In this article, we briefly summarize the experiments performed during the first run of the Advanced Wakefield Experiment, AWAKE, at CERN (European Organization for Nuclear Research). The final goal of AWAKE Run 1 (2013-2018) was to demonstrate that 10-20 MeV electrons can be accelerated to GeV energies in a plasma wakefield driven by a highly relativistic self-modulated proton bunch. We describe the experiment, outline the measurement concept and present first results. Last, we outline our plans for the future.

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Hardlock: Real-time multicore locking
Multiple threads executing on a multicore processor often communicate via shared objects, allocated in main memory, and protected by locks. A lock itself is often implemented with the compare-and-swap operation. However, this operation is retried when the operation fails and the number of retries is unbounded. For hard real-time systems we need to be able to provide worst-case execution time bounds for all operations. The paper presents a time-predictable solution for locking on a multicore processor. Hardlock is an on-chip locking unit that supports concurrent locking without the need to get off-chip. Acquisition of a lock takes 2 clock cycles and release of a lock 1 clock cycle.

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Sex-specific difference in migration schedule as a precursor of protandry in a long-distance migratory bird

Protandry, the earlier arrival of males at the breeding grounds relative to females, is common in migratory birds. However, due to difficulties in following individual birds on migration, we still lack knowledge about the spatiotemporal origin of protandry during the annual cycle, impeding our understanding of the proximate drivers of this phenomenon. Here, we use full annual cycle tracking data of red-backed shrikes Lanius collurio to investigate the occurrence of sex-related differences in migratory pattern, which could be viewed as precursors (proximate causes) to protandry. We find protandry with males arriving an estimated 8.3 days (SE = 4.1) earlier at the breeding area than females. Furthermore, we find that, averaged across all departure and arrival events throughout the annual cycle, males migrate an estimated 5.3 days earlier than females during spring compared to 0.01 days in autumn. Event-wise estimates suggest that a divergence between male and female migratory schedules is initiated at departure from the main non-breeding area, thousands of kilometres from-, and several months prior to arrival at the breeding area. Duration of migration, flight speed during migration and spatial locations of stationary sites were similar between sexes. Our results reveal that protandry might arise from sex-differential migratory schedules emerging at the departure from the main non-breeding area in southern Africa and retained throughout spring migration, supporting the view that sex-differential selection pressure operates during spring migration rather than autumn migration.

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Closed-loop control with unannounced exercise for adults with type 1 diabetes using the Ensemble Model Predictive Control

This paper presents an individualized Ensemble Model Predictive Control (EnMPC) algorithm for blood glucose (BG) stabilization and hypoglycemia prevention in people with type 1 diabetes (T1D) who exercise regularly. The EnMPC formulation can be regarded as a simplified multi-stage MPC allowing for the consideration of Nen scenarios gathered from the patient's recent behavior. The patient's physical activity behavior is characterized by an exercise-specific input signal derived from the deconvolution of the patient's continuous glucose monitor (CGM), accounting for known inputs such as meal, and insulin pump records. The EnMPC controller was tested in a cohort of in silico patients with representative inter-subject and intra-subject variability from the FDA-accepted UVA/Padova simulation platform. Results show a significant improvement on hypoglycemia prevention after 30 min of mild to moderate exercise in comparison to a
similarly tuned baseline controller (rMPC); with a reduction in hypoglycemia occurrences (<70 mg/dL), from 3.08% ±3.55 with rMPC to 0.78% ±2.04 with EnMPC (P < 0.05).

**Optimal allocation of HVDC interconnections for exchange of energy and reserve capacity services**

The increasing shares of stochastic renewables bring higher uncertainty in power system operation and underline the need for optimal utilization of flexibility. However, the European market structure that separates energy and reserve capacity trading is prone to inefficient utilization of flexible assets, such as the HVDC interconnections, since their capacity has to be ex-ante allocated between these services. Stochastic programming models that co-optimize day-ahead energy schedules with reserve procurement and dispatch, provide endogenously the optimal transmission allocation in terms of minimum expected system cost. However, this perfect temporal coordination of trading floors cannot be attained in practice under the existing market design. To this end, we propose a decision-support tool that enables an implicit temporal coupling of the different trading floors using as control parameters the inter-regional transmission capacity allocation between energy and reserves and the area reserve requirements. The proposed method is formulated as a stochastic bilevel program and cast as mixed-integer linear programming problem, which can be efficiently solved using a Benders decomposition approach that improves computational tractability. This model bears the anticipativity features of a transmission allocation model based on a pure stochastic programming formulation, while being compatible with the current market structure. Our analysis shows that the proposed mechanism reduces the expected system cost and thus can facilitate the large-scale integration of intermittent renewables.
Multi-objective optimization of a circular dual back-plate MEMS microphone: tradeoff between pull-in voltage, sensitivity and resonance frequency

