Parallelism of Paradigms in Non-Classical Computation

Richard E Overill*
Department of Computer Science
King's College London
The Strand
London
WC2R 2LS
U K
reo@dcs.kcl.ac.uk

1 Introduction

The degree of parallelism of a physical process defines one metric for the computational capacity of that process. The number of states present at any instant gives a theoretical upper bound on the amount of computational work that can be leveraged from that process.

The means by which physical processes harness parallelism and the degrees of parallelism that they are able to achieve differ significantly between non-classical paradigms. It is possible, even likely, that a study of this aspect of non-classical computation will furnish a framework within which to assess the potential computational capabilities of different physical systems.

We now offer some examples of this approach.

*contributed to the GC-7 workshop, York, 18–19 April 2005

2.1 Quantum Computation

In the case of quantum computation an n-qbit qregister is represented as a coherent linear superposition of 2^n states. This paradigm offers a potential exponential degree of parallelism equal to 2^n.

2.2 DNA & RNA Computation

In the nucleic acid computational paradigm a mole of nucleic acid contains roughly an Avagadro Number ($N_A \sim 6 \times 10^{23}$) nucleic acid molecules. Each molecule is regarded as a code string formed from an 'alphabet' of 4 'letters' (the bases). Thus the degree of parallelism here is N_A.

2.3 GA, AIS & Swarm Computation

In the genetic algorithm, artificial immune system and swarm computation paradigms a population of chromosomes, antibodies or insect agents respectively is allowed to evolve and learn by optimising against some form of fitness function. The chosen population size N of each generation determines the degree of parallelism available.

2.4 The Computational Universe

The ultimate extension of these ideas is to regard the entire universe as an analogue computer or computation, as proposed by Seth Lloyd in 2002. By reformulating the laws of physics in terms of information theory the universe can be shown to perform up to 10^{106} operations per second and to contain at least 10^{92} bits – in fact the universe has performed the maximum number of operations permitted by the laws of physics.

3 Summary

We suggest that the degree of parallelism associated with a physical process provides a useful metric of its potential computational capacity or capability, at least to zero order.