Accessing Earth Observation data using JPEG2000

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ABSTRACT: Applications like, change detection, global monitoring, disaster detection and management have emerging requirements that need the availability of large amounts of data. This data is currently being captured by a multiplicity of instruments and Earth Observation (EO) sensors originating large volumes of data that needs to be stored, processed and accessed in order to be useful. The authors of this paper have been involved on an ESA-founded project, called HICOD2000 to study the applicability of the new image encoding standard – JPEG2000 - to EO products. This paper presents and describes the system that was developed for HICOD2000 project, which allows, not only the encoding and decoding of several EO products, but also supports some of the security requirements identified previously that allows ESA to define and apply efficient EO data access security policies and even to exploit some EO products electronic commerce over the Internet. This system was integrated with the existing ESA Ground Segment systems specifically the Services Support Environment (SSE). **Keywords**: DRM, JPEG2000, Earth Observation, encryption, protection tool

1 INTRODUCTION

Change detection, global monitoring, disaster detection and management applications have emerging requirements that need the availability of large amounts of data. This data is currently being captured by a multiplicity of instruments and Earth Observation (EO) sensors producing large amounts of data that needs to be stored, processed and accessed in order to be useful – as an example, ENVISAT accumulates, in a yearly basis, several hundred terabytes of data.

The authors of this paper were involved on an ESA-sponsored project, called HICOD2000 to study the applicability of the new image encoding standard – JPEG2000 – to Earth Observation (EO) products. This paper presents and describes the set of applications that were developed in the HICOD2000 project which allows, not only the encoding and decoding of several EO products, but also supports some of the security requirements identified previously that allows ESA to define and apply efficient EO data access security policies and even to exploit some EO products electronic commerce over the Internet.

During the project development, the work was mostly performed on ENVISAT and SPOT5 satellites EO data. The ENVISAT satellite contains a payload of eight measuring instruments and each of the resulting products has been examined during the project to determine the JPEG2000 coding suitability. As a result, several products have been identified: MERIS, ASAR, GOMOS, ATTSR, RA2 and SCIAMACHY. Each of the products is currently coded in ESA´s proprietary format called Payload Data Segment (PDS) which is a non compressed data format which usually results in quite large product files, not very suitable for Internet transfers. SPOT5 vegetation products were also considered in the HICOD2000 system. These products are stored in the NCSA’s Hierarchical Data Format (HDF).

The JPEG2000 encoding process that was adopted in the project had into consideration the fact that no information loss should occur in the resulting JPEG2000-flavoured version of the original EO products. JPEG2000 is used in lossless coding operation to allow the exact recovery of the original product (bit by bit). This represents one of the big results of the proposed system – the possibility to compress the ENVISAT and SPOT5 EO products to lossless JPEG2000 format, and later recover the original format without information loss – this was a requirement due to the fact that there were already in place a great set of legacy PDS data manipulation tools that would not be affected by the encoding scheme. In fact, the HICOD2000 system could be plugged in these legacy systems.

Security was also a critical issue on the system. The possibility to directly protect the EO data and to manage the access to that protected data was something that the system also had to support. Since the project was using JPEG2000 technology to have a newer representation of the EO products, it was also developed a mechanism to allow these JPEG2000 EO products to be protected. The approach was to protect the content itself and not only the data channel – like what is easily found on SSL/TLS network connections. This opened new possibilities to ESA in terms of new business models and the definition of new EO data access policies – for instance it could be possible to “lock” the access to some sensitive data on a specific EO product and to allow the access to the remaining data (this parameterization could also be done on a user basis).

The solution adopted was based on one of the parts of JPEG2000 standard, called JPSEC, which deals with code-stream protection. Therefore it was developed a method to protect the EO product according to its resolution levels, and it was integrated a DRM solution 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 models, and allow the price differentiation of its own EO products according to the resolution level selected by the client. On the client side a visualization tool was improved to control the resolution level access according with the one the client purchased.

Finally, this system was integrated with the existing ESA Ground Segment systems specifically the Services Support Environment (SSE) and is now on a test phase.

2 JPEG2000, JPSEC AND DRM SOLUTION

Remote sensing applications handle large size images. An efficient compression algorithm would save significant storage space. Also image manipulation, such as zoom, pan and metadata edition may be valuable features. Content security is also a relevant aspect to be considered, those images that have intrinsic value and must be protected both in terms of privacy protection, conditional access and B2B and B2C e-commerce business processes. The study of these problems and the creation of a system that could combine a solution to solve them, were key objectives of this work.

