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Editors

Sociology of the Sciences Yearbook 25

Simulation

Pragmatic Construction of Reality

Springer

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SIMULATION

Pragmatic Construction of Reality

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INTRODUCTION

CHAPTER 1

GÜNTER KÜPPERS,[*] JOHANNES LENHARD,[*] AND TERRY SHINN[**]

COMPUTER SIMULATION: PRACTICE, EPISTEMOLOGY, AND SOCIAL DYNAMICS

What does the word ‘simulation’ refer to? What is done during a simulation, and what are the technical, intellectual, and epistemological issues raised by it? Who are the practitioners of simulation? What sorts of problems are addressed? What is the scope and composition of the market? Finally, if anything, what does simulation have to do with transformations in science, in technology, and, if postmodern thinkers are to be believed, in the very structure and substance of contemporary society? This book attempts to address some of these questions, and in doing so, it often raises additional ones.

The word ‘simulation’ comes from the Latin *simulare*. For almost three centuries, the principal lexical meaning of simulation in the English, French, and German languages referred to ‘imitation’ or, alternatively, to ‘deception.’ In everyday parlance, someone simulates when he imitates a certain behavioral pattern, for instance, the actor in a drama, but also a malingerer who imitates the symptoms of a disease, in an authentic, albeit deceitful, way. A case from literature is Felix Krull, from Thomas Mann’s novel *Confessions of Felix Krull, Confidence Man* (1954). Krull studies medical literature to learn about the symptoms of a particular nervous disease, and subsequently simulates the disease to deceive military doctors and obtain a medical exemption from the army. A slightly different meaning of simulation is equated with illusion: In late Renaissance and Baroque painting, the imitation of tableau became fashionable. One famous example is a painting by Cornelius Gijsbrechts (about 1670) entitled *Back of Painting* (see Figure 1), which seems to depict what the title says. The spectator’s impression is of a real painting hanging on the wall, but showing the back of the canvas. This example of illusionistic painting in fine art may also count as an instance of simulation.

The meaning of the term simulation changed after World War II, as the definition given by the *Oxford English Dictionary* (fourth edition 1989) reflects: “The technique of imitating the behavior of some situation or process […] by means of a suitably analogous situation or apparatus, especially for the purpose of study, or the training of personnel.” In contemporary life, however, simulation has generally come to

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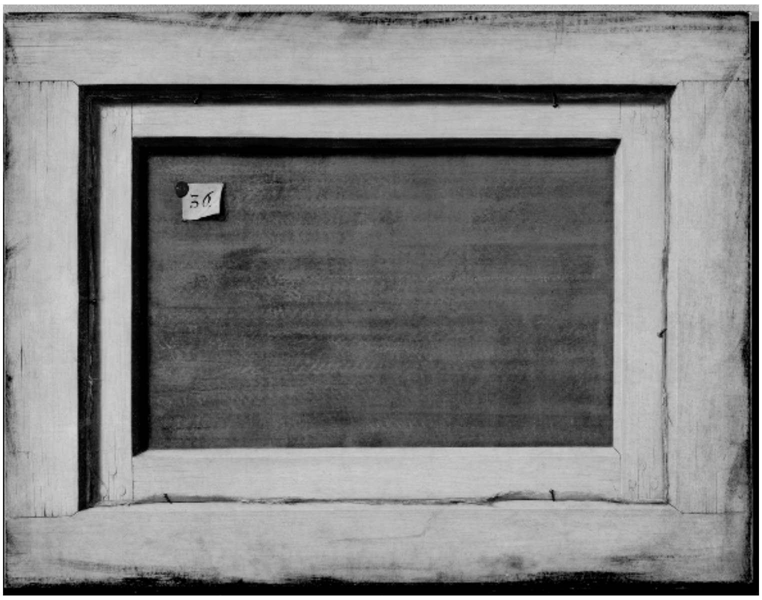

Figure 1. Cornelius Gijsbrechts: Trompe l'oeil. The reverse of a framed painting. (By courtesy of the Statens Museum for Kunst, Copenhagen. Photographer: SMK Foto.)

be equated with science and technology and is viewed as synonymous with computation and the digital computer.

