How to Run Simple Models with the Broadwick Framework

"Broadwick Examples"

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epic
Centre of Expertise on
Animal Disease Outbreaks

Introduction

- Broadwick Framework provides the underlying code for generating and running specific models

- To show how this works, we've generated some examples
  – This morning: running pre-written models
  – This afternoon: how to write your own models

Broadwick Examples

- Demonstration models have been written in the Broadwick Framework

- They have been compiled (built) together with the Broadwick Framework into one jar file
  BroadwickExamples-1.0-SNAPSHOT.one-jar.jar

- Files are on the USB stick, or

- Get the files from GitHub (see)
  http://epicscotland.github.io/broadwick.html

http://epicscotland.github.io/

EPIC Scotland Modelling

(Github user facing site)

Welcome to the EPIC Scotland Modelling webpages. Here you will find the epidemiological modelling code developed by EPIC members.

Code, built applications, data, and documents are in GitHub repositories: https://github.com/EPICScotland

Projects

PhylodynamicDataSets

PhylodynamicDataSets contains reference sequence data and trees for pathogens of interest to EPIC.
It also contains some R utility script files used to generate the data where applicable.

PhylodynamicDataSets **webpages are live at:** http://epicscotland.github.io/PhylodynamicDataSets

(the repository data and html pages are in the **gh-pages branch** of https://github.com/EPICScotland/PhylodynamicDataSets)

Broadwick

Main page	http://epicscotland.github.io/broadwick.html
Broadwick	Broadwick is a java framework for creating and running epidemiological models. Get the code from: https://github.com/EPICScotland/Broadwick
BroadwickTutorial	BroadwickTutorial contains tutorial materials on how to use the Broadwick Framework, and includes code stubs that you convert into working code as part of the tutorial. Get the code from https://github.com/EPICScotland/BroadwickTutorial
BroadwickExamples	BroadwickExamples contains some simple stochastic compartmental models written within the Broadwick framework. Get the code from https://github.com/EPICScotland/BroadwickExamples
MovementSimulations	The MovementSimulations repository is for movement simulation code and test data, and contains the AnimalMovementSimulations java project. Get the code from: https://github.com/EPICScotland/MovementSimulations

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Broadwick

Introduction

Broadwick is a framework for developing sophisticated epidemiological based mathematical models, and consists of several Java libraries and bespoke packages. The components of Broadwick are written in such a way that a scientist may combine them in order to rapidly prototype a model for a new specific scenario.

Features

- Supports single (e.g. within herd) or structured populations (e.g. multi-species or locations)
- Inclusion of movement over network data (e.g. Cattle movement Tracing System)
- Stochastic Individual Based simulations (including fast approximate options)
- Approximate Bayesian Computation inference for estimating model parameters from data via simulations
- Monte Carol Markov Chain inference for estimating model parameters from data

Get the code from: https://github.com/EPICScotland/Broadwick

BroadwickTutorial

← This afternoon

BroadwickTutorial contains tutorial materials on how to use the Broadwick Framework, and includes code stubs that you convert into working code as part of the tutorial.

Instructions for installing Broadwick, and a summary of the tutorial

- Broadwick_Demo_Install_Instructions.pdf (April 2014)
- MainTutorialTasks.pptx (17 June 2014)

Code stubs and Broadwick framework available as zipped files from https://github.com/EPICScotland/BroadwickTutorial

There are 9 video tutorials in the Videos Folder (large files)

- Download Broadwick (video 1)
- Download and install Netbeans (video 2)
- Create a simple SIR Model with Broadwick (video 3)
- Create a Stochastic SIR model (Video 4-7)
- Download Stochastic SIR model code (Video 4a)
- Stochastic flow part 1 - Background to implementation (Video 4)
- Stochastic flow part 2 - Theta events, reading data (Video 5)
- Stochastic flow part 3 - Handling fired events (Video 6)
- Stochastic flow part 4 - Build, run and plot output (video 7)
- Use Multithreading with Broadwick (Video 8)
- Use ABC with Broadwick (Video 9)

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For reference: UML diagram of classes and methods describing how to construct a stochastic model - Stochastic_UML_Diagram.pdf

Get the code from https://github.com/EPICScotland/BroadwickTutorial

Demonstration files

BroadwickExamples

BroadwickExamples contains some simple stochastic compartmental models written within the Broadwick framework.
To run these you will need the built jar file BroadwickExamples-1.0-SNAPSHOT.one-jar.jar and the xml configuration files: Broadwick_with_(XXX).xml

Instructions for running the examples, and an outline of how to write your own (but see the tutorial above for detailed instructions) can be found in the BroadwickExamples/doc directory:

- HowTo_RunBroadwickExamples_QuickStart.pdf (16 June 2014)
- HowTo_WriteBroadwickModel_QuickStart.pdf (16 June 2014)

