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Understanding Organization (Self) Beyond Computation

We have blithely carried on for 60 years under the assumption that Church's thesis is correct--that ordinary machines can do no more computation than a Turing machine. Quantum mechanics suggests that Church's thesis does not apply to quantum computation. The centerpiece of the arguments of Seth Lloyd and Steve Wolfram are (implicitly!) that Church was correct. But others, e.g., Warren Smith, have been trying to chip away at Church. If it turns out that Church's thesis is not correct, then our whole approach to computational modeling, computational biology, artificial intelligence, and artificial life may have to be rethought. At one level that shouldn't surprise us--after hundreds of years of solid mathematical underpinnings, physics had two equally major upsets (as the incorrectness of Church's thesis would be for computer science) at the beginning of the 20th century.

Whether Church’s thesis is correct or not there is a yet bigger question—it just has completely different answers in the two cases. That bigger question is how it is that biological systems are able to self organize and self adapt at all levels of their organization—from the molecular, through the genomic, through the proteomic, through the metabolic, through the through the neural, through the developmental, through the physiological, through the behavioral level. What are the keys to such robustness and adaptability at each of these levels, and is it the same self-similar set of principles at all levels? If we could understand these systems in this way it would no doubt shed fantastic new light on better ways to organize computational and post-computational systems across almost all sub-disciplines of computer science and computer engineering.

Thus our grand challenge is to find a new “calculus” for computational systems that let us begin to control the complexities of these large systems that we are today building on an ad-hoc basis, and holding together with string and baling wire, instead of with genuine understanding.

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Rodney Brooks is the Fujitsu Professor of Computer Science and Engineering at MIT, and director of the MIT Artificial Intelligence Laboratory. He received B.Sc. and M.Sc. degrees in pure mathematics from the Flinders University of South Australia and a Ph.D. in computer science from Stanford in 1981. He has held research positions at CMU and MIT, and a faculty position at Stanford before joining the faculty at MIT in 1984.

After early work in model-based vision and model-based robotics Brooks developed the subsumption architecture and the behavior based approach to robotics. Concurrently he was the main compiler developer for Lucid Common Lisp. In the 1980's he developed robots based on insects, and in the 1990's worked on humanoid robots. Recently he has turned his attention to fundamental questions of what makes something living and is developing a new research program with three prongs: building robots with properties that living systems have but which robots have not previously had, building large scale computational experiments exploring self organization in many different forms, and trying to abstract mathematical principles from these first two endeavors.

Rodney Brooks is also Chairman and CTO of iRobot Corporation, and on the boards and advisory boards of numerous robotics and AI companies, and on the editorial boards of numerous journals. His most recent book is "Flesh and Machines: How Robots Will Change Us" from Pantheon, 2002. His most recent interesting paper is "The Relationship Between Matter and Life", Nature vol 409, pp409-411, 2001. His most recent movie is "Fast, Cheap, and Out of Control", Sony Classic Pictures, 1997.

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