AG Gross: All Things Quantum, Mathematical Physics, and the Theory of Data Analysis

http://www.qc.uni-freiburg.de

Research

The group works on the interface between quantum mechanics, mathematical physics, and applied math. Our main emphasis lies on the application of rigorous mathematical methods to problems in quantum information theory and many-body theory. Conversely, we aim to use methods originating in quantum physics to classical problems, e.g. in machine learning theory. We value mathematical rigor, creativity, and a broad mindset.

People

Set up in late 2011, the group is very young and international. Lead by a „Juniorprofessor", it currently consists of 9 members from five countries.

[Two additional positions (one postdoc, one PhD) opening in 2014 – applications welcome!]

Two Sample Projects Waiting for Candidates

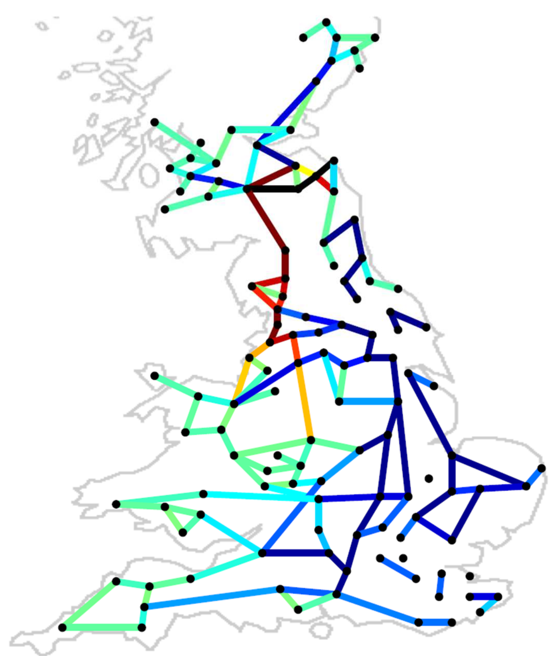
Efficient Network Recovery

Reconstructing networks from empirical data is a task that appears e.g. In biology (neural networks), quantum physics (coupling strengths between sites), and classical mechanics.

In the past years, new developments in statistical estimation theory (related to *compressed sensing*) have suggested non-trivial tricks for speeding up this process. While these have been shown numerically to yield good results, a rigorous mathematical proof is still missing.

This project has two components: First, come up with mathematical proofs for the numerically observed performance increases. Second, apply these findings to the particular case of state estimation in power grids – a task increasingly inportant as the grid moves to more decentralized, renewable energy sources.

While expertise on the first part is present in our group, we would team up with experts on network theory and power grids (from Göttingen and Jülich) for part two.



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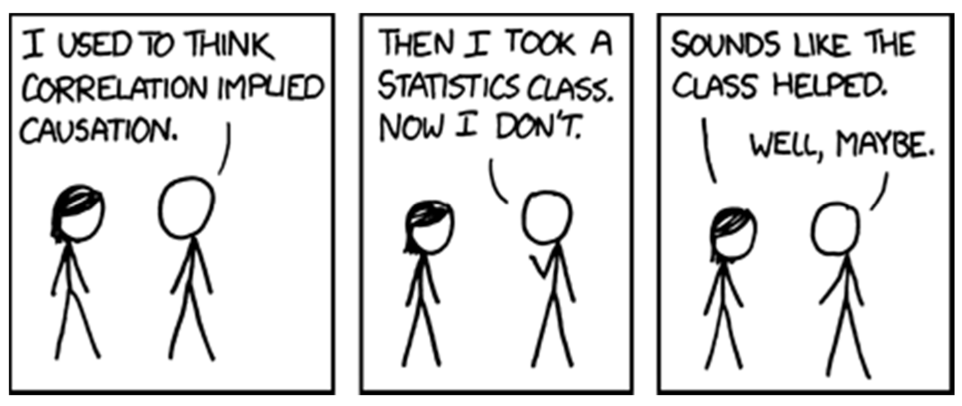
We note that the mathematical techniques involved here have found wide applications in the past five years: from quantum state estimation, over algorithms for face recognition, to prediction of user preferences in online shops.

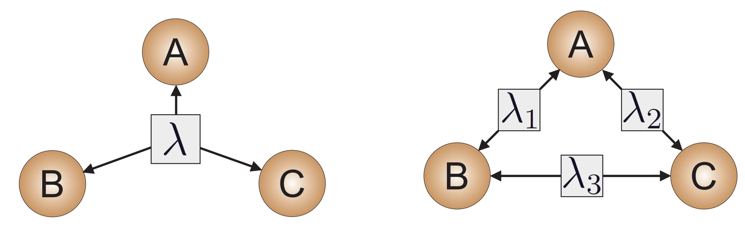
Causal Discovery and Quantum Non-Locality

Does smoking cause cancer? Or is there a gene that makes an individual more susceptible both to tumor growth and to tobacco addiction?

Traditionally, statistician confined themselves to describing *correlations* and would avoid making statements on the more relevant and illusive relation of *causation*. Since the late 90s, a mathematical theory of inferring causation from empirical observations has started to emerge and remains very active.