Get the code from https://github.com/EPICScotland/BroadwickExamples

MovementSimulations

The MovementSimulations repository is for movement simulation code and test data, and contains the AnimalMovementSimulations java project.
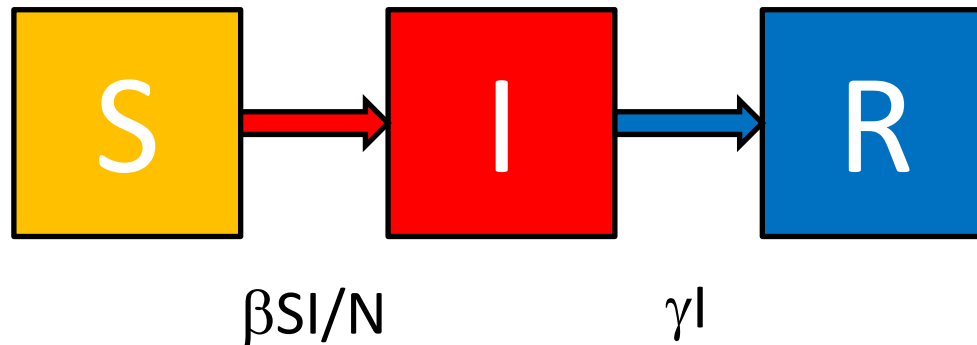
Simple Compartmental Model

- Assume fixed population of N individuals
- Model number of Susceptibles (S), Infecteds (I) and Recovereds (R) over time
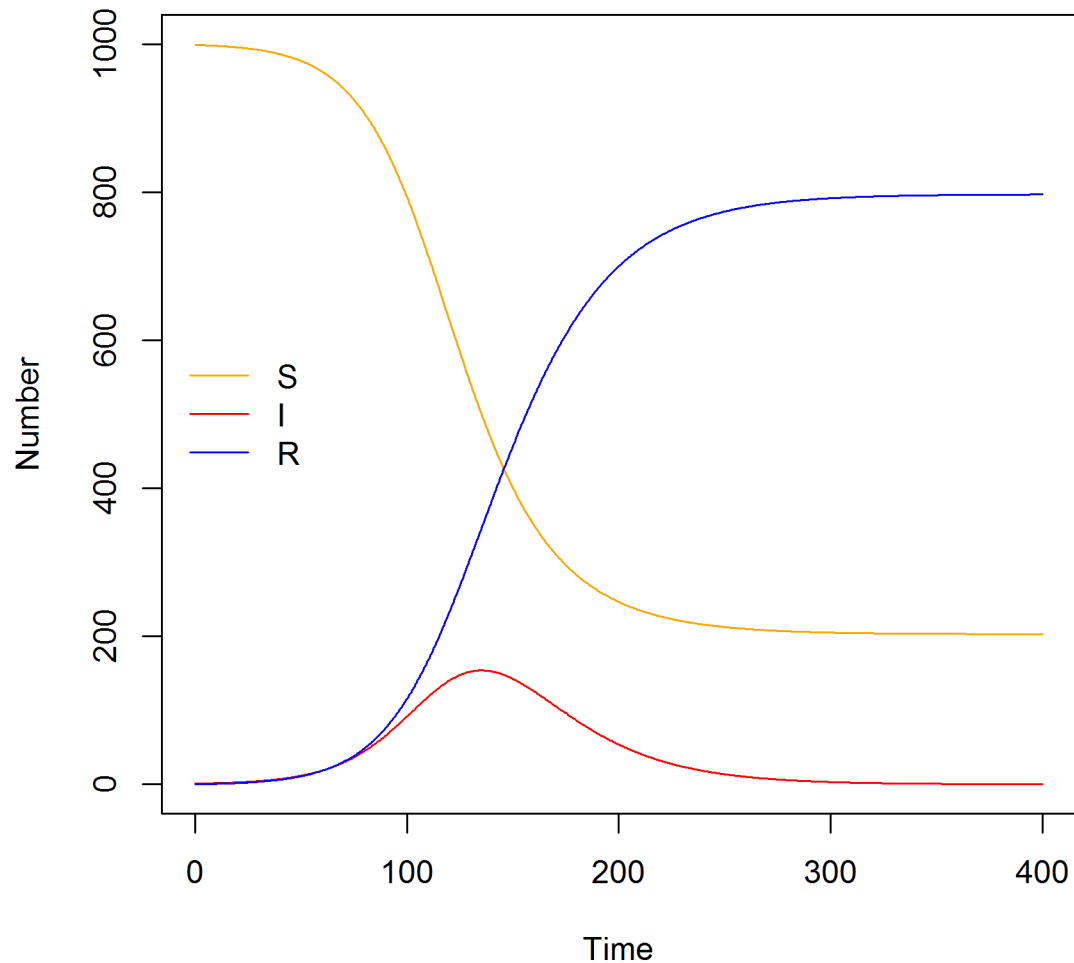- Assume that anybody can infect anybody else (if Susceptible)

$$\frac{dS}{dt} = -\frac{\beta SI}{N}$$

$$\frac{dI}{dt} = \frac{\beta SI}{N} - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

