Natural Computation—A Perspective from the Foundations of Quantum Theory

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Abstract. The framework of classical physics is based on a mechanical conception of nature, a conception which is mirrored in the Turing model of computation. Quantum theory has, however, fundamentally challenged this conception. The mathematical formalism of quantum theory consists of a set of postulates, most of which are at odds with the corresponding postulates of classical physics. For example, quantum measurements may have a finite number of possible outcomes, are probabilistic, are disturbing of the measured system, and in general only yield information about a fraction of the state of the measured system. Moreover, the quantum formalism does not specify what kind of physical process constitutes a measurement. In the eighty-five years since its creation, these and other non-classical features have defied any coherent understanding in terms of a new conception of nature. In recent years, there have been numerous attempts to derive the mathematics of quantum theory from a small number of informationally-inspired physical postulates, and this is providing a new, clearer perspective on just what physical ideas are implicit in the quantum postulates. In this paper, I will outline one such derivation, describe some of its implications for the assumptions implicit in Turing’s model of computation.

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