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Modelling *societies*

It is now possible to simulate on a computer the complex interactions between people, organisations and technology, and study how they evolve over time. Such 'social simulation' is being used to conduct experiments and test out theories that would be difficult, or impossible, to test in the real world. Nigel Gilbert explains how it all works and discusses some of the research that is currently underway.

Introduction

We know that collaborations between universities and companies are important for innovation, but what kinds of collaborations are most effective? How can the conflicting demands made for the water in Europe's river basins by individuals, farmers, water utilities, the environment and transport be reconciled? What is the most effective way of persuading farmers to manage their farms in an environmentally friendly way? How do people manage their money so that they have enough to get by, despite varying calls on their savings?

These very different questions have one important factor in common. They all involve studying complex interactions between people, organisations (farmers, universities, utility companies, and so on) and technology over time.

One way of exploring these issues that is growing in importance is to build computer models that simulate the situations in which we are interested. Researchers can then experiment with the models, which is of course easier, quicker and involves fewer ethical and practical problems than experimenting with societies.

However, the simulations used by social scientists are fundamentally different from most of those used in engineering. If you design a simulation of airflow over a wingspan, for example, you expect that you will be able to make accurate predictions of parameters such as drag from the model. With models of human institutions, however, prediction is a probably unattainable goal (although some people are still trying to develop reliable models of stock exchange price changes). This is because social dynamics are usually complex, meaning that at best only qualitative and coarse-grained predictions are possible. The same applies to some physical phenomena, such as turbulence. Nevertheless, modelling is useful. It can allow one to gain a much deeper understanding of the factors that are important in a social setting, which policy 'levers' can make a difference to outcomes and which are unlikely to do so.

In this article, I will describe briefly a few of the areas where social simulation has been used. It is still a very recent approach (most of the work has been done within the last ten years) and one that is developing rapidly. Consequently, much of its potential is still to be exploited, especially in linking academic research using simulation to practical policy-making.

Representing complex human interactions

> Computer models are natural candidates for social science theories …

Simulation with computer models has a long history in engineering and the physical sciences, where it is used as a way of understanding and predicting the behaviour of anything from atoms to bridges. However, until recently it was thought that computational modelling had little to contribute to the social sciences, except in a few specialised areas such as macro-economic modelling.

The breakthrough came in the early 1990s when artificial intelligence researchers showed that computer programs called 'multi-agent systems' could be written to represent individual people or organisations and their interactions. Today, the field of social simulation is expanding rapidly throughout the world, and has its own – electronic – journal, the *Journal of Artificial Societies and Social Simulation* (see Further Reading).

