JPEG2000 Image Compression and Visualization for Desktop and Mobile Clients

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Abstract: This paper presents an architecture for JPEG2000 image compression and distribution using a Digital Rights Management (DRM) platform in the context of the PIMHAI project. The proposed architecture, based on a client-server interaction, will allow the users to upload images in PCIDSK database (PIX) format using a web-application front-end, and to perform the lossless JPEG2000 compression of such images. The resulting JPEG2000 images are then protected using cryptographic techniques and its intellectual property rights are managed digitally. In the context of the PIMHAI project, the proposed architecture will allow the storage of smaller and cryptographically protected image files in the database. The user access rights enforcement will prevent the access to the images by non authorized users. Another important feature is the decreasing of the connection time in the mobile client, through the expensive and slower wireless channel, to access the images in the database.

Keywords: image compression; JPEG2000; DRM; mobile environment JPIP.

Reference to this paper should be made as follows: Serra, A., Dias, L., Serrão, C. and Dias, M. (2006) 'JPEG2000 Image Compression and Visualization for Desktop and Mobile Clients', *Int. J. Internet Protocol Technology*, Vol. 1, No. 3, pp.XXX–XXX.

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1 Introduction

This paper presents an architecture for JPEG2000 (ISO/IEC 15444-1, 2000; ISO/IEC 15444-2, 2001) image compression and distribution using a Digital Rights Management (DRM) platform in the context of the PIMHAI (PIMHAI 2006) project. The proposed architecture, based on a client-server interaction, will allow the users to upload images in PCIDSK database (PIX) format (PCI Geomatics, 2001) using a web-application front-end, and to perform the lossless JPEG2000 compression of such images. The

resulting JPEG2000 images are then protected using strong cryptographic techniques and its intellectual property rights (IPR) are managed digitally.

The proposed server side architecture includes a DRM platform, designated by Open and Secure Digital Rights Management (OpenSDRM) (Serrão et al., 2003a), a large image database, and the necessary compression services, including a security feature named JPEG2000 Security (JPSEC) (ISO/IEC 15444-8, 2005). The server-side services are available through service oriented architecture (SoA) implemented using web-services mechanisms. Two classes of web-services are implemented: the first is the JP2 web-service class, allowing the PIX image upload and compression in JPEG2000 file format with or without security constraints or digital rights management. This class of web-services is integrated with another system called JPEG2000 Black Box (J2KBB). The second class of web-services is the GeoServices web-service class, which allows the user interaction with the image catalogue database. Through this class of web-services users can, after registration and authentication, interact with the image database to access and visualize the images as well as to access to their metadata and geo-reference data. The access to the images and their visualization may be constrained by the DRM platform.

The client application is available in two platforms: standard desktop and mobile device. On the standard desktop the user may interact with the server to register, authenticate, upload PIX images, and visualize JPEG2000 compressed images, as well as associated metadata. On the mobile device, in addition to the desktop features, excluding PIX upload, through the use of a GPS device, the client is location aware and is able to query the Microsoft MapPoint GIS web-service (MapPoint web services, 2006) for a specific area. Moreover, the mobile client when visualizing JPEG2000 images uses the JPEG2000 Interactive Protocol (JPIP).

In the context of the PIMHAI project (PIMHAI, 2006), the proposed architecture will allow the storage of smaller and cryptographically protected image files in the database. The user access rights enforcement will prevent the access to the images or image parts by non authorized users avoiding information disclosure. Another important feature is the decreasing of the connection time in the mobile client, through the expensive and slower wireless channel, to access the images in the database.

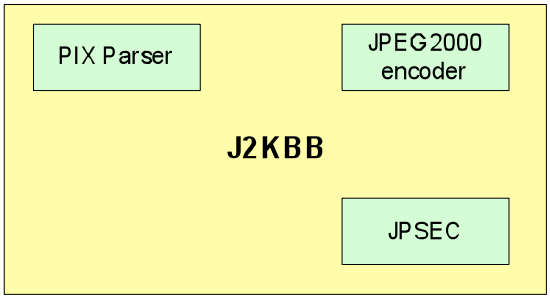
2 JPEG2000 compression of hyperspectral data

The compression module creates an environment for seamlessly converting between hyperspectral data in PIX format to JPEG2000 and to perform the reverse conversion. This module 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 JPEG2000 black-box (J2KBB). The J2KBB (Figure 1) can be used either in stand-alone operation or integrated in, eventually, any image distribution system since it provides an API that allows it to be invoked from the outside.