2.1 *JPEG2000 image compression standard*

The image compression standard JPEG2000 (Boliek, Martin 2002) brings not only powerful compression performance but also new functionality unavailable in previous standards (such as region of interest, scalability and random access to image data, through flexible code stream description of the image). The compression performance using JPEG2000 overcomes JPEG, with the drawback of a much higher complexity. For software and hardware platforms, the complexity of JPEG2000 is believed to be around ten times higher than JPEG (Taubman, David S. & Marcellin, Michael W. 2001). This is a crucial problem for its adoption for real-time systems such as earth observation satellites.

JPEG2000 introduces flexibility in the transmission of images with a progressive improvement in image quality. The standard supports the capability of transmitting arbitrary regions of interest inside the image, with greater fidelity than others. It is also capable of providing lower resolution and/or low quality representations of an image for quick viewing, by only decoding a selected portion of the total transmitted image. JPEG2000 is able to code a wide range of images, from black and white, to grayscale, full-color (24 bit/pixel) images, to hyper-spectral space and planetary images that typically contain several dozen-color bands (Taubman, David S. & Marcellin, Michael W. 2001). Another important feature is the ability to provide error-resilience during transmission; that is to say, an error during progressive transmission will only affect a small portion of the final image rather than the whole image. As it stands currently, an image than has been compressed to the same final size with JPEG2000 and JPEG, will show much less visible artifacts with the first, due to the increased ability of wavelets to represent an image at low resolution than with the later, where the individual 8x8 blocks become noticeable for large compression ratios (Fig. 1). The two formats behave similarly for high quality reproductions but JPEG2000 increasingly outperforms JPEG as more and more compression is introduced, while maintaining the same visual fidelity (Taubman, David S. & Marcellin, Michael W. 2001).

Figure 1. JPEG (left) and JPEG2000 (right) low bit-rate comparison.

2.2 *JPEG2000 Security*

The issue of secure access to satellite imagery, is sensitive, since they contain value that image producers and providers, think that requires protection. Part 8 of the JPEG2000 standard, called JPSEC (Conan, Vania 2005) provides solutions to this problem by specifying a set of standardized tools and solutions that ensures security of transaction, protection of contents, and protection of technologies, allowing applications to generate, consume, and exchange JPEG2000 secured bit-streams. JPSEC addresses, among other applications: encryption (flexible mechanism to allow for encryption of image content and metadata), source authentication (verification of authenticity of the source), data integrity (data integrity verification), conditional access (conditional access to portions of an image or its associated metadata), ownership protection (protection of the content owner rights). In order to protect the content techniques such as digital signatures, watermarking, encryption, and key generation and management, are used.

2.3 *Digital Rights Management*

An effective implementation of the JPSEC was combined with a Digital Rights Management (DRM) solution, which deploys protection and security, and controlled access to content and which is particularly relevant in the digital content e-commerce. This DRM solution, called OpenSDRM (Serrão, C. et al. 2003), which is composed of several optional elements covering the content distribution value chain, from content production to content usage. It covers several major aspects of the content distribution and trading: content production, preparation and registration, content, interactive content distribution, content negotiation and acquisition, strong actors and user's authentication and conditional visualization and playback.

3 EO PRODUCTS COMPRESSION AND PROTECTION

3.1 *The Payload Data Segment*

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.

The resulting products are stored in the Payload Data Segment file format (PDS) which contains a Main Product Header (MPH) and a Specific Product Header (SPH) followed by product dependent data. Some products have Measurement Data Segments (MDS) where the measurement data is stored either in integer or floating point format, depending on the product. This data format does not feature any compression and so can usually result in quite large product files, not very suitable for Internet transfer. Knowing that the current JPEG2000 standard does not specify the manipulation of floating point data, each of the ENVISAT instruments products was examined to determine it's suitability for JPEG2000 coding (Boliek, Martin 2002, Christopoulos C., Skodras A. & Ebrahimi T. 2000), and as a result several have been identified: MERIS (ESA 2002e), ASAR (ESA 2002b), GOMOS (ESA 2002d), ATTSR (ESA 2002a), RA2 (ESA 2002c) and SCIAMACHY (ESA 1998, ESA 1999).

