The GeoMason Cookbook

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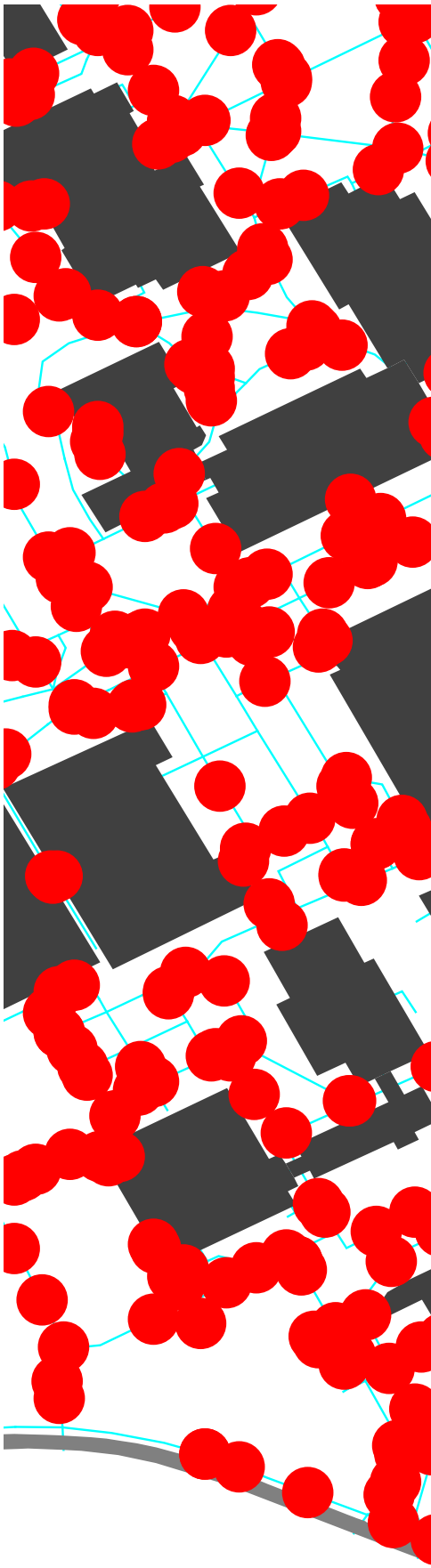

Where to Obtain GeoMason
http://cs.gmu.edu/~eclab/projects/mason/extensions/geomason/

Thanks to Sean Luke, Andrew Crooks, Keith Sullivan

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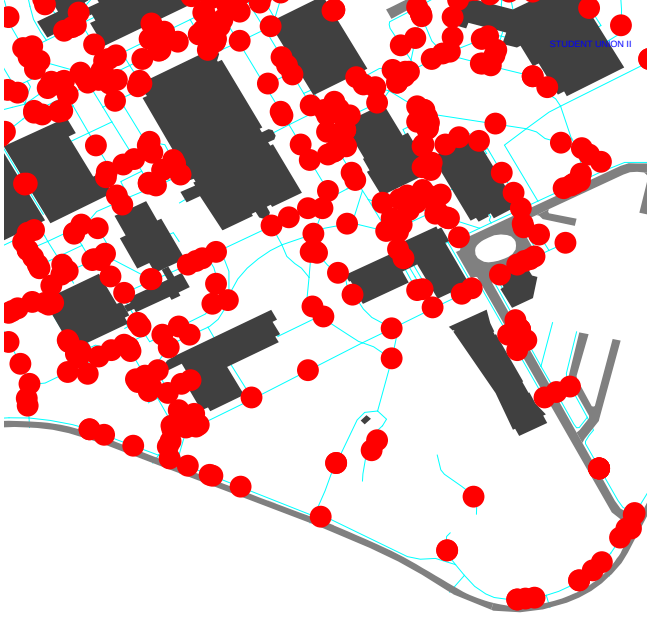
http://cs.gmu.edu/∼eclab/projects/mason/extensions/geomason

Contents



Chapter 1

Introduction

GeoMason is a MASON extension that adds basic geospatial capability.

1.1 Architectural Layout

MASON is a sophisticated multi-agent simulation library. Unfortunately it does not natively support geospatial data. GeoMason is a MASON extension that embues MASON with some limited geospatial awareness. With GeoMason one is able to load, display, and manipulate data that is, in some way, grounded to the Earth's surface. This Cookbook provides a set of "recipes" for using GeoMason.

