Central European Quantum Information Processing workshop

CEQIP 2013
BOOKLET

5-9/06/2013
Valtice, Czech Republic

http://ceqip.eu/2013

CONFERENCE PROGRAM

WEDNESDAY 05/09

17:00-17:45 I **Marcus Cramer**: Quantification of entanglement using simple measurements
17:45-18:10 C **Tomáš Rybár:** Quantum walks in electric fields
18:15-18:40 C **Miguel Navascues:** How energy conservation limits our measurements

19:00 WELCOME BARBIQUE (chateaux coutryard)

THURSDAY 06/09

09:00-09:45 I **Fernando Brandao:** Product-state approximations to quantum ground states
09:45-10:10 C **Mark Howard:** Contextuality and Universal Quantum Computation

10:15-10:45 Break and refreshment

10:45-11:10 C **David Reeb:** (Im-)Proving Landauer's Principle
11:15-11:40 C **Lea Kraemer:** Generalized Entropies
11:45-12:10 C **Lídia Del Rio:** Relative thermalization

12:15 Lunch (Valtická rychta)

14:30 CONFERENCE BIKE TRIP
19:00 BIER EVENING (Valtická rychta)

FRIDAY 07/09

09:00-09:45 I **Andris Ambainis:** The power of exact quantum algorithms
09:45-10:10 C **Valerio Scarani:** Super-polynomial complex quantum states

10:15-10:45 Break and refreshment

10:45-11:10 C **Marcin Pawlowski:** Amplification of arbitrarily weak randomness
11:15-11:40 C **Gonzalo de La Torre:** Certifying that a process is as intrinsically random
11:45-12:10 C **Phuc Thinh Le:** Properties of the random seed input to Bell tests

12:30 Lunch (Valtická rychta)

14:30-15:30 T **Jan Bouda:** Classical zero-error communication ...
15:30-15:55 C **Marcin Jarzyna:** Matrix product states for quantum metrology

16:00-16:30 Break and Refreshemnt

16:30-17:15 I **Andreas Winter:** Zero-error quantum communication
17:15-17:45 C **Stefan Baeuml:** Limitations on quantum privacy swapping

18:00 CHATEAUX VALTICE excursion
19:00 CONFERENCE DINNER (chateaux cellars – Salón vín)

SATURDAY 08/09

09:00-09:45 I **Daniel Nagaj:** Quantum 3-SAT is QMA_1-complete
09:45-10:10 C **Piotr Cwiklinski:** The Power of Noisy Fermionic Quantum Computation

10:15 Break and refreshment

10:45-11:30 I **Ramon Munoz Tapia:** Improve your estimation by abstaining...
11:30-11:55 C **Michal Sedlák:** Optimal discrimination of quantum measurements

12:00 Lunch (Valtická rychta)

14:00-14:45 I **Marcus Huber:** On the role of entanglement in quantum thermodynamics
14:45-15:10 C **Margherita Zuppardo:** Distribution of entanglement via separable states

15:15-15:45 Break and Refreshment

15:45-16:10 C **Marcin Zwierz:** Universality of the Heisenberg Limit
16:15-16:40 C **Janek Kolodynski:** Efficient tools for quantum metrology with decoherence
16:45 Group photo

17:00-19:00 Poster session (lecture hall)

19:00 RAUT (lecture hall)
19:00-23:00 CIPHER GAME

SUNDAY 09/09

09:00-09:25 C **Teiko Heinosaari:** Noise-Disturbance Relation for Quantum Measurements
09:30-09:55 C **Peter Rapčan:** Direct estimation of decoherence parameters

10:00-10:30 Break and refreshment

10:30-10:55 C **Alex Monras:** Learning Quantum Markov Chains
11:00-11:25 C **Mária Kieferová:** Quantum Walks on Necklaces and Mixing
11:30-11:55 C **Nikolay Nahimov** and **Daniel Reitzner:** Grover's algorithm with faulty and non-faulty marked items *joined with* Fault-ignorant Quantum Search

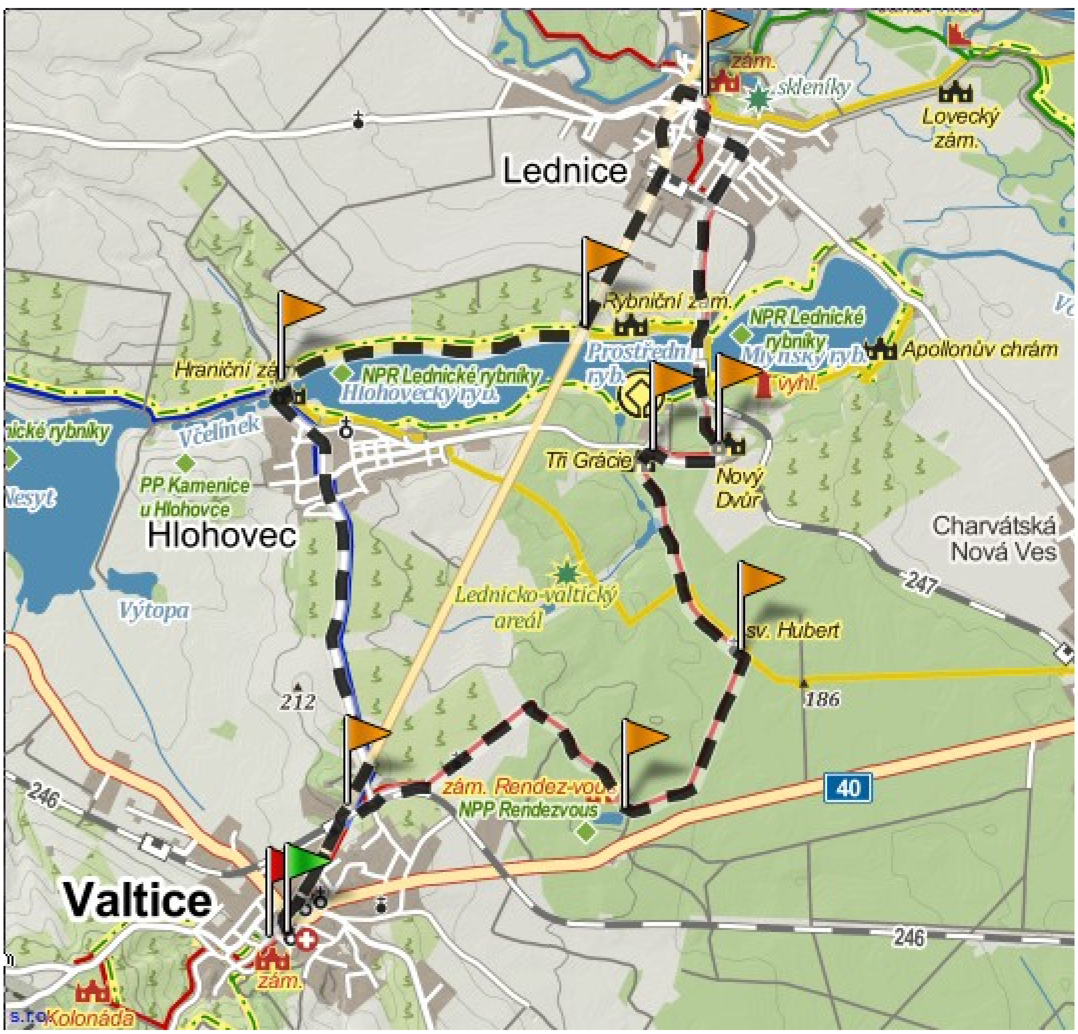
12:00 Lunch (Valtická rychta)

CONFERENCE TRIP

The bike trip starts at point “Bikes” (look at back side of this booklet), which is the location of bike rental. Please be there 14:15. Below you can see the plan. The target is the chateaux in Lednice with its really beautiful surroundings (also part of UNESCO area). We expect to be there at 16:00 at latest. Please have in mind that, unfortunately, no one is allowed to cycle inside the chateaux park. We recommend to leave Lednice before 17:30. It is up to you whether you want to return back using the same way, or take the direct road, or visit yet another small chateaux in Hlohovec (if yes, then start sooner). You have a map. Please return the bikes before 19:00 to the same place, where we started.

