Project Matsu Technical Note
Using Dyadic Grids for
Managing and Analyzing Data

Open Cloud Consortium
Open Data Group

June 1, 2012
Version 1.2 6/21/2012

Contents

1 Introduction

One of the goals of the Matsu project is to use an open source cloud-based infrastructure to make high quality satellite image data accessible through an Open Geospatial Compliant (OGC)-compliant Web Map Service (WMS). Another goal is to develop an open source cloud-based analytic framework for analyzing individual images, as well as collections of images. For example, with a collection of images, one could identify changes in a region over time. A third goal is to generalize this framework to manage and analyze other types of spatial-temporal data.

2 Matsu Data Flow

Here is a summary of the data flow:

1. Transmit data from NASA's EO-1 Satellite to NASA ground stations and then to NASA Goddard.

2. Align data and generate Level 0 images.

3. Transmit Level 0 data from NASA Goddard to the Open Cloud Consortium's (OCC) Open Science Data Cloud (OSDC).

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4. Store Level 0 images in the OSDC Storage Cloud for long-term storage.

5. Within the OSDC, Launch Virtual Machines (VMs) specifically built to render Level 1 images from Level 0 data. Each Level 1 band is saved as a distinct image.

6. Store Level 1 band images in the OSDC Storage Cloud for long-term storage.

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7. Run Hadoop MapReduce jobs to read in Level 1 images. As part of the job configuration, which bands to load are specified, allowing for visual images to be created as well as filters showing heat, oil on water, etc. Most images or filters are a combination of several bands. Geo-spatial data is extracted from the geo-TIFF images.

8. Divide ("chunk") images into manageable sizes, suitable for processing and display on the WMS. We use *dyadic decompositions* for the

zooming / chunking. A region is divided into 4 images (zoom + 1), then into 16 images (zoom + 2), then into 64 images (zoom + 3), etc. MapReduce is well suited for chunking the images in this way.

9. Tag each chunked image with the bounding box, date, time, dyadic level, and bands used. Convert to the PNG format to simplify further processing.
10. Store PNG images in the Hadoop Distributed File System (HDFS) as SequenceFiles for use with later analytics.
11. Load PNG files into Accumulo for access by the WMS. Accumulo is the tile store.
12. Apply Augustus and R-based analytics to analyze the images.

Note: Steps 1–3 are handled by NASA as part of their daily operations. Steps 4–6 are run by NASA on the OSDC for Matsu and other projects. Steps 7–12 are specifically for Project Matsu are under development.

Satellite data comes from the Hyperion (hyper-spectrum) and ALI (multi-spectrum) instruments on NASA's Earth Observation Satellite 1 (EO-1).

3 Creating Image Chunks

Level 1 band images cover narrow strips of large geographical distances. For the WMS, we want boxes at increasing zoom levels. For the analytics, we want a dyadic decomposition of the geographical space.

To perform this, the bands are read and the images are broken into pieces, covering various areas. For each each zoom level, a smaller and smaller region is selected and processed. That is, we create the dyadic grid of the images on ingest, so that models can be run the decomposition in the reducer or in later MapReduce runs.

There are two distinct MapReduce runs. The first is the build images for display. The second is to apply some analytic or model on the images created in the first MapReduce process. The second may be run several times for different analytics.

4 Processing

To build the tile cache for display in WMS and a dyadic decomposition for use with analytics, the band images have to be broken into smaller pieces and aligned. The mapper loads images with specified date, geographical region, and bands. The bands are assembled to create an image, and then the bytes are partitioned by bounding boxes.

In the reducer, the images are built as PNGs and saved to the HDFS. The images stored in HDFS are:

- PNG files that can be more easily used with image libraries than the 16-bit geo-TIFFs of the original band data.
- A combination of specific bands. For example, parallel directory paths can exist in the HDFS, one with standard visual images and the other with temperature maps (for tracking forest fires).

A separate jobs then loads images into Accumulo.

At this point, global satellite data has been converted to images of a fixed size at various resolutions. This allows the WMS to "zoom in" on a region. It also provides a grid for use with analytic.

MapReduce jobs map the images by bounding box. All images that fall into a region go to the same partition of the reduce step. The size / resolution of this region is fixed. For example, data is read at the finest zoom level, but but is mapped with a key identifying the, lets say, zoom level 7 region it falls into. This gives us $2^{2z} = 2^{2\cdot 7} = 16384$ processing batches (in total) sent to reducers.

Within a reduce, this gives a dyadic decomposition starting at the region and going to the highest available zoom level. box. The images at each split of the decomposition can be processed separately, but with knowledge of the other levels within the same batch, but not the other regions.

5 Storage

The MapReduced images are stored in HDFS and Accumulo. The images in Accumulo are the web tiles.

Accumulo offers distributed, fault-tolerated data storage. Images that are frequently requested can be cached in a layer between the NoSQL database and the WMS. Accumulo holds both the map images and any result of an analytic MapReduce runs, to be serve up with the image as a layer.

HDFS is for use with MapReduce Jobs. Image data is stored in HDFS with the geospatial bounding box, date-time stamp, zoom level, instrument, and band data. If a new analytic is to be run, the HDFS images are used as input. The result is written back to HDFS to be loaded into Accumulo. The analytic has to be coded and implemented as a MapReduce job before it can be run, but once it is completed, it can be applied to any image data still available in the HDFS. As a practical matter, older data will be periodically purged.

6 Dyadic Spatial-Temporal Grids

The approach can be used to process a variety of other types of data. Given a time-varying dataset, for each date-time stamp, we divide (chunk) the data dyadically into different zoom levels (typically 0–15). Each dataset chunk is identified by: date-time stamp, geospatial bounding box, zoom level, and perhaps additional data or metadata fields.

7 About Project Matsu

Matsu is an Open Cloud Consortium (OCC)-sponsored project. The source code and documentation will be made available on GitHub under Open Cloud Consortium (`https://github.com/opencloudconsortium`).

The OCC is a not for profit that manages and operates cloud computing infrastructure to support scientific, environmental, medical and health care research. The OCC is focused on using this technology to make scientific advances by working with scientists in a variety of disciplines. Visit us at `http://opencloudconsortium.org` or, for more information, email `info {at} opencloudconsortium {dot} org`.

Open Data is a member of the OCC. Open Data began operations in 2001, specializes in building predictive models over big data, and is one of the pioneers using technologies such as Hadoop and NoSQL databases so that companies can build predictive models efficiently over all of their data. More information can be found at `http://opendatagroup.com` or by emailing `info {at} opendatagroup {dot} com`.