Chapter 2
Historical Introduction

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Why Read This Chapter? To understand the historical context of simulation in the social sciences and thus to better comprehend the developments and achievements of the field.

Abstract This chapter gives an overview of early attempts at modelling social processes in computer simulations. It discusses the early attempts, their successes and shortcomings and tries to identify some of them as forerunners of modern simulation approaches.

2.1 Overview

The chapter is organised as follows: the next section will discuss the early attempts at simulating social processes, mostly aiming at prediction and numerical simulation of mathematical models of social processes. Section 2.3 will then be devoted to the non-numerical and early agent-based approaches, while Sect. 2.4 will give a short conclusion, followed by some hints at further reading.

2.2 The First Two Decades

Simulation in the social sciences is nearly as old as computer simulation at large. This is partly due to the fact that some of the pioneers of computer science – such as John von Neumann, one of the founders of game theory – were at the same time pioneers in the formalisation of social science. In addition, Herbert A. Simon, one of the pioneers

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in formalising social science, was an early adopter of computer-assisted methods of building social theories. Thus the first two decades of computational social science saw mathematical models and their inelegant solutions, microsimulation and even the first agent-based models before the name of this approach was coined.

Among the first problems tackled with the help of computer simulation were predictions of the future of companies ("industrial dynamics", Forrester 1961), cities ("urban dynamics", Forrester 1969) and the world as a whole ("world dynamics", Forrester 1971) in the early 1960s and 1970s by Jay W. Forrester as well as predictions of the consequences of tax and transfer laws for both the individual household and the national economy in microanalytical simulation, an attempt that started as early as 1956 (Orcutt 1957). Other early attempts at the prediction of elections and referendum campaigns also became known in the 1960s, such as Abelson and Bernstein's simulation analysis of a fluoridation referendum campaign within the Simulmatics project directed by de Sola Pool (Abelson and Bernstein 1963). What all these early simulations have in common is that they were aimed at predicting social and economic processes in a quantitative manner, and that computer simulation was seen as a "substitute for mathematical derivations" (Coleman 1964, p. 528). Despite Simon and others having already taught computers to deal with non-numerical problems as early as 1955 (*"Logic Theorist, the first computer program that solved non-numerical problems by selective search"*, Simon 1996, pp. 189–190), 10 years later Coleman still believed that "the computer cannot solve problems in algebra; it can only carry out computations when actual numbers are fed into it (Coleman 1964, p. 529).

The remainder of this section will give a short overview of system dynamics and microanalytic simulation – simulation approaches that continue to be promoted by learned societies such as the System Dynamics Society and the International Microsimulation Association, each celebrating their 50th anniversary with international conferences held in Boston in July 2007 and Vienna in August 2007, respectively –, before going into the details of some other early models that remained more or less isolated and are now all but forgotten.

System dynamics was developed by Jay W. Forrester in the mid-1950s as a tool to describe systems which could be modelled with large sets of difference and differential equations containing functions whose mathematical treatment would have been difficult or impossible. The general idea behind system dynamics was, and is, that a system, without considering its components individually, could be described in terms of its aggregate variables and their changes over time. The best known examples of system dynamics models are Forrester's (1971) and Meadows et al. (1974) world models which were inspired by the Club of Rome and won public attention in the 1970s when they tried to forecast the world population, the natural resources, the industrial and agricultural capital and the pollution until the end of the twenty-first century by describing the annual change of these aggregate variables as functions of their current states and numerous parameters which had some empirical background.

Microsimulation was first described in papers by Orcutt (1957) who designed a simulation starting with a (sample of a) given population and simulating the individual fate of all the members of this population (sample) with the help of transition probabilities empirically estimated from official statistics. Transitions represent changes in the circumstances of an individual, e.g. switching to a different job, achieving a higher educational level, marriage, birth of a child or death. These models have mainly been used for predicting demographic changes and the effects of tax and transfer rules. Usually they do not take into account that the overall changes of the aggregated variables of the population (or the sample) may affect individual behaviour. Thus in the sense of Coleman (1990, p. 10) these models neglect the "downward causation" (i.e. the influence of the aggregate on the individual) and focus only on the "upward causation", namely the changes on the macro level, which are the result of the (stochastically simulated) behaviour of the individuals.

