A02

58

NEW TRENDS IN QUANTUM INFORMATION

edited by

Ammar Sakaji, Ignazio Licata
Jatinder Singh, Sara Felloni

ARACNE editrice S.r.l.

www.aracneeditrice.it
info@aracneeditrice.it

via Raffaele Garofalo, 133/A–B
00173 Roma
(06) 93781065

ISBN 978–88–548–3411–8

1st edition: July 2010

Table of Contents

9 There's Plenty of Hidden Information at the Quantum Bottom
IGNAZIO LICATA

15 Effective Physical Processes and Active Information in Quantum Computing
IGNAZIO LICATA

33 Q-Numbers, Paravector Logic, Geometric Qubit and Information Processing in Eight Dimensions
VICTOR I. TARKHANOV AND MICHAEL M. NESTEROV

53 Quantum Information Manipulation: Topology, Formal Languages, Groups
MARIO RASETTI AND CHIARA MARLETTO

81 The Problem of Quantum Measurement and Entangled States: Interactions Among States and Formation of Detector Images
FARIEL SHAFEE

111 Hidden Statistics Approach to Quantum Simulations
MICHAIL ZAK

125 Quantum Information and Statistical Inference
Alessandra Luati

155 Quantum Potential as Information: A Mathematical Survey
Robert Carroll

191 Formulas for Mutually Unbiased Bases in Systems of Qudits
Maurice R. Kibler

211 Dynamic Single-Slit and Double-Slit for the Entanglement in Triple-Qubits Systems
W.X. Yan,Wenfang Li, X.P. Li, T.D. Wen and L.P. Xu

223 Quantum Entanglement with Gaussian States
Jatinder P. Singh and Devendra Singh

247 Impossibility of Probabilistic Splitting of Quantum Information
I. Chakrabarty and B.S.Choudhury

257 A Gradient System on the Quantum Information Space Realizing the Karmarkar Flow for Linear Programming – A Clue to Effective Algorithms –
Yoshio Uwano and Hiromi Yuya

277 Quantum Algorithms by Diagrams of States: Deutsch and Grover's Algorithms
Sara Felloni and Giuliano Strini

299 Quantum Robot: Quantum Mind Control on a Quantum Computer
P.A. Zizzi

319 Practical Quantum Communication and the Quantum Communication Workshop 2010
Sara Felloni

341 QKD Standardization in ETSI
Gaby Lenhart and Thomas Länger

There's Plenty of Hidden Information at the Quantum Bottom

Ignazio licata*
ISEM, Institute For Scientific Methodology, PA, Italy

Quantum computation is not just a technological promise, but the most challenging test for the conceptual problems in Quantum Mechanics. Nowadays Experimental Metaphysics (A. Shimony) is a well-established activity much more complex than any old contraposition between naïve realism and slippery randomness. We could say that Schrödinger's cat has been tamed and is leading us along the most charming paths of the physical world. At the same time, there are emerging problems which suggest to deeply reflect on the connections between Physics and Computation Theory. In fact, it is well known that even if all de-coherence problems were solved, quantum computing performances should not be qualitatively different from the classical computer ones, except for few cases when the superposition state makes possible to transform an exponential time of computation in a polynomial time. NP-complete problems appear thus impregnable even by traditional quantum computing, to such an extent that it has been suggested to consider the impossibility to use the known Physics' laws to build a computer able to solve NP-complete problems as a new principle – just like thermodynamic ones- (Aaronson, 2005).

It is known that a Quantum Turing Machine can be formally defined so as to extend the classical paradigm to the calculation with qbit (see, for example, Perdrix and Jorrand, 2006). The outcome is however controversial: within such scheme Quantum Computation does not seem more powerful, but only more effective. And more: in some cases it is possible to demonstrate that the performances of the Turing scheme-based Quantum computing can be obtained also by classical systems in polynomial time (Ahronov, 2007; Calude, 2007). All that sounds paradoxical. In fact, the local and classical world emerges from the non-local quantum one. This one permeates any aspect of the physical world. Turing Machine is a computation model strongly connected to classical, local

*Ignazio.licata@ejtp.info

and deterministic physics. So the proper question is whether the Turing model is really the best scheme for quantum information. The idea of qbit allows to expand easily the traditional concepts of algorithm and universality, but on the other hand the great informational resources of quantum correlations are penalized. In particular, with “quantum gates”, the constrains of reversibility and unitarity limit the possibility to detect quantum information just to the outputs of superposition states; and yet nothing prevents us from thinking of a different approach to quantum systems which, within peculiar experimental arrangements, can get qualitatively different answers and be endowed with oracular skills, so turning into a resource all non-locality features, even those which are traditionally regarded as a limit within the classical scheme, such as de-coherence, dissipation and probabilistic responses.