In this study, the optimization of a circular dual back-plate condenser microphone has been done in order to increase the pull-in voltage, sensitivity and resonance frequency simultaneously. Microphone’s diaphragm is assumed as a circular micro-plate subjected to symmetric two-sided electrostatic force. An accurate eighth order polynomial function is determined as the first mode shape of the circular micro-plate and Galerkin decomposition method is employed to find the analytical formulations for the microphone metrics performance. The analytical relations are validated by comparing them with finite element results. Next, the applied voltage, gap size, diaphragm radius and thickness are assumed as the design variables and modified non-dominated sorting genetic algorithm is utilized for multi-objective optimization procedure. Considering low standard deviations and high mean values, a new design point is chosen among the suggested optimal points so that there is an increment in each of three objective functions. Compare to a fabricated sample of a dual back-plate microphone, for the new design point, pull-in voltage has increased more than 3.6 times, sensitivity has improved 4% and resonance frequency has extended 24%.

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Three-spin solid effect and the spin diffusion barrier in amorphous solids
Dynamic nuclear polarization (DNP) has evolved as the method of choice to enhance NMR signal intensities and to address a variety of otherwise inaccessible chemical, biological and physical questions. Despite its success, there is no detailed understanding of how the large electron polarization is transferred to the surrounding nuclei or where these nuclei are located relative to the polarizing agent. To address these questions we perform an analysis of the three-spin solid effect, and show that it is exquisitely sensitive to the electron-nuclear distances. We exploit this feature and determine that the size of the spin diffusion barrier surrounding the trityl radical in a glassy glycerol–water matrix is <6 Å, and that the protons involved in the initial transfer step are on the trityl molecule. 1H ENDOR experiments indicate that polarization is then transferred in a second step to glycerol molecules in intimate contact with the trityl.

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Towards subdiffraction imaging with wire array metamaterial hyperlenses at MIR frequencies

We describe the fabrication of metamaterial magnifying hyperlenses with subwavelength wire array structures for operation in the mid-infrared (around 3 µm). The metadevices are composed of approximately 500 tin wires embedded in soda-lime glass, where the metallic wires vary in diameter from 500 nm to 1.2 µm along the tapered structure. The modeling of the hyperlenses indicates that the expected overall losses for the high spatial frequency modes in such metadevices are between 20 dB to 45 dB, depending on the structural parameters selected, being promising candidates for far-field subdiffraction imaging in the mid-infrared. Initial far-field subdiffraction imaging attempts are described, and the problems encountered discussed.

Efficient sound radiation using a bandgap structure

This work reports on the use of bandgaps to increase the efficiency of sound radiation employing defect modes on a phononic crystal (PnC). A PnC consisting of a 2D array of studs on an aluminum plate is considered, and a defect is created by removing four studs. Numerical simulations predict 8 dB higher radiation efficiency and significantly more uniform directivity of sound due to the piston-like defect modes that suppress interference between acoustic waves. An experimental study of the vibrational response is carried out in order to validate the numerical result. Comparisons of the radiation efficiency and the directivity index between the numerical and experimental results show good agreement. These findings may pave the way to use bandgap structures as effective acoustic radiators.
Symbolic computation of differential equivalences

Ordinary differential equations (ODEs) are widespread in many natural sciences including chemistry, ecology, and systems biology, and in disciplines such as control theory and electrical engineering. Building on the celebrated molecules-as-processes paradigm, they have become increasingly popular in computer science, with high-level languages and formal methods such as Petri nets, process algebra, and rule-based systems that are interpreted as ODEs. We consider the problem of comparing and minimizing ODEs automatically. Influenced by traditional approaches in the theory of programming, we propose differential equivalence relations. We study them for a basic intermediate language, for which we have decidability results, that can be targeted by a class of high-level specifications. An ODE implicitly represents an uncountable state space, hence reasoning techniques cannot be borrowed from established domains such as probabilistic programs with finite-state Markov chain semantics. We provide novel symbolic procedures to check an equivalence and compute the largest one via partition refinement algorithms that use satisfiability modulo theories. We illustrate the generality of our framework by showing that differential equivalences include (i) well-known notions for the minimization of continuous-time Markov chains (lumpability), (ii) bisimulations for chemical reaction networks recently proposed by Cardelli et al., and (iii) behavioral relations for process algebra with ODE semantics. Using ERODE, the tool that implements our techniques, we are able to detect equivalences in biochemical models from the literature that cannot be reduced using competing automatic techniques.
Generating Maximal Entanglement between Spectrally Distinct Solid-State Emitters