3.2 *The PDS parser*

The PDS parser is a tool able to assemble and disassemble PDS files. The parser starts the parsing process by identifying the product through is MPH header present in all products. After that it reads the SPH header, which is specific to each product. From this point forward, the parser is able do read all product specific data and separates it in two classes: JPEG2000 compressible data and metadata. The JPEG2000 compressible data, the image samples present on the MDS, are stored in raw files, one per band. The metadata, all data not suitable for JPEG2000 compression, is stored in a XML kind file. The reconstruction process (unparsing) start by reading the metadata file to identify the product and after that reads all metadata and raw data to the reconstructed file into its original order.

3.3 *The Hierarchical Data Format*

The SPOT5 satellite products, considered in the project, are about vegetation. The vegetation products are stored in the Hierarchical Data Format (HDF). The HDF format is a self describing and extensible file format which uses tagged objects that have standard meanings. The purpose is to store both known format description and data in the same file (NSA 2003). Shortly, this format consists in data structures organized in a hierarchy. No compression algorithm is applied to the data structures resulting in quite large files.

3.4 *The HDF parser*

The HDF parser parsing process separates the data in two different classes: JPEG2000 compressible data and metadata. As in the case of the PDS format, also the HDF format contains data which is not suitable for JPEG2000 compression. The suitable data structures for JPEG2000 encoding are the Scientific Data Sets, which contain the image samples. Other structures are considered as metadata and will be stored in an XML kind file.

3.5 *The protection tool*

The implemented protection tool is JPSEC compliant. The JPEG2000 syntax requires that any two consecutive bytes in the encrypted packet body must not have a value greater than 0xFF8F (Conan, Vania 2005). The protection tool security relies in the security of the Advanced Encryption Standard (AES) in output feedback mode (OFB). The algorithm checks the presence of bytes with value 0xFF living them in clear text, to the others ciphering is applied. Although some bytes kept in clear text this algorithm protects 99.15% of the coded image data (Hongjun, Wu & Di, Ma 2004).

3.6 *Putting all together: the HICOD2000 Black Box*

The conversion process of EO products, either PDS or HDF, to JPEG2000, and vice versa, is automatic. A tool named HICOD2000 Black Box (H2KBB) was developed to perform the conversion process in an unattended way. The H2KBB (Fig. 2) is a set of tools combined in such a way that the input file type is detected and the compression or decompression process is automatically started.

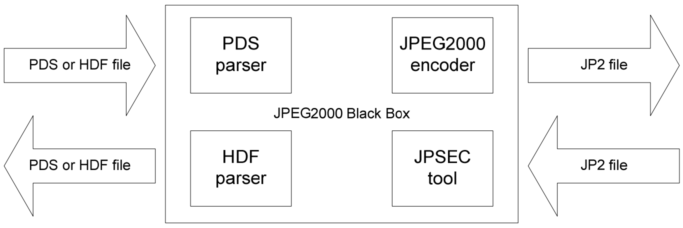

Figure 2. JPEG2000 Black Box

The H2KBB identifies the input file type from the file signature. If the file is a PDS or HDF file it will invoke the appropriate parsing tool and generate the correct compression and decompression command lines to be handed to the JPEG2000 codec. The codec used was the Kakadu that can be found in www.kakadusoftware.com. To be able to identify the original EO product from the JPEG2000 file, the H2KBB inserts a tag in the decoding command line with the parser identification. After this the compression phase is started. If required the compressed file will be protected by the JPSEC protection tool.

On detecting a JPEG2000 input file the reverse path is made. If the JPEG2000 file has been protected it must be handed to the JPSEC protection tool to remove the protection. Next it will be decompressed using the embedded command line in the JPEG2000 file. The last step is invoking the correct parser to reconstruct the original file.

4 SSE INTEGRATION

The Service Support Environment (SSE) project was developed to be the foundation of a future EO services related marketplace. Prior to the introduction of the SSE, each service provider needed to develop its own portal, including all the non-service related infrastructure and then it needed to make the availability of the service known to the potential clients, while on the other hand, the potential clients do not easily find the available services, and when they do, these usually supply only a fraction of the user needs, forcing him to use several providers. The SSE portal (services.eoportal.org) was developed to address these problems, while at the same time developing the EO economy through the development of the already mentioned "marketplace".
The two main components resulting of this activity are:

- The SSE portal, where users access the available services, order the products they are interested in, pay for them in a secure manner and with a large selection of payment methods, and track the progress of their order.
- The MASS toolbox, which service providers can use to chain their services into the MASS catalogue, eventually combining with other services to produce added-value services.