The bus leaves from the point “Bus” (look at back side of this booklet) at 14:30 and returns back from Lednice at 18:00 (please be there on time).

What to do in Lednice? You can visit the chateaux exhibition (takes around 60 minutes, costs 150 CZK and is not included in the conference fee), or visit the gallery, or have a walk around the lake, or take a boat, or enjoy the garden, or simply relax with bier and ice cream. No specific activity is organized there.

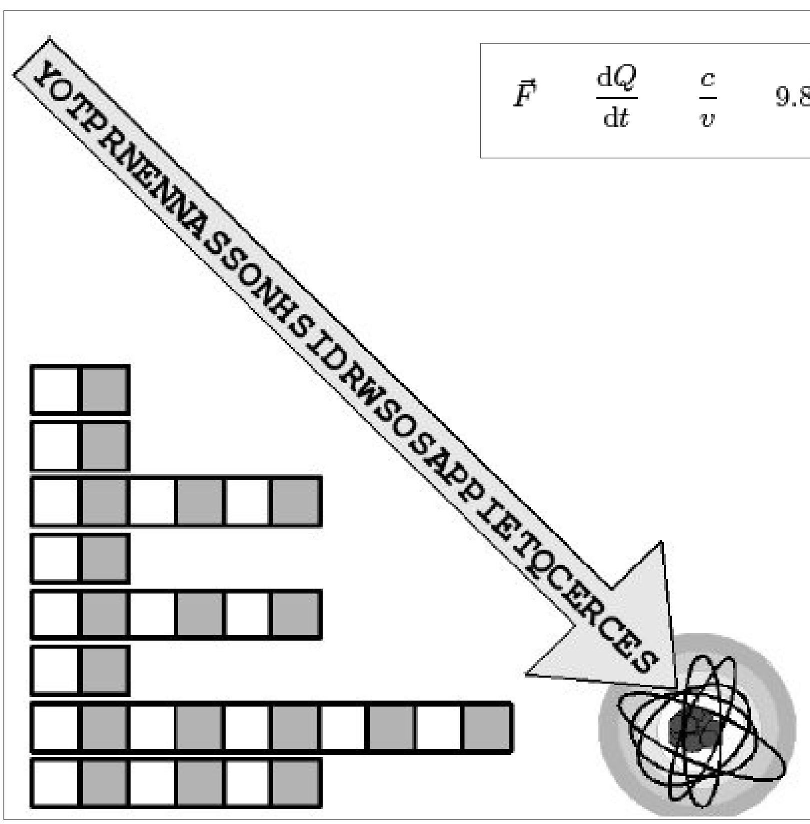


CIPHER GAME

Everyone is welcome to participate. The ultimate goal is to have fun while solving some puzzles in order to find CEQIP password. And there is some prize for winning team, but each participant will be somehow rewarded. More details after registration.

Frequent (not necessarily asked) questions
How to participate? Make a team and register on **Saturday** between **18:45 – 19:00**.
How to make a team? Well, this is up to you. Communication should help, or be close to registration point.
When does it start? We expect to **start at 19:15** during the Saturday's dinner.
When does it ends? When you find the **CEQIP password**. We hope around eleven o'clock like last year. For sure not later than Sunday morning :-)
How many puzzles? Traditionally for cipher games this information is hidden, but **seven**.
Do we need to solve all of them? This information is secret. Very likely the password is hidden already in this booklet, or in the book of abstracts.
What if we cannot solve some puzzle? After a while you can ask for some **hints**.
What is the CEQIP password? You will find out soon …
Can we drink, or eat during the game? You must. The dinning room (being the same as conference room) will be open. Although the ciphers are located in the surroundings of the chateaux, you can have your base camp inside.
Do I need some special equipment? Yes, but you will obtain it at the registration.
Can you give me an example? Yes, here is the first and the last cipher from the last year entitled **Equations** and **Qrypton**, respectively. No special equipment is needed to solve these. Free your mind.

$\vec{F}$ $\quad \frac{\mathrm{d}Q}{\mathrm{d}t}$ $\quad \frac{c}{v}$ $\quad 9.81$ $\quad \vec{v}$ $\quad 1.602\times10^{-19}$



INVITED TALKS

Andris Ambainis (Riga)

The power of exact quantum algorithms

A quantum algorithm is exact if, on any input data, it outputs the correct answer with certainty (probability 1). We present the first example of a Boolean function f(x_1, ..., x_N) for which exact quantum algorithms have superlinear advantage over the deterministic algorithms. Any deterministic algorithm that computes our function must use N queries but an exact quantum algorithm can compute it with O(N^{0.8675...}) queries. We also present two other new exact quantum algorithms for EXACT_k and THRESHOLD_k functions (i.e. determining whether the number of input bits that are equal to 1 is equal to k or at least k) which are faster than any classical algorithm. Based on arxivs: 1211.0721 and 1302.1235. The second part is joint work with Jānis Iraids and Juris Smotrovs.

Fernando Brandao (London)

Product-state approximations to quantum ground states

In the talk I will present recent results showing new bounds on the usefulness of product states for approximating the groundenergy of quantum local Hamiltonians. I will show applications of the bounds to the quantum PCP conjecture and to obtaining new algorithms for computing the mean-energy of certain classes of Hamiltonians (such as planar and dense models). Based on joint work with Aram Harrow.

Marcus Cramer (Ulm)

Quantification of entanglement using simple measurements

I will report on some recent results concerning ways to quantify entanglement in manybody systems. At the hand of experimentally available systems, I will demonstrate how already available measurements can suffice to quantify the amount of entanglement: Given a set of observables, we consider all density matrices that are compatible with measured expectation values of these observables. Amongst these density matrices, we find the one with the least amount of entanglement as quantified by a suitable entanglement measure. In this way, we determine a lower bound on the entanglement that must have been present in the state that gave rise to the observations. Examples will include results on a recent experimental quantification of the entanglement of bosons in optical lattices.

Marcus Huber (Bristol)

On the role of entanglement in quantum thermodynamics

Understanding the thermodynamics of quantum systems is of fundamental importance, from both theoretical and experimental perspectives. We will introduce and analyze two exemplary model systems that provide an ideal test-bed for exploring quantum thermodynamics. So far, however, the importance of quantum effects in these systems has remained elusive. We first briefly review a framework of entanglement quantification and use it to show that entanglement, the paradigmatical quantum effect, is connected to the task of extracting work from quantum batteries. More importantly we reveal that it plays a fundamental role in small self-contained quantum refrigerators, as it can enhance cooling and energy transport -- except notably when the efficiency is close to the Carnot limit. Hence a truly quantum refrigerator can outperform a classical one. Furthermore, the amount of entanglement alone quantifies the enhancement in cooling. More generally, our work shows that entanglement opens new possibilities in thermodynamics.

Daniel Nagaj (Wien)

Quantum 3-SAT is QMA_1-complete

Together with David Gosset we finally managed to prove that Q-3-SAT is a quantumly-tough nut to crack (and not only NP-complete). The talk will be about basic clocks, more involved clocks, and complicated clocks consisting each of several clocks, with all of them running in parallell (in 2D). We will also discuss how hard it is to bring something 1-epsilon to exactly 1, which is why we have to keep writing the annoying subscript in QMA_1 for now.

Ramon Munoz Tapia (Barcelona)

Improve your estimation by abstaining...

