Big Data on Big Maps
Displaying Vast Amounts of Geospatial Data

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Safe Harbor Statement

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Session Agenda

1. Big Data on Big Maps
2. Planet Dataset
3. Preparing the Data
4. Rendering
5. Summary
Big Data on Big Maps

• Goal: Render every street, road, route, and interstate highway
• Input: OpenStreetMap planet file
• Output: PNG image (57600x28800 pixels, or 4x8 ft)
  – Printable resolution for a wall-sized banner
• Target area: Defined bounding box, e.g. contiguous USA region
• Divide target area into smaller “tiles” (square areas)
• The application should create different tile sizes and resolutions based on the desired output image size and bounding region to render
Target area

Area is divided into smaller tiles
Each tile is 4 by 4 degrees
Target area is 64 longitude degrees by 32 latitude degrees
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Planet Dataset

• OpenStreetMap planet dataset (.pbf) is 36GB
  – Protocolbuffer Binary Format is a compressed file format, about half of the size of a gzipped planet. It’s about 5x faster to write and read.
  – It supports random access at the file-block granularity. Each file-block is independently decodable and contains ~8k OSM entities.
Example OSM XML File

```xml
<?xml version="1.0" encoding="UTF-8"?>
<osm version="0.6" generator="CGImap 0.0.2">
  <bounds minlat="54.0889580" minlon="12.2487570" maxlat="54.0913900" maxlon="12.2524800"/>
  <node id="298884269" lat="54.0901746" lon="12.2482632" user="SvenHRO" uid="46882" visible="true" version="1" changeset="676636" timestamp="2008-09-21T21:37:45Z"/>
  <node id="261728686" lat="54.0906309" lon="12.2441924" user="PikoWinter" uid="36744" visible="true" version="1" changeset="323878" timestamp="2008-05-03T13:39:23Z"/>
  <node id="1831881213" version="1" changeset="12370172" lat="54.0900666" lon="12.2539381" user="lafkor" uid="75625" visible="true" timestamp="2012-07-20T09:43:19Z">
    <tag k="name" v="Neu Broderstorf"/>
    <tag k="traffic_sign" v="city_limit"/>
  </node>
  ...
  <node id="298884272" lat="54.0901447" lon="12.2516513" user="SvenHRO" uid="46882" visible="true" version="1" changeset="676636" timestamp="2008-09-21T21:37:45Z"/>
  <way id="26659127" user="Masch" uid="55988" visible="true" version="5" changeset="4142606" timestamp="2010-03-16T11:47:08Z">
    <nd ref="292403538"/>
    <nd ref="298884289"/>
    ...
    <nd ref="261728686"/>
    <tag k="highway" v="unclassified"/>
    <tag k="name" v="Pastower Straße"/>
  </way>
  <relation id="56688" user="kmvar" uid="56190" visible="true" version="28" changeset="6947637" timestamp="2011-01-12T14:23:49Z">
    <member type="node" ref="294942404" role=""/>
    ...
    <member type="node" ref="36493006" role=""/>
    <member type="way" ref="4579143" role=""/>
    ...
    <member type="node" ref="249673494" role=""/>
    <tag k="name" v="Küstenbus Linie 123"/>
    <tag k="network" v="VVW"/>
    <tag k="operator" v="Regionalverkehr Küste"/>
    <tag k="ref" v="123"/>
    <tag k="route" v="bus"/>
    <tag k="type" v="route"/>
  </relation>
  ...
</osm>
```
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5. Renderer
Preparing the Data – Osmosis and Hadoop

• Data is read in file-blocks from .pbf file using Osmosis
• File-blocks are transferred to HDFS
• HDFS file-blocks are joined and preprocessed to get Way instances
• Ways are used to obtain geometries and their tags
• Relations and Nodes are filtered out
• JGeometry and Map<String, Object> are created using the Way’s coordinates and the Way’s tags respectively.
.pbf file-blocks to HDFS

SequenceFile.Writer out = SequenceFile.createWriter(conf,  
    SequenceFile.Writer.file(fOut),  
    SequenceFile.Writer.keyClass(Text.class),  
    SequenceFile.Writer.valueClass(ArrayPrimitiveWritable.class));

Text k = new Text();  
ArrayPrimitiveWritable v = new ArrayPrimitiveWritable();

while (fileIn.available() > 0) {
    int headerLength = fileIn.readInt();  
    BlobHeader blobHeader = readHeader(headerLength, fileIn);  
    byte[] blobData = readRawBlob(blobHeader, fileIn);

    k.set(blobHeader.getType());  
    v.set(blobData);  
    out.append(k, v);
}
Join file-blocks to corresponding Way