From the user point of view, access to the SSE portal is like the access to any other Web site, where he can register, browse the list of available products, create an order, pay for it and track its status. The most noticeable difference should be the wide range of available services.

The real difference however is from the service provider's point of view. A crucial factor in the design of the SSE system is the possibility of interoperability and chaining of services. This means that a service provider does not need to build its services from scratch, starting by processing the raw satellite (and ancillary) data – it can request the parts it needs from other service providers and just perform the steps required to create his products. This is done in several ways, first through the use of standard technologies such as XML, SOAP or WSDL which facilitates the development, and through the provision of a toolbox that simplifies the integration of the services within the SSE portal.

Figure 3. SSE service order page.

In order to make our solution available on the SSE portal, as a data conversion service, the service needed to be converted into SOAP based services.

On the SSE portal side this was done by configuring the service using three files, a WSDL file, a XSL style Sheet and a Schema file. These files are used to design the user interface (Fig. 3), catch and validate the service parameters, and link to the web service provider Toolbox server, were the service should be installed.

On the service server side, the Toolbox functionalities, allow the specification of the operation that has to be performed when a SOAP message is received. When a message is sent, from the SSE portal to the web service provider Toolbox server, the web service, previously installed and configured, through the use of XML Schema Definition (XSD) files, triggers the solution application. The result of this application is caught by the Toolbox and then sent to the SSE Portal in a compatible SOAP message. This message states the unsuccess or success of the service with the resulting link to the product.

5 IMAGE ACCESS SOLUTION

In order to display JPEG2000 EO products and to control the access to such products there was the need to create a client module that integrated these functionalities.

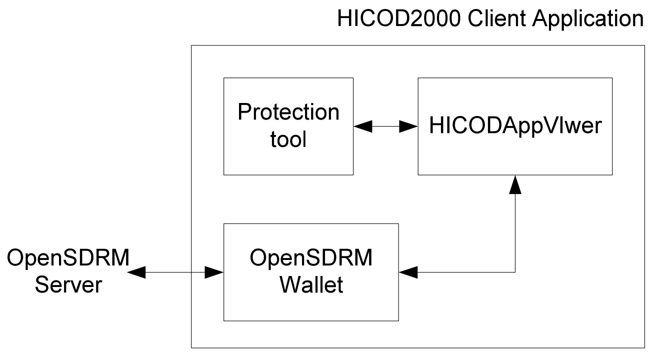

Figure 4. Client architecture.

The client module (Fig. 4) is composed of three main components, the JPEG2000 viewer application, the protection tool (described in section 3.5.) and the OpenSDRMWallet.

5.1 *JPEG2000 viewer*

The function of the JPEG2000 viewer component is to visualize and interact with EO JPEG2000 products. This component can open both JPEG2000 regular files and JPEG2000 EO products protected or not.

The most relevant user requests will be to access images, and to navigate through those images. Therefore, when the user uses this component to open an image it checks if the image is protected or not. If the image is unprotected then it is automatically rendered on the viewer allowing the user to navigate freely to any of the image available resolutions.

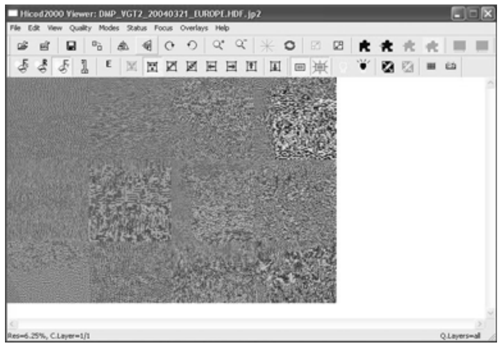

Figure 5. Protected image rendering.

If the viewer detects that the image is protected (Fig. 5), the viewer has to contact the OpenSDRMWallet to obtain the appropriate keys to decipher the image at each of the possible resolutions the user is trying to access and has acquired the right to do so. If those keys are returned with success to the viewer, they are handed to the JPSEC tool to decipher the image so it can be rendered correctly on the viewer. The viewer is signaled to render the image up to the requested resolution level (Fig. 6).