Knowing the state of a system is a key task in quantum information processing. An unknown quantum state can only be unveiled by means of measurements. The aim is then to find the measurement protocol that yields the best estimate of a family of input states. I will analyse the effects of introducing the possibility of giving an inconclusive estimate or abstain. This approach can be of interest when the standard protocol fails to achieve the minimum standard of performance required for some specific task, but some number of inconclusive responses, or abstentions, is affordable. I first discuss the discrimination problem with abstention, where it is somehow a natural ingredient. I then present the issue of parameter estimation (phase and direction) with general pure states of an arbitrary number N of qubits. For large N the problem is formulated in the continuous as a minimisation of certain action for which analytical expressions can be obtained. I will show that abstention enable drastic improvements, up to the extent of attaining the Heisenberg limit. I finally discuss the estimation in noisy settings and show that abstention does not enable to surpass the recent bounds on the unattainability of the Heisenberg scaling. This talk is based on the papers: Phys. Rev. A 86, 040303 (2012), New J. Phys. 14 105015 (2012), Phys. Rev. Lett. 110, 100501 (2013).

Andreas Winter (Barcelona)

Zero-error quantum communication

Entanglement, and more generally non-local correlations, are among the most fascinating aspects of quantum theory. Their fundamental manifestation is in the violation of Bell inequalities, but it is well-known that they also enhance the communication capabilities of channels. In particular zero-error communication (originally developed by Shannon in 1956, it continues to inspire work in combinatorics) offers a rich field of study of different non-local effects: The zero-error capacity of classical channels is enhanced by entanglement, and even more by general no-signalling correlations. This is in contrast to the ordinary, Shannon, capacity of the channel, and can be related to so-called pseudo-telepathy games. I will report on recent developments in the zero-error information theory of quantum channels, assisted by entanglement, feedback and general no-signalling correlations. [Joint work Runyao Duan and Simone Severini.]

CONTRIBUTED TALKS

Stefan Baeuml, Matthias Christandl and Andreas Winter.

Limitations on quantum privacy swapping

Motivated by the potential use of some bound entangled states in quantum key distribution (QKD), we deal with the question whether states that can be used for QKD can be distributed via entanglement swapping with bound entangled input states. We present an upper bound on the distillable key of the state resulting from a generalised entanglement swapping protocol that can decrease significantly in the case of bound entangled input states.

Piotr Cwiklinski, Fernando de Melo and Barbara Terhal.

The Power of Noisy Fermionic Quantum Computation

We consider the realization of universal quantum computation through braiding of Majorana fermions supplemented by unprotected preparation of noisy ancillae. It has been shown by Bravyi [Phys. Rev. A 73}, 042313 (2006)] that under the assumption ofperfect braiding operations, universal quantum computation is possible if the noise rate on a particular 4-fermion ancilla is below $40%$. We show that above a noise rate of $89%$ on this ancilla the quantum computation can be efficiently simulated classically: we explicitly show that the noisy ancilla is a convex mixture of Gaussian fermionic states in this region. On the other hand, for noise rates below $53%$ we prove that the state is not a mixture of Gaussian states. These results are obtained by generalizing concepts in entanglement theory to the setting of Gaussian states and their convex mixtures. In particular we develop a complete set of criteria, namely the existence of a Gaussian-symmetric extension, which determine whether a state is a convex mixture of Gaussian states. Finally, using an isomorphism between Clifford algebras and tensor product of Clifford algebras, we rewrite our criteria based on Gaussian-symmetric extensions, in a more "`physical"' way.

Lídia Del Rio, Adrian Hutter, Renato Renner and Stephanie Wehner.

Relative thermalization

Thermalization of quantum systems has been intensively studied in recent years. Typically, one looks for conditions that drive a system in contact with an environment to a local thermal state. Here, we show that a more general and relevant question is "when does a system thermalize with respect to a particular reference?", which is defined as the system being in a local thermal state which, additionally, is uncorrelated with the reference. We derive two complementary conditions for relative thermalization of quantum systems in contact with an arbitrary environment: a state-independent condition, which reflects the global Hamiltonian and on the relative sizes of system and environment; and an state-dependent condition, which depends on the initial correlations between reference, system and environment, measured by a conditional entropy. Intuitively, a small system in a large environment is likely to thermalize with respect to a reference after a physical evolution, but only if the reference was not highly correlated with system and environment. Recent results on thermalization, which cover only the state-independent condition, come as a natural consequence of our results, in the particular case where the reference is trivial. Ultimately, our results determine when it is justified to apply the fundamental postulate of statistical mechanics to study the interaction between a thermal bath and a reference system.

Gonzalo de La Torre, Chirag Dhara and Antonio Acín.
Certifying that a process is as intrinsically random as it is observed to be
Contrary to classical physics, the predictions of quantum theory for measurement outcomes are of a probabilistic nature. Questions about the completeness of such predictions lie at the core of quantum theory and can be traced back to the early days of the theory. Bell tests, assuming that no instantaneous communication exists (no-signaling principle) and that measurement settings can be choosen at random, allows one to assess the randomness of an observed process while avoiding assumptions on the completeness of the theory used. However, assuming that measurement settings can be chosen at random introduces a circularity in the argument as this initial randomness cannot be certified. Hence, we ask the fundamental question: Under the assumptions of the lowest possible quality of initial randomness and the no-signaling principle, when can we certify that a probabilistic process is as intrinsically random as it is observed to be? We answer such question by providing a sufficient condition for the latter to happen and provide the first family of scenarios where the intrinsic randomness is strictly equal to the observed randomness for any system size. Moreover, our results can be used for a protocol of full randomness amplification without the need of privacy amplification in which the final bit approaches a perfect random bit exponentially fast on the number of parties.

Teiko Heinosaari and Takayuki Miyadera.
Qualitative Noise-Disturbance Relation for Quantum Measurements
The inherent connection between noise and disturbance is one of the most fundamental features of quantum measurements. In the two well-known extreme cases a measurement either makes no disturbance but then has to be totally noisy or is as accurate as possible but then has to disturb so much that all subsequent measurements become redundant. Most of the measurements are, however, something between these two extremes. In this contribution a structural relation between observables and channels is presented. This relation properly explains the trade-off between noise and disturbance without any specific quantification of noise and disturbance.

Mark Howard, Victor Veitch and Joseph Emerson.
Negativity, Contextuality and Universal Quantum Computation
Recent work has shown that, for a particular definition of discrete Wigner function, quantum states with a negative quasi-probability representation are necessary if one wishes to achieve universal quantum computation. Here we show that contextuality is a necessary resource for universal quantum computation by proving (for small prime dimensions) that states are negatively-represented if and only if they violate a state-dependent quantum non-contextuality inequality. We use the graph-based contextuality formalism of Cabello, Severini and Winter and introduce a construction that we conjecture proves our result for all prime qudit dimensions -- but which we have checked explicitly for $d<6$. Our results are also relevant to the question of identifying the largest ``classical'' subtheory of quantum mechanics.

Marcin Jarzyna and Rafał Demkowicz-Dobrzański.
Matrix product states for quantum metrology
We demonstrate that the optimal states in lossy quantum interferometry may be efficiently simulated using low rank matrix product states. We argue that this should be expected in all realistic quantum metrological protocols with uncorrelated noise and is related to the

elusive nature of the Heisenberg precision scaling in presence of decoherence.

Maria Kieferová and Daniel Nagaj.

Quantum Walks on Necklaces and Mixing

We analyze continuous-time quantum walks on necklace graphs — cyclical graphs consisting of many copies of a smaller graph (pearl). Using a Bloch-type ansatz for the eigenfunctions, we block-diagonalize the Hamiltonian, reducing the effective size of the problem to the size of a single pearl. We then present a general approach for showing that the mixing time scales (with growing size of the necklace) similarly to that of a simple walk on a cycle. Finally, we present results for mixing on several necklace graphs.

Janek Kolodynski and Rafal Demkowicz-Dobrzanski.

Efficient tools for quantum metrology with decoherence

Quantum metrology under the idealistic assumption of no decoherence offers enhancement of measurement precision that grows without restraint with the number of particles involved. Motivated by practical applications, we propose tools for quantifying the attainable quantum enhancement based on the geometry of quantum channels and semi-definite programming that account for the inevitable impact of the noise. As a result we obtain a simple and direct method yielding bounds that interpolate between the quantum enhanced scaling characteristic for small number of particles and the asymptotic regime, where quantum enhancement amounts to a constant factor improvement.

