Quantum Computing Algorithmics

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Main topics in Quantum Computing (QC) research:

- How to use QC in new areas: AI, machine learning, optimization, consequence management, etc.
- How to improve QC algorithms – e.g., QC for secure communications.
- How to use QC techniques in modeling and analyzing human behavior.
- How to go beyond simple QC: e.g., use Quantum Field Theory effects.

More than 40 publications on quantum-related topics, typical:

- O. Galindo, L. Bokati, V. Kreinovich, "Towards a More Efficient Representation of Functions in Quantum and Reversible Computing", Proceedings of the International Quantum Systems Association (IQSA) Workshop on Quantum Structures, Prague, Czech Republic, September 9-13, 2019.

Why Quantum Computing (QC)

- For many practical problems, computers are still too slow
  (example: tornado prediction)
- There is a physical limitation on computer speed: speed of light: for a laptop it takes 1 nsec to go from one side to another
- To speed up, we need smaller components; they are already comparable with molecules; if smaller – we need quantum physics.
- Quantum effects are nuisance for deterministic computers.
- However researchers turned lemons into lemonade

- Grover's algorithm searches unsorted data in square root time –
  and **fast search** is important in **critical situations**

- Shor's algorithm factors large integers, thus decodes RSA –
  potentially enabling us to **break** all modern **computer security** tools
- Good news: we can use an unbreakable **quantum cryptography**
- At 1st glance, only problem is hardware -- but other problems remain

Algorithmic Problems: What We Did, What We Work On

- 1st: Can we further speed up the existing quantum algorithms? Speed is important in **critical situations**
- Our answer so far: quantum crypto, Deutsch-Jozsa (= checking whether an input is relevant) are optimal; we are analyzing other quantum algorithms
- 2nd: How can we use quantum computers to solve other problems?
- Our answer: yes, for optimization, UQ – critical for **consequence management**, for **AI** algorithms like SAT solvers and **machine learning**
- 3rd: How can we make designing quantum algorithms (QA) easier? Usual algorithms are formed by easily combinable blocks, but QA aren't.
- Our answer: we proposed a new way of representing functions in quantum computing that makes combining QA much easier
- 4th: Can we use more complex quantum effects to further speed up computations?
- Our answer: yes: we can potentially use QFT effects, we can use quantum space-time effects, we can use possible acausal effects

Quantum Computing Ideas Help Analyze Human Behavior

- Traditional social sciences assume that people behave rationally
- But our ability to process data is limited, so we make seemingly irrational decisions; Nobel prizes were awarded for this (Kahneman)
- 1970s experiments on kids showed many effects similar to quantum: two-door experiment with kids similar to two-slit quantum effects
- Lately, this analogy has led to many successful applications of quantum techniques and ideas to analyze human behavior
- 1^{st} question: how to use it? Our result: Schroedinger eigenmap dimension reduction can help. We hope: to be able to **detect malicious activities**.
- 2^{nd} question: why? Penrose's original hypothesis that brains actively use quantum effects was not confirmed. Our result: we explain why.
- 3^{rd} question: quantum formulas are only 1^{st} order approximation; what next? how to get formulas beyond quantum?
- Our result: our explanation of why quantum naturally leads to formulas for next approximations

Quantum Computing Algorithmics: Relevant Capabilities

- Developing quantum algorithms for optimization, uncertainty quantification, and consequence management
- Developing quantum algorithms to speed up AI and machine learning
- Quantum techniques to analyze human behavior (and detect malicious one)