Job job = Job.getInstance(conf);
job.setMapperClass(JoinMapper.class);
job.setReducerClass(JoinReducer.class);
job.setInputFormatClass(
    org.apache.hadoop.mapreduce.lib.input.SequenceFileInputFormat.class);
job.setOutputKeyClass(LongWritable.class);
job.setOutputValueClass(OSMGenericWritable.class);
FileInputFormat.addInputPath(job, new Path(fInput));
FileOutputFormat.setOutputPath(job, fOut);
job.waitForCompletion(true);
Build WayWritable

```java
Job job = Job.getInstance(conf);
job.setMapperClass(BuildMapper.class);
job.setReducerClass(BuildReducer.class);
job.setInputFormatClass(
    org.apache.hadoop.mapreduce.lib.input.SequenceFileInputFormat.class);
job.setOutputKeyClass(LongWritable.class);
job.setOutputValueClass(OSMGenericWritable.class);
job.setOutputKeyClass(LongWritable.class);
job.setOutputValueClass(WayWritable.class);

FileInputFormat.addInputPath(job, new Path(fInput));
job.setOutputFormatClass(
    org.apache.hadoop.mapreduce.lib.output.SequenceFileOutputFormat.class);
FileOutputFormat.setOutputPath(job, fOut);

job.waitForCompletion(true);
```
Preparing the Data - Spark

• Data is a spatially-partitioned RDD
• Each output cell (tile) is a partition
• Spatial data (JGeometry) is accessible
Filtering and partitioning

JavaPairRDD<LongWritable, WayWritable> pairWayRDD = sc.newAPIHadoopFile(
    srcFile,
    SequenceFileInputFormat.class,
    LongWritable.class,
    WayWritable.class,
    sc.hadoopConfiguration());

SpatialJavaRDD<WayWritable> wayRDD = SpatialJavaRDD.fromJavaRDD(
    pairWayRDD.map(t->{return new WayWritable(t._2());}),
    new WayWritableRecordInfoProvider(8307),
    WayWritable.class);

JGeometry gridGeom = JGeometry.createLinearPolygon(
    new double[]{gridMBR[0], gridMBR[1], gridMBR[0], gridMBR[3], gridMBR[2],
                 gridMBR[3],gridMBR[2], gridMBR[1], gridMBR[0], gridMBR[1]},
    2, 8307);
SpatialOperationConfig spatialOpConf = new SpatialOperationConfig(SpatialOperation.AnyInteract, gridGeom,
    spatialConf.getTolerance());
SpatialJavaRDD<WayWritable> filteredSpatialRDD = wayRDD.filter(null, spatialOpConf);

List<SpatialPartition> partitions = GridPartitioning.generateGridPartitions(gridMBR, cellWidth,
    cellHeight, spatialConf);
JavaPairRDD<PartitionKey, WayWritable> partRDD = GridPartitioning.partition(filteredSpatialRDD,
    partitions);

GridPartitioning.savePartitionedRDD(partRDD, partitions, WayWritable.class, destFile,
    sc.hadoopConfiguration());
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• Spark transforms the data into a spatial-aware RDD
• Each partition (cell) gets rendered to a PNG file
• RDD aggregation action to generate the full image
Load grid partitions to render

GridPartitionedRDD<WayWritable> reader = GridPartitioning.createReader(srcFile, WayWritable.class, sc);
JavaPairRDD<PartitionKey, WayWritable> partRDD = reader.getPartitionedRDD();
Map<Integer, SpatialPartition> partMap = reader.getSpatialPartitionsMap();

SimpleRenderer renderer = new SimpleRenderer();
JavaRDD<ImageInfo> imagesRDD = partRDD.mapPartitionsWithIndex(
    (pIndex, iterator)->{
        SpatialPartition part = partMap.get(pIndex);
        ImageInfo image = renderer.render(part, new ValueIterator<>(iterator));
        return Collections.singletonList(image).iterator();
    },
    true);

ImageInfo zeroImage = new ImageInfo(0, mbr); //Empty image
ImageInfo fullImage = imagesRDD.aggregate(
    zeroImage,
    (aggrImage, image)->{
        return renderer.aggregateImages(aggrImage, image);
    },
    (aggrImage1, aggrImage2)->{
        return renderer.combineImages(aggrImage1, aggrImage2);
    });
ImageFileUtil.saveBytesToFile(destFile, fullImage.getImageBytes());
public ImageInfo render(SpatialPartition partition, Iterator<WayWritable> records) {
    OOWTile tile = new OOWTile(partition.getMbr());
    TileRenderingContext tc = new TileRenderingContext(tile);

    ImageInfo image = new ImageInfo(partition.index(), partition.getMbr());
    while (records.hasNext()) {
        WayWritable info = records.next();
        Map<String, String> tags  = info.getTagMap();

        double[] xys = info.getGeom().getOrdinatesArray();
        WorldMercatorUtils.lonLatToMeters(xys);
        tc.renderLineString(xys, tile.getMbrMercator());
    }

    byte[] imageBytes = tc.saveToBuffer();
    image.setImageBytes(imageBytes);
    return image;
}
Render of all the roads in United States

Every street, road, route, and highway was scaled and rendered to fit in the image
Whole image vs Tile

Whole image combined

San Francisco tile
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Summary

10 minutes to render

United States region filtered out and ready for rendering in less than 30 minutes

4.5 Billion records in OSM planet file

3-machine Cluster
1 driver, 2 executors
1 core, 12 CPUs x86_64
62 GB RAM
Discover more at:

• Planet dataset:
  – http://wiki.openstreetmap.org/wiki/Planet.osm

• OSM-PBF Format

• Oracle Big Data Spatial and Graph OTN

• JGeometry
  – https://docs.oracle.com/database/121/SPAJV/oracle/spatial/geometry/JGeometry.html

• Oracle Big Data Spatial and Graph documentation
  – http://docs.oracle.com/bigdata/bda49/index.htm

• Osmosis
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