Computation and Simulation

Johannes Lenhard

Abstract

Intro
The digital computer, since its invention about 60 years ago, has become a widely used instrument that heavily influences scientific practice. The present chapter will concentrate on the digital computer and consequently will understand simulation as digital computer simulation. Roughly in parallel to the development and spread of the computer, simulation has become established as a new means for knowledge production. The amount of computing power that has become available over the last 25 years is undoubtedly one reason for this development. However, computer simulation affects the social, cognitive and organizational spheres of science. In particular, simulation practices involve the concept of interdisciplinarity in many and partly new ways.

(1) historical development
Digital computer simulation emerged in the scientific-military context of the Manhattan project. This first pioneering phase (about 1940-1960) saw an interdisciplinary effort to establish computation and simulation in the context of 'big science'. This phase comprises the cybernetics group and the Macy conferences, the spread of the first machines like ENIAC, and a variety of newly invented mathematical modelling techniques like Monte Carlo or cellular automata.
During a second historical phase, roughly from 1960-80, the field of simulation underwent disciplinary specialization. Computer science came into being; it was – and still is – controversial whether it constitutes an own discipline or is of an interdisciplinary nature.
The third phase is linked to the wide availability of smaller machines – personal computers and workstations – that made computation and simulation largely independent of 'big science' and transformed them into a virtually ubiquitous phenomenon. A spectrum of computational sciences appeared. From the beginning on, most of these fields perceived themselves as transforming existing disciplinary fields into interdisciplinary ones.

(2) relation to education
Simulation/gaming and virtual reality pretend to produce a virtual environment that can substitute the 'real' environment for certain – and especially educational – purposes. This field conceives itself as an own, cross-cutting discipline that has an interdisciplinary nature because to produce an appropriate virtual environment presents a highly interdisciplinary task. It will also be discussed how aspects of education and research interact in fields like medicine (e.g. endoscope simulator), engineering (design and testing of vehicles) and science (climate models).

(3) relation to research
Typically, simulation is applied in complex modelling tasks. One important feature of simulation models is that they can consist out of a multi-disciplinary variety of relatively autonomous sub-models. These models can be coupled in a technical sense and turn the simulation model into an interdisciplinary object. The characteristics of this simulation-based type of interdisciplinary integration will be discussed.
The impact of the organisational context – big computing centers vs. distributed PCs – will also be taken into account in this section.

(4) specific areas
Climate science will be presented as a paradigmatic case.
Simulation models are essential for predictions in this area. Two important topics will be analyzed: First, the network-like integration of different disciplinary models into a model of the climate system that is not based on an overarching theory. This case exemplifies important features of simulation modelling, including social and cognitive organisation of complex modelling tasks.
Second, the simulation models work as 'boundary objects' between policy and science.

(5) what works and what has not worked
Computer simulation is very influential because it directs the framing of problems and questions formulated by science. There is a corridor where complex interdisciplinary questions can be tackled by computer simulation, but this corridor is limited by computational complexity – a concept that has been developed to mark the limits of applying computational power. During the development of simulation, there have been frequent surprises about what is possible, e.g. the computer as a general purpose machine, and also what seems to be impossible, see, e.g., the missing results of artificial intelligence.

(6) needs and prospects
Simulation and computing still change the face of science, hence diagnoses may be outdated quickly. A critical understanding of the technological nature of this instrument and its implications is still missing.
Computer simulation often comes along with a distributed architecture. The kind of interdisciplinarity involved here is not yet fully conceptualized.

(7) essential readings and links