We show how to create maximal entanglement between spectrally distinct solid-state emitters embedded in a waveguide interferometer. By revealing the rich underlying structure of multiphoton scattering in emitters, we show that a two-photon input state can generate deterministic maximal entanglement even for emitters with significantly different transition energies and linewidths. The optimal frequency of the input is determined by two competing processes: which-path erasure and interaction strength. We find that smaller spectral overlap can be overcome with higher photon numbers, and quasimonochromatic photons are optimal for entanglement generation. Our work provides a new methodology for solid-state entanglement generation, where the requirement for perfectly matched emitters can be relaxed in favor of optical state optimization.

Deconvolution of autoencoders to learn biological regulatory modules from single cell mRNA sequencing data

Background: Unsupervised machine learning methods (deep learning) have shown their usefulness with noisy single cell mRNA-sequencing data (scRNA-seq), where the models generalize well, despite the zero-inflation of the data. A class of neural networks, namely autoencoders, has been useful for denoising of single cell data, imputation of missing values and dimensionality reduction. Results: Here, we present a striking feature with the potential to greatly increase the usability of autoencoders: With specialized training, the autoencoder is not only able to generalize over the data, but also to tease apart biologically meaningful modules, which we found encoded in the representation layer of the network. Our model can, from scRNA-seq data, delineate biological meaningful modules that govern a dataset, as well as give information as to which modules are active in each single cell. Importantly, most of these modules can be explained by known biological functions, as provided by the Hallmark gene sets. Conclusions: We discover that tailored training of an autoencoder makes it possible to deconvolute biological modules inherent in the data, without any assumptions. By comparisons with gene signatures of canonical pathways we see that the modules are directly interpretable. The scope of this discovery has important implications, as it makes it possible to outline the drivers behind a given effect of a cell. In comparison with other dimensionality reduction methods, or supervised models for classification, our approach has the benefit of both handling well the zero-inflated nature of scRNA-seq, and validating that the model captures relevant information, by establishing a link between input and decoded data. In perspective, our model in combination with clustering methods is able to provide information about which subtype a given single cell belongs to, as well as which biological functions determine that membership.

General information
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Y-DWMS - A digital watermark management system based on smart contracts

With the development of information technology, films, music, and other publications are inclined to be distributed in digitalized form. However, the low cost of data replication and dissemination leads to digital rights problems and brings huge economic losses. Up to now, existing digital rights management (DRM) schemes have been powerless to deter attempts of infringing digital rights and recover losses of copyright holders. This paper presents a YODA-based digital watermark management system (Y-DWMS), adopting non-repudiation of smart contract and blockchain, to implement a DRM mechanism to infinitely amplify the cost of infringement and recover losses copyright holders suffered once the infringement is reported. We adopt game analysis to prove that in Y-DWMS, the decision of non-infringement always dominates rational users, so as to fundamentally eradicate the infringement of digital rights, which current mainstream DRM schemes cannot reach.

General information
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Detecting malicious nodes via gradient descent and support vector machine in Internet of Things

IoT devices have become much popular in our daily lives, while attackers often invade network nodes to launch various attacks. In this work, we focus on the detection of insider attacks in IoT networks. Most existing algorithms calculate the reputation of all nodes based on the routing path. However, they rely heavily on the assumption that different nodes in the same routing path have equal reputation, which may be not invalid in practice and cause inaccurate detection results. To solve this issue, we formulate it as a multivariate multiple linear regression problem and use the K-means classification algorithm to detect malicious nodes. Further, we optimize the routing path and design an enhanced detection scheme. Our results indicate that our proposed methods could achieve a detection accuracy rate of 90% or above in a common case, and the enhanced scheme could reach an even lower false detection rate, i.e., below 5%.

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Research output: Contribution to journal > Journal article – Annual report year: 2019 > Research > peer-review

Comparison of two microphone array geometries for surface impedance estimation
This study examines the estimation of the surface impedance of an absorber with microphone arrays. Two array geometries are compared - a rigid spherical array and a double layer planar array. The impedance is estimated via reconstructing the sound field (pressure and particle velocity) on the absorber’s surface, using a plane wave expansion. The comparison is carried out by studying the numerical properties of the two arrays as well as through experimental tests.

