a set of proprietary tools to work with the original file formats and wasn't keen in replacing everything. Therefore the HICOD2000 project developed a lite-version of the HICOD2000 black-box that could be integrated with existing proprietary applications to retrieve the original EO product file format from the JPEG2000 file, without any losses. This would then be passed to the legacy applications that could open them without any problems. If the original EO product was protected the final user would have to obtain all the necessary cryptographic keys to decipher the entire JPEG2000 EO product, recovering the full original EO product [12][13].

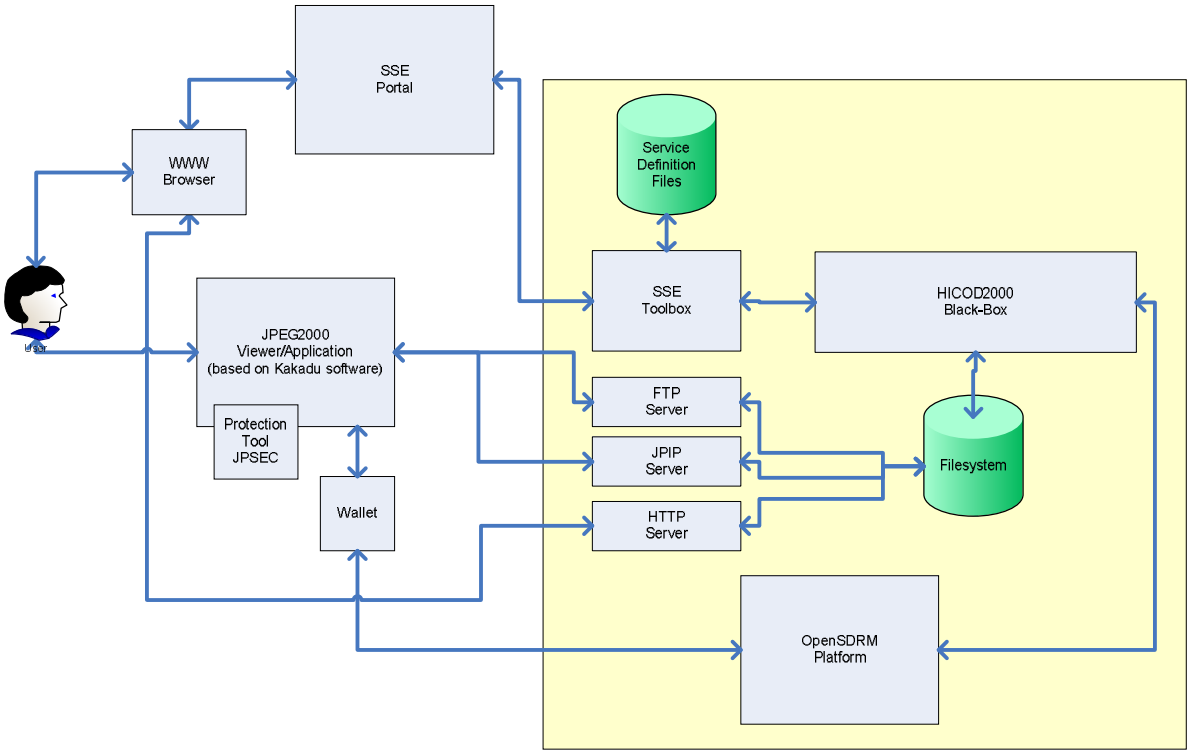

Figure 4 - HICOD2000 integrated architecture

The second and perhaps, the most important integration point occurred at the service provision side. One of the other ESA R&D projects developed an EO portal capable of integrating several services and service providers – these could range from image provision to data conversion services. All these services were available at one unique point. This was accomplished by supplying each of the service providers with a standardised way to integrate their specific service with the EO portal (SSE portal) [21]. This mechanism is the SSE Toolbox – a

software tool distributed freely by ESA to any service provider that allows it to be able to define their service business model and the specific inputs and outputs – using a descriptive language defined in XML – WSDL.
The Toolbox, upon the definition of the service, creates the necessary data to be defined at the SSE portal when registering the service. These files allow the creation of an automatic business form that allows final users to specify the parameters for the service – in the specific case of HICOD2000 parameters are:

- EO product identifier: this is the ESA product identifier that identifies the EO products at the service provider side;
- User identifier: this is a unique user identifier assigned by the DRM platform;
- Order identifier: this value is generated automatically by the SSE portal when placing the user order on the system;
- Delivery Method: this is a selection field that allows the user to select how the final JPEG2000 EO product is going to be delivered to the user (HTTP [19], FTP [16] or JPIP [15]).

When a user places an order on the SSE portal, it contacts the SSE Toolbox at the service provider premises that invokes the H2KBB. The H2KBB converts the EO product into a protected JPEG2000 file that is place on a specific output directory. The service provider SSE Toolbox returns the URL of the newly created JPEG2000 file, upon successful completion. This URL is formed with base on the user delivery method selection. The URL is presented to the user on the SSE portal that accesses the image on the service provider side, using one of the previously selected delivery methods.
At the client side, a specific application is launched allowing the user to navigate the JPEG2000 image. If the image is protected, the viewer requests the user authentication to download the appropriate keys from the DRM platform and deciphers the image [13]. After this, the user can also be entitled to save the JPEG2000 in the original EO Product format (either PDS or HDF [18]).

5. Conclusions

In general the work that was performed to ESA and that is described in this paper is part of a set of exploratory actions to find new technologic opportunities to integrate in ESA processes. In this specific case, HICOD2000 proved to ESA that JPEG2000 was an interesting technology that could be used to encode and distribute some EO products.
This work also helped ESA to realise some other opportunities presented by JPEG2000 Parts 8 and 9 on what concerns to security and access control to EO products data and on interactivity access to such data.
The HICOD2000 system, presented at the service provider site was integrated with the ESA SSE portal enlarging the set of EO services available at that portal.

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