S → I → R

βSI/N   γI

Infection rate   Recovery rate

Deterministic Solution to SIR Model

N=1000 beta=0.1/N gamma=0.05

Demonstration models

- All use Broadwick Stochastic algorithms
  - Event driven: calculating the probability of infection and recovery for individuals
  - Choice of Gillespie Algorithm or Fixed Step Tau-Leap (approximate Gillespie, faster)
- BasicSIR: stochastic SIR model
- IndividualSIRModel: stochastic SIR model with named individuals and who-infected-whom
- NetworkSIRModel: as above, but individuals only infect each other over a network

Configuration Files

- Models in the "one-jar" file are run using XML configuration files
  - Broadwick_with_DummyModel.xml
  - Broadwick_with_BasicSIRModel.xml
  - Broadwick_with_IndividualSIRModel.xml
  - Broadwick_with_IndividualNetworkModel.xml

Broadwick_with_BasicSIRModel.xml

General framework part of configuration file:

```xml
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<project>
  <logs>
        <console>
          <level>info</level>
          <pattern>[%thread] %-5level %msg %n</pattern>
        </console>
        <file>
          <name>epic.basic.basicsirmodel.log</name>
          <level>info</level>
          <pattern>[%thread] %-5level %msg %n</pattern>
          <overwrite>true</overwrite>
        </file>
   </logs>
```

Broadwick framework log file

Broadwick_with_BasicSIRModel.xml

Model specific part of configuration file:

```
<models>
        <model id="Broadwick Project">
          <classname>epic.basic.BasicSIRModel</classname>
          <parameter id="filename" value="basicsir_test"/>
          <parameter id="verbose" value="false"/>
          <parameter id="maxTime" value="1000000"/>
          <parameter id="tauStep" value="0"/>
          <parameter id="N" value="1000"/>
          <parameter id="initI" value="1"/>
          <parameter id="beta" value="0.1"/>
          <parameter id="gamma" value="0.05"/>
        </model>
   </models>
</project>
```

The model to run

Specific parameters for the model

Command Line Operation

- Broadwick is designed to be run from the command line, and/or in batch scripts
- Bring up your command line:
  - Windows: Start -> (search) "prompt" -> command prompt
  - Mac: (Launch Pad) -> Terminal

- Go to the directory of the jar and xml files
- To run a model type this (all one line):

java –jar BroadwickExamples-1.0-SNAPSHOT.one-jar.jar –c Broadwick_with_BasicSIRModel.xml

Expected Results

Broadwick_with_DummyModel.xml

Command:

java -jar BroadwickExamples-1.0-SNAPSHOT.one-jar.jar -c Broadwick_with_DummyModel.xml

Expected results:

lots of:

[JarClassLoader] INFO: findResources..

[main] INFO Running broadwick Version 1.1 Build (SJLDELL - unknown : 2014-06-14 11:49)
[main] INFO Running broadwick for the following models [Broadwick Project]
[pool-1-thread-1] INFO Running Broadwick Project [epic.broadwickexamples.DummyModel]
[pool-1-thread-1] INFO Initialise Dummy Model
[pool-1-thread-1] INFO Run Dummy Model
[pool-1-thread-1] INFO stringParam=ABCDEFG
[pool-1-thread-1] INFO intParam=1
[pool-1-thread-1] INFO doubleParam=2.0
[pool-1-thread-1] INFO Finalise Dummy Model
[pool-1-thread-1] INFO END
[main] INFO Simulation complete. 0:00:00.056

SUCCESS !

Broadwick_with_BasicSIRModel.xml

Command:

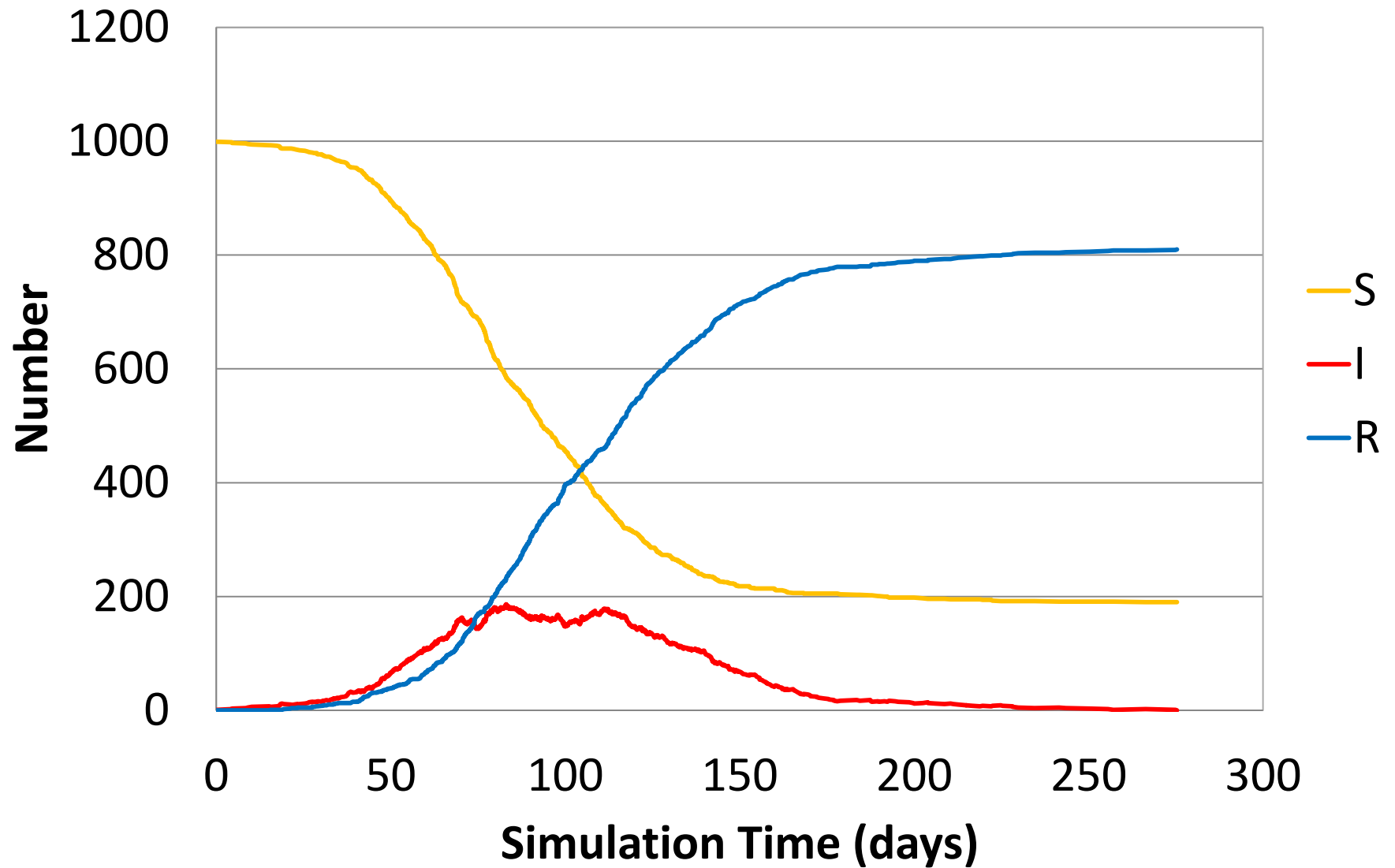java -jar BroadwickExamples-1.0-SNAPSHOT.one-jar.jar -c Broadwick_with_BasicSIRModel.xml

Expected results – also written to log file epic.basic.BasicSIRModel.log

[main] INFO Running broadwick Version 1.1 Build (SJLDELL - unknown : 2014-06-14 11:49)
[main] INFO Running broadwick for the following models [Broadwick Project]
[pool-1-thread-1] INFO Running Broadwick Project [epic.basic.BasicSIRModel]
[pool-1-thread-1] INFO BasicSIRModel - init
[pool-1-thread-1] INFO seed   = 12345
[pool-1-thread-1] INFO maxTime= 1000000.0
[pool-1-thread-1] INFO tauStep   = 0
[pool-1-thread-1] INFO N   = 1000
[pool-1-thread-1] INFO initI   = 1
[pool-1-thread-1] INFO beta   = 0.1
[pool-1-thread-1] INFO gamma   = 0.05
[pool-1-thread-1] INFO BasicSIRModel - run
[pool-1-thread-1] INFO BasicSIRModel - final simulation time = 275.3055756207629
[main] INFO Simulation complete. 0:00:00.246

and output file = basicsir_test.txt

Basic SIR Model

Broadwick_with_IndividualSIRModel.xml

Command:

java -jar BroadwickExamples-1.0-SNAPSHOT.one-jar.jar -c Broadwick_with_IndividualSIRModel.xml

Expected results – also written to log file epic.sir.IndividualSIRModel.log

[main] INFO Running broadwick Version 1.1 Build (SJLDELL - unknown : 2014-06-14 11:49)

[main] INFO Running broadwick for the following models [Broadwick Project]

[pool-1-thread-1] INFO Running Broadwick Project [epic.sir.IndividualSIRModel]

[pool-1-thread-1] INFO IndividualSIRModel - init

[pool-1-thread-1] ERROR Could not find parameter susceptibility in configuration file.