The fluoridation referendum campaign model already mentioned above was one of the first models that can be classified as an early predecessor of today's agent-based models. It consisted of a large number of representatives of people living in a community faced with the option of compulsory fluoridation of drinking water – an issue often discussed in the 1960s – which they would have to vote upon at the end of a longish campaign, in which the media and local politicians were publishing arguments in favour of or against this issue. In this model, 500 individuals are exposed to information spread by several communication channels or sources and additionally, they also exchange information among themselves. It depends on their simulated communication habits to which extent they actually receive this information and, moreover, to which extent this leads to changes in their attitudes towards the referendum issue. Abelson and Bernstein defined 51 rules of behaviour, 22 of which are concerned with the processing of information spread over the communication channels, whereas 27 rules are related to the information exchange among individuals. Another two rules determine the final voting behaviour at the end of the referendum campaign. The rules for processing the information from public channels and those for processing the information exchanged among individual citizens are quite similar; rule A3 and rule B2 read, for instance, "Receptivity to [source] *s* is an inverse function of the extremity of [individual] *i*'s attitude position."

While this early model did not endow the model individuals with an appropriate repertoire of behaviours, it nevertheless displays a relatively broad range of communication possibilities among the model individuals – something that was neither aimed at in the classical microanalytical simulation approach, nor in the cellular automata approach adopted in the early 1970s in Thomas Schelling's seminal paper on segregation. One of the shortcomings of Abelson and Bernstein's model in the eyes of its critics was the fact that it "has never been fully tested empirically" (Alker 1974, p. 146). They also contested the adequacy of its "static representations of citizen belief systems defined primarily in terms of assertions held, assertions acceptance predispositions, with associated, more general, conflict levels" (Alker 1974, p. 146). Moreover, the assertions were modelled numerically (not a problem with the proponents of a mathematical sociology who would even have used a large system of differential equations to model the citizens' attitude changes) where obviously real citizens' attitudes were never mapped on to the set of integer or real numbers. Nowak et al. (1990, p. 371) give further reasons for the fact that this approach was dropped for decades, "the ad hoc quality of many of the assumptions of the models, perhaps because of dissatisfaction with the plausibility of their outcomes despite their dependence on extensive parameter estimation, or perhaps because they were introduced at a time when computers were still cumbersome and slow and programming time-consuming and expensive."

Simulmatics suffered basically the same fate as Abelson and Bernstein's model: Simulmatics was set up "for the Democratic Party during the 1960 campaign. . . . The immediate goal of the project was to estimate rapidly, during the campaign, the probable impact upon the public, and upon small strategically important groups within the public, of different issues which might arise or which might be used by the candidates" (de Sola Pool and Abelson 1961, p. 167). The basic components of this simulation model were voter types, 480 of them, not individual voters, with their attitudes towards a total of 48 so-called "issue clusters", i.e. "political characteristics on which the voter type would have a distribution". Voter types were mainly defined by region, agglomeration structure, income, race, religion, gender and party affiliation. From different opinion polls and for different points of time these voter types were attributed four numbers per "issue cluster": the number of voters in this type and "the percentages pro, anti and undecided or confused on the issue" (168). For each voter type empirical findings about cross-pressure (e.g. anti-Catholic voters who had voted for the Democratic Party in the 1958 congressional elections and were likely to stay at home instead of voting for the Catholic candidate of the Democrats) were used during a simulation run to re-adjust the preferences of the voters, type by type. It is debatable whether this would classify as a simulation in current social simulation communities, but since this approach at least in some way resembles the classical static microsimulation, where researchers are interested in the immediate consequences of new tax or transfer laws with no immediate feedback, one could argue that Simulmatics was a simulation project – though with as little sophistication as static microsimulation.

Thus the first two decades of computer simulation in the social sciences were mainly characterised by two beliefs: that computer simulations were nothing but the numerical solution of more adequate mathematical models, and that they were most useful for predicting the outcome of social processes whose first few phases had already been observed. This was also the core of the discussion opened in 1968 by Hayward Alker who analysed, among others, the Abelson-Bernstein community referendum model and came to the conclusion that this "simulation cannot be 'solved': one must project what will be in the media, what elites will be doing, and know what publics already believe before even contingent predictions are made about community decisions. In that sense an open simulation is bad mathematics even if it is a good social system representation." (Alker 1974, p. 153)