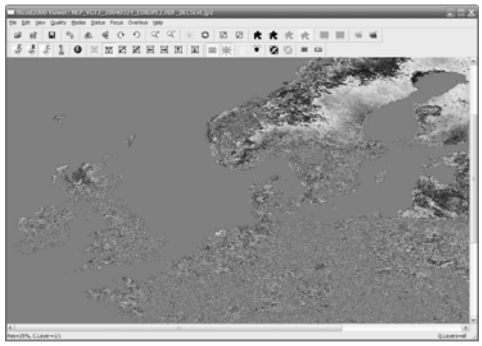

Figure 6. Image rendering after protection removal.

5.2 *OpenSDRMWallet*

The OpenSDRMWallet component is used to control the access to content licensing information as well as to cryptographic keys needed to decipher image data. This component determines how a given content can be used by a given user. Being a license repository the OpenSDRMWallet can be invoked by the local machine to retrieve the keys to a given license. If the license is not found on the repository the OpenSDRMWallet connects to the OpenSDRM license server, and tries to download a license. The returned license is then stored, securely, on the user-side.

6 CONCLUSIONS

Satellite imaging is one of the areas that can take advantage of the new image coding standard JPEG2000. Not only in terms of image compression, a quite relevant aspect, but also from the perspective of other parts in the standard, namely security.

The efficient compression scheme of JPEG2000 can handle images with higher quality and dimensions and provide satellites with increased storage capability. The standard can also provide more flexibility due to the compression options it offers. This could help satellite providers to reduce time-to-market in solutions for satellite imaging e-commerce, which can be turned into an important competitive advantage.

In general, the described solution was developed as part of a set of exploratory actions to find new technological 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. The outcomes of the project have proved that some HCOD2000 technologies may be applied in EO systems. One of the major opportunities, for the future exploitation of the solution presented, is the application of JPEG2000 for lossless compression of a range of ENVISAT products, as well as further research following the JP3D JPEG2000 extension activities, namely in coping with floating point data sets, in order to be able to comply with all the possible EO products conversion.

REFERENCES

Boliek, Martin (ed.) 2001. *JPEG 2000 Image Coding System: Extensions*. ISO/IEC.

Boliek, Martin (ed.) 2002. *JPEG 2000 Image Coding System: Core Coding System*. ISO/IEC.

Christopoulos C., Skodras A. & Ebrahimi T. 2000. The JPEG2000 Still Image Coding System: An Overview. In *IEEE Transactions on Consumer Electronics*, Vol. 46, No. 4, pp. 1103-1127.

Conan, Vania (ed.) 2005. *JPEG 2000 Image Coding System: Secure JPEG 2000*. ISO/IEC.

ESA 1998, *SCIAMACHY Level 1b to 2 Off-Line Processing: Algorithm Theoretical Basis Document, Issue 1B.* European Space Agency.

ESA 1999, *SCIAMACHY Level 0 to 1c Processing: Algorithm Theoretical Basis Document, Issue 1*. European Space Agency.

ESA 2002a. *The AATSR Handbook, Issue 1.0*. European Space Agency.

ESA 2002b. *ASAR Product Handbook, Issue 1.0*. European Space Agency.

ESA 2002c. *ENVISAT RA2/MWR Product Handbook, Issue 1.0*. European Space Agency

ESA 2002d. *GOMOS Product Handbook, Issue 1.0*. European Space Agency.

ESA 2002e. *MERIS Product Handbook, Issue 1.0*. European Space Agency.

Hongjun, Wu & Di, Ma 2004. *Efficient and secure encryption schemes for JPEG2000*. *IEEE International Conference on Acoustics, Speech, and Signal Processing,* Vol. 5, pp. 869-872.

NSA 2003. *HDF4 User's Guide – HDF4 Release 2.0*. National Center for Supercomputing Applications.

Serrão C., Neves D., Kudumakis P., Barker T. & Balestri M. 2003. *OpenSDRM – An Open and Secure Digital Rights Management solution*, *IADIS International Conference e-Society 2003,* Vol. 2, pp.647-650.

Taubman, David S. & Marcellin, Michael W. 2002. *JPEG2000: Image Compression Fundamentals, Standards and Practice*. Kluwer Academic Publishers