Chapter 2

Reading and Writing Geospatial Data

This chapter covers recipes for reading and writing vector and grid based geospatial data.

2.1 Reading Geospatial Data

This section covers reading geospatial data into MASON using GeoMason.

2.1.1 Reading a Shape File

Problem

You want to read vector geospatial data stored in a Shape file.

Solution

Create a GeomVectorField and use ShapeFileImporter.read() to load data into it.

```
1 GeomVectorField vectorField = new GeomVectorField();
2
3 try {
4    ShapeFileImporter.read("file:foo.shp", vectorField);
5 } catch (FileNotFoundException ex)
6 {  /* handle exception */  }
```

Discussion

Though there exist other GeoMason classes capable of reading Shape files — GeoToolsImporter and OGRImporter — the native GeoMason shape file importer, ShapeFileImporter, is recommended, especially given that it has no third party dependencies as the other importer classes do.

Given the general static nature of shape files, the above code snippet is likely to be in a SimState subclass constructor. Alternatively you may place it in the start() though be mindful that means that the shape file will be loaded again each time the simulation is restarted.

Note that the units of the loaded vector layer will be those of the underyling coordinate reference system. So if the shape file is in meters, such as is found in data in Universal Transverse Mercator (UTM), then all loaded geometry will similarly be in meters. Also note that GeoMason uses the Java Topology Suite (JTS) to store all the geometry. JTS uses a flat Cartesian plane for all points; so be aware of this when loading data from a non-planar reference system. That is, if you naïvely load, say,

native lat/lon data, which corresponds to coordinates along a ellipsoid, that you will have introduced distortions in the implicit projection you have just done to a 2D plane. Moreover, these distortions will be more pronounced for large surface areas.

2.1.2 Reading Multiple Vector Layers

Problem

You want to read in more than one thematic layer of vector data.

Solution

After ensuring that each layer uses the same coordinate reference system, read in each layer, and then synchronize the minimum bounding rectangles (MBR) for all the layers.

```
1  GeomVectorField firstVectorField = new GeomVectorField();
2  GeomVectorField secondVectorField = new GeomVectorField();
3  GeomVectorField thirdVectorField = new GeomVectorField();
4
5  try {
6     ShapeFileImporter.read("file:foo.shp", firstVectorField);
7     ShapeFileImporter.read("file:bar.shp", secondVectorField);
8     ShapeFileImporter.read("file:baz.shp", thirdVectorField);
9  } catch (FileNotFoundException ex)
10 {  /* handle exception */  }
11
12 Envelope globalMBR = firstVectorField.getMBR();
13
14 globalMBR.expandToInclude(secondVectorField.getMBR());
15 globalMBR.expandToInclude(thirdVectorField.getMBR());
16
17 firstVectorField.setMBR(globalMBR);
18 secondVectorField.setMBR(globalMBR);
19 thirdVectorField.setMBR(globalMBR);
```

Discussion

It is possible that the disparate shape files may have different coordinate reference systems, as can happen if the shape files came from different sources. It is vitally important to ensure that all the layers have the same coordinate reference system before being loaded into GeoMason. For example, a vector layer that uses lat/lon coordinates will have radically different geometry values from another vector layer that uses UTM even though they may cover the same area on Earth. Essentially, GeoMason is not a GIS so it will not do on-the-fly projections of the data. Users can use a real GIS tool, such as QuantumGIS [1], to manually reproject data prior to loading into GeoMason.

It is important to ensure that all the layers have the same MBR otherwise they will not align properly when displayed. Naturally, this is optional if you do not intend on rendering the layers. Regardless it would be prudent to do so anyway on the chance that later you change your mind and want to see the GeoVectorFields. The highlighted lines 12-19 show how to synchronize the MBRs between loaded GeomVectorFields. Basically, you get the MBR of the first GeomVectorField, expand it to include the area of the MBRs for the remaining GeomVectorFields, and then set them all to the one all-inclusive MBR.

[1] http://www.qgis.org/

As noted in recipe 2.1.1, given the general static nature of shape files, this code snippet is likely to be done in the SimState constructor; however, again, the layers could also be loaded via start(), though that means loading the shape files every time the simulation is re-run.