In recent decades, simulation has increasingly become established as a new means of knowledge production and especially representation of complex dynamics in science and technology as well as a tool for the development of new and better technical artifacts in a rapidly expanding range of fields. Undoubtedly, one essential reason for this development is the amount of computing power that has become available over the last twenty-five years, and it is perhaps not inappropriate to think of simulation as 'computer simulation,' so strongly connected is simulation to the computer and computer science. The diversity of the sites of usage, applications, and practitioners connected with computer simulation today have turned it into a pervasive and often prominent social, organizational, and cognitive sphere that either directly or indirectly, unwittingly or consciously, impacts on the lives of most people.

Computer simulations are applied in science, technology, engineering, different areas of technical and professional training, economics, leisure, and art. To illustrate the broad field of applications, we cite three examples: In science, the dynamics of galaxies, encompassing billions of stars, cannot be grasped theoretically or experimentally. The fundamental theories are known and unquestioned, but the resulting mathematical equations cannot be treated by the traditional analytical methods. Computer simulation is currently viewed as the sole acceptable path for exploring a complex universe. In technology and engineering, the situation is similar. The investigation of how colliding cars behave and how passengers become injured can be conducted in experimental crash tests. Yet many automotive companies prefer virtual collision tests conducted during the R&D phase rather than awaiting experimentation using advanced prototype vehicles. Finally, climate change has become a major issue in science, in policy, and in the media. What will be the consequences of global warming? Computer simulations are the main instrument for obtaining predictions here as well.

Traditional scientific knowledge has generally taken the form of either theory or experimental data. However, where theory and experiment stumble, simulations may offer a third way. The central question is: What are the characteristics of this mode, and how reliable is simulation-based knowledge? If computer simulations provide a new way beyond theory and experiment, that is, if they are not merely numerical solutions of theoretical problems, new practices of validation and assessment also become necessary. Alternatively, the roles of simulation within science may prove more restricted, and its epistemological effects more limited.

It is important to ask: Does simulation constitute a newly emergent scientific discipline? There exist over a score of scholarly journals in the Science Citation Index database specifically connected to simulation; yet does this necessarily signify that simulation should be regarded as a scientific or technical discipline? Is this number of reviews as elevated as one might anticipate for a ‘revolutionary’ full-fledged research domain? Indeed, it proves extremely difficult to identify the social and organizational locus of computer simulation. There are no university departments in the field, no diplomas, no established intellectual corpus, or certified body of skill. But does it necessarily follow that in terms of social and organizational significance, simulation represents nothing more than a merely loosely coupled, fragmented body? It may be queried whether simulation is not instead a historically important, perhaps even historically unusual, research instrument. One thing is certain, simulation is a relatively new entity, whose usages are in flux and whose ‘good practices’ have not yet even been determined in full.

Computer simulation is a domain of growing interest to sociologists, historians, and philosophers of science. Sociologists query the organizational and material conditions that surrounded simulation’s foundations, question the dynamics and structure of the movement, interrogate the internal form of the occupation/profession, and focus on its relations with other bodies as well as the size and scope of its market. They are concerned with the shape of the computer simulation field, the expression of its diverse forms of symbolic capital, the forms and rules of competition, what counts as legitimacy, and finally, they are concerned with the relations between the field of simulation and other science, technology, and fields beyond (Bourdieu 1975, 2001). For their part, historians of science demand to know the backdrop of simulation activities; who practiced it; where, why, and how. To what extent does computer simulation constitute an extension of earlier practice and forms of knowledge, and to what extent does it comprise something unprecedented? Finally, due to the complex and ambiguous linkage between simulation, models, and representation, philosophers of science too are increasingly drawn to this often elusive domain. They are interested in the epistemology and methodology of simulation and also in the complex relations extant between theory, models, simulation models, computation, and the material laborant to which they all refer. In order to frame a clearer understanding of the aforementioned problems, this book assembles contributions from the intersection of all three domains.