In other words, Quantum Turing Machines constrain the quantum system to yes/no answers, whereas the real computational vocation of QM would be to use superposition and non-locality to obtain probabilistic oracles and beyond Turing barrier performance.

The recent debate on hyper computation has raised new questions both on the computational abilities of quantum systems and the Church-Turing Thesis role in Physics (Syropoulos, 2008).

Processing information is what all physical systems do. Such intuition first expressed by Rolf Landauer with exemplary clarity has recently risen from the ranks giving birth to extremely interesting and promising developments. The latest computational models have increasingly undermined the privileged position of Turing-Computation model and the role of Church-Turing thesis, as well. The various kinds of Unconventional Computing focus on either different vocations than Turing-Machine, such as the attention for the spatial and temporal features of computing, or schemes of information processing related to refined forms of non-linearity, fuzziness and infinite or non-computable many values (C. Teuscher et al. 2008).

We propose here the idea of “geometry of effective physical process” as the essentially physical notion of computation (Licata 2007, reprinted in this volume; Licata & Resconi 2009). In other words, computation is strongly tied to the very physical nature of the system and its global configuration, and the ”algorithm” is the evolution itself of the system. The notion of geometry has also a significance directly connected to the task: computation - considered as an activity oriented by an observer -depends on the adopted experimental configuration, and the hypercomputational potentialities - far from being limit situations only occurring in exotic physical environments - depend upon the transformations of the system’s geometry. Consequently the term ”programming” takes on a completely new meaning just in relation to the particular geometry the experimental apparatus defines.. In the same way as Gödel outcomes are considered ”limiting” within the Hilbert axiomatic program, whereas they reveal the open logic of mathematics if regarded from a more general viewpoint, the super-Turing possibilities of oracles emerge from a vision which links geometry to information.

The problem of alternative models becomes crucial in quantum computing.

The recent works on Adiabatic Quantum Computation and Quantum Neural Networks (Tien Kieu, 2004; Perus et al., 2004) thus suggest that a model for the ”Schrödinger Machines” has to be searched in a different direction as well as the classical paradigm appears as a ”Turing Cage” for the computational potentialities of Quantum Physics.

The quantum case has to be dealt with in different way. Here an ”active information” field (Bohm and Hiley, 2005) makes its appearance; it has no equivalent in Classical Physics and indicates the non-local features of quantum domain (superposition and ERP-Bell Correlation).The essential trait of Quantum Physics is non-locality, which could naturally perform the hypercomputation’s feature: exploring ”many worlds” in finite time by means of superposition and entanglement (Licata 2007). The Active information described is deeply different from classical one: it is, in fact, intrinsically not-Shannon computable; if it were so, it would mean to violate the Bell Theorem on the impossibility of a QM with local hidden variables. The QC hyper-computational potentialities thus derive from the ”unbounded” active information role in acting as ”oracular source” in particular experimental configurations. (Licata, 2008).

Such aspects could be important not only from a technological point of view-for nonlocal communication, cryptography, and exponentially-fast computation -, but they could reveal us something significant on the Universe origin and maybe on Quantum Physics structure itself. It has been hypothesized that the current arrangement of Quantum Theory (Born Rules) is the fossil of a quantum state far from equilibrium con strong non-local correlations and that has played a fundamental role in primordial universe (Licata & Chiatti, 2009; Valentini, 2002; 2010). Investigating the possibility to reproduce those conditions in laboratory could be the access to extraordinary and completely new resources.

In this volume we have tried to provide a panorama of these trends. On one hand the physics of traditional, Turing-based Quantum Computing – crucial to clarify the old foundational problems and surely decisive in the future in nanotechnology and quantum communication - , on the other the possibility of a broader concept of quantum information which will lead to a new pact between quantum dissipative field theory and the concept of computation in physical systems

The Editors (*Ammar Sakaji, Ignazio Licata, Jatinder Singh, and Sara Felloni*) owe the authors and the Editorial Board of Electronic Journal of Theoretical Physics (EJTP) which has been the “cradle” of the whole project, a lot. Ignazio Licata is particularly grateful to Mike Stennet, Cris Calude and to the HyperComputation group; Sara Felloni has been the precious *trait d’union* with the new tendencies emerged in “Practical Quantum Communication and the Quantum Communication Workshop 2010”, that event has been organized and supported by UNIK, the University Graduate Center of Kjeller, located at the Kjeller Technology Cluster, Oslo, Norway, and it has been co-supported by NISNet - The Norwegian Network in Information Security .