2.1.3 Reading a Shape File and Some of Its Attributes

Problem

You want to read a Shape file and only some of its associated attributes.

Solution

Read in a shape file as in recipe 2.1.1, but specify the desired attributes by creating a Bag of Strings containing attribute names, and then passing that Bag to ShapeFileImporter.read().

Reading Attributes

```
1  GeomVectorField vectorField = new GeomVectorField();
2
3  Bag desiredAttributes = new Bag();
4  desiredAttributes.add("NAME");
5  desiredAttributes.add("TYPE");
6
7  try {
8     ShapeFileImporter.read("file:foo.shp", vectorField, desiredAttributes);
9  } catch (FileNotFoundException ex)
10 {  /* handle exception */  }
```

Each spatial object is wrapped in a MasonGeometry object which, in turn, also stores any associated attributes. Use the appropriate MasonGeometry get*Attribute() method to retrieve the attribute value.

Using Attributes

```
1  Bag geometries = vectorField.getGeometries();
2
3  for (int i = 0; i < geometries.size(); i++)
4  {
5      MasonGeometry geometry = (MasonGeometry) geometries.objs[i];
6
7      int type = geometry.getIntegerAttribute("TYPE");
8      String name = geometry.getStringAttribute("NAME");
9  }
```

Discussion

Most shape files have an associated set of attributes describing each feature. For example, buildings will have names, roads will have a number of lanes, bridges will have a type, and so on. These attributes can be strings, numbers, or boolean values.

By default GeoMason will not load any associated attributes — if you want any attributes you will have to ask for them by name. You do this by filling a Bag with strings of desired attribute names, and then passing that Bag to a ShapeFileImporter.read() invocation, as shown in the highlighted lines 3-5 and 8 in the code example "Reading Attributes." This will then load each MasonGeometry object that corresponds to each spatial entity with a set of attribute/value pairs. These attributes can be later retrieved with an appropriate call to getStringAttribute(), getIntegerAttribute(), or getDoubleAttribute();

you can also invoke getAttribute() to retrieve the value object directly. An example of using these methods is shown in the code snippet "Using Attributes."

Unfortunately this does mean you have to know ahead of time the available attributes and their respective names. If you do not know the available attributes, you can use a GIS such as QuantumGIS or ArcGIS to discover the attribute names.

2.1.4 Reading an ARC/Info ASCII Grid File

Problem

You want to read an Arc/Info ASCII Grid file.

Solution

Create a GeomGridField and an InputStream opened on the grid file, then use ArcInfoASCGridImporter() to load the data into the grid field from the open input stream.

```
1         GeomGridField gridField = new GeomGridField();
2
3         InputStream inputStream = new FileInputStream("foo.asc");
4         ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

Essentially a GeomGridField is a wrapper round a MASON Grid2D object that embues some limited geospatial characteristics – essentially it's a georeferenced MASON Grid2D.

ArcInfoASCGridImporter.read() will use one of two Grid2D MASON subclasses, IntGrid2D or DoubleGrid2D, depending on whether integer or real-value data is used, respectively. Unfornately GeoMason is not smart enough to figure out ahead of time which underlying MASON Grid2D subclass to use so you have to specify that via the GridDataType argument to ArcInfoASCGridImporter.read(); i.e., GridDataType.INTEGER for integer based grid data or GridDataType.DOUBLE for real-value based grid data.

Many times you can readily intuit the underlying data type of an ASC/Grid file. E.g., a grid of population values such as Landscan values [2] will likely use integers, wheres one of elevation postings, such as found in Digital Elevation Models, will likely use floating point values. However, if you do not know whether integers or floats are used in a given grid file, you can peep at it with a text editor to find out. If you have a UNIX-like command line, you can use "head -7" to look at the first seven lines of text in an ASC/Grid file. Regardless of how you look at the data, it should be readily apparently whether the file contains all integers or floats.

2.1.5 Reading a Mix of Grid and Vector Data

Problem

You want to read in multiple layers that are a mix of vector and grid geospatial data.

Solution

After ensuring that all the layers have the same coordinate reference system, read all the layers into GeomVectorField or GeomGridFields, as appropriate, and then synchronize their respective minimum bounding rectangles.

[2] http://www.ornl.gov/sci/landscan/