Lea Kraemer, Frédéric Dupuis, Joseph M. Renes, Renato Renner and Philippe Faist

Generalized Entropies

In this work, we study an entropy measure for quantum systems that generalises the von Neumann entropy as well as its classical counterpart, the Gibbs or Shannon entropy. We show that this generalized entropy satisfies many desirable properties and that it is closely related to smooth entropies, a family of entropy measures used to characterize a wide range of operational quantities. As such, the proposed generalized entropy serves as a potential candidate for a unifying measure of uncertainty.

Alex Monras and Andreas Winter

Learning Quantum Markov Chains: The Completely-Positive Realization Problem

The positive realization problem (PRP) consists in determining whether a linear system can be realized with positive maps acting on positive vectors. An immediate application (and its original motivation) is to determine whether a stochastic process can be represented as a Hidden Markov Model, or equivalently, generated by a stochastic finite-state machine. The PRP and its solutions have far-reaching consequences in many areas of systems and control theory, and is nowadays an important piece in the broad field of positive systems theory. We study the completely-positive realization problem (CPRP), as a natural noncommutative generalization of the PRP. We show how the CPRP relates to the existence of quantum representations of a given stochastic process. Thus, the solvability of the CPRP provides for a realization in terms of Quantum Markov Chains, the natural generalization of HMMs, and encompass a wide variety of practical and relevant situations. We find necessary and sufficient conditions for the solvability of the CPRP. These conditions turn out to be that there exists a "semidefinite-representable cone" which is stable under the action of the linear system. This reveals a pleasant parallelism with the celebrated "polyhedral cone condition" of Dharmadhikari for the PRP. We also show that the solution to a CPRP can be verified by semidefinite programming, and discuss the challenges that an efficient solution of the CPRP would need to overcome. Our results have potential applications in device-independent characterization, and reverse-engineering of stochastic processes and quantum processors, and more generally, of dynamical processes with quantum memory.

Nikolay Nahimov and Dmitry Kravchenko

Grover's algorithm with faulty and non-faulty marked items

Grover's algorithm is a quantum query algorithm solving the unstructured search problem of size N using O(\sqrt{N}) queries. It is known that any deterministic or randomized algorithm needs linear time (number of queries) to solve the above problem. Thus, Grover's algorithm provides a significant speed-up over any classical algorithm. The running time of the algorithm (number of queries), however, is very sensitive to errors in queries. Regev and Schiff have shown that if query has a small probability of failing (reporting that none of the elements are marked), then quantum speed-up disappears: no quantum algorithm can be faster than a classical exhaustive search by more than a constant factor. We study the behaviour of the algorithm in the model there query may report some marked elements as unmarked. Similar model have been studied in \cite{AB+13}, where each marked element has its own probability to be reported as unmarked, independent on probabilities of other marked elements. If all marked elements are faulty (have non-zero probability of failure) then, as it follows from \cite{RS08} result, one need O(N) queries to find any of marked elements. Although, the model of \cite{AB+13} technically allows one non-faulty marked element, this case is not included into analysis. The analysis is focused on the behaviour of the algorithm for large number of steps. As opposite to \cite{AB+13} we allow both faulty and non-faulty marked elements. We show what in this setting it is indeed possible to find one of non-faulty marked elements in O(\sqrt{N}) queries. As N grows, the algorithm with m non-faulty and k faulty marked elements behaves more and more like the algorithm with just m non-faulty marked elements. We also analyse the limiting behaviour of Grover's algorithm for a large number of steps and show the existence of limiting state \rho_{lim}. Similarly to \cite{AB+13} we show that convergence time is O(N). We outline possible applications of our results

Miguel Navascues and Sandu Popescu.

How energy conservation limits our measurements

Observations in Quantum Mechanics are subject to complex restrictions arising from the principle of energy conservation. Determining such restrictions, however, has been so far an elusive task, and only partial results are known. In this paper we discuss how constraints on the energy spectrum of a measurement device translate into limitations on the measurements which we can effect on a target system with non-trivial energy operator. We provide efficient algorithms to characterize such limitations and, in case the target is a two-level quantum system, we quantify them exactly. Our work thus identifies the boundaries between what is possible or impossible to measure, i.e., between what we can see or not, when energy conservation is at stake.

Marcin Pawlowski and Piotr Mirononwicz.

Amplification of arbitrarily weak randomness

We demonstrate that amplification of arbitrarily weak randomness is possible using quantum resources. We present a randomness amplification protocol that involves Bell experiments. We report on two Bell inequalities which can amplify arbitrarily weak randomness and give detailed analysis for one of them. Our analysis includes finding a sufficient violation of Bell inequality as a function of the quality of randomness. It has a very important property that for any quality the required violation is strictly lower than possible to obtain using quantum resources. Among other things it means that the protocol takes a finite amount of time to amplify any randomness.

Peter Rapčan, Vladimír Bužek Jochen Rau and Mário Ziman.

Direct estimation of decoherence parameters

The decoherence rate is a nonlinear channel parameter that describes quantitatively the decay of the off-diagonal elements of a density operator in the decoherence basis. We address the question of how to experimentally access such a nonlinear parameter directly without the need for complete process tomography. In particular, we design a simple experiment working with two copies of the channel, in which the registered mean value of a two-valued measurement directly determines the value of the average decoherence rate. No prior knowledge of the decoherence basis is required.

David Reeb and Michael M. Wolf

(Im-)Proving Landauer's Principle

We formulate in precise mathematical and microscopic terms the minimal setup for Landauer's Principle. Based on this, we give a rigorous proof of an improved version of the Principle, which is formulated in terms of an equality rather than inequality and involves information-theoretic quantities. This shows that, in finite dimensions, Landauer's well-known bound holds with equality only if the erasure process essentially does not do anything. We then use this equality version to explicitly sharpen the usual Landauer bound in cases where the assisting reservoir is of finite size. The key technical element for this part is a new and tight lower bound on the relative entropy between two states in terms of their entropy difference and the dimension of the underlying space. This inequality has other applications in thermodynamics and information theory, and the derived finite-size effects may be relevant for small thermodynamic devices such as error-correcting mechanisms.

Daniel Reitzner , Peter Vrana, David Reeb, and Michael M. Wolf

Fault-ignorant Quantum Search

We investigate the problem of quantum search on a noisy quantum computer. Taking a fault-ignorant approach, we design quantum algorithm that solve the task for various different noise strengths, possibly unknown beforehand. One rationale is to avoid costly overheads, such as traditional quantum error correction. Proving lower bounds on algorithm run-times, which may depend on the actual level of noise, we find that the quadratic speedup is lost. Nevertheless, for low noise levels, our algorithms outperform the best noiseless classical search algorithm.

Tomáš Rybár, Christopher Cedzich, Albert H. Werner, Andrea Alberti, Maximilian Genske and Reinhard F. Werner

Propagation and spectral properties of quantum walks in electric fields

We study one-dimensional quantum walks in a homogeneous electric field. The field is given by a phase which depends linearly on position and is applied after each step. The long time propagation properties of this system, such as revivals, ballistic expansion and Anderson localization, depend very sensitively on the value of the electric field Phi, e.g., on whether Phi/(2pi) is rational or irrational. We relate these properties to the continued fraction expansion of the field. When the field is given only with finite accuracy, the beginning of the expansion allows analogous conclusions about the behavior on finite time scales.

Valerio Scarani, Huy Nguyen Le, Yu Cai and Xingyao Wu

Super-polynomial complex quantum states

We give an explicit construction for classes of quantum states of qubits, whose complexity grows super-polynomially in the number of qubits. The complexity measure considered is the tree size of a quantum state, which is in principle computable and closely related to the size of a multi-linear formula. Several conjectures and partially known relations to entanglement and quantum computational power will be discussed. Based on arXiv:1303.4843.