[pool-1-thread-1] INFO Optional parameter susceptibility (=wanning immunity) is not set, but this is OK

[pool-1-thread-1] INFO seed   = 12347

[pool-1-thread-1] INFO maxTime= 1000000.0

[pool-1-thread-1] INFO tauStep = 0

[pool-1-thread-1] INFO N   = 1000

[pool-1-thread-1] INFO initI   = 1

[pool-1-thread-1] INFO IndividualSIRModel - run

[pool-1-thread-1] INFO IndividualSIRModel - final simulation time = 319.6001125147772

[pool-1-thread-1] INFO IndividualSIRModel - SUSCEPTIBLE:249   INFECTED:0   RECOVERED:751

[main] INFO Simulation complete. 0:00:00.356

and output files:

individualsir_test_modelState.txt, individualsir_test_transmissions.txt, individualsir_test_allEvents.txt

Individual SIR Model Outputs

- *modelState.txt
  - Numbers of S, I, R over time

- *allEvents.txt
  - Record of all events, e.g.:
    - Time, Event Name, From:State -> To:State
    - 20.26,INFECTION,IA000000059:INFECTED -> IA000000132:INFECTED
    - 21.23,RECOVERY,IA000000260:INFECTED -> IA000000260:RECOVERED

- *transmissions.txt
  - Record of the transmission events (who infected whom) only

Individual SIR Model Outputs
Transmission Network (in Cytoscape)
Who infected Whom

Index case
(black)
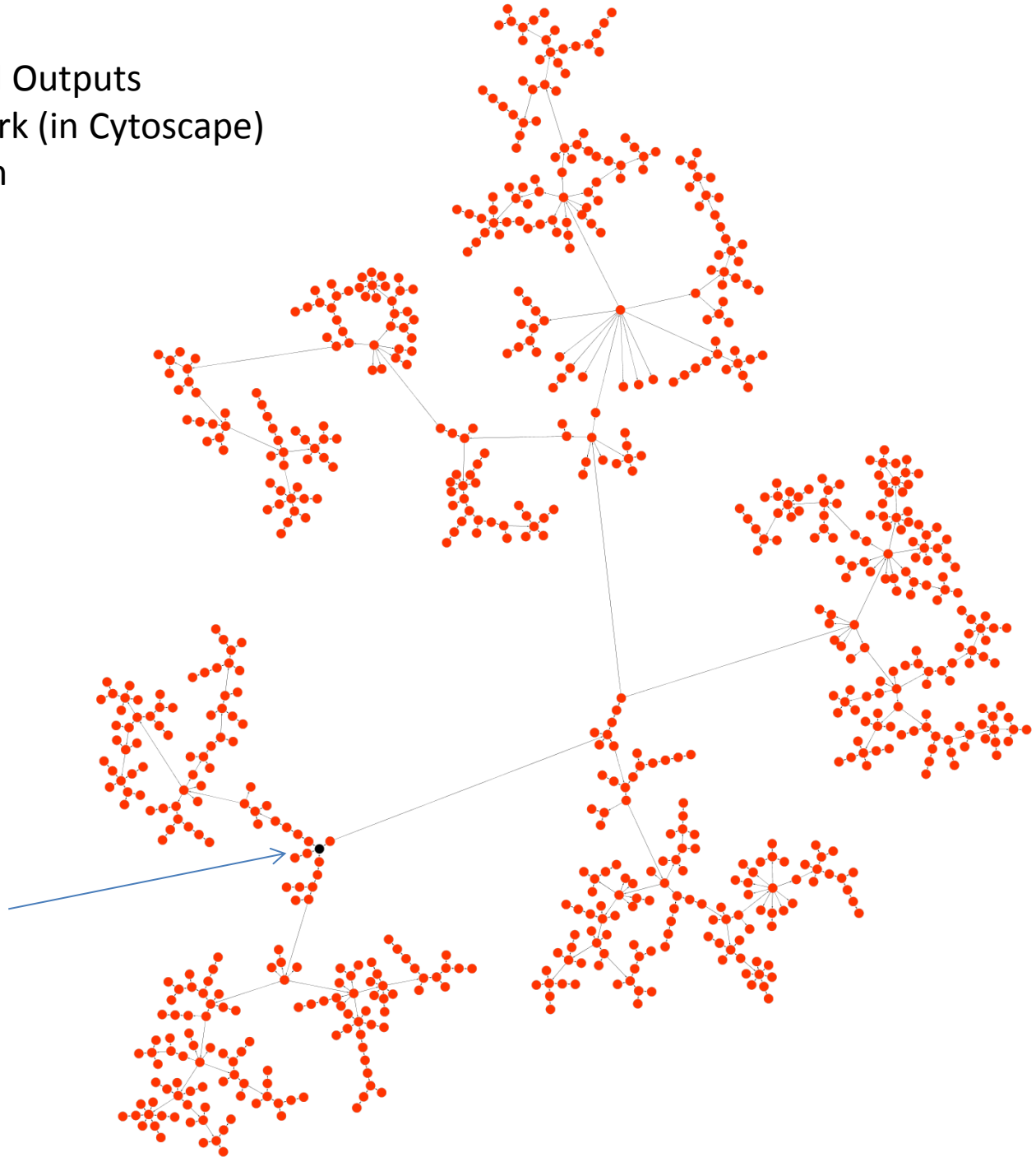
Broadwick_with_IndividualNetworkModel.xml