Figure 1 JPEG2000 Black Box architecture



Two of the J2KBB core sub-systems are the PIX products parsing and the JPEG2000 encoder. In a very generic way, the functionality of the PIX products parser consists in extracting from the original products format the JPEG2000 encodable data and metadata, as well as some additional information to be used in the original product reconstruction. The PIX products parser extracts raw data into separate files and meta-information from the PIX 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 (ISO/IEC 15444-2, 2001). In this way all the necessary data to recover the original product is stored together. The inverse process is accomplished invoking the JPEG2000 decoder to extract the raw files, as well as meta-data, and hand them to the parser which will use the information to rebuild the original file.

The encoding/decoding sub-system is based on one of the most well known JPEG2000 encoders, called Kakadu (Kakadu, 2006). This encoder receives the output of the PIX products parser and produces a JPEG2000 PIX product image. The encoding parameters are specified on a file that was created by the PIX products parser – 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. Like the PIX products parser this compression sub-system is reversible, allowing that from the JPEG2000 generated product the original file format may be recovered.

3 JPEG2000 hyperspectral data protection

One important feature on the developed system consists on the capability of offering granular protection to JPEG2000 PIX products – the capability to offer strong protection

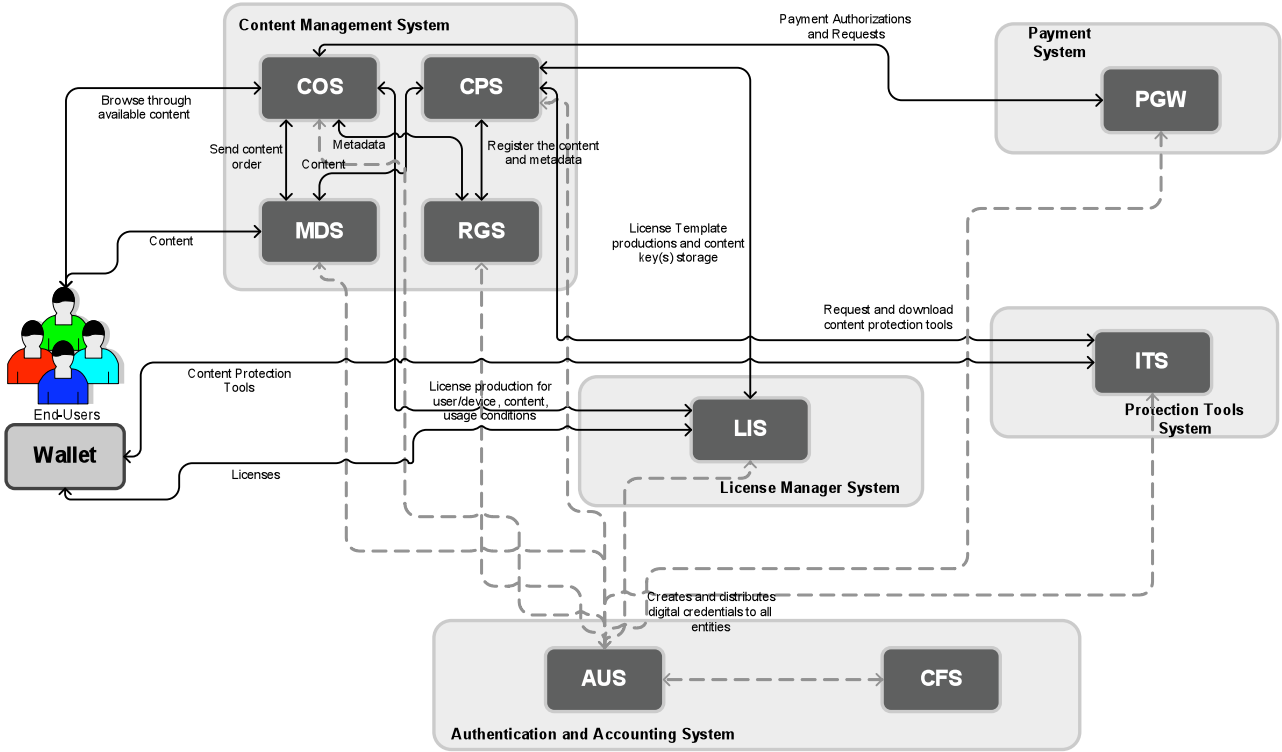
(Serrão et al., 2003b) to the global PIX product as well as the capability to protect just some parts of the product while others remained in clear.