```
GeomVectorField vectorField = new GeomVectorField();
GeomGridField gridField = new GeomGridField();

try {
   ShapeFileImporter.read("file:vector.shp", firstVectorField);

   InputStream inputStream = new FileInputStream("grid.asc");
   ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
} catch (FileNotFoundException ex)
{  /* handle exception */  }

Envelope globalMBR = vectorField.getMBR();

globalMBR.expandToInclude(gridField.getMBR());

vectorField.setMBR(globalMBR);
gridField.setMBR(globalMBR);
```

Discussion

The same issues apply here as noted in recipe 2.1.2 — i.e., not only do the coordinate reference systems need to be identical between layers, but the MBRs also need to be synchronized. Also, as in recipe 2.1.4, you will have to specify the appropriate GridDataType that corresponds to type of data found in the grid file.

One typical scenario this recipe covers is overlaying political boundaries over grid data.

2.1.6 Reading Other Kinds of Geospatial Data

Problem

GeoMason natively supports shape files and ARC/Info ASCII Grid files. However, you have geospatial data that is in neither one of those formats you would like to use.

Solution

(To be written)

```
(To be written)
```

Discussion

2.2 Writing Geospatial Data

This section covers recipes involving saving geospatial data from GeoMason constructs to files.

2.2.1 Writing a Shape File

Problem

You want to save a GeoMason vector field to a Shape file.

Solution

Use ShapeFileExporter.write() to save the vector field to a Shape file.

```
ShapeFileExporter.write("foo", vectorField);
```

Discussion

Obviously it doesn't make sense to write a shape file for shape files you've already read in because the data presumably hasn't changed. This recipe is, instead, useful for scenarios where you have a vector layer of data that you've created wholly within your simulation and wish to save so that you can load it into a proper GIS.

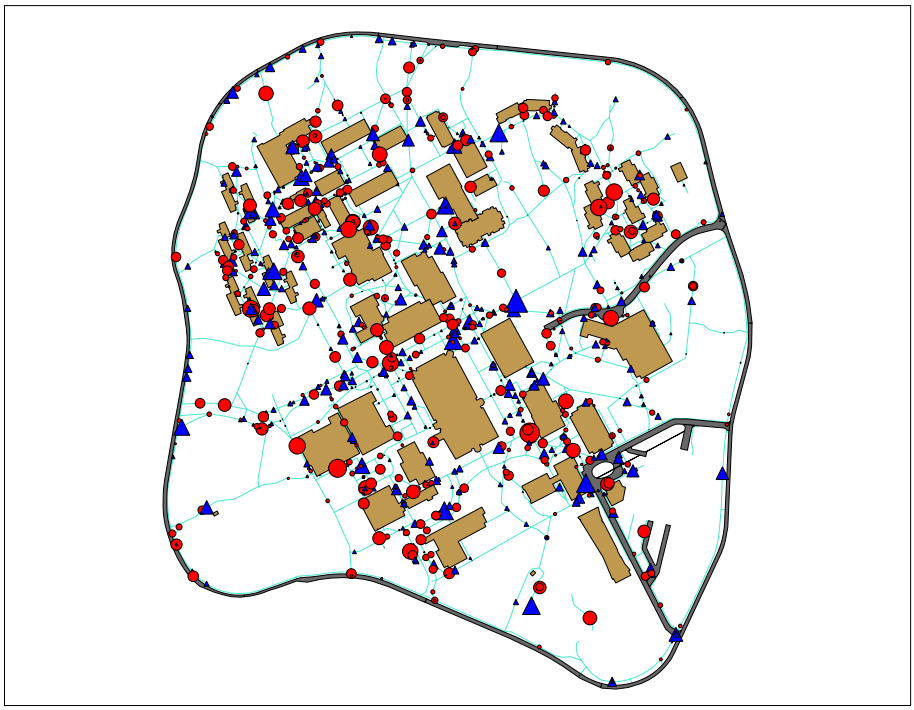


Figure 2.1 Snapshot of "Campus World" demo .

Consider the GeoMason "Campus World" demo that has agents moving along walkways.[3] The buildings, walkways, and roads were loaded from shape files, but the agents were created stochastically from within the simulation and stored in their own GeomVectorField. When the simulation ends a shape file describing these agents is written out to a shape file that can be loaded along with the original shape files for analysis. These agents have the following three attributes: their age, movement rate, and whether they are student or faculty. Fig. 2.1 depicts these shape files after they were loaded into a GIS with the faculty agents rendered as blue triangles, students as red dots, and their relative sizes scaled to their respective movement rates.

Shape files are not single files but are instead comprised of a few mandatory files with the extensions .shp, .dbf, and .idx. The first argument to ShapeFileExporter.write() specifies the file name prefix used to generate these files from the given GeomVectorField.

There is an optional shape file that contains the coordinate reference system and uses the file name extension .prj. This function does not write this file.[4] However, if the GeomVectorField was itself sourced

[3]This demo is included with GeoMason, and can be found as sim.app.geo.campusworld

[4]However, a future incarnation of GeoMason may do so.

from a shape file, then its corresponding .prj file can be copied over using the new file extension used in the call to write(). Alternatively, if the GeomVectorField was *not* read from a shape file, and so does not have a corresponding .prj file, you may still be in luck if you loaded other vector layers from shape files. If that's the case, you can likely arbitrarily use one of their .prj files.

If you want to automatically save a snapshot of a GeomVectorField after each simulation run, you can place this call to write() within finish() inside your SimState subclass.

2.2.2 Writing an ARC/Info ASCII Grid File

Problem

You want to write GeoMason grid data to an ARC/Info ASCII Grid file.

Solution

Create a Writer for the grid file and use ArcInfoASCGridExporter.write() to write the GeomGridField.

