The Repast Simulation/Modelling System for Geospatial Simulation

Andrew Crooks

CASA
University College London
1 - 19 Torrington Place
London

http://www.casa.ucl.ac.uk
http://www.gisagents.blogspot.com
Introduction

• Introduce Repast
• Install Java, Repast etc.
• Import some sample models
• Describe core Repast components
• Run some models
• Examples/discussion of Raster and Vector Integration
• Summary
What is Repast?

- **Recursive Porous Agent Simulation Toolkit.**
- Open Source.
- Provides functionality to create, run, display, and collect data from agent-based models.
  - More time can be spent developing models.
- One of the few generic toolkits which support both raster and vector integration.
- But this comes at a price: need to have basic programming skills.
Selected ABM tools

Source: North et al (2005) Agent-Based Modeling with Agent Analyst
Getting Started

• First we install all the necessary components to create and run a Repast model
  – Java
  – Eclipse
  – Repast (note the extra packages in the lib folder)
Development Environment

Integrated Development Environment

e.g. IDEA

Java source code

```
int a = 12;
if (a == b)
b++;
else
a++;
```

Editor -> Java compiler -> JVM

Java libs

Repast libs

Where the models come from:

- International Conflict Research Group at ETH Switzerland: https://www.icr.ethz.ch/teaching/archive/compmmodels/
- Repast Source folder
- Various other places from the internet

Note later how there are many different ways to create and utilize the Repast toolkit.
Recap

• Introduced Repast
  – Installed Repast, Java and Eclipse
  – Imported some models

• Today:
  – Run through some of Repasts core functionality
  – Discussion and examples of Geospatial agent-based models

• Note that much of this can be supported by the articles on the CD.
Basic Structure of most Repast Models

Start Program → Build Model Method → Build Display Method → Build Schedule Method

Run Phase:
- Pre-Step Method
- Step Method
- Post-Step Method

Build model Phase:
- Start Program → Build Model Method
Inbuilt Charting options

- **Time series**: used defined variable(s) over time.
- **Histograms**: bar chart showing a variable distribution.
- **Scatter plot**: snapshot of two variables
- Can be extended e.g. s
Inbuilt Data Collection

- Inbuilt data recording facilities (Data Recorder) to .txt files (as comma, space or tab delimited).
- Movies and snapshots.
### Controls Overview

<table>
<thead>
<tr>
<th>Start Multi-Run</th>
<th>Start</th>
<th>Step</th>
<th>Initialize</th>
<th>Stop</th>
<th>Pause</th>
<th>Setup</th>
<th>Load</th>
<th>View settings</th>
<th>Exit</th>
</tr>
</thead>
</table>

**Start Multi-Run**: starts a batch run of a simulation.

**Start**: starts the simulation when it is paused or has not yet been started, iterating through the scheduled behaviour.

**Step**: starts the simulation when it is paused or has not yet been started, iterating through a single iteration the scheduled behaviour.

**Initialize**: starts the simulation but pauses before iterating any scheduled behaviour.

**Pause**: pauses the simulation.

**Setup**: "sets up" the simulation by executing the user defined setup code.

**Load Model**: pops up a dialog allowing the user to specify a model to load.

**View Settings**: will display the various model settings panel if it is hidden or destroyed.

**Exit**: will shutdown the simulation and exit.
Example application

- Run through the segregation polygon model highlighting the basic functionality.
  - Debug mode
  - Vector models don’t use Repasts displays but can use the same charting options
- See how source code can be attached.
Exploration of the Models

• The models provided allows one to explore the various models:
  – Note:
    • How schedules are set,
    • Which spaces are used,
    • Displays are built
    • What is being recorded.
  – There may be some errors due to files being in the wrong place

• Many different ways to create models
• Only use Repast functionality as needed.
Space in Repast

• 2 main types:
  • Cellular
  • GIS vector
• Layers can be combined
• Space has Two purposes:
  • Contain a collection of agents (e.g. the world).
  • Define Spatial relationship of agents relative to each other.
• Another type of space is Network space.
• See Repasts “Overview of Spaces”
  http://repast.sourceforge.net/how-to/spaces.html
Cellular Space

- **Boundaries**
  - Grid or Torus
- **Cell’s shape**
  - Regular or hexagonal
- **Cell’s content**
  - One object or a collection of agents
- Also includes Raster-Space (inbuilt functions for reading ASCII & .pgm files)
Common Neighbourhoods in Cellular Space

• The models include here use a variety of neighbourhoods
Raster Integration

- Agents can either be the cells imported into the model or sit on top of the cells and interact with the surface generated using raster data.

- See gisModel in RepastModels

Reading in a raster data and creating a landscape (ESRI ASCII file) A: the original file from a GIS. B: the resulting space created in Repast.
Raster Integration (cont)

- Agents can either be the cells imported into the model or sit on top of the cells and interact with the surface generated using raster data.
- Agent movement is a matter of changing the agent's internal x and y coordinates, removing it from its previously occupied cell and adding it to the new one.
  - See moveAgent() in sugarScape model
- Example models:
  - gisModel (just colours in the landscape based on cell value)
  - sugarScape for .pgm integration (probing also searches for a best spot (moveToBestSpot()))
  - Fire for .txt file (see how information spreads and agents die and move)
A Model for Emergency Evacuation - KXPEM

Developed by Christian Castle
Basic Pedestrian Model
One Level
KXPEM User Interface

Movie
Urban Growth in Latin American Cities

Vector GIS

- More complicated (own packages) but highly adaptable.
- Agents either
  - Points (Generic agent).
  - Polygons (Vector agent) (static) => detailed boundaries.
- Needs its own displays: ESRI’s ArcGIS or OpenMap.
- See:
  [http://repast.sourceforge.net/how-to/Gis_How_To.html](http://repast.sourceforge.net/how-to/Gis_How_To.html)
Storing Neighbourhood Information