Command:

(example_UK_cities.txt, example_UK_cities_links.txt must be in the same directory as the jar file)

java -jar BroadwickExamples-1.0-SNAPSHOT.one-jar.jar -c Broadwick_with_IndividualNetworkModel.xml

Expected results – also written to log file epic.sir.IndividualNetworkModel.log

[main] INFO Running broadwick Version 1.1 Build (SJLDELL - unknown : 2014-06-14 11:49)
[main] INFO Running broadwick for the following models [Broadwick Project]
[pool-1-thread-1] INFO Running Broadwick Project [epic.network.IndividualNetworkModel]
[pool-1-thread-1] INFO IndividualNetworkModel - init
[pool-1-thread-1] ERROR Could not find parameter susceptibility in configuration file.
[pool-1-thread-1] INFO Optional parameter susceptibility (=wanning immunity) is not set, but this is OK
[pool-1-thread-1] INFO Network Model locationsFile = example_UK_cities.csv
[pool-1-thread-1] INFO Network Model linksFile = example_UK_cities_links.csv
[pool-1-thread-1] INFO Network Model locationType = LATLONG
[pool-1-thread-1] INFO 170 locations read from file
[pool-1-thread-1] INFO 181 links read from file
[pool-1-thread-1] INFO Initialising infection from CN000111,Stoke-on-Trent,53.0,-2.13
[pool-1-thread-1] INFO Number of susceptibles in network = 106
[pool-1-thread-1] INFO Number of infecteds in network = 1
[pool-1-thread-1] INFO seed = 12349
[pool-1-thread-1] INFO maxTime   = 1000000.0
[pool-1-thread-1] INFO tauStep   = 0
[pool-1-thread-1] INFO N   = 107
[pool-1-thread-1] INFO initI = 1
[pool-1-thread-1] INFO IndividualNetworkModel - run
[pool-1-thread-1] INFO IndividualNetworkModel - final simulation time = 152.54159155869897
[pool-1-thread-1] INFO IndividualNetworkModel - SUSCEPTIBLE:3   EXPOSED:0   INFECTED:0   RECOVERED:104
[main] INFO Simulation complete. 0:00:00.710

Individual Network Model Outputs

- *modelState.txt, *allEvents.txt, *transmissions.txt
  - Same as in Individual SIR Model outputs

- *locations.txt
  - The locations of the network nodes (one line = one vertex):

  Name,Location,Latitude,Longitude
  CN000144,Edinburgh,55.95,-3.35
  CN000145,Glasgow,55.8667,-4.43333
  CN000146,Inverness,57.5333,-4.05

- *initialNetwork.net
  - The (undirected) links between the network nodes (one line = one edge):

  Name,Location,Latitude,Longitude,Name,Location,Latitude,Longitude
  CN000145,Glasgow,55.8667,-4.43333,CN000142,Campbeltown,55.4333,-5.6

- *individualStates_initial.txt, *individualStates_final.txt, *individualStates_[number].txt
  - The infection state of each network node at each simulation step (one file per step), e.g:

  Name,Location,Latitude,Longitude,State
  CN000144,Edinburgh,55.95,-3.35,SUSCEPTIBLE
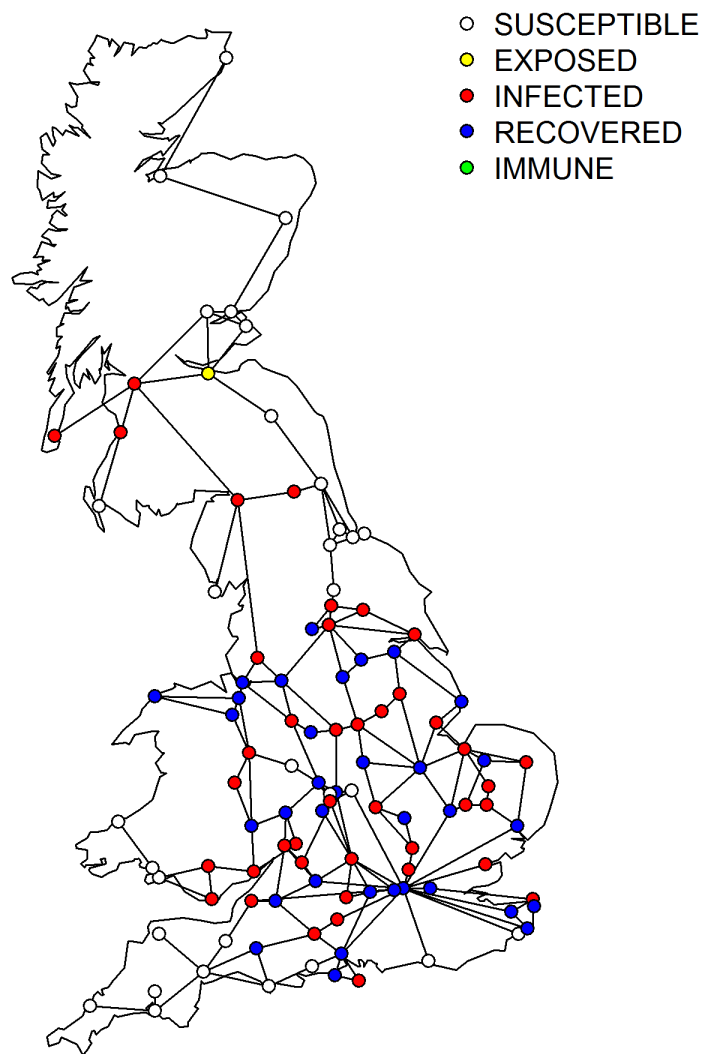
individualnetwork_test_individualStates_initial.txt