```
1 try {
2    BufferedWriter writer = new BufferedWriter( new FileWriter("foo.asc") );
3    ArcInfoASCGridExporter.write(gridField, writer);
4    writer.close();
5 } catch (IOException ex)  {
6    /* handle exception */
7 }
```

Discussion

This recipe is useful for saving grid data from a simulation run such that you can later import it into a GIS for analysis.

Unlike calls to ArcInfoASCGridImporter.read(), you do not have to specify a data type. Instead, the call to ArcInfoASCGridExporter.write() automatically handles that detail for you.

As in recipe 2.2.1 you can place this snippet into finish() to automatically write a grid file when the simulation ends.

Chapter 3

Using Geospatial Data

In this chapter we discuss interacting with geospatial data using GeoMason. These kinds of interactions are mostly queries such as asking in what political boundaries an agent is located or determining nearby entities.

3.1 Determining What Political Entity an Agent is In

Problem

You have a simulation with polygons for boundaries that delineate political entities such as countries, counties, or voting districts. In that simulation you also have agents that move across these kinds of boundaries and you would like to know the political entity in which that agent is located.

Solution

Problem Solution

```
1         GeomGridField gridField = new GeomGridField();
2
3         InputStream inputStream = new FileInputStream("foo.asc");
4         ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

3.2 Locating Nearby Geospatial Objects

Problem

You want to find all the objects within a certain distance from a specific thing.

Solution

Problem Solution

```
1         GeomGridField gridField = new GeomGridField();
2
3         InputStream inputStream = new FileInputStream("foo.asc");
4         ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

3.3 Finding Adjacent Geospatial Objects

Problem

You want to find adjacent geospatial objects. For example, for a given country, you want to get a list of neighboring countries that share a common border.

Solution

Problem Solution

```
        GeomGridField gridField = new GeomGridField();

        InputStream inputStream = new FileInputStream("foo.asc");
        ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

3.4 Moving Agents Along Paths

Problem

You have a path, such as a road or trail, along which you want to move an agent.

Solution

Problem Solution

```
        GeomGridField gridField = new GeomGridField();

        InputStream inputStream = new FileInputStream("foo.asc");
        ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

3.5 Computing Line Intersections

Problem

You want to find all the intersections for a set of lines. For example, you may want to locate all road junctions.

Solution

Problem Solution

```
        GeomGridField gridField = new GeomGridField();

        InputStream inputStream = new FileInputStream("foo.asc");
        ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

3.6 How to Calculate the Shortest Path on a Network

Problem

You want to find the shortest path between two points in a network such as set of roads.