Around the same time, the quantitative study of *quantum non-locality* become a vibrant research field. The starting point was Bell's Theorem, which in a precise way describes how quantum correlations fail to be compatible with classical preconceptions of how the world works (e.g. that physical properties exist independently of whether or not they are observed). (Some here believe this to be one of the deepest structural insight about Nature ever to have been discovered).



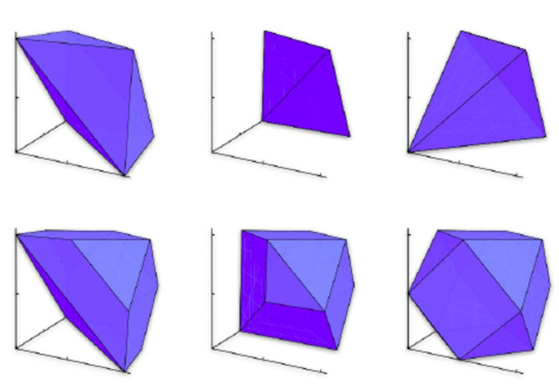


Very recently some researchers have found that many of the problems in causal inference share a mathematical formulation with those in quantum non-locality. In some way, non-locality can be seen as the failure of the classical concept of causal relations when applied to the quantum world.

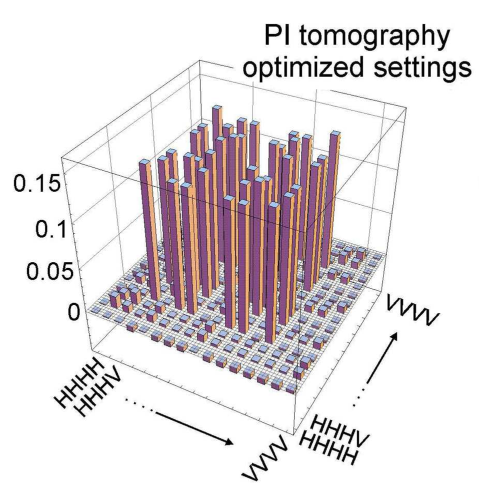
While focusing on quantum problems, we have developed a novel information-theoretic way of dealing with such causal inference problems. We want to now turn these ideas into tools for the classical treatment of causal models. To complement our quantum expertise, we work with experts on classical inference (Tubingen).

A host of numerical and analytical challenges that can be addressed on the M.Sc. level await an enthusiastic candidate.

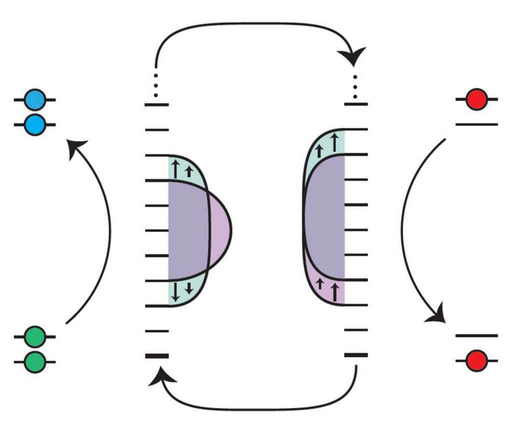
Some Other Recent Projects in the Group



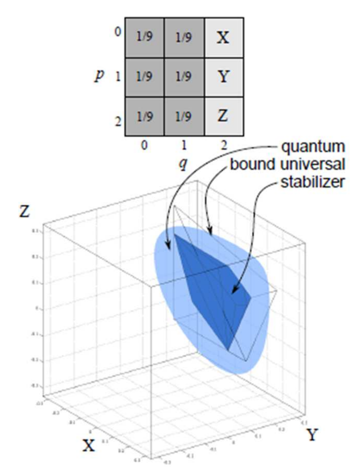
Entanglement from local data, generalized Pauli constraints, symplectic geometry, asymptotic rep theory



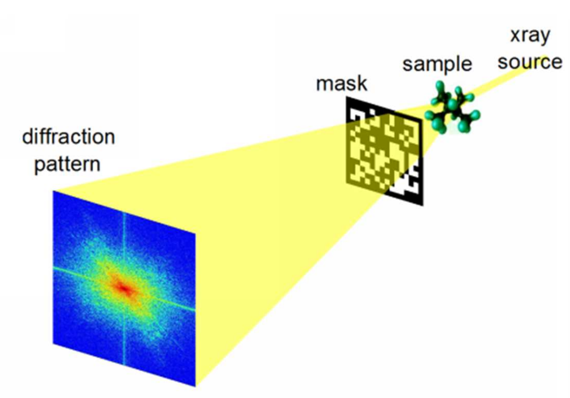
Experimental characterization of optical quantum states



Quantum thermodynamics, resource theory of coherence, negative quantum entropies



Phase space distributions for the efficient simulation of noisy quantum systems and analysis of quantum entropies



Data reconstruction from quadratic measurements: rigorous analysis of novel convex optimization approach