Michal Sedlák and Mario Ziman

Optimal discrimination of quantum measurements

We formulate discrimination problem for quantum measurements in the language of process positive operator valued measures (PPOVM). In this framework we present how a discrimination of a pair of Von Neumann qubit measurements can be converted into discrimination problem for a pair of pure states defining those possible measurements. In this way, the problem can be analytically solved using the results known for discrimination of states. This holds not only for minimum-error and unambiguous strategy, but also for strategy that interpolates between them, so called discrimination with fixed failure rate. We extend the result to the discrimination of imperfect measurements. We present a case study for unambiguous discrimination of two symmetric 3-outcome POVMs that demonstrates that optimal scheme is not always based on use of a maximally entangled state.

Phuc Thinh Le, Lana Sheridan, Jeysthur Ang and Valerio Scarani

Properties of the random seed input to Bell tests

The violation of Bell inequalities can be used to certify in a black-box scenario important quantum information properties such as the information leaked to the eavesdropper in quantum key distribution, quality of private randomness expansion, quantum state and measurement. However, it has been recently recognized that these conclusions hold under the extra assumption of measurement independence (or "free will"). We study the effect of reduced measurement dependence in Bell scenarios and proved an upper bound on the min-entropy of the input seeds to Bell tests below which no conclusion can be drawn. Our result illuminates the ultimate role of measurement dependence in Bell scenarios, that is reducing (and moreover excluding) the probability of certain input choices, and also shows how important is the choice of figure of merit of measurement dependence. We also report the positive benefit in purposely biasing the observed input probability distribution as a way to counteract the effect of reduced measurement dependence.

Margherita Zuppardo, Alessandro Fedrizzi, Geooff Gillett, Matthew Broome, Marcelo Pereira de Almeida, Mauro Paternostro, Andrew White and Tomasz Paterek.

Experimental distribution of entanglement via separable states

Information gain in communication is bounded by the information encoded in the physical systems exchanged between sender and receiver. Surprisingly, this does not hold for quantum entanglement, which can increase even though the communicated system carries no entanglement at all. Here we demonstrate this phenomenon in a four-photon experiment where two parties sharing initially separable (unentangled) state get entangled by exchanging a photon that is at all times not entangled with either of them. Our result validates a long-standing assert in quantum information and has important practical implications in quantum networking, where entanglement must be reliably distributed across many nodes at low resource-cost.

Marcin Zwierz, Michael J. W. Hall, Dominic W. Berry and Howard M. Wiseman
Universality of the Heisenberg Limit
We prove a rigorous form of the Heisenberg limit for the average error over all phase shifts, applicable to any estimate of a completely unknown phase shift. Our result holds for arbitrary phase measurement schemes, and therefore rules out the possibility of super-Heisenberg measurements.

POSTERS

Nicolai Friis, Antony Lee, Kevin Truong, Carlos Sabín, Enrique Solano, Göran Johansson and Ivette Fuentes
Relativistic quantum information processing - teleportation in motion
We study the effects of relativistic motion on quantum teleportation and propose a realizable experiment where our results can be tested. We compute bounds on the optimal fidelity of teleportation when one of the observers undergoes nonuniform motion for a finite time. The upper bound to the optimal fidelity is degraded due to the observer's motion. However, we discuss how this degradation can be corrected. These effects are observable for experimental parameters that are within reach of cutting-edge superconducting technology. Our setup will further provide guidance for future space-based experiments.

Tomer Barnea, Jean-Daniel Bancal, Yeong-Cherng Liang and Nicolas Gisin
A tripartite quantum state violating the hidden influence constraints
The possibility to explain quantum correlations via (possibly) unknown causal influences propagating gradually and continuously at a finite speed $v > c$ has acquired a lot of attention recently. In particular, it could be shown that this assumption leads to correlations that can be exploited for superluminal communication. This was achieved studying the set of possible correlations that are allowed within such a model and comparing them to correlations produced by local measurements on a four-party entangled quantum state. Here, we report on a quantum state that allows for the same conclusion involving only three parties.

Jan Bouda, Matej Pivoluska, Martin Plesch and Colin Wilmott
Quantum Secret Sharing -- Beyond No--Cloning
The goal of the secret sharing is to share a message (quantum or classical) among n parties in such a way, that only predetermined subsets of the participants can reconstruct it. Subsets of participants which can reconstruct the secret are called authorized. Any subset of participants which is not authorized is called unauthorized and cannot gain any information about the shared secret. In the classical secret sharing(i.e. the secret is a classical string), the only restriction is the monotonicity of authorized sets, that is, unauthorized set does not contain an authorized set.In other words, an authorized set cannot become unauthorized, by adding more participants to it. Thus access structure can be described as a list of minimal authorized sets. In quantum secret sharing (QSS), instead

of sharing a classical information an unknown secret state \psi is shared. This imposes another restriction for access structures – no cloning. No-cloning in this context translates to the following: If a subset of participants is authorized, it's complement is unauthorized. Otherwise two complementary sets would be able to reconstruct the secret and thus perform cloning of an unknown quantum state, which is impossible in quantum mechanics. No--cloning and monotonicity are the only restrictions for access structures in QSS. The goal of this work is to explore the possibility of overcoming the no--cloning restriction by assuming that the distributing party holds p copies of the state it wishes to share secretly. In other words, we will be seraching for QSS schemes, in which the distributing party encodes {\psi}^{\otimes p} into a n partite state in such a way, that every authorized set can reconstruct at least one secret state psi.

Marcin Zwierz and Howard M. Wiseman.
Nonlinear quantum metrology with noise
We derive the ultimate bounds on the performance of nonlinear measurement schemes in the presence of noise. In particular, we investigate the precision of a second-order nonlinear estimation scheme in the presence of the two most detrimental types of noise, photon loss and phase diffusion. We find that the second-order measurement scheme is affected by the photon loss in an analogous way as the linear scheme. Interestingly, in the presence of phase diffusion the second-order measurement scheme offers performance that is superior to its linear counterpart.

Erkka Haapasalo.
When do pieces determine the whole? Extreme marginals of a completely positive map
We will consider completely positive maps dened on tensor products of von Neumann algebras and taking values in the algebra of bounded operators on a Hilbert space and particularly certain convex subsets of the set of such maps. We show that when one of the marginal maps of such a map is an extreme point, then the marginals uniquely determine the map. We will further prove that when both of the marginals are extreme, then the whole map is extreme. We show that this general result is the common source of several well-known results dealing with, e.g., jointly measurable observables. We also obtain new insight especially in the realm of quantum instruments and their marginal observables and channels

Rafael Chaves, Jonatan Brask, Marcin Markiewicz, Jan Kolodynski and Antonio Acin.
Noisy metrology beyond the standard quantum limit
Parameter estimation is of fundamental importance in areas from atomic spectroscopy and atomic clocks to gravitational wave-detection. Entangled probes provide a significant precision gain over classical strategies in the absence of noise. However, recent results seem to indicate that any small amount of realistic noise restricts the advantage of quantum strategies to an improvement by at most a multiplicative constant. Here we identify a relevant scenario in which one can overcome this restriction and attain super-classical precision scaling even in the presence of uncorrelated noise. We show that the quantum improvement can be significantly enlarged when the noise is concentrated along some spatial direction, while the Hamiltonian governing the evolution which depends on the parameter to be estimated can be engineered to point along a different direction. In the case of perpendicular orientation, we identify a state which achieves optimal asymptotic precision scaling.

Michal Studzinski, Michal Horodecki and Marek Mozrzymas.

Commutant structuture of U...UU* transformations and its applications in quantum information theory

In this presentation we have found irreducible representations of the algebra of partially transposed permutation operators on last subsystem. We have solved this problem using representation approach, namely we show how to construct orthogonal operator basis for this case and calculate matrix elements of irreducible representations . Our method is inspired by representation theory of symmetric group S(n), theory of Brauer Algebras and Walled Brauer Algebras. We also show where such construction can be applied. Our method plays important role in quantum cloning theory, investigation of PPT property for some quantum states and most significance role - we are able to built constructive counterexamples to additivity of minimum output Renyi entropy of quantum channels based on the paper by Grudka et al (2003).