The emerging JPEG2000 – Part 8, called JPSEC (ISO/IEC 15444-8, 2005), aimed at the development of a protection scheme for JPEG2000 code-streams was the selected technology to protect the PIX products. The specified protection granularity of the PIX products is at the resolution level, up to a maximum of 6 different resolution levels (Serrão et al., 2003a).

Each of the JPEG2000-encoded PIX product resolution level was ciphered with a different key using the AES (OFB mode) algorithm (FIPS-197, 2001). 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 (ISO/IEC 15444-8, 2005).

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 PIX products using a DRM system (Serrão et al., 2003b). This DRM system, called OpenSDRM (Serrão et al., 2003a), was developed in the scope of an 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 (figure 2) in which every component can be separated (Serrão et al., 2003a). 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 system described on this paper.

Figure 2 OpenSDRM architecture



The J2KBB was integrated with OpenSDRM using the publicly available WSDL interfaces (Serrão et al., 2003a), to provide DRM functionalities such as: user authentication, content registration, content encryption keys registration, and license management.

Therefore when J2KBB is converting a PIX product to JPEG2000 format a parallel DRM process is also triggered: the OpenSDRM registers the PIX product, assigning a unique identifier that is inserted inside the JPEG2000 PIX 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 PIX product (Serrão et al., 2003a).

During the J2KBB PIX products protection, the content encryption keys are established and registered on the DRM platform – a logical connection between the PIX product unique identifier and the content keys.

Whenever a final user selects a product from the PIX catalogue, 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 PIX 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 Geoserver

The Geoserver application responds to client requests on image browsing and downloading with user rights enforcement.

The Geoserver interface, written in PHP, is based in web services allowing the clients to access its information through any current internet browser as well as proprietary applications since it exports its interface through Web Services Description Language (WSDL) (W3C, 2001). This interface is composed by two main classes of web services: JP2 web service and Geoservices.

The JP2 class of web services allows the uploading of PIX image files, which will be compressed in JPEG2000 and protected if the user chooses to do so, and the browsing and downloading of JPEG2000 images.

The Geoservices class of web services allows the browsing of geo referenced images in JPEG and JPEG2000 format. This class of web services is mainly used on the mobile client.