Solution

Problem Solution

```
        GeomGridField gridField = new GeomGridField();

        InputStream inputStream = new FileInputStream("foo.asc");
        ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

3.7 Calculating Agent Information from Underlying Grid Data

Problem

You wish to to compute something based on values found in a grid an agent occupies. For example, a grid may represent a hectare and an agent may want to consume certain amount of vegetation and water found there.

Solution

Problem Solution

```
        GeomGridField gridField = new GeomGridField();

        InputStream inputStream = new FileInputStream("foo.asc");
        ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

3.8 Having an Agent Follow a Gradient

Problem

You have slope information that you would like an agent to follow.

Solution

Problem Solution

```
1         GeomGridField gridField = new GeomGridField();
2
3         InputStream inputStream = new FileInputStream("foo.asc");
4         ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

Chapter 4

Displaying Geospatial Data

This chapter gives recipes for displaying GeoMason fields in MASON.

4.1 Displaying a GeomVectorField

Problem

You want to show the contents of a GeomVectorField in a MASON display.

Solution

Create a GeomVectorFieldPortrayal in the MASON GUIState subclass, associate it with its corresponding GeomVectorField, set up an appropriate MASON or GeoMason field portrayal, and attach it to a MASON Display2D object.

```
1  public class MyMasonGUI extends GUIState
2  {
3      private Display2D display;
4      private JFrame displayFrame;
5
6      // ... other variable declarations
7
8      private GeomVectorFieldPortrayal myPortrayal = new GeomVectorFieldPortrayal();
9
10     @Override
11     public void init(Controller controller)
12     {
13         super.init(controller);
14
15         display = new Display2D(ARBITRARY_WIDTH, ARBITRARY_HEIGHT, this);
16
17         display.attach(myPortrayal, "My Vector Layer");
18
19         displayFrame = display.createFrame();
20         controller.registerFrame(displayFrame);
21         displayFrame.setVisible(true);
22     }
23
```

```
24      @Override
25      public void start()
26      {
27          super.start();
28          setupPortrayals();
29      }
30
31      private void setupPortrayals()
32      {
33          MyState world = (MyState)state;
34
35          myPortrayal.setField(world.vectorLayer);
36          myPortrayal.setPortrayalForAll(new GeomPortrayal(Color.CYAN, true));
37
38          display.reset();
39          display.setBackdrop(Color.WHITE);
40
41          display.repaint();
42      }
43
44      // ... other code
45  }
```

Discussion

Line 36 creates a portrayal that draws all the lines in cyan; the optional second parameter, which is set to true, indicates that polygons should be filled.

4.2 Displaying a GeomGridField

Problem

You want to show the contents of a GeomGridField in a MASON display

Solution

Set up an appropriate field portrayal for the wrapped Grid2D object found inside the GeomGridField .

```
1   public class MyMasonGUI extends GUIState
2   {
3       private Display2D display;
4       private JFrame displayFrame;
5
6       // ... other variable declarations
7
8       private FastValueGridPortrayal2D myPortrayal = new FastValueGridPortrayal2D();
9
10      @Override
11      public void init(Controller controller)
12      {
13          super.init(controller);
```

```
14
15          display = new Display2D(ARBITRARY_WIDTH, ARBITRARY_HEIGHT, this);
16
17          display.attach(myPortrayal, "My Grid Layer");
18
19          displayFrame = display.createFrame();
20          controller.registerFrame(displayFrame);
21          displayFrame.setVisible(true);
22      }
23
24      @Override
25      public void start()
26      {
27          super.start();
28          setupPortrayals();
29      }
30
31      private void setupPortrayals()
32      {
33          MyState world = (MyState)state;
34
35          myPortrayal.setField(world.gridLayer.getGrid());
36          myPortrayal.setMap(new SimpleColorMap(0, 1, Color.black, Color.white));
37
38          display.reset();
39          display.setBackdrop(Color.WHITE);
40
41          display.repaint();
42      }
43
44      // ... other code
45  }
46
```

Discussion

A GeomGridField is effectively a wrapper round a MASON Grid2D object, which means you can use the display techniques for Grid2D objects. Just use the GeomGridField.getGrid() method to fetch the underlying IntGrid2D or DoubleGrid2D object, as appropriate for the data type you specified when you read the grid data. (See recipe 2.1.4 for how to specify the grid data representation.)

The above code sample is for reading a grid layer that's presumably comprised of just ones and zeroes. So a FastValueGridPortrayal2D will suffice to render that layer, as shown in line 8, along with an associated SimpleColorMap to show the zeros in black and the ones in white, as seen in line 36. The grid is attached to the field as in non-GeoMason MASON simulations; line 35 shows the getGrid() call necessary to get at the underyling MASON IntGrid2D.

4.3 Displaying Boundary Lines Over a Grid Field

Problem

You want to overlay political boundaries on grid data.

Solution

Load the vector and grid layers as per recipe 2.1.5. Then set up the portrayals such that the vector layer is rendered on top of the raster layer.

Reading the layers