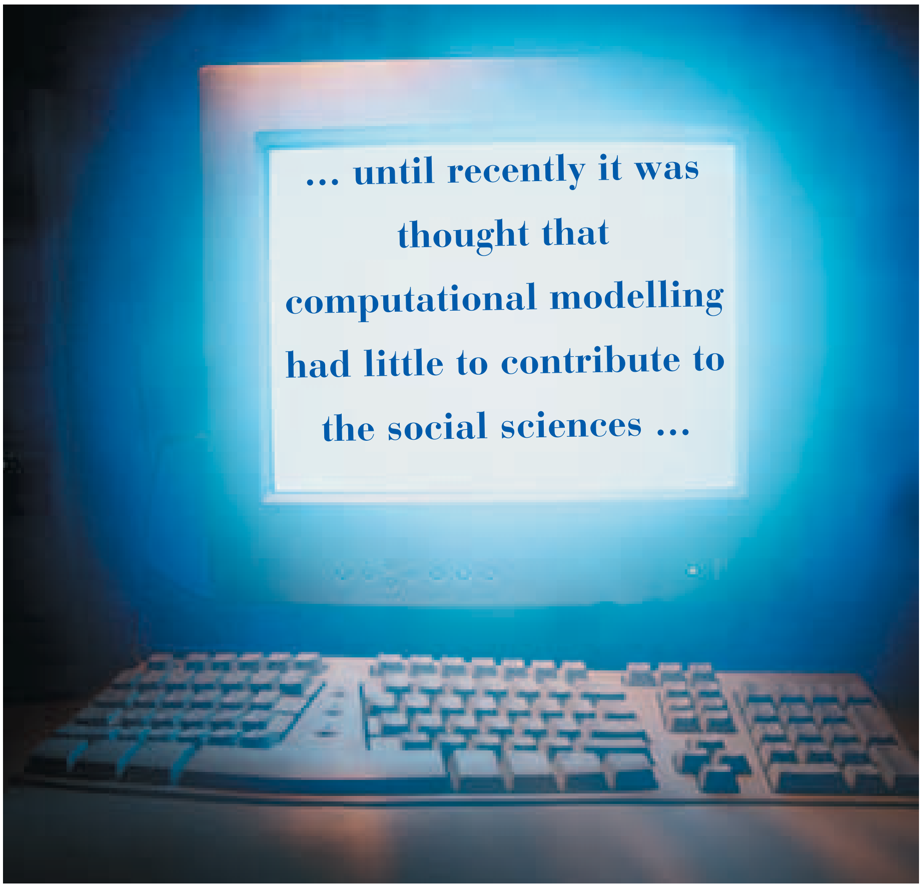
Social scientists often write their theories in textual form. While ordinary language is good at describing complicated and time-dependent relationships, it is rather difficult to make these descriptions precise. In some other sciences, particularly physics, mathematics is the favoured medium for theories. However, mathematics tends to have difficulty dealing with the dynamics of complex systems involving interactions between many heterogeneous elements. This of course is exactly what societies are, and explains why mathematics has never achieved the same place in the social sciences as it has in physics.