2.3 Computer Simulation in Its Own Right

The Simulmatics Corporation mentioned in the previous subsection did not only work in the context of election campaigning, but later on also as a consulting agency in other political fields. Their Crisiscom model is another example of an early forerunner of current simulation models of negotiation and decision making processes. At the same time it is an early example of a simulation not aimed at prediction but at "our understanding of the process of deterrence by exploring how far the behaviour of political decision makers in crisis can be explained by psychological mechanisms." (de Sola Pool and Kessler 1965, p. 31) Crisiscom dealt with messages of the type "actor one is related to actor two", where the set of relations was restricted to just two relations: affect and salience. In some way, Crisiscom could also be used as part of a gaming simulation in which one or more of the actors were represented by human players, whereas the others were represented by the computer program – thus it can also be classified as a predecessor of participatory simulation (see Chap. 10 in this volume).

The 1970s and 1980s saw a number of new approaches to simulate abstract social processes, and most of them now were actual computer simulations, as – in terms of Thomas Ostrom – they used the "third symbol system" (Ostrom 1988, p. 384) directly by translating their ideas from the first symbol system, natural language, into higher level programming languages instead of using it as a machine to manipulate symbols of the second symbol system, mathematics. Although this was already true for Herbert Simon's Logic Theorist, the General Problem Solver and other early artificial intelligence programs, the direct use of the "third symbol system" in social science proper was not introduced before the first multilevel models and cellular automata that integrated at least primitive agents in the sense of software modules with some autonomy.

Cellular automata (Farmer et al. 1984; Ilachinski 2001) are a composition of finite automata which all follow the same rule, are ordered in a (mostly) two-dimensional grid and interact with (receive input from) their neighbours. The behaviour of the individual cells is usually quite simple: they only have a small number of states among which they switch according to relatively simple transition rules. Prime example is the famous game of life (Gardener 1970), where the cells are either alive or dead and change state according to two simple rules: (a) a cell stays alive if it has exactly two or three live neighbouring cells, otherwise it dies; (b) a dead cell bursts into life if there are exactly three live cells among its eight neighbours. The great variety of outcomes on the level of the cellular automaton as a whole enthused researchers in complexity science and laid the headstone for innumerable cellular automata in one or two dimensions.

One of the first applications of cellular automata to problems of social science is Thomas Schelling's (1971) segregation model, demo versions of which are nowadays part of any distribution of simulation tools used for programming cellular automata and agent-based models. This model shows impressively that segregation and the formation of ghettos is inevitable even if individuals tolerate a majority of neighbours different from themselves.

Another example is Bibb Latané's Dynamic Social Impact theory with the implementation of the SITSIM model (Nowak and Latané 1994). This model, similar to Schelling's, also ends up in clustering processes and in the emergence of local structures in an initially randomly distributed population, but unlike Schelling's segregation model (where agents move around the grid of a cellular automaton until they find themselves in an agreeable neighbourhood) the clustering in SITSIM comes from the fact that immobile agents adapt their attitudes to the attitudes they find in their neighbourhood according to the persuasive strength of their neighbours.

Other cellular automata models dealt with *n*-person cooperation games and integrated game theory into complex models of interaction between agents and their neighbourhoods. These models, too, usually end up in emergent local structures (Hegselmann 1996).

Another game-theory-related computer simulation, run by Axelrod (1984), showed the Tit-For-Tat strategy in the iterated prisoner's dilemma as superior to all other strategies represented in a computer tournament. The prisoner's dilemma had served game theorists, economists and social scientists as a prominent model of decision processes under restricted knowledge. The idea stems from the early 1950s, first written down by Albert Tucker, and is about "two men, charged with a joint violation of law, [who] are held separately by the police. Each is told that (1) if one confesses and the other does not, the former will be given a reward . . . and the latter will be fined . . . (2) if both confess, each will be fined . . . At the same time, each has good reason to believe that (3) if neither confesses, both will go clear." (Poundstone 1992, pp. 117–118) In the non-iterated version the rational solution is that both confess – but if they believe they can trust each other, they can both win, as both will go clear if neither confesses. Axelrod's question was under which conditions a prisoner in this dilemma would "cooperate" (with his accomplice, not with the police) and under which condition they would "defect" (i.e. confess, get a reward and let the accomplice alone in prison). Strategies in this tournament had to define which choice – cooperate or defect – each player would make, given the history of choices of both players, but not knowing the current decision of the partner. Then every strategy played the iterated game against every other strategy, with identical payoff matrices – and the Tit-For-Tat strategy proved to be superior to 13 other strategies proposed by economists, game theorists, sociologists, psychologists and mathematicians (and it was the strategy that had the shortest description in terms of lines-of-code). Although later on several characteristics of a number of the strategies proposed could be analysed mathematically, the tournament had at least the advantage of easy understandability of the outcomes – which, by the way, is another advantage of the "third symbol system" over the symbol system of mathematics.