Plot individual states output using R script: plotGBDiseaseMap.R (one image per step)
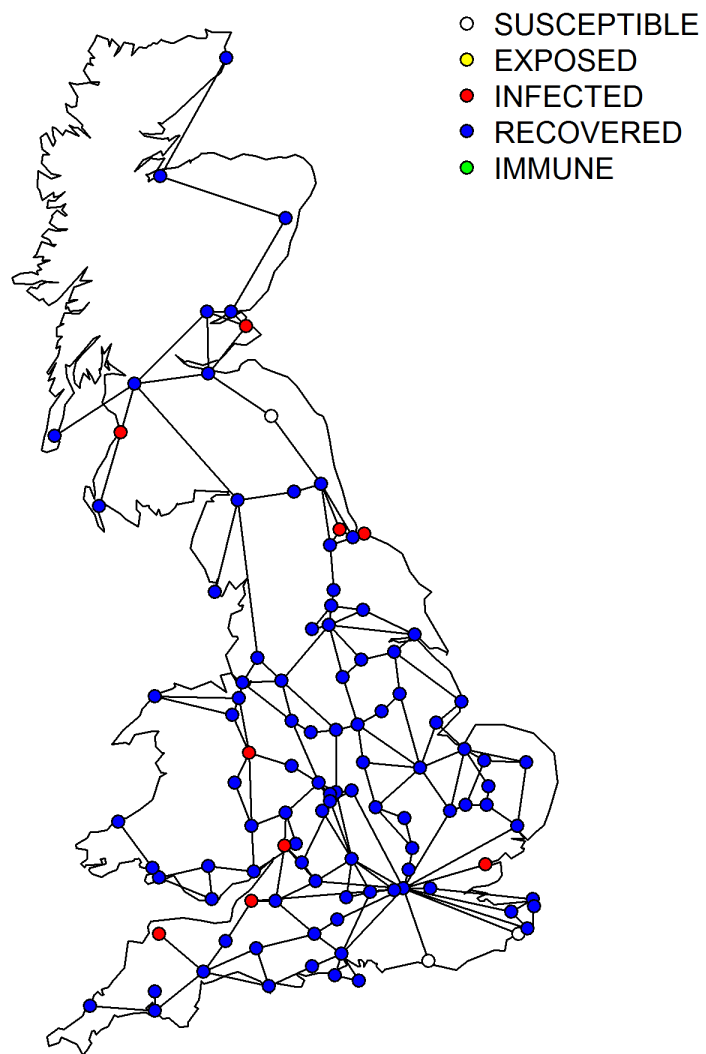
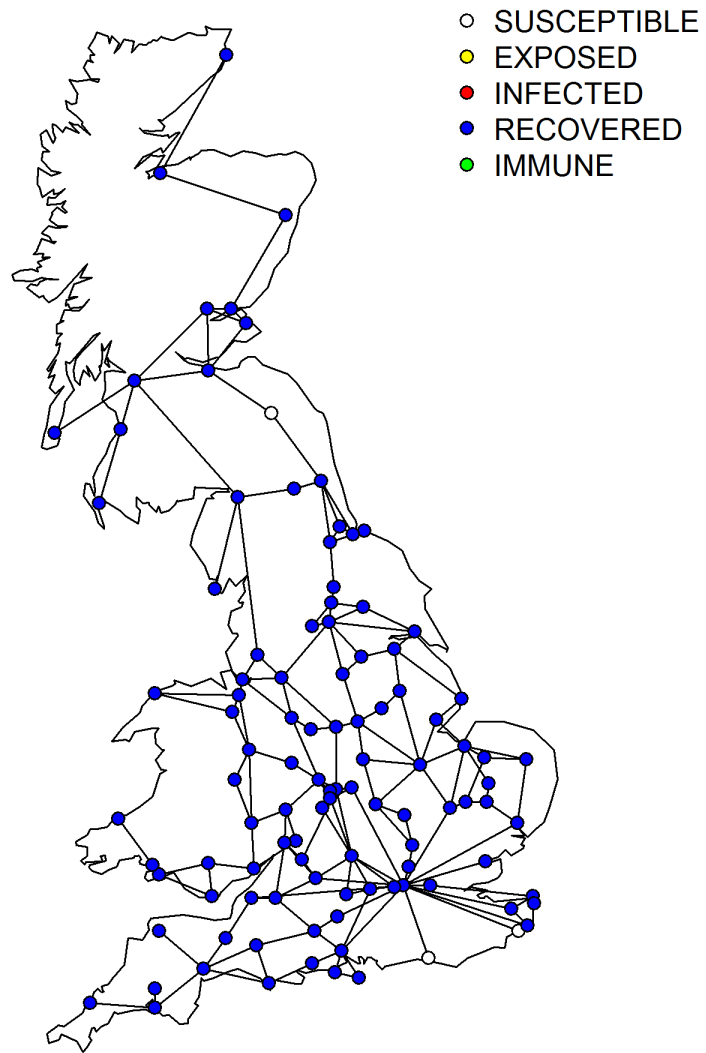**individualnetwork_test_individualStates_000000020.txt**