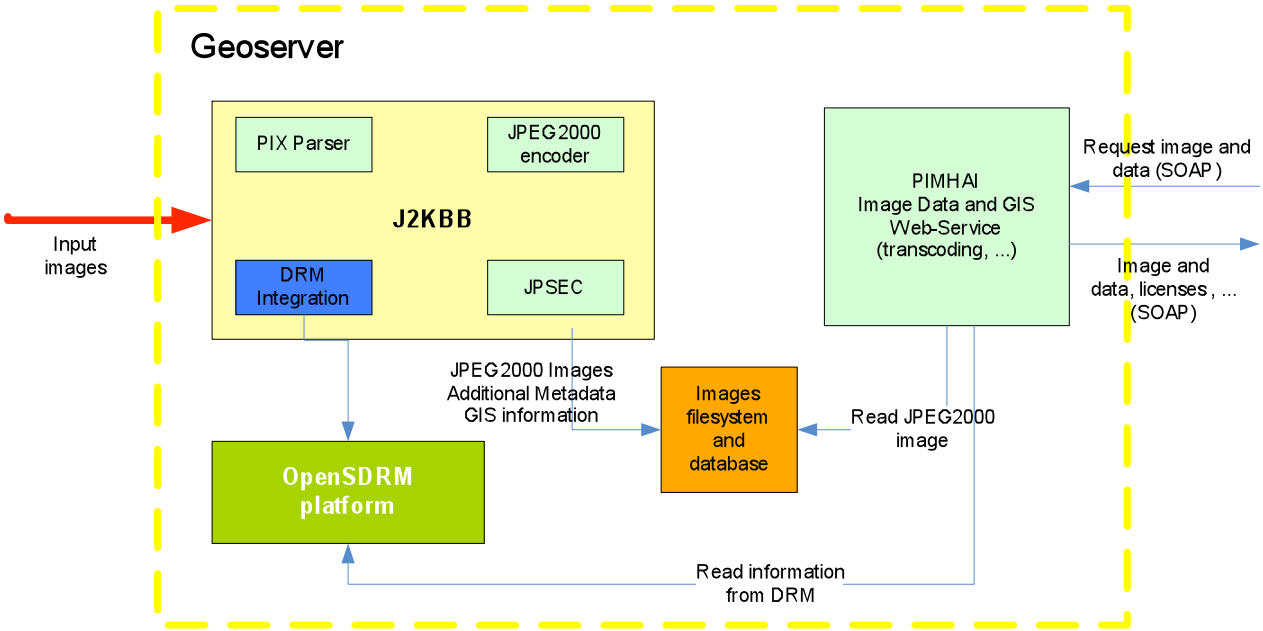
The Geoserver application handles user registration and authentication services, PIX images upload and compression in JPEG2000, and image and metadata browsing.

The Geoserver is composed by the following components (figure 3):

1. J2KBB which is responsible by the PIX files compression and protection;
2. JPIP server which delivers the JPEG2000 images in a interactive way to the clients;
3. MySQL server which stores the metadata related to each of the images uploaded to the system.
4. DRM integration module responsible for all the interactions with the OpenSDRM platform.

All the interactions with the Geoserver require user authentication. The process of uploading a PIX image to the server is a very simple one. Upon registration and authentication the user may invoke the upload service to select and send the PIX image to the Geoserver. Once the upload is complete the server starts to apply JPEG2000 compression and protection, the latter if requested by the user, and stores the images on the file system and its associated metadata in the database. To visualize an image the user browses through the image catalogue and selects the desired image which will be delivered to the user. When an image has been uploaded with user rights constraints the Geoserver verifies them before starting to deliver the requested image.

Figure 3 Geoserver modules



5 Desktop Geoclient

The desktop client application may be implemented in the form of web pages or in a custom application, since it makes use of the web services interface exported in WSDL by the Geoserver. This section describes a browser based client application (desktop Geoclient) and in the next section a custom application (mobile Geoclient) will be described.

The desktop Geoclient is an application written in PHP running in most of currently available internet browsers.

Through this application, upon registration and authentication, the user may upload, browse, and download any image in the catalogue, except when user rights constraints and enforcement won't allow it.

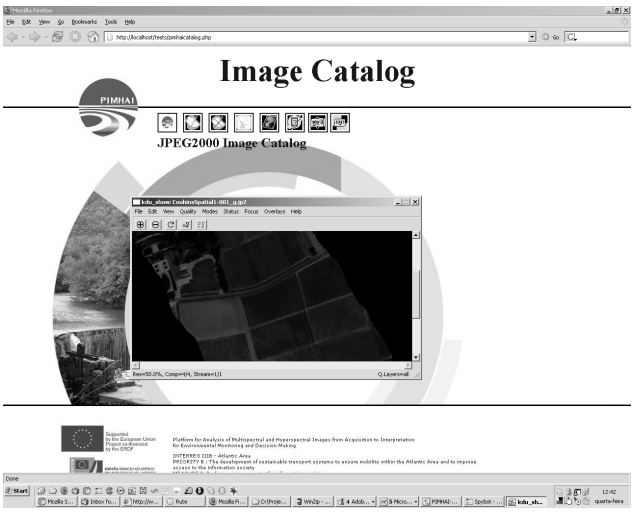
The user may upload an image in PIX format by click the upload link where he will be asked to select the image to upload, the metadata available to other users and any desired usage constraints.

