A piece of the interaction

Oxford University's Dr Bob Coecke explores the idea that the study of interactions will help science develop a better understanding of the quantum world…

Quantum information and computation emerged from a change of attitude; namely, not to conceive quantum 'weirdness' as a bug, but rather as a feature. This change of attitude led to the discovery of many new physical phenomena and capabilities, such as quantum teleportation and quantum key-exchange, each of which provides a step towards a quantum information society. Recently, the change of attitude also resulted in new manners of reasoning about and representing quantum entities, something which opened new avenues towards reconciling the world of the (not so) very small (anymore) with the world of our everyday experiences. While in the development of genuine quantum informatic technology we still have some hills to climb, exciting new results have exposed unexpected and very promising synergies between quantum technology development and quantum foundations research.

Since its inception, many leading scientists (including Einstein) have been very unhappy with the world view dictated by quantum theory. This resulted in a whole industry of attempts to reconcile the quantum world with ours. While the resulting quest is arguably still one of the greatest philosophical challenges of the foundational sciences, at the end of the previous century it had become an uninspired debate between advocates of different so-called 'interpretations'. The quantum informatic endeavour injected some fresh perspectives into the debate, but these were disjointed from the actual progress towards quantum information technology. Some very exciting recent results changed this situation. They provided evidence for the fact that quantum foundations research can go hand-in-hand with technological progress. A new synergy was born between the conceptual and the practical.

Quantum theory predicts 'non-local correlations'. These are correlations between spatially separated events, which can only occur in the presence of instantaneous long-distance interaction. The subtlety here is that these correlations cannot be used to communicate any information faster than light. This fact guarantees that quantum theory is not in contradiction with Einstein's relativity theory. However, quantum correlations do not provide the only kind of non-local correlations that can live hand-in-hand with relativity theory. Recent work has shown how different (un)physical correlations of the quantum kind can be used to boost the computational power of classical computation. This led to important new insights on how the availability of certain kinds of correlations in a physical theory reflect how the quantum world and the world of our experiences interact with each other, and how we can exploit these interactions in an optimal manner.

There is, moreover, a growing realisation that the path towards understanding the quantum world will involve gaining a deeper understanding of the specific nature of quantum correlations. This will require a framework that allows one to compare different theories of interacting entities. Computer scientists have been developing frameworks to do so for quite a while now. They constitute the backbone for modelling the distributed hardware and software agents that are now part of our everyday life: mobile phones, internet terminals, electronic social networks, etc., resulting in a range of 'logics of interaction'.

The information society is indeed all about interaction. Our society, the economy, politics – all of these are fundamentally rooted within paradigms of interaction, be it plain human communication, the interaction of markets, or the interaction of nations. And there is increasing evidence that nature has been trying to tell us for over a century now that its smallest constituents are best understood in terms of a theory of interaction. Grasping and exploiting nature's message will require an interdisciplinary endeavour involving specialists in quantum information, computer scientists who are specialists in logics of interaction, and, not in the least, quantum foundations experts.

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