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Robust estimation of voltage harmonics in a single-phase system
A frequency adaptive technique relying on a linear Kalman filter (KF) is presented here for robust estimation of voltage harmonics under variable frequency conditions in a single-phase system. A relatively simple frequency-locked loop (FLL) is combined with the linear KF (LK-FLL) to achieve frequency adaptive ability and avoid the use of a non-linear KF. In contrast to the non-linear extended KF (EKF), the LKF-FLL technique has several advantages such as robustness, linearity, simple tuning, having fewer states, requiring no derivative actions, while offering low complexity, excellent convergence, and computational efficiency. When compared to the non-linear extended real KF, it can generate a faster dynamic response and more accurate steady-state estimation of the harmonics under frequency variations. It can also provide an improved estimation for off-nominal frequency conditions when compared to the discrete Fourier transform (DFT) method. The effectiveness of the technique is verified by various simulated and real-time experimental case studies.

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Compression of dry lysozyme targets: The target preparation pressure as a new parameter in protein thin film production by pulsed laser deposition
Film growth of the well-known protein, chicken lysozyme, produced by the dry technique, pulsed laser deposition (PLD), from a compressed powder target has been investigated as a function of the target preparation pressure. PLD is a versatile technique for fabricating high quality films of inorganic materials, but the laser beam will typically produce fragments of molecules in the target and subsequently in the deposited films. We demonstrate that the pressure applied to compact the target prior to the laser irradiation is an important parameter that determines the deposition rate as well as the extent of fragmentation of the deposited molecules. The deposition process was carried out in vacuum using dry targets prepared with compaction pressure in the range 10–160 bar. The residual water in pockets of the lysozyme molecules drives fragments or intact lysozyme out of the target. At the intermediate fluence of 2 J/cm ², the deposition rate of the material (fragments or intact molecules) rises from 3 to 9 ng/cm² per shot as the compaction pressure increases from 10 to 160 bar. However, the number of intact molecules falls down by almost two orders of magnitude in the same pressure range. This is explained by a stronger cohesion of the target material prepared at higher compression pressure, such that more energy and thus a higher temperature are required for the onset of material ejection. At the highest compression pressure, it means that no intact molecules survive the ejection. The results indicate that there is a pressure range where both a reasonable deposition rate and a considerable fraction of intact molecules in the films can be achieved. These experimental observations are consistent with the results of coarse-grained molecular dynamics simulations, where the fraction of intact lysozyme molecules is observed to vanish as the maximum temperature in the irradiated target increases.

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Publication information
Linear codes associated to skew-symmetric determinantal varieties
In this article we consider linear codes coming from skew-symmetric determinantal varieties, which are defined by the vanishing of minors of a certain fixed size in the space of skew-symmetric matrices. In odd characteristic, the minimum distances of these codes are determined and a recursive formula for the weight of a general codeword in these codes is given.

Designing collaborative blockchained signature-based intrusion detection in IoT environments
With the rapid development of Internet-of-Things (IoT), there is an increasing demand for securing the IoT environments. For such purpose, intrusion detection systems (IDSs) are one of the most important security mechanisms, which can help defend computer networks including IoT against various threats. In order to achieve better detection performance, collaborative intrusion detection systems or networks (CIDSs or CIDNs) are often adopted in a practical scenario, allowing a set of IDS nodes to exchange required information with each other, e.g., alarms, signatures. However, due to the distributed nature, such kind of collaborative network is vulnerable to insider attacks, i.e., malicious nodes can generate untruthful signatures and share to normal peers. This may cause intruders to be undetected and greatly degrade the effectiveness of IDSs. With the advent of blockchain technology, it provides a way to verify shared signatures (rules). In this work, our motivation is to develop CBSigIDS, a generic framework of collaborative blockchained signature-based IDSs, which can incrementally build and update a trusted signature database in a collaborative IoT environment. CBSigIDS can provide a verifiable manner in distributed architectures without the need of a trusted intermediary. In the evaluation, our results demonstrate that CBSigIDS can enhance the robustness and effectiveness of signature-based IDSs under adversarial scenarios.
Individual differences in replicated multi-product experiments with Thurstonian mixed models for binary paired comparison data

Often sensory discrimination tests are performed with replications for the assessors. In this paper, we suggest a new way of analyzing data from a discrimination study. The model suggested in this paper is a Thurstonian mixed model, in which the variation from the assessors is modelled as a random effect in a generalized linear mixed model. The setting is a multi-product discrimination study with a binary paired comparison. This model makes it possible to embed the analyses of products into one analysis rather than having to do an analysis for each product separately. In addition, it is possible to embed the model into the Thurstonian framework obtaining d-prime interpretations of the estimates. Furthermore, it is possible to extract information about the assessors, even across the products. More specifically, assessor specific d-prime estimates are obtained providing a way to get information about the panel. These estimates are interesting because they make it possible to investigate if the assessors are assessing in a specific way.