GENESIS AND BACKDROP

Prior to the appearance of simulation in science, itself now linked to digital computers (and for that matter even to any form of computer), a kind of simulation was already applied in technology. In the late nineteenth century, nautical design was sometimes assisted by data and ideas obtained by studying the behavior of miniature ship hulls carefully displaced through a variety of hydraulic conditions. Development of such early simulation was stimulated by the passage from sail to steam and from wood to steel. Traditional knowledge about wooden hulled sailing boats had been outdated by iron as new materials for the construction of bigger and faster ships developed. Experiences with the new steamboats were rare.

This early real-world simulation may be associated with a form of early technical modeling that differed from previous practices based on the extension and modification of noncodified craft data and on lessons drawn from observing unfortunate design errors. France had a different nautical tradition based on applying mathematics and deductive principles to ship building. However, this often remained disconnected from observational inputs. At that time, the theories to describe the relation between the resistance of a body in water flow and its velocity were available to physics. However, the resulting equations had no general solution because of nonlinearities. Hence, when investigating the influence of different hull shapes, one had been limited to trial and error – a costly affair with full-size ships. Later on, the wind tunnel was employed as a simulation instrument to investigate the dynamic properties of objects in air flow in a very similar way. It may reasonably be hypothesized that the form of simulation practiced during this era may have acted as a sort of bridging mechanism that drew diverse and divergent design practices more closely together.

The twentieth century witnessed a huge growth in the frequency of this kind of 'real-world' simulation that takes place in reality and not in the symbolic realm of a digital computer. Already in the interwar era, simulation had been proposed and developed for the solution of technology-related problems. In 1929, German engineers took out patents for a device designed for training pilots in airplanes, dirigibles, and submersibles. The apparatus involved elementary indicators of vehicle altitude, an altitude control system, and an interactive system between the two mechanisms based on electromechanical devices. Response flight simulators permit the training of pilots who have to react correctly in risky situations – without risking a 'real' crash. Throughout World War II, simulated flight and gunnery training became common. In the later stages of the war, physicists and engineers sometimes managed to harness analog computers to simulation, with astounding consequences. The introduction of the computer permitted critical advances on three fronts: (1) Simulated experience became more 'realistic' due to finer-grained responses and shorter response time. (2) More situations and variables could be introduced. (3) The new capacity to inject information into simulation based on the real-time solution and representation of complex mathematical equations not only refined simulated learning but also transformed simulation into a research tool. Very soon, simulation moved beyond training and became a central instrument in technical design, particularly for aircraft and rocket development. One perceives here the genesis of a virtual simulation cycle in which the 'reality-constrained' feaures in technology simulation fuel and advance the 'symbol-bounded' features in science simulation; and the symbol-bounded methodologies, representations, and proofs of simulation in science nurture the realities embodied in technological simulations.

The advent of the digital computer triggered a radical transformation that changed simulation from a refined technology for imitation into a full-scale polyvalent research instrument. Nonetheless, at first glance, the shift within simulation might appear to be rather trivial and mainly technical, constituting an important advance, but not a decisive one. In flight training, for example, analog devices were replaced by digital computing devices. Yet, despite this technical substitution, for all ostensible purposes, the flight simulator remains a flight simulator. However, this seeming invariance obscures a fundamental discontinuity. The transition from analog devices to digital simulation models, which, for example, describe the dynamic behavior of a plane's wings, transformed the very essence of even the flight simulator by enabling it to generate physically possible, even likely, aircraft performance, which to date had not yet been observed. In effect, the flight simulator commanded by a digital computer is capable of extending a vehicle's latent material conditions and the scope of pilot experience beyond observed routines. The meaning of simulation is thereby deeply transformed. This book is devoted to digital computer simulation. It will focus on the new aspects introduced through computer simulations, distinguishing them from older usages.

