Cellular Automata and the Quest for Artificial Self-Reproducing Structures

Martin Kutrib

Institut für Informatik, Universität Giessen
Arndtstr. 2, 35392 Giessen, Germany
kutrib@informatik.uni-giessen.de

More than half a century ago John von Neumann had become interested in the question of whether computing machines can construct copies or variants of themselves, whether artificial self-reproducing structures exist. At that time DNA had not yet been discovered as the genetic material in nature, nor did von Neumann have the tools for building a real machine at the bio-chemical or genetic level. He started to investigate the logic necessary for replication and found one of the cornerstones in the theory of automata. He employed a mathematical device which is a multitude of interconnected finite-state machines operating in parallel to form a larger machine. He showed that it is logically possible for such a nontrivial computing device to replicate itself ad infinitum. Such devices are commonly called cellular automata, and can be considered as homogeneously structured models for massively parallel computing systems. The global behavior of cellular automata is achieved by local interactions only. While the underlying rules are quite simple, the global behavior may be rather complex. In general, it is unpredictable.

We will review von Neumann's self-reproducing cellular automaton. Then the general question is considered as to what kind of logical organization is *sufficient* for an artificial structure to be able to reproduce itself. The question is not precise and admits to trivial versions as well as interesting ones. Thus, simpler machines than von Neumann's are shown to be capable of reproducing themselves. So, the question as to what kind of logical organization is *necessary* for an artificial structure to be able to reproduce itself arises immediately. This brings us to so-called universal constructors, which are structures that can construct any structure (of the same type) described in its input and, in addition, can provide a copy of their input to the structure constructed.

Inspired by these ideas and results, further issues concerning artificial structures and self-reproduction are presented.