To have a proper visualization of the JPEG2000 images the user must have installed a plug-in or external application able to display JPEG2000 images. In the case of protected images the external application (Serrão et al., 2005) includes a wallet component which is responsible by verifying the user rights and requests the proper license to allow image visualization. When an image is selected in the catalogue browsing page two ways may follow:

1. The image has no usage constraints and the JPEG2000 plug-in or external application will display it.
2. The image has usage constraints and the visualization follows a process of license verification and downloading to unprotect the image accordingly with the defined user constraints.

Figure 4 shows an example of image visualization using an external application. The visualized image has no user constraints attached.

Figure 4 JPEG2000 image visualization on desktop Geoclient



The user is able to recover the original PIX format since the compression process is lossless. To be able to do so, the user must download the image and run a local version of the J2KBB. The reason for not doing this on the server side is the lost of one of the gains obtained in compressing the PIX images in JPEG2000: bandwidth. The JPEG 2000 images are much smaller than PIX images as seen o table 1.

Table 1 Compression ratio of JPEG2000 compressed PIX images

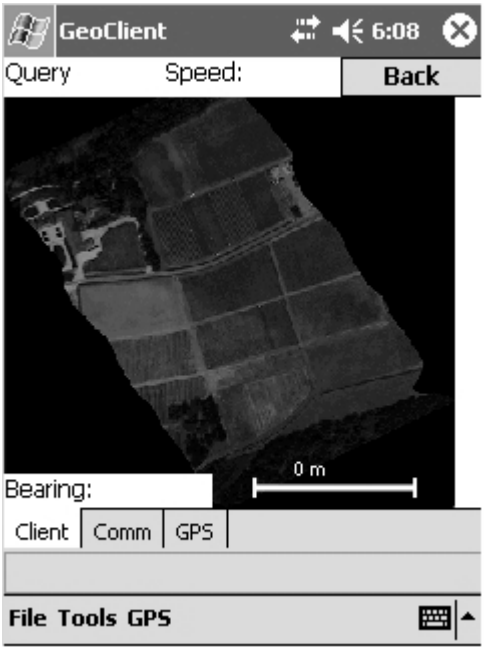
PIX image file	PIX size (bytes)	JP2 size (bytes)	Compression ratio (%)
CouhinsSpatial1-001.pix	4137472	2801618	32,29
CouhinsSpatial2-002.pix	4137472	2981116	27,95
CouhinsSpatial3-003.pix	3727872	2742270	26,44
CouhinsSpatial4-004.pix	3727872	2569744	31,07
CouhinsSpectral-001.pix	10249216	6947075	32,22
Luchey-001.pix	14665216	9651248	34,19
Luchey-001_g.pix	22584832	10667250	52,77
Luchey-001_r.pix	15860736	9955244	37,23

6 Mobile Geoclient

The present architecture was designed to allow the interaction with users that may be on the field, where airborne imagery is available. The development of a client application for mobile devices provides the necessary flexibility for this purpose.

The mobile Geoclient application allows browsing of either the images as well as their associated metadata through the available web-services interface on the Geoserver. To access an image the mobile client downloads and visualizes the image (Figure 5). Whenever zooming areas are available those are signalled on the image, allowing the client to access them in the same way that the initial image. When browsing the images, the client may access available metadata for each image. If the mobile client is location aware, i.e. has a GPS device, it can query the MapPoint (MapPoint, 2006) web-service for GIS information relative to a specific area.

Figure 5 JPEG2000 image visualization on mobile Geoclient



Another important feature in the mobile client is the ability to access the compressed JPEG2000 images through the JPEG2000 Interactive Protocol (JPIP) (ISO/IEC 15444-9, 2004). The JPEG2000 images consumed by the mobile client are usually resource demanding becoming infeasible to download and visualise the whole image. Being a resource constrained device, the use of the JPIP protocol allows the mobile client to interactively retrieve lower resolutions of the image, minimizing the needs for both high processing and storage capacities. Moreover, since PDA devices have small displays with relatively low resolution, the use of decreased resolution images does not have an impact on visual image quality.