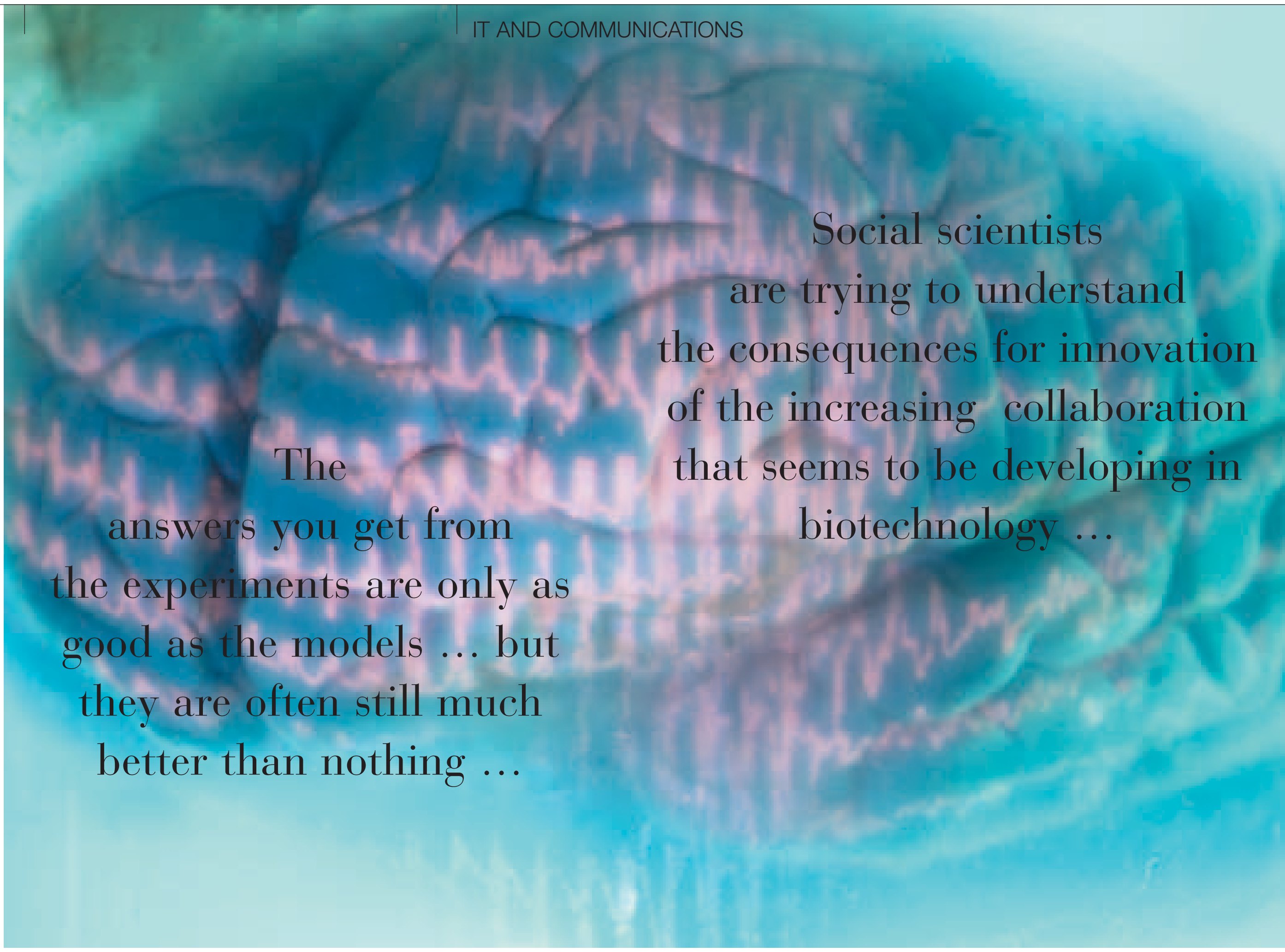
Computer models

In contrast, computer programs are precise (they have to be if they are to run on a computer); are capable of modelling many different kinds of element together with their interactions within the same program (using 'object-oriented' programming); and are pre-eminent in representing processes, ie changes that happen over time. Computer models are thus natural candidates for social science theories. It may seem strange to think of a computer program as a theory, but that is how they can be used: like any theory, they can tell a story about how the world works.

For example, a computer program, given a 'pension' each month as income for a simulated retired person and some pre-specified needs for food, housing costs, holidays, consumer durables and so on, could make decisions about what to buy and when, according to built-in rules. The rules that make up the program might be a theory of how people make budgeting decisions. The theory can be tested and refined against examples of what real people have done with their money. The program can be used as the basis for experiments to understand the relative influence on personal budgeting of learning from trial and error, of rational calculation and of imitation of the spending patterns of others.

Edmund Chattoe and I did just this in recent research funded by the Economic and Social Research Council. A budgeting model was constructed based on what people who had recently retired said about the way in which they managed their money. The interviews showed that almost all households divide their expenditure into three parts that are managed differently. Bills such as those for a mortgage and electricity can often be predicted exactly up to a year in advance and are often paid 'automatically', not even being regarded as part of disposable income.





Expenditure of the second type can be made more or less regular by habit (or other mechanisms of monitoring and control), so it is possible to budget approximately for it, based on past experience. An example of expenditure of this kind is provided by the weekly shopping trip, which always costs about the same, provided the same sorts of things are bought.

The third kind of expenditure involves items that are large, unexpected or unique and these will be financed out of money that is deliberately kept separate, for example, in a savings account. Experiments with the computer model showed the value of having two accounts, one for current expenditures and one for savings, in reducing the effort involved in budgeting.

The model also brought home the fact that households can adjust either or both their budget and their set of activities when there is a mismatch between them. If there is not enough money to pay for a trip to the cinema for the family, they can stay in and watch television. While this is fairly obvious, it is not adequately reflected in existing economic theories of consumer behaviour, and it adds a significant degree of complication to the task of keeping the household within budget. We found that as a result, households arrived at rules of thumb to guide their budgeting and often maintained these rules over decades, even when there were marked changes in personal circumstances.

The model was used to explore the effectiveness of some of these budgeting heuristics. One way in which the model could now be taken forward would be to use it as an educational simulator for people just starting to manage their own money, or who find budgeting difficult.

‘What-if’ experiments

In the social sciences, experiments are often impossible or unethical, because they would have to be done on people, or even on whole societies. Instead, experiments can be done on computer models. The answers you get from the experiments are only as good as the models – if the model is flawed, so will be the experimental results – but they are often still much better than nothing.

