GeoInformatics · Practical 2

Dave Murray-Rust, Corentin M. Fontaine

CECS, School *of* GeoSciences

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This practical encourages you to understand the principles of agent-based modelling (ABM). It focuses on the modelling of population demographics. Practical 3 will extend this social model to the spatial dimension.

Open ended questions following task descriptions are there to encourage experimentation and help to focus on the interesting bits.

The next assignment will cover this session and Practical 3, and will be due by the 4^{th} February. In order to allow you to create the correct graphs in this session, the assignment questions relating to this practical are given at the end of this practical sheet.

1 Theoretical background

The 5 key notions to remember when working with ABM:

1. **Social**: agent-based models focus on action and interactions between the studied agents
2. **Autonomy**: Agents have control over their actions and internal state in order to achieve their goal(s).
3. **Cognition**: Agents (re)act according to some rules. These behaviours can range from simple stimulus-response decision making to the point where actors are proactive, take initiative, and have larger intentions.
4. **Complexity**: The modelled relationships between agents — actions, feedback, reactions — portray a non-linear system.
5. **Dynamics**: The delay between one's action and another's reaction portay a non-static and non-equilibrium system.

After Parker et al. (2003, p.317-318), that you may want to read for more details (available on WebCT).

2 ABM in practice: the principles of demography

You are going to explore the process of demography. To start with the basics, the population is only composed by identical hermaphroditic agents. Each agent has a certain age which make them belong to one of the three following categories: young, mature or old. Only mature agents can have babies, according to a certain fertility rate. All agents can die, according to their mortality rate.

TASKS:
(1) The code starts with just two classes of agents - Young and Mature. Add a third class of agents to represent the elederly.

> **HINT:** Add the "Old" class, by copying the Mature class, but not allowing for children. Add a mechanism for Matures to turn into Olds when they reach Agent.OLD_AGE. Olds should automatically die when they reach 120 years old

(2) Test different combinations of fertility/mortality rates and compare aggregate outputs. Can you make the population stable?

> **HINT:** You can set the parameters from the "Parameters" pane in the Repast window to save reloading the model each time. Unfortunately, due to a bug in Repast, if your population hits 0, you will have to reload the model.

3 ABM in practice: advanced demography

Considering social systems are usually open systems, immigration (people in) and emigration (people out) should also be taken into account. These can be approached different ways — e.g. absolute numbers, ratios, ... — and either over the entire population or for different groups.

TASKS:
(3) Alter the code so migration is included.

> **HINT:** Look for instructions in the Demographics file about where to do migration.

(4) Test different combinations of fertility/mortality/migration values and compare outputs. What is the effect of migration over the population evolution trend? Does immigration help with stability?

Demographic model are usually built for projections. Official bodies are keen to know what population structure they should expect in the (near) future so they can adapt their policy strategies. For example, if you expect a baby boom, you might want to anticipate the need for more nursing facilities.

No one can accurately predict the future. Projections are therefore built on past and current knowledge of population behaviours and using different approaches. One way to deal with future uncertainty is the use of scenarios, as the Intergovernmental Panel on Climate Change (IPCC) do to tackle many drivers of climate change. A scenario is, in this context, a storyline that describe how specific aspect of the world may unfold in the future. The narratives are usually established in contrast with one another so distinct society choices are considered. Quantitative measures may be added but it is not always the case.

Three different population trajectories were chosen by the IPCC in their "Special Report on Emission Scenarios" (SRES) to reflect future world demographic uncertainties based on published population projections (http://www.grida.no/publications/other/ipcc%5Fsr/?src=/climate/ipcc/emission/). Follows the essence of the storylines focusing on the demographic aspects (see figure 1 for visual):

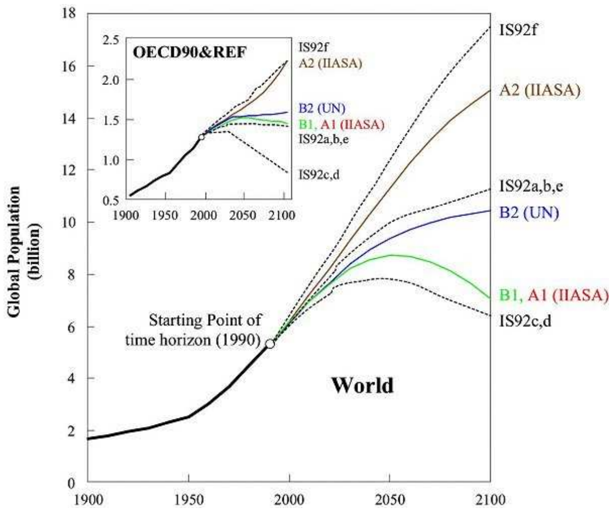
Lower Demographics combines low fertility with low mortality and central migration rate assumptions. After peaking, the world population declines.

Current Demographics describe a continuation of historical trends towards a completion of the demographic transition that would lead to a level global population, and is consistent with recent faster fertility declines in the world together with declining mortality rates. This median scenario projects very low population growth in today's industrialized countries.

Higher Demographics assumes a significant decline in fertility for most regions and a stabilization at above replacement levels.

These are world projections; in this particular case, you should assume that this region will behave in a similar manner.

Figure 1: World population projections (after IPCC SRES report, 2001)



TASKS:

(5) Translate the qualitative information in parameter values useful for the model, using the given baseline parameters. The model is set up with a set of baseline parameters; you should run it for 100 ticks, and then update the parameters with your new values. You should assume that the first 100 ticks represent the historical data, and the rest of the run is your projection based on your parameters.

> **HINT:** If the model is running very fast, you can set a delay between ticks in the "Run Options" panel of Repast to allow you to pause the model at an appropriate point.

> **HINT:** It is possible to "Freeze-Dry" your model state, to avoid having to start from scratch each time. Pause the model in the desired state, and choose "Freeze Dry" from the menu. Select "XML File", and choose a file. Now in the Scenario Tree, right click on "Data Loaders", and set a new XML Data Loader using the file you just saved.

(6) Run the model for each scenario and compare outputs. Are the observed trends based on your parameter estimates coherent with the one given in the storyline?

4 Assignment

1. Discuss how the fertility and mortality settings affect the shape of the age pyramid (histogram) for the model *without* migration. ($\leq$100 words and 2 histograms)

2. Explain the effect of migration on population dynamics (e.g. stability). ($\leq$100 words)

3. Discuss one scenario trend compared to the others, and also to the IPCC scenario graphs. ($\leq$200 words and up to 2 graphs).

References

Parker, D. C., Manson, S. M., Janssen, M. A., Hoffmann, M. J., Deadman, P., 2003. Multi-agent systems for the simulation of land-use and land-cover change: A review. Annals Of The Association Of American Geographers 93 (2), 314–337.