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Big Data on Big Maps

Displaying Vast Amounts of Geospatial Data

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October 4, 2017

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Session Agenda

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

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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

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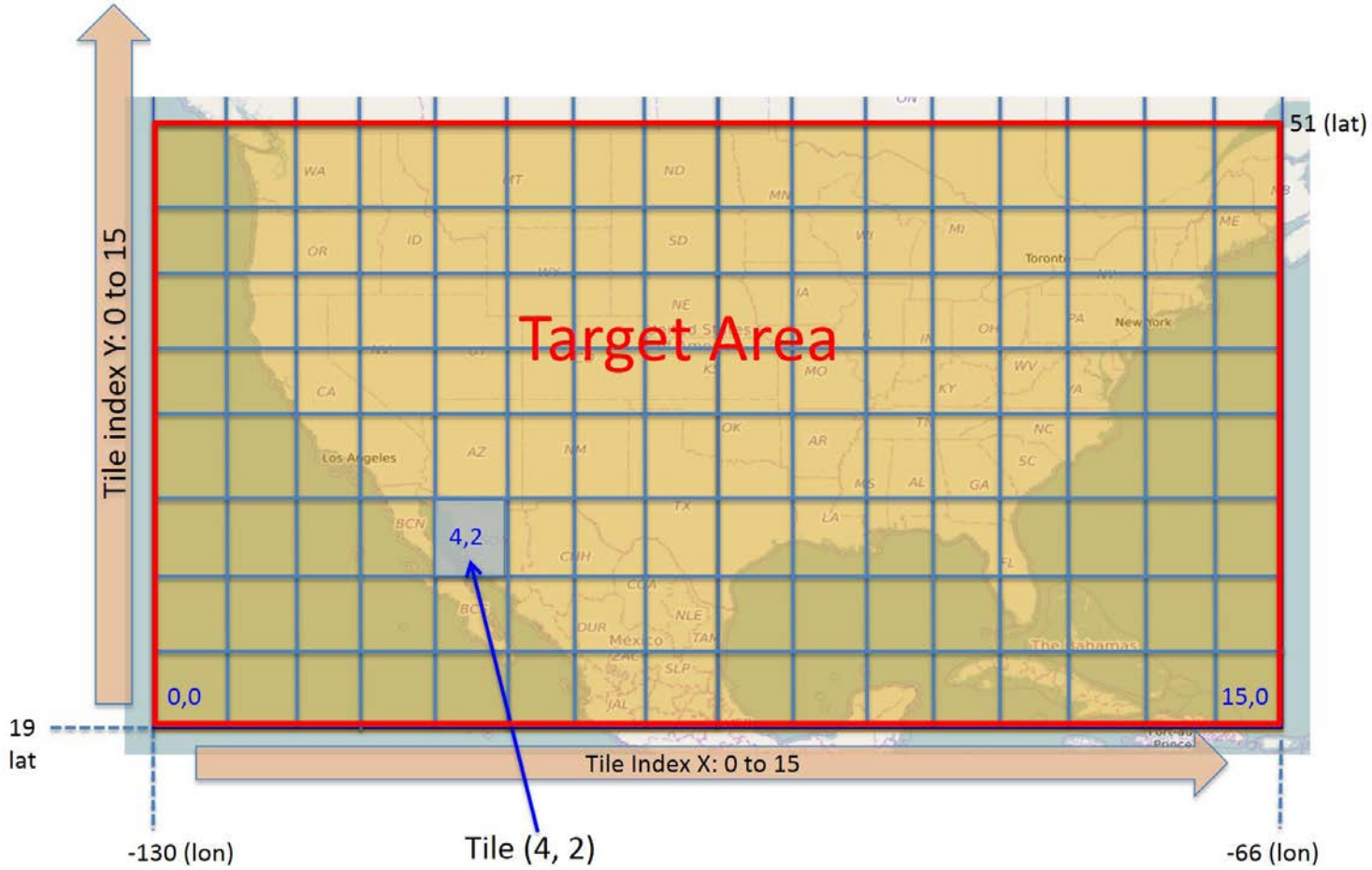
Target area



