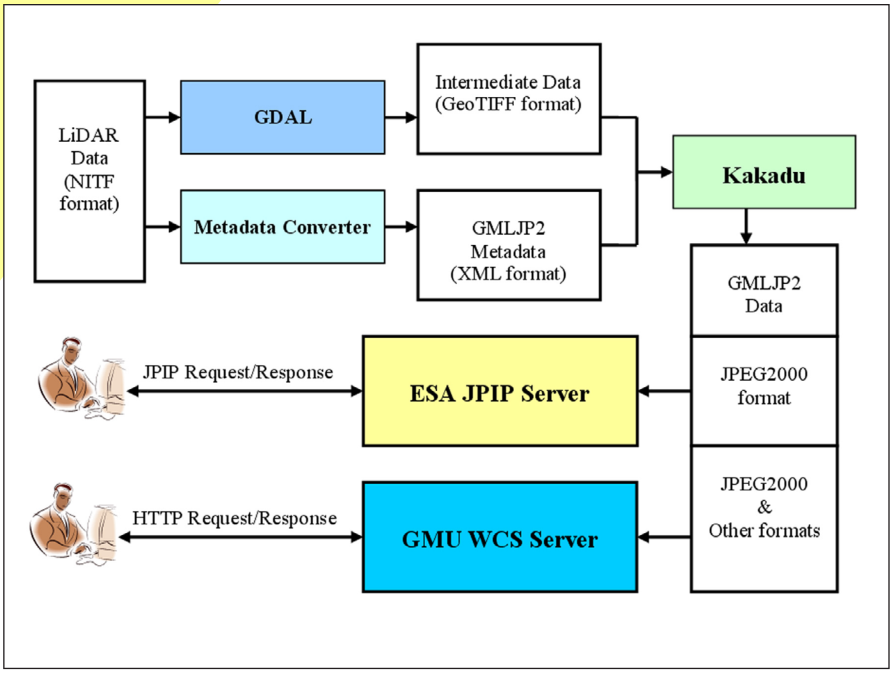

Figure 1. GMU GMLJP2 WCS implementation framework.

Using Open Standards to Integrate LiDAR and Geoprocessing

LiDAR Integration in an OGC Testbed

In the OGC (Open Geospatial Consortium) Web Services Activity Phase 9 (OWS-9) Testbed, a service implementing the OGC Web Coverage Service (WCS) Interface Standard was developed to serve LiDAR data in the High Resolution Elevation Format (HRE). HRE is used by US National System for Geospatial Intelligence (NSG) partners. As stated in the OWS-9 Call for Participation, "Participants will also investigate the use of GMLJP2 (OGC Geography Markup Language for JPEG 2000 Encoding Standard) as a wrapper for LIDAR data.

Participants shall prototype LIDAR (LAS—LASer File Format Exchange) data after processing to High Resolution Elevation (HRE) gridded format on a Web Coverage Service 2.0 implementation. The WCS implementation shall support the ability to deliver this data using the JPEG 2000 Interactive Protocol (JPIP) standard."

Challenges for LiDAR under cyberinfrastructure are summarized as follows. On one hand, heterogeneity in metadata formats hinders data distribution and sharing. On the other hand, data transmission based on common protocols (e.g., HTTP) is recognized to be inefficient for high volume data.

To tackle these challenges, two solutions were proposed. GMLJP2, a platform-independent format, was utilized to encode and generate homogeneous LiDAR metadata. The JPIP protocol, which provides for efficient compression of image data, was used for data transmission.

Both the GMLJP2 and JPIP protocols were integrated under the OGC WCS standard, which is widely implemented by geospatial software vendors to provide a common data accessing service for multi-dimensional spatio-temporal

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AN INTRODUCTION TO CSISS/GMU

The Center for Spatial Information Science and Systems (CSISS) is an interdisciplinary research center chartered by the provost and affiliated with the College of Science at George Mason University, Fairfax VA. CSISS currently operates the Laboratory for Advanced Information Technology and Standards (LAITS). It is a member of the National Committee on Information Technology Standards - Technical Committee L1, and a member of the Open GIS Consortium (OGC).

CSISS Mission

- To conduct world-class research in spatial information science and system.
- To provide state-of-art research training to post-doctoral fellows, Ph.D. and Master students in the field.

