Quantum Cybernetic Control of Complex Systems

EPSRC DTG Centre in Complex Systems and Processes

Supervisors: **Dr Gerardo Adesso, School of Mathematical Sciences**

Dr David Branson III, Department of Mechanical, Materials and Manufacturing, Faculty of Engineering

'More is different',[1] complex systems are more than just the sum of their parts: ultimately their function is ruled by emergent behaviours, i.e. cooperative phenomena arising from the interaction of their individual components. Developing efficient ways to control and manipulate complex systems is pivotal for applications to robotics and bioengineering and to understand fundamental processes in living and artificial systems, both at the classical and the quantum scale.

Within the context of quantum cybernetics, a novel information-theoretic approach to the control of general regulative processes supported by quantum systems, we want to address the question of controllability of complex systems, both classical and quantum. The work will first focus on defining a satisfactory measure for how complex a system isin a way that is able to capture and quantify emergent behaviour. There are many measures of complexity[2], and we will focus on the concept of statistical complexity, which has been recently used to show that quantum models for complex systems feature a reduction in statistical complexity (i.e., less data needed to predict the system's future state) compared to classical models[3]. We will thus explore a promising range of applications of quantum models to reduce the computational demands of optimising and controlling in real time prototypes of cognitive robotics and complex data management. The second aim of the project is to exploit the inherent complexity of quantum systems as an enhancer strategy for control. The student will formally assess the additional resource enabled by quantumness for the regulation of complex systems, inspired by coding and compression theorems in quantum information and communication theory[4]. This is expected to lead to a deeper understanding of self-regulating systems, e.g. in biology, and, furthermore, to adapt this for decision making systems and machine learning.

We are looking for an open-minded, forward-thinking and highly motivated PhD student, willing to complete our team. The candidate is expected to have a strong background in applied mathematics and quantum physics. Experience with classical cybernetics is desirable but not required. The student will be trained in a combination of currently signposted subjects including big data, cognitive robotics, and quantum technology. The project will ultimately address questions of minimal

---

[1] P.W. Anderson, Science 4047, 177 (1972)
[2] S. Lloyd, Measures of Complexity, http://web.mit.edu/esd.83/www/notebook/Complexity.PDF
[3] M. Gu, K. Wiesner, E. Rieper, and V. Vedral, Nature Commun. 3,763 (2012)
[4] M. M. Wilde, Quantum Information Theory (Cambridge University Press, 2014)

modelling of large-scale systems and of the interplay between complexity and controllability in a truly interdisciplinary investigation.