The student of the practices, epistemology, and social dynamics of computer simulation wants to know how and why this important transformation came about. Was it connected with the introduction of new problems, or even a new species of problem on the research agenda that could not be examined other than by simulation? Did the acceptance and spread of simulation in science signify the introduction of some new, commonly accepted form of proof of the reliability of simulation outputs? Does simulation represent a general switch, whereby a younger generation sets itself apart from older generations through the adoption of a formerly low-status and little used technique? And, beyond all this, can the prevalence of simulation in science today be likened to a 'paradigm shift': Does it necessarily entail the emergence of a new way of knowledge production incommensurable with the common ones (that is, theory and experiment)? Or more conservatively, is simulation instead mainly a tremendously powerful generic instrument, constituting an enabling device? These questions themselves reveal that simulations mark a multifaceted change, as indicated by the following four interacting factors:

1. The pace of evolution in the speed and capacity of calculation in computer technology (Humphreys 2004) obtained through the technological development of hardware and software makes increasingly complex problems accessible. The steep increase in speed and quantity is an important determinant of the possibilities and limiting conditions of simulation as an instrument. Developments in high energy physics (Merz, this volume) and in economics (Boumans, this volume) document how the availability of the computer as a technological instrument has opened up new fields of application that have, in turn, permanently driven the

scientific characteristics of simulation. On a slightly different register, the total reliance of nanotechnology research on the computer demonstrates, for instance, that computer simulations go far beyond simply generating a mutual adaptation between science and the computer: The computer has changed the very nature and form of the questions being asked in this field and has transformed the models being constructed (Johnson and Winsberg, this volume). The technology of the computer is by no means fixed, and with increasing computing power, things change decisively.

2. This development is connected closely to the capacity to generate visualizations, to process images, or more generally, to handle ever more sophisticated man-machine interfaces. Computer images render visible the fine-grained details of atoms (in nanoscience, see Johnson and Winsberg, this volume) as well as the global dynamics of the climate (both in Technicolor). Such graphics underline the character of simulation as an 'observational instrument,' but one in which the concept 'observation' assumes an entirely novel meaning. They can enable access to complex patterns of behavior undetected by classical instruments such as telescopes or microscopes. Whereas telescopes and microscopes render phenomena visible by affecting the *scale* of 'tangible' entities through optical processes of resolution, simulation renders 'visible' the affects of parameters and forces such as time, dynamic interactions, and so forth that are not dealt with by optics-related transformations. Thus, simulation, by constructing images, may translate absolutely nonvisual events into a visual media! Often there is no opportunity to compare simulated images with the original – there may be no possible perspective from which to view things like this, or it may even be that the depicted material does not exist in the real world. Hence, simulations may equip virtual worlds with visual and other qualities that do not mirror those of real-world processes. Ihde (this volume) analyzes the computer as a new 'epistemology engine' that succeeds the 'camera obscura' as the paradigm in epistemology.
3. Language is also an essential factor in the development of simulation. The evolution of complex and powerful programming languages has turned simulation into a manageable instrument. Algorithms implemented in software packages have made simulation methods, at least partly, a ready-made tool. The structure and features of programming language, for example, object orientation, determine to an important extent how programs can be conducted and how the practice, including the social practice, of programming operates. Shinn (this volume) considers the significance of this evolution in some detail.
4. Today, simulation has penetrated innumerable spheres of social experience, becoming manifest in ways totally undreamed of thirty or forty years ago! In the realm of medicine, 'artificial organ transplants' are tested in a simulated human body before being implanted in patients. Simulations form an essential part in the design and manufacture of technological artifacts from cars to bridges and buildings. The market for computer games and simulated film sequences is an instance in which increasingly more realistic virtual worlds are offered. What may reasonably be described as the cultural evolution of simulation, or co-evolution of culture and simulation, is also an important factor, because it opens up new atti-