CSISS Research Focus

- Theory and methodology of spatial information science;
- Standards and Interoperability of spatial data, information, knowledge and systems;
- Architecture and prototype of widely distributed large spatial information systems, such as NSDI, GSDI, and GEOSS, as well as service-based spatial knowledge and decision-making systems;
- Exploration of new information technologies that have potential applications in Spatial Information Science (SIS);
- The applications of SIS in the society sectors having either national interests or major commercial values, such as renewable energy, location-based mobile services, intelligent transportation, and homeland security.

coverages such as sensor data, satellite imagery, image time series, point clouds, and meshes.

GMLJP2

The OGC Geography Markup Language (GML) standard defines a model and XML grammar for the encoding of geographic information including geographic features, coverages, observations, topology, geometry, and coordinate reference systems, units of measure, time, and value objects. JPEG 2000 is a wavelet based encoding for imagery that provides the ability to include XML data for description of the image within the JPEG 2000 data file. The GMLJP2 Implementation Standard defines the OGC standard method of using GML within JPEG 2000 images for geographic imagery.

JPIP is a compression streamlining protocol that works with JPEG 2000 to produce an image using the least bandwidth required. JPIP has the capacity to download only the requested part of a picture, saving bandwidth, computer processing on both ends, and time. It allows for the relatively quick viewing of a large image in low resolution, as well as a higher resolution part of the same image.

Implementation Scenario

A general program was built by George Mason University (GMU) CSISS to convert data from NITF format to JPEG2000 format and transform native Tagged Record Extensions (TREs) to GML metadata. Also, a JPIP server was set up by ESA (the European Space Agency) to deliver results from the WCS service to clients using the JPIP protocol.

The open source geospatial package Geospatial Data Abstraction Library (GDAL) was utilized in data reformatting and re-projection because it supports multiple geospatial data formats, including GeoTIFF and NITF (National Imagery Transmission Format). However, GDAL does not support the JPEG2000 format with its default configuration, so it was re-configured with the OpenJPEG library (or Japser library) to support JPEG2000 data in the GMU's GMLJP2 WCS implementation mentioned in the paragraph above.

The ESA JPIP server was configured to support the JPIP protocol. It was found that the ESA JPIP server doesn't directly support the JPEG2000 file generated from GDAL. So Kakadu software (including command line tools and APIs, freely obtained from Kakadu Software, www.kakadusoftware.com) was used to generate the output data in JPEG2000 format.

In the implementation, GeoTIFF serves as an intermediate data format between NITF and JPEG2000. That is, the original source data in NITF format is converted to the data in GeoTIFF format using GDAL, and then the GeoTIFF file is converted to the output JPEG200 file using Kakadu. A metadata converter was developed to transform metadata information in NITF format to GMLJP2 metadata in XML format. Finally, the ESA JPIP server delivers the responses in JPIP protocol, and GMU WCS server handles the HTTP requests.

The whole process is illustrated in **Figure 1**.

Demonstration and Implications of the OWS-9 Testbed LiDAR study

The *OGC® OWS-9 OWS Innovations WCS for LIDAR Engineering Report* (one of nine OGC Engineering Reports that resulted from OWS-9) demonstrates that LiDAR data can be converted, using open standards, to data that can be processed using conventional GIS and image processing software.

A code sample available in the Engineering Report demonstrates how the XML-encoded metadata that is converted from LiDAR HRE data is inserted into the XML Box of the JPEG 2000 header file. The sample request and response of GMLJP2 WCS are also shown.

The LiDAR industry has advanced with the IT industry's hardware advances. The LiDAR work done in OWS-9 shows that the industry can now begin to take full advantage of software advances such as Web services, apps, and the cloud. WCS is an extraordinary standard that enables flexible access to, and integration of, sensor data, images, simulation models, statistics data and other types of data and geoprocessing services. Because it is a web service interface standard, it opens the door to communication and integration with countless geospatial data sources and processing services.

LiDAR now has an entry point for countless new applications. As the cost and size of LiDAR systems shrink, the commercial opportunities and market size grow, bolstered by open interface and encoding standards implemented in both proprietary and open source software.

[1]**Cyberinfrastructure:** environments that support advanced data acquisition, data storage, data management, data integration, data mining, data visualization and other computing and information processing services distributed over the Internet (Wikipedia)

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