Piotr Cwiklinski, Michal Horodecki, Marek Mozrzymas, Lukasz Pankowski and Michal Studzinski.

Local random quantum circuits are approximate polynomial-designs - numerical results

We numerically investigate the statement that local random quantum circuits acting on n qubits composed of polynomially many nearest neighbour two-qubit gates form an approximate unitary poly(n)-design [F.G.S.L. Brandão et al., arXiv:1208.0692]. Using a group theory formalism, spectral gaps that give a ratio of convergence to a given t-design are evaluated for a different number of qubits n (up to 20) and degrees t (t = 2, 3, 4 and 5), improving previously known results for n = 2 in the case of t = 2 and 3. Their values lead to a conclusion that the previously used lower bound that bounds spectral gaps values may give very little information about the real situation and in most cases, only tells that a gap is closed. We compare our results to the another lower bounding technique, again showing that its results may not be tight.

Sergey Filippov, Alexey Melnikov and Mario Ziman.

Quantum-informational aspects of entanglement-annihilating processes

We make a conjecture about general structure of an entanglement-annihilating (EA) channel, i.e. a quantum channel which destroys entanglement of any multipartite state it acts upon: EA-channel is a particular combination of positive (but not necessarily completely positive) maps followed by measure-and-prepare processes on subsystems. This hypothesis is justified by a number of bipartite and multipartite examples with local and non-local noises. Sufficient condition for the channel to be EA is found: the Choi matrix should be biseparable (with respect to corresponding partitions). Being important for quantum communication, channels of the form E^{\otimes n} are considered and particular results are obtained for depolarizing channels, namely, the fundamental noise level of multiqubit entanglement annihilation (1-1/sqrt{5})=0.553 is found.

Arvind Arvind.

Extremal extensions of entanglement witnesses

A method to produce extensions of entanglement witnesses which preserves their extermal character will be described. It will be shown that inner automorphisms of the set of P maps which are not CP, produce extremal extensions of these maps that help in entanglement detection. By constructing such an extension of the well-known Choi map, we strengthen its power to unearth PPT (positive under partial transpose) entangled states. We further show that the class of maps generated from the Choi map via an inner automorphism naturally detects the entanglement of states in the orthogonal complement of certain unextendable product bases (UPB). Thus a connection between UPB and the Choi map is established. In another application of the method a new class of bound entangled states will be unearthed.

Łukasz Pawela, Piotr Gawron, Zbigniew Puchała and Jan Sladkowski.
Enhancing pseudo-telepathy in the Magic Square game
We study the possibility of reversing an action of a quantum channel. Our goal is to find a specific channel that reverses as accurately as possible an action of a given quantum channel. To achieve this goal we use semidefinite programming. We show the benefits our method using the quantum pseudo-telepathy Magic Square game with noise. Our goal is to move the pseudo-telepathy region to higher noise parameter values α. We obtain results showing that it is possible to reverse the action of a noise channel using semidefinite programming.

Przemysław Sadowski and Jarosław Miszczak.
Exploring quantum networks with faulty sense of direction
We consider a scenario of exploring a network of quantum information processing nodes with a faulty sense of direction. We provide a model of quantum network exploration based on quantum walk on cycle and mobile agents and we study its properties. We also develop a method of describing and analyzing the behavior of quantum mobile agents.

Dariusz Kurzyk, Piotr Gawron and Łukasz Pawela.
Decoherence effects in quantum qubit flip game using Markovian approximation
We consider an implementation of quantum version of penny flip game, whose implementation is influenced by the environment that causes the decoherence of the system. In order to model the decoherence we assume Markovian approximation of open quantum system dynamics. We focus our attention on the phase damping, amplitude damping and amplitude raising channels. Our results show that the Pauli strategy is no longer a Nash equilibrium under decoherence. We attempt to optimize the players' control pulses in the aforementioned setup to allow them to achieve higher probability of winning the game compared to the Pauli strategy.

Martina Miková, Michal Sedlák, Ivo Straka, Michal Mičuda, Mario Ziman, Miroslav Jezek, Jaromír Fiurášek and Miloslav Dusek.
Optimal Unambiguous Discrimination of Two Incompatible Quantum Measurements
The discrimination of quantum measurements belongs to current topics of quantum information processing. We have experimentally demonstrated one-copy optimal unambiguous (probabilistic) discrimination of two, in general incompatible, von Neumann measurements. To be optimal, this quantum information processing requires pairs of entangled particles and as part of the analyzing protocol conditionally performed unitary operation depending on the measured results on a probe particle. One of the two known von Neumann measurements was randomly chosen and applied on the probe particle of the entangled pair. After that the state of the second particle of the entangled pair was analyzed. The analysis exploited electronic feed-forward to conditionally changed the state of the particle. Subsequently by the unambiguous state discrimination conclusive or inconclusive results was reached. In our experiment we discriminated two general polarization measurements on a single photon. Our linear optical protocol requires pairs of photons entangled in polarization. Each polarization measurement on one photon can give

two results, represented the two basis states. It corresponds to measurement on a probe photon by the detector D1 or D2 (see Fig. 1). If the probe photon was detected in basis state corresponding to the click of detector D1, then we directly applied the unambiguous state discrimination on the second photon. In the case, when detector D2 clicked, the state of the second photon needed to be modified (to get the same state as when the probe photon was detected by detector D1). This modification was done by means of electronic feed-forward. The core of the analysis in our setup was formed by two chained Mach-Zehnder interferometers implemented by polarization maintaining fiber optics, therefore the state of the second photon was transformed from polarization modes into the spatial modes. A phase modulator in the first interferometer is the part of the electronic feed-forward and via it the conditional phase shift was applied. Then each of the two measurements corresponds to one of the two nonorthogonal states of the second photon. These two states where distinguished by the unambiguous state discrimination implemented by the second interferometer. Detections of the photon by detector D3 represented inconclusive results. Signal from the detector D4 (D5) identify unambiguously the first (the second) measurement from the tested set.

Marek Smaczynski.
Self-organizing Kohonen maps as a tool to study quantum chaotic systems
We analyze with the use of neural network a model of quantum dynamical system called „generalized baker map" subjected to periodic interaction with an environment, which can describe quantum measurements. Under the condition of strong classical chaos and strong decoherence due to large coupling with the measurement device, the spectra of the evolution operator exhibit an universal behavior. Studying showed that self-organizing Kohonen network map can recognize certain general features in quantum chaotic system.

Paul Erker.
Exploring Quantities of Information in Single-Shot Scenarios
With this poster I would like to contribute a presentation of the recent progress that has been made in establishing Quantities of Information in Single-Shot Scenarios. As known the Von Neumann entropy and Mutual Information play a significant role in the asymptotic case of Quantum Information Theory. Smooth versions that pose a generalization of these quantities for non-i.i.d. resources have been developed. One of the latest achievement in this field was the improvement and extension of this framework for Non-Asymptotic Quantum Information Theory which is relevant for the characterization of a wide range of elementary quantum information processing tasks. The discussion of these and subsequent results is the purpose of this work.

Marcin Markiewicz, Tomasz Paterek and Anna Przysiężna.
Genuinely multipartite temporal quantum correlations
Within this contribution we propose a scheme for obtaining genuine temporal multi-point quantum correlations by performing POVM measurements on a single quantum system. Our method is based on a protocol for sequential preparation of MPS states by application of subsequent unitary gates on a chain of particles (initially in product state). In particular, we present a temporal GHZ paradox for arbitrary number of qubits. The main possible advantage is that within this scheme we can obtain genuine \$n\$-partite quantum correlations between \$n\$ parts by local operations and quantum communication of a single particle, whereas there is no need for shared entanglement between any number of parties when performing the protocol.