The JPIP protocol is defined in Part 9 of the JPEG2000 standard (ISO/IEC 15444-9, 2004). This protocol makes use of the JPEG2000's scalability properties (ISO/IEC 15444-1, 2000). JPIP can respond to real-time application requests, delivering pieces of a JPEG2000 image in arbitrary order. In order to avoid the need to store multiple versions of an image at different resolutions and the retransmission of redundant data, JPIP takes advantage of JPEG2000's resolution hierarchy (ISO/IEC 15444-9, 2004).

JPEG2000 Part 9 defines an image delivery mechanism essentially different that the one for conventional web image transmission. The latter requires the whole image to be transferred, using the HTTP protocol, from the server to the client. The client then decodes the image with a separate JPEG2000 decoder. The HTTP transport system is totally generic and has no information regarding the JPEG2000 images it may transfer. By contrast, JPIP allows the client to define a "focus-window" with the user's spatial region, resolution and components of interest (Taubman and Prandolini, 2003). The requests may have different image delivery options, which correspond to different data types for the server response (ISO/IEC 15444-9, 2004):

1. The server returns complete JPEG2000 images for a requested region at a specified resolution. The transfer has limited efficiency since there can be redundant retransmission of data when multiple requests are considered.

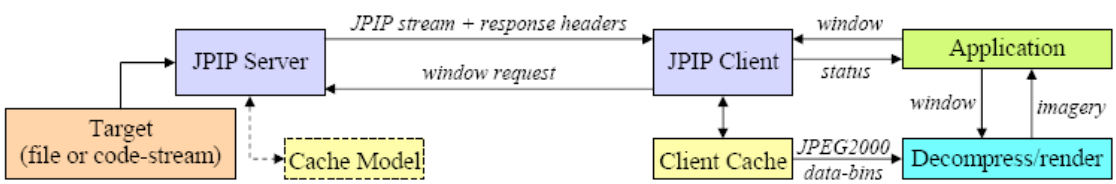
2. The server returns a new stream type called JPT stream. This can contain header data, sample data or metadata. The sample data is made of the tile-parts relative to the requested region of the image up to the requested resolution level. There is an increase in efficiency over the first option, since tile-parts that are pertinent to more than one request do not need to be resent.

3. The server returns a new stream type called JPP stream. The sample data is based on precincts at each resolution level. This is the most efficient image delivery option, since it does not have the scalability and spatial limitations of the second option, which are inherent to the tile oriented transmission.

The JPIP protocol is transport-neutral (ISO/IEC 15444-9, 2004). Its primary design objective is that transmission is made through HTTP without interference with existing HTTP infrastructure. Nevertheless, other transports can be used even more efficiently (e.g. TCP or UDP).

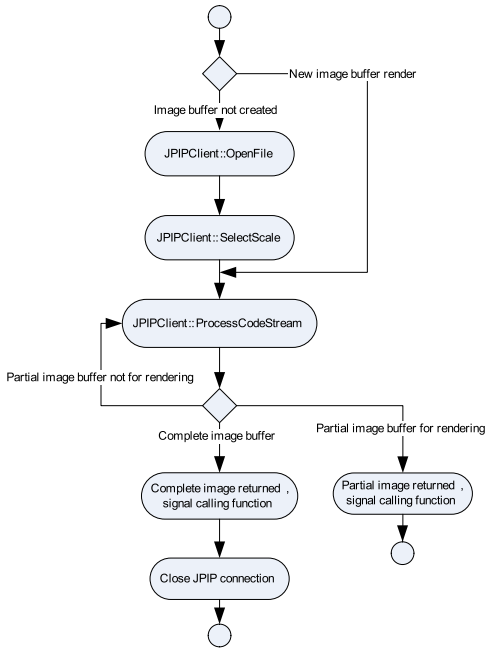
Figure 6 depicts the interaction between the client application and the remote server, when using the JPIP protocol. It should be noted that in this figure the decompression rendering process is separated from the client-server communication. It is also signalled the client's cache of data previously transmitted by the server, organized in data-bins. Optionally, the server may have a model of the client's cache to avoid retransmission of data the client had already received (ISO/IEC 15444-9, 2004; Taubman and Prandolini, 2003).

Figure 6 Generic client-server interaction in JPIP



The mobile Geoclient JPIP protocol interaction is depicted on figure 8.

