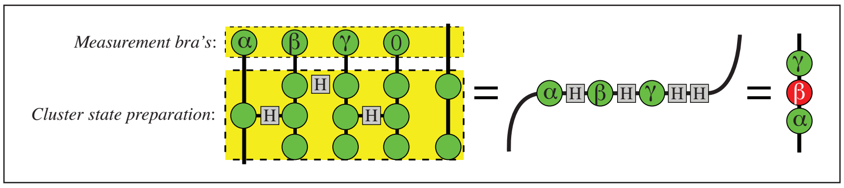
Where technology meets culture

Towards a quantum information society…

In the not too distant future, information technology will have to confront the challenge of the fundamentally quantum nature of physically embodied computing systems. Moreover, it is by now also well-known that this passage to the quantum scale comes with new computational opportunities, such as fast quantum algorithms, new modes of communication, and secure cryptographic protocols, which have no classical counterparts. Devices that enable quantum cryptography are now available for online purchase (id Quantique, MagiQ, SmartQuantum). However, many basic questions that are fundamental to the whole quantum informatics endeavour still remain to be answered, such as: 'What are the true origins of quantum computational algorithmic speed-up?' 'What are the limits of quantum information processing?' 'Which logical rules do interacting quantum systems obey?'

Answers to these questions will expose the true potential of quantum information technology, and will guide us towards a quantum information society. This endeavour needs to take place at the crossroads of the sciences, where technology meets culture. Indeed, in order to exploit the full potential of the capabilities the quantum world has provided us with, we will need to answer some of the deepest questions of science and philosophy, which aim to get a better understanding of the quantum world. Most likely the conclusions will dramatically change our overall conception of reality. The *QICS STREP entitled Foundational Structures in Quantum Information and Computation* seeks to expose the foundational structures that govern the behaviours of quantum informatic entities. This challenge is addressed in a number of complementary, but at the same time strongly interacting, strands.



One such strand involves both the design and study of the capabilities of novel quantum information processing architectures, which are radically different from the standard ones. One such model is measurement-based quantum computing (MBQC), where the information processing is realised by the act of observation. One of the key features of quantum theory is indeed that observations distort the state of a system. Understanding the nature of quantum measurement is one of the biggest challenges of foundational science, usually referred to as the measurement problem. MBQC turns this conceptual bug into a feature, ready for study and exploitation.

The QICS endeavour is highly multi-disciplinary, combining research in the foundations of computing, physics, logic and mathematics. While such an ambitious project obviously involves a high level of risk, the first two years of the project received glorifying reviews, pointing at the unexpected synergies between the different thematic strands, linking up radically separate areas of research, such as the fundamental non-local nature of quantum reality, MBQC, and a new area of mathematics, called categorical logic. The reviewers suggested an extension of the project to further explore the unforeseen novel intriguing avenues.

One of these avenues exploits the full potential of categorical logic, replacing the usual complex symbolic manipulations of quantum theory with a purely graphical formalism. While it obviously makes those computations much easier, up to the level that it trivialises them, it is also a great tool for knowledge transfer between disciplines, since it does not depend on prior knowledge of a certain mathematical formalism. Ongoing experiments explore the extent to which a (classical) computer can perform these graphical manipulations, ultimately leading to what could be referred to as automated quantum reasoning. The picture on this page is an example of such a graphical derivation within the context of MBQC.

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