- Stored in a .GAL File
- Can be created using GeoDa: https://www.geoda.uiuc.edu/
Combining the GAL file and the Segregation Model
Converting a GIS Layer into a Series of Agents

<table>
<thead>
<tr>
<th>Feature ID</th>
<th>Geographical Coordinate</th>
<th>Type</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22,22</td>
<td>Detached</td>
<td>23</td>
</tr>
<tr>
<td>2</td>
<td>23,12</td>
<td>Flat</td>
<td>51</td>
</tr>
<tr>
<td>3</td>
<td>23,32</td>
<td>Semi-detached</td>
<td>100</td>
</tr>
</tbody>
</table>

Sample of GIS type data, representing a layer of data in a GIS.

GIS data in an agent-based model: House Agent is the agent type and is akin to a housing layer in GIS.
Models that use Vector Space:

• Example models
  – sluGISopenmap
  – OpenmapDemo
  – segModelPolygon
• These models can be combines and easily extended.
Adding Extra Layers
Vector Representation

Spatial representation within a model. A: street section composed of individual buildings. B: London composed of boroughs. Agents are shown as dots.
Comparison of Raster and Vector

Need to consider what type of space is needed
Reading in the data & building the model

<table>
<thead>
<tr>
<th>Ward</th>
<th>No. Red</th>
<th>No. Blue</th>
<th>No. Green</th>
<th>No. White</th>
<th>Other info</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>10</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Actions of individual agents will create changes in their physical environment.
Segregation Model Structure

Urban Environment

Agents Attributes

<table>
<thead>
<tr>
<th></th>
<th>No. of agents</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Agents</td>
<td>4</td>
<td>50%</td>
</tr>
<tr>
<td>Blue Agents</td>
<td>2</td>
<td>25%</td>
</tr>
<tr>
<td>Green Agents</td>
<td>2</td>
<td>25%</td>
</tr>
</tbody>
</table>

Red agent preferences

<table>
<thead>
<tr>
<th>Preference</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red with Red</td>
<td>&gt;= 50% Red</td>
</tr>
<tr>
<td>Red with Blue</td>
<td>&lt; 30%</td>
</tr>
<tr>
<td>Red with Green</td>
<td>&lt; 50%</td>
</tr>
<tr>
<td>Red with White</td>
<td>&lt; 10%</td>
</tr>
</tbody>
</table>
The addition and removal of agents
5% of the population are White at the start

Initial Conditions

<table>
<thead>
<tr>
<th>ID</th>
<th>Predominant Social Group</th>
<th>Total Population</th>
<th>No. of Red Agents</th>
<th>No. of Blue Agents</th>
<th>No. of White Agents</th>
<th>No. of Green Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Green</td>
<td>600</td>
<td>190</td>
<td>190</td>
<td>0</td>
<td>240</td>
</tr>
<tr>
<td>1</td>
<td>Red</td>
<td>600</td>
<td>300</td>
<td>120</td>
<td>0</td>
<td>174</td>
</tr>
<tr>
<td>2</td>
<td>Blue</td>
<td>600</td>
<td>120</td>
<td>30</td>
<td>0</td>
<td>130</td>
</tr>
<tr>
<td>3</td>
<td>Green</td>
<td>600</td>
<td>60</td>
<td>30</td>
<td>0</td>
<td>210</td>
</tr>
<tr>
<td>4</td>
<td>Blue</td>
<td>600</td>
<td>180</td>
<td>30</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>Red</td>
<td>600</td>
<td>300</td>
<td>180</td>
<td>0</td>
<td>60</td>
</tr>
</tbody>
</table>

Simulation Run

Type of Agent:
- Blue
- Green
- Red
- White
Predominant Social Group:
- Red
- Green
Segregation Simulation: 4 types of agents
Segregation Simulation: 4 types of agents

At one level everything is changing, at another level very little is changing.
By looking only at the aggregate information we lose what is happening at the boundaries.

Figure 5: Segregation within Areas and across Boundaries

A: The Entire Area, B: A Zoomed in Section of A
Who is using Repast?

- Designed for social scientists but not confined to it
- Examples include:
  - **Politics**: the rise and fall territories.
  - **Economics**: Banking strategies. Revenue management, evolution of firms, dynamics between firms, electricity markets
  - Segregation, Pedestrian modelling, disease transmission,
  - **Physical environment**: water shed modelling
  - **Landuse models**: SLUCE (change at urban rural fringe), LUCITA (Amazon farming), urbanisation.
  - **CASA**
  - Extensions also:
    - GeoGraph (3D extensions), AgentCell (biochemical reactions 3D) and parallel processing.
Useful Resources

• The Repast website http://repast.sourceforge.net/
• Murphy’s ‘How to Create a Repast Model’ tutorial http://www.u.arizona.edu/~jtmurphy/H2R/HowTo01.htm
• GIS and Agent-Based Modelling: http://gisagents.blogspot.com/
• Professor Cederman from the International Conflict Research Group at ETH Switzerland:
  – For Repast models: https://www.icr.ethz.ch/teaching/archive/compmodels/ws2004/models
  – For slides and more details on Repast https://www.icr.ethz.ch/teaching/archive/compmodels/ws2004/slides
Summary

• Shown the basic Repast structure and how to set up Repast.
• Import models –helps with the understanding of Repast and its limitations
• Examples of Raster and Vector Integration
Further Information and Examples

http://www.casa.ucl/repast/

http://www.gisagens.blogspot.com

http://www.casa.ucl.ac.uk/andrew/phd/