As part of the Common Agricultural Policy (CAP), there are schemes called ‘Agri-Environmental Measures’ that provide subsidies for farmers who agree to farm in a more environmentally friendly way. The European Union is funding the construction of a model that represents the decisions of farmers when given the option of signing a contract that pays them for farming in an environmentally friendly way. The decision process is modelled as a blend of rational calculation, imitation and influence from friends and neighbours, using theoretical ideas from social psychology and sociology about decision-making and the diffusion of ideas. This simulation will be useful to EU policymakers who need to design effective contract schemes and want to do ‘what-if’ trials with the model.

There are similarities between this and another area where the potential of simulation is becoming recognised: the modelling of consumer demand. Most studies of why people buy particular brands focus on the interaction between an individual's attributes – their attitudes, beliefs and so on – and the characteristics of the product. Some large companies are now building models of consumer markets that incorporate in addition the influence of other consumers (for example, the effect of fashion, status, and the gradual diffusion of personal recommendations).

These models are intended to help brand managers test the effect of marketing strategies. For instance, it is easy to see from these models the benefits of 'seeding' a new brand by distributing free samples when it is first put on the market (they are much less effective later on).

One of the benefits of this kind of simulation is that it is possible to model not just the consumers but also competing producers (who may be using different and varying brand management strategies). An example of this in environmental management is a large project supported by the EU that aims to help policy makers and others with the management of large-scale water resources. There are already some sophisticated models of water flow for the major European rivers developed by civil engineers and hydrologists. The aim of the project is to supplement these with models of the supply and demand for water. This means understanding and modelling not only consumers' changing water requirements but also the effect of institutional changes on the producers, such as the privatisation of the water utilities in the UK.

Abstract models

I have given examples of how computer modelling can be used in the social sciences for purposes with potential practical applications. In contrast, some social simulation research has focused on building much more abstract models, designed to explore fundamental social processes in their purest form.

For instance, social scientists are trying to understand the consequences for innovation of the increasing 'networking' and collaboration that seems to be developing in biotechnology between organisations such as firms, universities, research institutes and government. A model that includes abstract representations of competing organisations, each of which creates new 'products' based on the knowledge that they already have or can acquire from their collaborators, is being used to explore the conditions that encourage innovation. The idea underlying the model is that technical innovations are generated analogously to the way that new species are created in biological evolution.

Research on social simulation brings together issues in sociology with technologies developed first in computer science. It has been much influenced by interdisciplinary research on complex adaptive systems. Many natural systems (for example, brains, immune systems, habitats, societies) and increasingly, many artificial systems (parallel and distributed computing systems, artificial intelligence systems, the Internet) have apparently complex behaviours that emerge as a result of non-linear interactions among a large number of components at different levels of organisation. These are complex adaptive systems and they form the subject of much research to find common principles that apply generally. A great deal of this research is also carried out using simulation. Social simulation is thus able to draw in, and contribute to, some of the most exciting intellectual currents in academia today.

The future

At present, simulation is an unusual approach in the social sciences. This is partly because the number of social scientists capable of developing simulations is still very small. However, postgraduate courses are now beginning to include modules on simulation, a textbook is available (Gilbert and Troitzsch 1999) and an increasing number of people worldwide are beginning to take an interest in the potential of this new use of simulation. It is an area where the expertise of engineers, used to dealing with complicated situations using simulation techniques, could provide some valuable experience to social science, and one where social scientists and engineers can fruitfully collaborate. ■

Further reading

Rosaria Conte, Rainer Hegselmann and Pietro Terna (eds) (1997). *Simulating Social Phenomena*. Springer.

Nigel Gilbert and Klaus G. Troitzsch (1999). *Simulation for the Social Scientist*. Open University Press.

Timothy A. Kohler and George J. Gummerman (eds) (2000). *Dynamics in Human and Primate Societies: agent-based modelling of social and spatial processes*. Oxford University Press.

W.B.G. Liebrand, Andrzej Nowak and Rainer Hegselmann (eds) (1998). *Computer Modelling of Social Processes*. Sage.

Journal of Artificial Societies and Social Simulation: http://www.soc.surrey.ac.uk/JASSS/

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