18.337 Parallel Scientific Computing	February 7, 1995
Lecture 6	
Topic: Cellular Automata Machines	*1995 Scribe: Jose L. Jimenez*

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1 The MIT LCS Information Mechanics Group [3]

Information Mechanics is a research group at the MIT Laboratory for Computer Science (LCS) working on the physics of computation. This group has been active for 17 years, and its main theme has been to try to "put more physics" into the computer architecture. "If your computer looks like your physical system , the calculations go much faster."
Check out their WWW Home Page (http://www.im.lcs.mit.edu). It has many great pictures!

2 What are Cellular Automata?

A *Cellular Automaton* (CA) is a discrete dynamical system consisting of finite-state variables, or cells, arranged in a uniform grid. The overall dynamics is specified by a finite rule, by which at every time step each cell computes its new state from the current state of its neighbourhood. Surprisingly enough, cellular automata can faithfully model continuum systems such as fluids; unlike differential equations, they can be realized exactly by digital hardware.
They explode the model of serial computation, which could be done by a person; instead with CA we want nature to do something for us.

3 Why are they interesting?

The first reason of the interest of CA is that they can be implemented efficiently. Also they can be scaled down to microscopic realizations: the "computer without wires," operating by the interaction of fields. They can also be scaled up to very large number of computing elements: we would have then a computing material, the "Computronium". Last, but not least, they can perform *interesting* calculations *efficiently.*

4 What are Cellular Automata Machines?

Modeling with cellular automata is poorly supported by conventional scientific computers, whose architecture is optimized for the arithmetic treatment of continuum models. With a more appropiate architecture one can easily gain a performance factor of at least 10,000 in the simulation of cellular automata; this gain is of such magnitude that new classes of conceptual models have become computionally accesible, like simulation of fluid dynamics with molecular dynamics.

5 What are they good for?

CA machines hold more promise in areas where there are no alternatives to direct simulation at a very low level.. These are in general complicated problems like flow through porous media, for which the simulation from molecular dynamics seems the only method that can produce satisfactory results. Competition from simpler, more mature methods is overwhelming in most other problems.

6 The CAM-8 machine

CAM-8 is the latest product of over a decade of Cellular Automata machines and modeling research by the Information Mechanics group at the MIT Lab for Computer Science. CAM-8 is a fine-grained, spatially-organized mesh-architecture multiprocessor. The object of the project is to advance the state of Cellular Automata modeling of physics, by making available hardware that can take advantage of the inherent efficiency of simple, uniform, spatially organized computation. CAM-8 offers unprecedented performance in the fine-grained modeling of spatially-extended systems.

The specifications of the CAM-8 prototype are as follows:

- System clock: 25 Mhz
- Number of nodes: 8
- DRAM: 64 Mb
- SRAM: 2 Mb
- Site updates: 200 M/s
- Front End: SPARC station

It has been used to simulate a number of problems, including diffusion-limited aggregation and dendritic growth, phase separation, surface tension effects, lattice gas hydrodynamics, multiphase fluids, excitable media, digital circuitry simulation, real-time adaptive contrast enhancement and stereoscoping imaging. You can get more information on these applications, together with some really cool pictures at the IM WWW home page: http://www.im.lcs.mit.edu.

7 Conclusions

Cellular Automata are a step to move the computation closer to the physics. In order to do this CA machines are needed, because the perfomance of normal scientific computers when simulating CA is very poor.
Today they are best for spatial calculations. In the long run everything could be done with them (e.g. FPGA's).

8 References

[1] Toffoli, T., and Margolus, N. Cellular Automata Machines: A New Environment for Modeling. MIT Press, 1987.
[2] Margolus, N., Toffoli, T., and Vichniac, G. "Cellular Automata Supercomputers for Fluid-Dynamics Modeling." Physical Review Letters, vol. 56 (16), 1986.
[3] Infomation Mechanics group WWW Home Page: http://www.im.lcs.mit.edu.