```
GeomVectorField boundaries = new GeomVectorField();
GeomGridField gridField = new GeomGridField();

try {
   ShapeFileImporter.read("file:boundaries.shp", boundaries);

   InputStream inputStream = new FileInputStream("grid.asc");
   ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
} catch (FileNotFoundException ex)
{  /* handle exception */  }

Envelope globalMBR = boundaries.getMBR();

globalMBR.expandToInclude(gridField.getMBR());

boundaries.setMBR(globalMBR);
gridField.setMBR(globalMBR);
```

Displaying boundaries over the grid

```
public class MyMasonGUI extends GUIState
{
    private Display2D display;
    private JFrame displayFrame;

    // ... other variable declarations

    private FastValueGridPortrayal2D gridPortrayal = new FastValueGridPortrayal2D();
    private GeomVectorFieldPortrayal boundariesPortrayal = new GeomVectorFieldPortrayal();

    @Override
    public void init(Controller controller)
    {
        super.init(controller);

        display = new Display2D(ARBITRARY_WIDTH, ARBITRARY_HEIGHT, this);

        display.attach(gridPortrayal, "My Grid Layer");
        display.attach(boundariesPortrayal, "Political Boundaries");

        displayFrame = display.createFrame();
        controller.registerFrame(displayFrame);
        displayFrame.setVisible(true);
    }

    @Override
```

```
27      public void start()
28      {
29          super.start();
30          setupPortrayals();
31      }
32
33      private void setupPortrayals()
34      {
35          MyState world = (MyState)state;
36
37          myPortrayal.setField(world.gridField.getGrid());
38          myPortrayal.setMap(new SimpleColorMap(0, 1, Color.black, Color.white));
39
40          myPortrayal.setField(world.boundaries);
41          myPortrayal.setPortrayalForAll(new GeomPortrayal(Color.GRAY, true));
42
43          display.reset();
44          display.setBackdrop(Color.WHITE);
45
46          display.repaint();
47      }
48
49      // ... other code
50  }
```

Discussion

From the perspective of the GUIState, the vector layer of boundaries are just yet another field portrayal rendered on top of another showing grid data. If the minimum bounding rectangles (MBR) of the two fields were properly aligned — and that they have the same coordinate reference system! — then the boundaries should match up with the grid layer geospatial features.

You can load additional grid layers before the vector layer, and you can toggle their visibility in the MASON Display2D window. It's similarly possible to load multiple boundaries, though admittedly displaying them all at once may be confusing; however, this confusion may be somewhat mitigated with good choices for line colors and widths. Just ensure that the vector layers always are attach()'d *after* all the grid layers because otherwise the grid layers will obscure the boundaries.

4.4 Displaying a Dynamic Choropleth Map

Problem

You want to create a dynamic choropleth map with colors changing based on agent behavior.

Solution

Problem Solution

```
1           GeomGridField gridField = new GeomGridField();
2
3           InputStream inputStream = new FileInputStream("foo.asc");
4           ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

4.5 Displaying Raster Overlays

Problem

You have raster overlays you wish to render over vector data.

Solution

Problem Solution

```
        GeomGridField gridField = new GeomGridField();

        InputStream inputStream = new FileInputStream("foo.asc");
        ArcInfoASCGridImporter.read(inputStream, GridDataType.INTEGER, gridField);
```

Discussion

Chapter 5

Common Problems

5.1 Display All One Color

Problem
Rendering a GeomField just shows one solid color.

Solution
Problem Solution

```
foo
```

Discussion

5.2 Layers Do Not Align

Problem
The data between layers does not match.

Solution
Problem Solution

```
foo
```

Discussion

Chapter 6

Acknowledgements

Thanks the MURI project for their support via NSF grant #. For Andrew Crooks for valuable feedback. For Sean Luke, et al, for MASON.

Index