- ○ SUSCEPTIBLE
- ● EXPOSED
- ● INFECTED
- ● RECOVERED
- ● IMMUNE
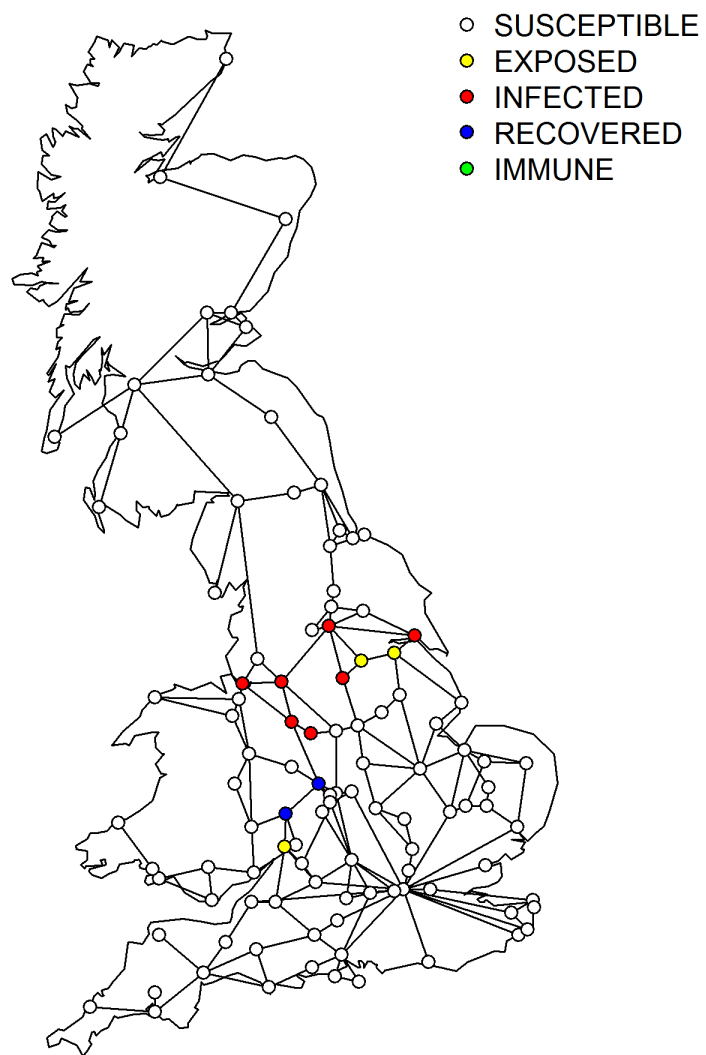
individualnetwork_test_individualStates_000000182.txt

Legend:
- ○ SUSCEPTIBLE
- ● EXPOSED
- ● INFECTED
- ● RECOVERED
- ● IMMUNE

individualnetwork_test_individualStates_000000300.txt

Legend:
- ○ SUSCEPTIBLE
- ○ EXPOSED
- ○ INFECTED
- ○ RECOVERED
- ○ IMMUNE

individualnetwork_test_individualStates_final.txt

○ SUSCEPTIBLE
○ EXPOSED
● INFECTED
● RECOVERED
● IMMUNE

Next Steps

Broadwick Tutorial

How to write your own models

This afternoon