Cellular automata later on became the environment of even more complex models of abstract social processes. They serve as a landscape where moving, autonomous, pro-active, goal-directed software agents harvest food and trade with each other. Sugarscape is such a landscape functioning as a laboratory for a "generative social science" (Epstein and Axtell 1996, p. 19) in which the researcher "grows" the emergent phenomena typical for real-world societies in a way that includes the explanation of these phenomena. In this artificial world, software agents find several types of food which they need for their metabolism, but in different proportions, which gives them an incentive to barter one kind of food, of which they have plenty, for another kind of food, which they urgently need.

Table 2.1 Overview of important approaches to computational social science

Approach	Used since	Characteristics
System dynamics	Mid-1950s	Only one object (the system) with a large number of attributes
Microsimulation	Mid-1950s	A large number of objects representing individuals that do not interact, neither with each other nor with their aggregate, with a small number of attributes each, plus one aggregating object
Cellular automata	Mid-1960s	Large number of objects representing individuals that interact with their neighbours, with a very restricted behaviour rule, no aggregating object, thus emergent phenomena have to be visualised
Agent-based models	Early 1990s, with some forerunners in the 1960s	Any number of objects ("agents") representing individuals and other entities (groups, different kinds of individuals in different roles) that interact heavily with each other, with an increasingly rich repertoire of changeable behaviour rules (including the ability to learn from experience and/or others, to change their behavioural rules and to react differently to identical stimuli when the situation in which they are received is different)

This kind of laboratory gives an insight under which conditions skewed wealth distributions might occur or be avoided; with some extensions (König et al. 2002) agents can even form teams led by agents who are responsible for spreading the information gained by their followers among their group.

2.4 Conclusion

This short guided tour through early simulation models tried to show the optimism of the early adopters of this method: "*If it is possible to reproduce, through computer simulation, much of the complexity of a whole society going through processes of change, and to do so rapidly, then the opportunities to put social science to work are vastly increased.*" (de Sola Pool and Abelson 1961, p. 183) 35 years later, Epstein and Axtell formulate nearly the same optimism when they list a number of problems that social sciences have to face – suppressing real-world agents' heterogeneity, neglecting non-equilibrium dynamics and being preoccupied with static equilibria – and claim that "the methodology developed [in Sugarscape] can help to overcome these problems" (Epstein and Axtell 1996, p. 2).

To complete this overview, Table 2.1 lists the approaches touched in this introductory chapter with their main features.

As one can easily see from this table, only the agent-based approach is able to "cover all the world" (Brassel et al. 1997), as only this approach can (a) include the features of all the other approaches, and (b) meet the needs of social science for models of individuals which are able to exchange symbolic messages that have to be interpreted by the recipients before they can take effect. When investigating large-scale social phenomena involving large numbers of individuals in more or less similar situations, then microsimulation, cellular automata, including sociophysics models (Chakrabarti et al. 2006; Ball 2005), or even system dynamics may provide a good (enough) approximation of what happens in human societies. But if we deal with small communities – including the local communities Abelson and Bernstein analysed –, then the process of persuasion, which needs at least one persuasive person and one or more persuadable persons, has to be taken into account, and this calls for agents of a richer structure than the early approaches could provide.

Further Reading

Most of the literature suggested for further reading has already been mentioned. Epstein and Axtell's (1996) work on generating societies gives a broad overview of early applications of agent-based modelling. Epstein (2006) goes even further as he defines this approach as the oncoming paradigm in social science. For the state of the art of agent-based modelling in the social sciences at the onset of this approach, the proceedings of early workshops and conferences on computational social science are still worth reading (Gilbert and Doran 1994; Gilbert and Conte 1995; Conte et al. 1997; Troitzsch et al. 1996).

And many early papers on computational social science were recently republished (Gilbert 2010).

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