- 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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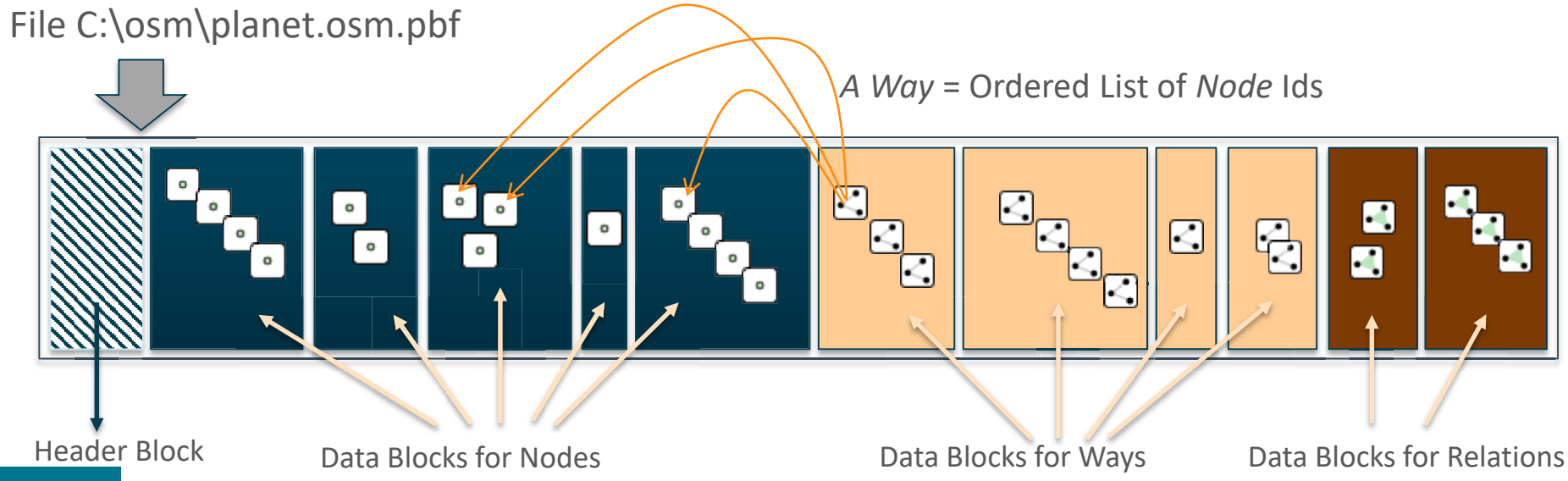
Planet Dataset

- 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.



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Example OSM XML File

```
<?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="364933006" 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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1. Big Data on Big Maps
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3. **Preparing the Data**
4. Rendering
5. Renderer

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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.

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.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);
}
```

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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.setMapOutputKeyClass(LongWritable.class);
job.setMapOutputValueClass(OSMGenericWritable.class);
job.setOutputKeyClass(LongWritable.class);
job.setOutputValueClass(OSMGenericWritable.class);

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

job.waitForCompletion(true);
```

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Build WayWritable

```
Job job = Job.getInstance(conf);
job.setMapperClass(BuildMapper.class);
job.setReducerClass(BuildReducer.class);
job.setInputFormatClass(
       org.apache.hadoop.mapreduce.lib.input.SequenceFileInputFormat.class);
job.setMapOutputKeyClass(LongWritable.class);
job.setMapOutputValueClass(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);
```

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Preparing the Data - Spark

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

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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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Renderer

- 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

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Load grid partitions to render

```
GridPartitionedRDDReader<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());
```

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Render images

```
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;
}
```

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Render of all the roads in United States

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

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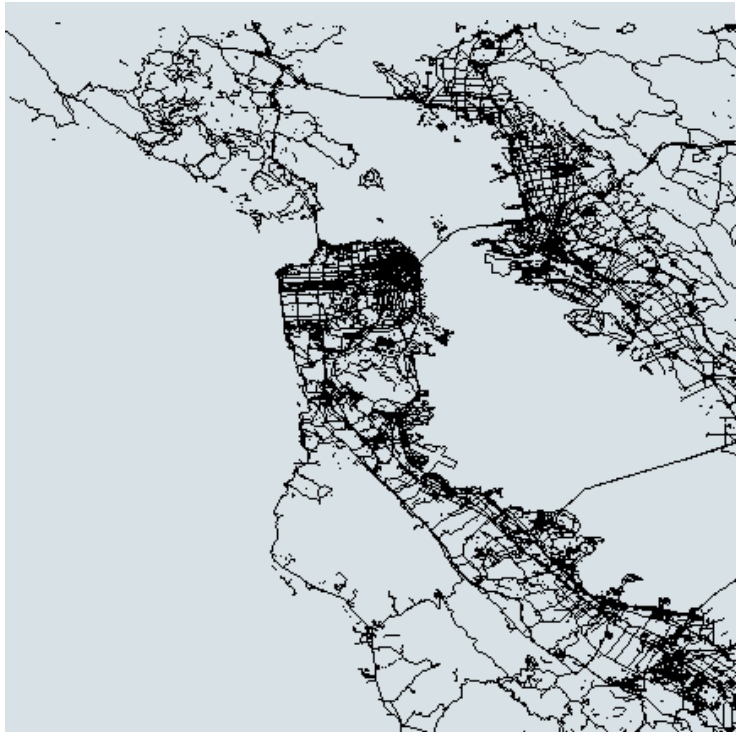
Whole image vs Tile

Whole image combined



San Francisco tile

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Summary

10 minutes to render

4.5

Billion records in OSM planet file

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

3-machine Cluster

1 driver, 2 executors

1 core, 12 CPUs x86_64

62 GB RAM

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Discover more at:

- Planet dataset:
  - http://wiki.openstreetmap.org/wiki/Planet.osm
- OSM-PBF Format
  - http://wiki.openstreetmap.org/wiki/PBF_Format
- Oracle Big Data Spatial and Graph OTN
  - http://www.oracle.com/technetwork/database/database-technologies/bigdata-spatialandgraph/overview/index.html
- 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
  - http://wiki.openstreetmap.org/wiki/Osmosis

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