Kavita Dorai.

Tomographic reconstruction of generic three-qubit states on an NMR quantum computer using only two-qubit detectors

NMR quantum computers are a useful testbed for probing multi-partite quantum entanglement. It has been recently theorised that there exist a set of three qubit generic pure states which can be determined completely from their two-party reduced density matrices. On a three-qubit NMR quantum computer, we experimentally generate such a generic three-qubit state as well as the maximally entangled GHZ and W states. We produce a series of tomographs of the final density matrix including that of the three-qubit generic state and their two qubit subspaces.

Raqueline A. M. Santos and Alexander Rivosh.

Some notes on discrete time quantum algorithm for NAND formulae evaluation

In the literature, quantum algorithms for solving the problem of evaluating boolean formulas were developed using both the continuous time and discrete time query model. In our work we perform a series of numeric experiments to answer some open questions considering the NAND formula evaluation algorithm: 1. What is the smallest N for which the algorithm becomes practically usable (where N is the number of variables)? In most articles the proof of correctness of algorithms requires significantly large N. Our simulations showed that for small N, like N=2^8, we can not distinguish when the formula evaluates as false or true. 2. How the algorithm performs when certain type of faulty oracles are used? 3. What else can be done to build new algorithms using the ideas of the algorithms we have so far?

Anna Szymusiak and Wojciech Slomczynski.

Global minimizers of the entropy of highly symmetric POVM

Which ensembles of initial states are optimal for a given POVM measurement? This problem of quantum communication can be expressed in mathematical terms as follows: we are looking for ensembles that maximize mutual information between themselves and the POVM measurement outcomes. For a group covariant measurement this can be restated equivalently as finding pure initial states that minimize the entropy of the measurement output. Due to the nonpolynomial form of the minimized function, an analytical solution of the problem apparently seems difficult to obtain. The method applied involves using the Hermite polynomial interpolation and some properties of group invariant polynomials. The single qubit case with a highly symmetric group covariant POVM is investigated in details. An example of application in higher dimensions will be presented in case of SIC-POVMs in dimension three.

David Lyons and Scott Walck.

Entanglement verification using local unitary stabilizers

Local unitary stabilizer subgroups constitute powerful invariants for distinguishing various types of multipartite entanglement. In this paper, we show how stabilizers can be used as a basis for entanglement verification protocols on distributed quantum networks using minimal resources. As an example, we develop and analyze the performance of a protocol to verify membership in the space of Werner states, that is, multi-qubit states that are invariant under the action of any 1-qubit unitary applied to all the qubits.

Laszlo Ruppert, Daniel Virosztek and Katalin Hangos.
Pauli channel tomography with unknown channel directions
In this paper we estimate the parameters of the qubit Pauli channel using the channel matrix formalism. The main novelty of this work is that we do not assume the directions of the Pauli channel to be known, but they are determined through the tomography process, too. The results show that for optimally estimating the contraction parameters and the channel matrix we should have input qubits and measurements in the channel directions. However, for optimally estimating the channel directions, we should use different tomography conditions.

Stefan Schauer and Martin Suda.
Effects of Noise on the Security of Entanglement Swapping based QKD Protocols
In this contribution we discuss the effects of noise in a quantum channel on the security of quantum key distribution (QKD) protocols based on entanglement swapping. Therefore, we look at two different models of quantum noise, the depolarization channel and the decoherence channel. Based on these models we examine at first the effects on entanglement swapping and further the implications on the security parameters in quantum cryptography. We are able to show that a fidelity of at least F = 0.9428 is necessary to guarantee the security of the protocol.

Andrej Gendiar, Michal Daniska and Tomotoshi Nishino.
Influence of the hyperblic geometry on entanglement
Consider an infinite set of inhomogeneous non-Euclidean lattice geometries characterized by negative Gaussian curvatures. The set of the hyperbolic lattices is constructed in such way that it converges monotonously to Euclidean flat geometry. Each lattice geometry is infinitely large consisting of strongly correlated spin interactions. By means of a generalized Density Matrix Renormalization Group algorithm, the quantum and classical phase transition are investigated in high accuracy. We show that the universality classification turns out to reveal mean-field behavior even for infinitesimally small deviations from the Euclidean geometry. Von Neumann quantum entanglement entropy clearly reflects presence of the phase transitions, however, the critical behavior induced by the hyperbolic geometry is strongly suppressed by permanent exponential decay of the correlation functions.

Abuzer Yakaryilmaz.
Quantum alternation: What is wrong with quantum nondeterminism?
In this talk, we are planning to give some interpretations of the results given in one of our recent paper. Recently, we introduce quantum alternation as a generalization of (strong) quantum nondeterminism, and then show that one-way constant-space alternating quantum Turing machines can recognize any recursively enumerable language. Its classical counterpart, on the other hand, can recognize all and only regular languages. In fact, alternating Turing machines with certain space-bounds cannot recognize all recursively enumerable languages. Such a big gap between the quantum and classical cases leads us to questioning our model. Since our model is a straightforward generalization of quantum nondeterminism, we focus on ``what can be wrong with quantum nondeterminism?'' and try to figure out ``non-physical'' part of quantum nondeterminism.

Waldemar Klobus, Andrzej Grudka, Wieslaw Laskowski and Marcin Markiewicz.

Activation of nonlocality by performing multiple entanglement swappings

We consider multiple entanglement swappings performed on a chain of bipartite states. Each state does not violate CHSH inequality. We show that before some critical number of entanglement swappings is achieved the output state does not violate this inequality either. However, if this number is achieved then for some results of Bell measurements obtained in the protocol of entanglement swapping the output state violates CHSH inequality.

László Ruppert, Katalin Hangos and Dénes Petz.

Conditional SIC-POVMs: the generalization of SIC-POVMs for arbitrary subspaces

The measurement of a quantum mechanical system is of a probabilistic nature, so even determining a measurable quantity requires statistical methods. We examine state estimation scenarios when some parameters of the state are a priori given. We obtain the best estimation schemes by minimizing the average squared Hilbert-Schmidt distance. We introduce a new generalization of SIC-POVMs and examine its properties both analytically and numerically. Finally we give an application for full state tomography.

Gábor Balló and Katalin Hangos.

Comparison of experiment design approaches for Pauli channel tomography

The paper discusses a comparative study of experiment design approaches for quantum channel tomography. It is known that for Pauli channels, in case of a known channel structure, an optimal experimental design strategy can be found in the set of configurations, i.e. pure input state - projective measurement pairs. However, as the optimal configuration depends on the structure, we need other approaches in case of a completely unknown Pauli channel. The following experimental designs were studied: one assuming a fixed channel structure, one with random inputs and random measurements, and an adaptive approach based on the optimization of the observed Fisher information. Based on optimal configurations obtained from the adaptive strategy, a semi-random nonadaptive method is proposed, where the representing Bloch vectors of the input pure state and the measurement are parallel. It was found that for the qubit Pauli channel, the high resource requirement of the adaptive strategy does not worth the negligible performance increment compared to the semi-random strategy.

Martin Plesch and Matej Pivoluska.

Perfect randomness from a single weak source

Within this paper we examine production of (almost) perfect randomness with the use of untrusted quantum devices and a weak source of available randomness. We show that in the limit of infinite keys production of perfect random numbers is possible with a single weak source. For finite key lenght and finite tolerance of errors in the devices the quality of randomness produced depends rather on the tolerated deviation from quantum limit than from the quality of original random source.

Michael Nölle, Martin Suda and Winfried Boxleitner.

H2SI – A New Perceptual Colour Space

In this paper we introduce a new colour space which is equipped with a metric that shares many properties with the human perception of colour, and we derive its the most important geometric properties. The new colour space is embedded in a triplet quantum space and is well suited for algorithmic purposes, as we demonstrate with the 'Eigen' colour decomposition of images.

Lívia Dani, Matyas Koniorczyk, Vladimir Buzek.

