Nature computes

BY SELIM G. AKL

In our never-ending quest to understand the workings of Nature, we humans began with the biological cell as a good first place to look for clues. Later, we went down to the molecule, and then further down to the atom, in hopes of unravelling the mysteries of Nature.

Today, however, a growing number of scientists are suggesting that the most essential constituent of the universe is the bit, the unit of information and computation. Not the cell, not the molecule, not the atom, but the bit may very well be the ultimate key to reading Nature's mind.

Does Nature compute? Indeed, we can model all the processes of Nature as information processes. For example, cell multiplication and DNA replication are seen as instances of text processing. A chemical reaction is simply an exchange of electrons, that is, an exchange of information between two molecules. The spin of an atom, whether it spins up or spins down, is a binary process, the answer to a "yes or no" question. Information and computation are present in all natural occurrences, from the simplest to the most complex. From reproduction in ciliates to quorum sensing in bacterial colonies, from respiration and photosynthesis in plants to the migration of birds and butterflies, and from morphogenesis to foraging for food, all the way to human cognition, Nature appears to be continually processing information.

Computer scientists study information and computation in Nature in order to:

1. better understand natural phenomena. We endeavour to show that the computational paradigm is capable of modelling Nature's work with great precision. Thus, when viewed as computations, the processes of Nature may be better explained and better understood at their most basic state.
2. exhibit examples of natural algorithms whose features are sufficiently attractive, so as to inspire effective algorithms for conventional computers. Nature's algorithms may be more efficient than conventional ones and may lead to better answers in a variety of computational situations.
3. identify problems where natural processes themselves are the only viable approach toward a solution. Such computational problems may occur in environments where conventional computers are inept, in particular when living organisms, including the human body itself, are the subject of the computation.
4. obtain a more general definition of what it means "to compute." For example, is there more to computing than arithmetic and logic? Natural phenomena involve receiving information from, and producing information to, the external physical environment – are these computations?

The motto of the Queen's School of Computing is "Sum ergo computo", which means "I am, therefore I compute". The motto speaks at different levels. At one level, it expresses our identity. The motto says that we are computer scientists. Computing is what we do. Our professional reason for being is the theory and practice of computing. It also says that virtually every activity in the world in which we live is run by a computer, in our homes, our offices, our factories, our hospitals, our places of entertainment and education, our means of transportation and communication. Just by virtue of living in this society, we are always computing.

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At a deeper level, the motto asserts that "Being is computing." Computing permeates the universe and drives it: every atom, every molecule, every cell, everything, everywhere, at every moment, is performing a computation. To be is to compute.

Today, more than ever, it is great to be a computer scientist. Never before has there been a more exciting period in the history of computing. Not only is our field shaping all aspects of today's society, but information and computation are being recognized as fundamental to life itself! ■

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