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Life for life: biologically inspired computation for future computing applications

Paul Marrow

Pervasive ICT Research Centre, BT plc, Orion 1 PP 12, Adastral Park, Martlesham Heath, Ipswich IP5 3RE, UK
paul.marrow@bt.com

The diversity and complexity of the natural world has attracted considerable attention among both biologists and computer scientists (Camazine et al. 2001). Biological systems are complicated and interconnected on many different spatial and temporal scales. Present day computer systems are also more complex than ever before, but have reached this stage in a much shorter time. Computers and embedded computing devices are used to manage processes in many aspects of human society, often in the form of ICT (Information and Communications Technology) linking together computing and telecommunications. Some application sectors are particularly complex because of their close involvement with human society, for example the healthcare sector. Novel applications are needed to deal with problems in this area; but in the long term we also need new ways of computing in order to keep up with increasing demands upon systems. Can we draw upon insights from the living world in devising applications and novel systems for the healthcare sector? There certainly is a track record in nature-inspired computing that suggests its relevance in solving challenging problems.

Evolution has been a key focus for understanding in biological research, ever since Darwin. The dynamics of the evolutionary process generate complex outcomes even from relatively simple interactions (Marrow et al. 1996). Consequently there has been much attention paid to evolution and other biological phenomena as sources of software design and computational algorithms (Shackleton & Marrow 2000), drawing on such areas as social insects (Camazine et al. 2001), biological ecosystems (Marrow et al. 2003), evolution (Poon et al. 2000) and development (Tateson 1998). These sources of inspiration are perhaps particularly appropriate when solutions are needed that are distributed, component- or population-based. In the case of ICT this is often the case as computational software solutions must be able to operate across telecommunications networks. Evolutionary algorithms can be used to solve design and optimisation problems (Poon et al. 2000). The interaction between populations in biological ecosystems inspired the DIET multi-agent platform (Marrow et al. 2003), a tool for researching distributed software applications. Developmental processes provide inspiration for channel allocation in dynamic mobile telecommunications networks (Tateson 1998). Shackleton and Marrow (2000) present a range of examples of nature-inspired computing applications.

Development of novel computational algorithms that run on current computational architectures is one way of tackling the demands on today's and the near future's computer systems. Novel hardware is another approach, drawing upon different materials with novel properties. But we also need to look at new ways of designing computational architectures, irrespective of the hardware used, which can be used as general bases for programs. This is a much more challenging area than thinking of novel algorithms that can run on conventional computational architectures, but also one in which it may be worth considering biological systems, which persist in complicated architectures at different levels. For example, multiple individuals making up populations linked together in ecological communities. At the same time developmental processes produce the complex morphologies of individuals from relatively simple (although complex in detail) individual cells, and complex molecular processes manage and operate processes within cells. All these levels are worth considering. Living systems may be a source of inspiration at many different levels.

Given the near ubiquity of current computer systems, and unsolved problems in many areas relating to conventional applications, why should we focus attention on areas very different from the core of current computing?

This is because of the continually increasing demands expected of computing and ICT applications - and the increasing importance of their solutions. This is particularly important in sectors such as healthcare where results from ICT may be associated with critical decisions by staff. Communication and coordination between nodes in ICT applications is particular important in contexts such as: emergency service deployment, electronic patient record management, distributed medical imaging or collaborative information tools for clinicians. Such applications can be designed and run on conventional computers by current conventional algorithms - but they are constrained by the same limitations as apply to other applications in other sectors.

In this sector, if improvements can be gained by seeking out novel approaches to computing then they could be lifesaving. Hence drawing inspiration from life, in the sense of biological diversity, could have benefits for multiple peoples' lives if their treatment is affected by the interaction between clinicians and ICT applications.

References

Camazine, S Deneubourg, J-L, Franks, N, Sneyd, J, Theraulaz, G, Bonabeau, E 2001 Self-Organisation in Biological Systems. Princeton.

Marrow, P Dieckmann, U Law, R 1996 Evolutionary dynamics of predator-prey systems: an ecological perspective. J Math Biol 34(5/6), 556-578.

Marrow, P Hoile, C Wang, F Bonsma, E 2003 Evolving preferences among emergent groups of agents. In: *Adaptive Agents and Multi-Agent Systems*, Alonso, E, Kudenko, K & Kazakov, D (eds.) LNAI 2636, pp. 159-173. Springer.

Poon, KF Conway A Wardrop, G Mellis, J 2000 Successful application of genetic algorithms to network design and planning. BT Technol J 18(4), 32-41.

Shackleton, M & Marrow, P (eds.) 2000 Nature-inspired computation, special issue BT Technol J 18(4). http://www.btexact.com/publications/bttj?doc=4253

Tateson, R 1998 Self-organising pattern formation: fruit flies and cell phones. Proc. 5th Intl. Conf. Parallel Problem Solving from Nature (PPSN-V), pp. 732-741. Springer.