Process optimized quantum cloners

We use the approach of K. Audenaert and B. De Moor (PRA 65, 030302 (2002)) to design 1 to 2 quantum bit cloners without any heuristics, purely via an algorithmic method. The nature of the optimization leads us the introduction of the notion of process optimized cloners. These are quantum cloners optimized for the average fidelity of their joint output state with respect to a product of multiple originals. We design 1 to 2 quantum bit cloners using the numerical method for finding completely positive maps approximating a nonphysical one optimally, via semidefinite programming. We discuss the properties of the so-designed cloners as well as their relations to those known to be optimal with respect to the clone fidelity. (For more details see Koniorczyk et al., arXiv:1304.1326)

Ryszard Weinar.

Minimal capacity of classical channel in the teleportation protocol

We study the activation of entanglement in teleportation protocols. To this end, we a present derivation of the average fidelity of teleportation process with noisy classical channel for qudits. In our work we do not make any assumptions about the entangled states shared by communicating parties. Our result allows us to specify the minimum amount of classical information required to beat the classical limit when the protocol is based on the Bell measurements. We also compare average fidelity of teleportation obtained using noisy and perfect classical channel with restricted capacity. The most important insight into the intricacies of quantum information theory that we gain is that though entanglement, obviously, is a necessary resource for efficient teleportation it requires a certain threshold amount of classical communication to be more useful than classical communication. Another interesting finding is that the amount of classical communication required to activate entanglement for teleportation purposes depends on the dimension d of the system being teleported but is not monotonic reaching maximum for $d=4$

Šimon Valko

Nonuniform unitary 1-designs

We investigate the existence of private quantum channels if a nonuniform source of randomness is available. In particular we show that especially for small keys generated by imperfect randomness sources the modified private quantum channel overcomes the extractor-based approach.

Shenggen Zheng, Jozef Gruska, Daowen Qiu

On the state complexity of semi-quantum automata

Some of the most interesting and important results concerning quantum finite automata are those showing that they can recognize certain languages with (much) less resources than corresponding classical finite automata. This paper shows three results of such a type that are stronger in some sense than other ones because (a) they deal with models of quantum automata with very little quantum-ness (so-called semi-quantum two- and one-way with one qubit memory only); (b) differences, even comparing with probabilistic classical automata, are bigger than expected; (c) a trade-off between the number of classical and quantum basis states needed is demonstrated in one case and (d) languages used to show that are very simple and often explored ones in automata theory, with seemingly little structure that could be utilized.

Andrew Frigyik

Bregman divergence and its application

A class of distortions termed functional Bregman divergences is defined, which includes squared error and relative entropy. A functional Bregman divergence acts on functions or distributions, and generalizes the standard Bregman divergence for vectors and a previous pointwise Bregman divergence that was defined for functions. It is shown that the mean minimizes the expected functional Bregman divergence over a set of functions or distributions. It is shown how this theorem applies to the Bayesian estimation of distributions. Denes Petz extended the idea of Bregman divergence to operator algebraic setting. Our goal is to understand the ramifications and the connections between the two approaches.

John Lapeyre.

Entanglement distribution in complex networks

Quantum computation and information protocols require entangling widely separated systems. I examine this task on networks with a given initial distribution of entanglement over short ranges. In general, both operations that distribute, and that concentrate entanglement are required to produce long-range entanglement. Assumptions on the network topology and initial states dictate the figures of merit and optimal protocols. I will present progress on the minimum initial entanglement for regular lattices, as well as protocols for complex networks. An example of the latter, I give an exact calculation of entanglement resulting from combining distribution with one level of concentration from neighboring paths at the critical point of the Erdos-Renyi graph.

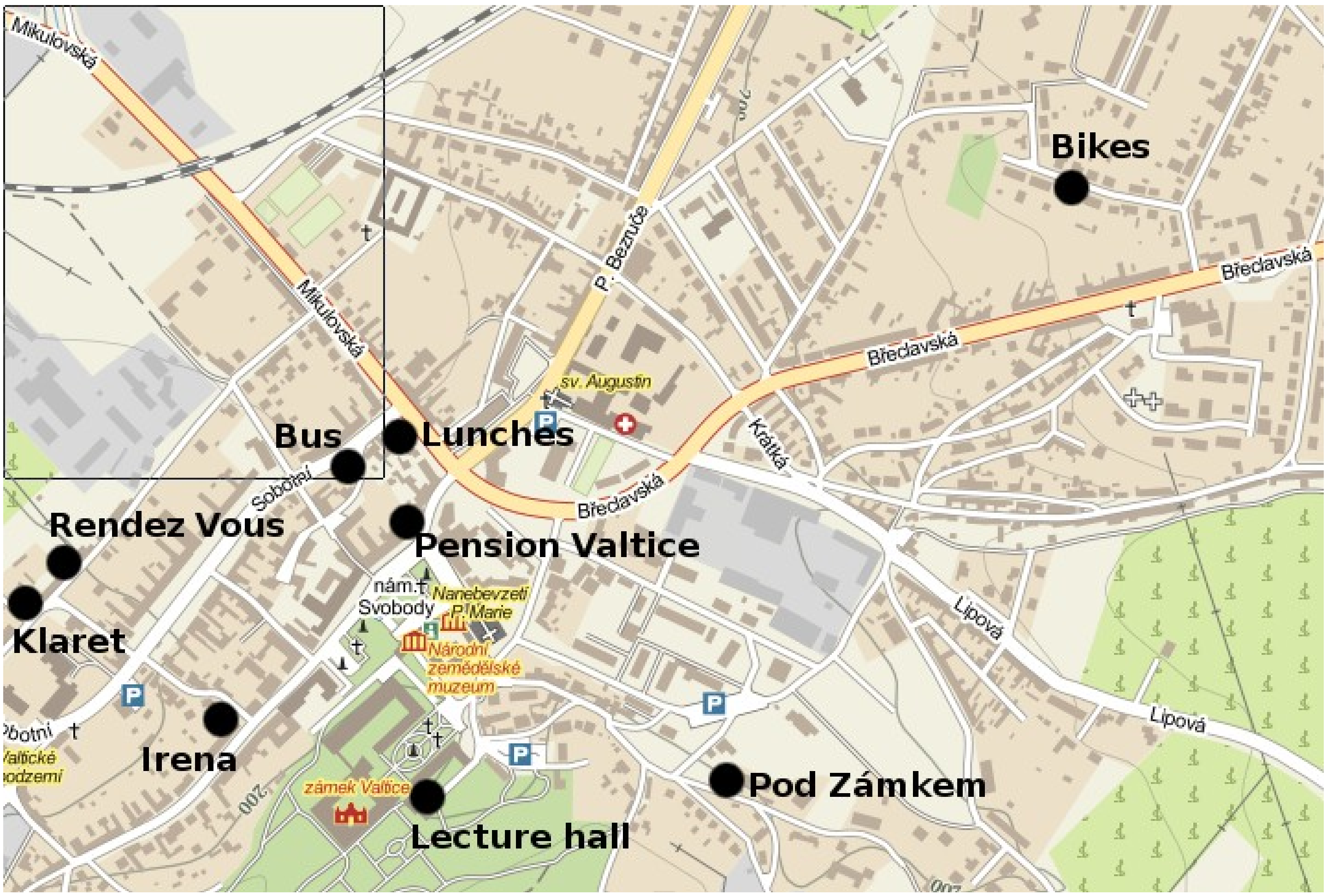
TUTORIAL

Jan Bouda

Classical zero-error communication over classical and quantum channel

One of the main questions of information theory is whether it is possible to communicate information through a (particular) noisy channel with a zero probability of error, and what is the bit rate one can achieve. In this tutorial I'll present the basic analysis of the scenario, namely the communication of classical information through a noisy channel (memoryless, both classical and quantum), without feedback or entanglement.

MAP OF VALTICE



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ceqip.eu@gmail.com , http://ceqip.eu/2013