Ignazio Licata, EJTP Editor

References

[1] Aaronson S., NP- Complete Problems and Physical Reality, ACT SIGACT News, vol 36, n.1, pp.30-52

[2] Aharonov, D., Landau, Z., Makowsky, J. (2007) , The quantum FFT can be classically simulated , http://arxiv.org/abs/quant-ph/0611156

[3] Bohm, D. , Hiley, B.J. (2005),The Undivided Universe, Routledge

[4] Calude, C., De-quantizing the Solution of Deutsch’s Problem , International Journal of Quantum Information, Vol. 5, No. 4 (2007), pp. 1-7

[5] Chiatti, L, Licata, I. (2009), The Archaic Universe; Big Bang, Cosmological Term and the Quantum Origin of Time in Projective Cosmology, Int. Jour. of Theor. Phys., 48, 1003-1018, http://arxiv.org/abs/0808.1339

[6] Licata, I. (2007), Effective Physical Processes and Active Information in Quantum Computing , http://arxiv.org/pdf/0705.1173

[7] Licata I. (2008) ”Emergence and Computation at the Edge of Classical and Quantum Systems” in ”Physics of Emergence and Organization”, World Scientific, 2008, http://arxiv.org/abs/0711.2973

[8] Licata, I, Resconi, G. (2009) Quantum Computing in Non Euclidean Geometry, http://arxiv.org/abs/0911.0842

[9] Licata, I, Resconi, G. (2010), Computation, Physics and Geometry: an Unitary Perspective, submitted in Phys. Lett A.

[10] Kieu, T.D. (2004),A Reformulation of Hilbert's Tenth Problem Through Quantum Mechanics, in Proc. Roy.Soc. A, 460, pagg.1535-1545

[11] Perdrix, S. , Jorrand,P. (2006), Classically-controlled Quantum Computation, Electronic Notes in Theoretical Computer Science, 135, 33, pp. 119-128

[12] Perus, M. , Bishof, H., Loo, C.K. (2004), Quantum-Implemented Selective Reconstruction of High-Resolution Images, e.print in http://arxiv.org/abs/quant-ph/0401016

[13] Syropoulos, A. “Hypercomputation. Computing Beyond the Church-Turing Barrier”, Springer, 2008

[14] Teuscher, C.,Nemenman, I,.,Alexander, F.J (eds), (2008) Novel Computing Paradigms: Quo Vadis?, Phys D, 237, 8

[15] Valentini, A. (2002), Subquantum Information and Computation, Pramana J. Physics, 59(2), pp. 269–277

[16] Valentini A. (2009), Beyond the Quantum, Physics World, November 2009, pp. 32—37, http://arxiv1.library.cornell.edu/abs/1001.2758

Effective Physical Processes and Active Information in Quantum Computing

Ignazio Licata*
ISEM, Institute For Scientific Methodology, PA, Italy

Abstract

The recent debate on hypercomputation has arisen new questions both on the computational abilities of quantum systems and the Church-Turing Thesis role in Physics. We propose here the idea of "effective physical process" as the essentially physical notion of computation. By using the Bohm and Hiley active information concept we analyze the differences between the standard form (quantum gates) and the non-standard one (adiabatic and morphogenetic) of Quantum Computing, and we point out how its Super-Turing potentialities derive from an incomputable information source in accordance with Bell's constraints. On condition that we give up the formal concept of "universality", the possibility to realize quantum oracles is reachable. In this way computation is led back to the logic of physical world.

1 Introduction: "Purely Mechanical" (Turing, 1948)

One of the liveliest spheres in contemporary research is the study of the deep conceptual connection between Physics and Computation. Any physical system can be considered as an information processor continuously dialoguing with the external environment. The initial values are transformed into the final ones by the system's internal dynamics. The fundamental problem we deal with when working on such scenario is the role of Turing Computation in describing the informational activity of physical systems. The Church-Turing Thesis (CTT), in its strong form, states that any processing of syntactic information can be described by means of a suitable TM. To be more precise, any

*Ignazio.licata@ejtp.info