Figure 7 Geoclient JPIP server interaction



Analyzing Figure 8, when an image is requested from the JPIP server and no connection has yet been established, JPIP client main function starts to call OpenFile. This function prepares for JPIP transmission and for dynamic decompression. Afterwards, the SelectScale function adjusts the image resolution requested from the server, so that it has the lowest possible value, higher then the display resolution. The next stage of the retrieval process consists of a series of calls to the ProcessCodeStream function that performs the dynamic decompression of the target image for the selected level of resolution. An image buffer stores the evolution of this decompression. The partial results of the dynamic decompression are returned, at regular intervals, and the calling function is correspondingly signalled. When the server has finishing serving the requested image, the ProcessCodeStream function signals this event, the final image is returned, and the connection is closed.

7 Conclusions

This paper described a system for JPEG2000 image visualization in both desktop and mobile clients in the scope of the PIMHAI project.

The images used are in the PIX format and need to be interpreted and converted to a JPEG2000 compressible format; this is the role of the J2KBB. The images may be constrained to usage rights enforced by the OpenSDRM platform. The Geoserver through a well defined web services interface is able to compress , protect and catalogue the uploaded images PIX images. The desktop client accesses to the image catalogue through an internet browser, but needs to use a JPEG2000 image viewer able to interface with the DRM platform to verify and request the appropriate usage license. The mobile Geoclient application has the capability to use the JPIP protocol and thus reducing the needed bandwidth on image retrieval and allow interactive image transfer.

In this paper we have proven the capability of the JPEG2000 image encoding standard and of the implemented system to be able to compress with efficiency great volumes of visual information, without any data loss, and with gains in terms of space. Moreover, the additional parts of JPEG2000 provide the necessary functionalities to protect the generated JPEG2000 image code-stream and the flexible and interactive access to image data through a network connection. The integration of this protection and interactive access functionalities and a DRM platform, allows the specification of business models that can control the access to the generated visual information in a fine grained manner.

The system deployment either in normal desktop PCs as well as on PocketPCs allows a much more ubiquitous access to visual information has one of the major goals of the PIMHAI project.

References

FIPS-197 (2001) 'Advanced Encryption System (AES)', 26 November 2001

ISO/IEC 15444-1 (2000) 'JPEG 2000 image coding system – Part 1: Core Coding System', 2000

ISO/IEC 15444-2 (2001) 'JPEG 2000 image coding system – Part 2: Extensions', 2001

ISO/IEC 15444-8 (2005) 'JPEG 2000 image coding system – Part 8: Secure JPEG2000', 2005

ISO/IEC 15444-9 (2004) 'JPEG 2000 image coding system – Part 9: Interactivity tools, APIs and protocols', 2004

Kakadu homepage (2006) http://www.kakadusoftware.com as seen on 14/07/2006

MapPoint web services (2006) http://www.microsoft.com/mappoint/products/webservice/default.mspx as seen on 14/07/2006

PCI Geomatics (2001) 'PCIDSK Database Reference Manual version 8.2', PCI Geomatics, 16 November 2001

PIMHAI homepage (2006) http://www.pimhai.ietr.org as seen on 14/07/2006

Serrão C., Neves D., Kudumakis P., Barker T., and Balestri M. (2003a) 'OpenSDRM – An Open and Secure Digital Rights Management solution', *IADIS 2003*, Lisboa, Portugal, May 2003

Serrão C., Serra A., Fonseca P., and Dias M. (2003b) 'A Method for Protecting and Controlling Access to JPEG2000 Images', *SPIE 2003 Annual Meeting*, San Diego, California, United States of America, August 2003

Serrão C., Serra A., and Dias M. (2005) 'HICOD2000 – Integrated System for Coding, Protection and Trading of

Earth Observation Products in JPEG2000', Proceedings of Visualization, Imaging, and Image Processing (VIIP2005),

Taubman D., Prandolini R. (2003) 'Architecture, philosophy and performance of JPIP: internet protocol standard for JPEG2000', *International Symposium on Visual Communications and Image Processing (VCIP2003)*, *SPIE* volume 5150, pp. 649-663

World Wide Web Consortium (W3C) (2001) 'Web Services Description Language v 1.1', 15 March 2001