A hybrid modelling method for improving estimates of the average energy-saving potential of a building stock

Assessing the energy-saving potential in a building stock requires accurate prediction of the energy use in buildings, as well as estimating effects of imposing energy-conservation measures. Bottom-up building physics-based building stock energy models are widely used for this purpose. However, deficient data (e.g. data related to the use of the building) compel modellers to use normative assumptions in its place, thereby compromising the accuracy of building-physics based models. Furthermore, validation of building-physics based building stock energy models is often lacking. In the present study, a hybrid bottom-up building stock energy model was developed in order to overcome the drawbacks of traditional building-physics (engineering) based modelling methods. Using a sample of more than 100,000 residential buildings, individual building-physics based models were calibrated against energy use data in a multiple linear regression setting, thereby providing a novel hybrid bottom-up building stock energy model. Furthermore, embedding building-physics based building energy models in a statistical model made it possible to validate the model by means of common statistical measures. The proposed hybrid model provided significantly more accurate estimates of the energy use in an unseen sample of buildings than a purely building-physics based building stock energy model. Moreover, as the hybrid model included a unique building-physical description of each building in the sample, it could be used for estimating the effect of imposing an arbitrary energy upgrade. This way of setting up a hybrid building stock energy model provides a simple, yet accurate, approach for estimating the energy-saving potential of a building stock that could be used for informing policy makers and other stakeholders.
Optical sampling to enhance Nyquist-shaped signal detection under limited receiver bandwidth

Insufficient receiver bandwidth destroys the orthogonality of Nyquist-shaped pulses, generating inter-symbol interference (ISI). We propose using an optical pre-sampler to alleviate the requirement on the receiver bandwidth through pulse reshaping. Experiments and simulations using an optically shaped 40-Gbaud Nyquist-shaped on-off-keying signal (N-OOK) show receiver sensitivity improvements of 4- and 7.1-dB under 18- and 11-GHz receiver electrical bandwidths, respectively.

Enhanced Modal Dispersion Estimation Enabled by Chromatic Dispersion Compensation in Optical Vector Network Analysis

Component characterization is fundamental for understanding the limits of optical devices, sub-systems, and transmission systems. With the introduction of space division multiplexing in optical fiber transmission systems, new impairments, such as mode dependent loss and differential mode dispersion arise. Spatially-diverse optical vector network analyzers are capable of measuring these characteristics in a fast single sweep over a very large bandwidth. As a result of this large bandwidth, these analyzers are sensitive to differential chromatic dispersion within the interferometric measurement setup. This study discusses the influence and compensation of differential chromatic dispersion in such systems. Partial chromatic dispersion compensation is demonstrated to improve the representation and accuracy of impulse response measurements obtained from optical vector network analyzers for fibers and components with large differential chromatic dispersion. Analysis of a 39-core few-mode multi-core fiber is discussed, reporting variances of -2.9-0.1 ps/nm, and 0.6-6.9 ps/nm for the two mode groups, respectively, between the few-mode cores. A correlation with the total impulse response is observed. Furthermore, a maximum propagation skew of 20 ns between cores is observed after 13.6 km.
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Pages: 4001-4007
Publication date: 15 Aug 2019
Peer-reviewed: Yes

Publication information
Journal: Journal of Lightwave Technology
Volume: 37
Issue number: 16
Article number: 8736774
ISSN (Print): 0733-8724
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
Original language: English
Keywords: Component analysis, Device characterization, Differential mode dispersion, Mode dependent loss, Optical vector network analysis, Space division multiplexing
DOIs:
10.1109/JLT.2019.2923112
Source: Scopus
Source ID: 85070478583
Research output: Contribution to journal › Journal article – Annual report year: 2019 › Research › peer-review

Proton-driven plasma wakefield acceleration in AWAKE
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- 20MeV 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.

General information
Publication status: Published
Organisations: Department of Physics
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Publication date: 12 Aug 2019
Peer-reviewed: Yes

Publication information
Journal: Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences
Volume: 377
Issue number: 2151
Article number: 0418
ISSN (Print): 1364-503X
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
Original language: English
Electronic versions:
Fulltext
DOIs:
10.1098/rsta.2018.0418
Source: Scopus
Source ID: 85068359005
A multispectral camera system for automated minirhizotron image analysis

Aims: Roots are vital organs for plants, but the assessment of root traits is difficult, particularly in deep soil layers under natural field conditions. A popular technique to investigate root growth under field or semi-field conditions is the use of minirhizotrons. However, the subsequent manual quantification process is time-consuming and prone to error. Methods: We developed a multispectral minirhizotron imaging system and a subsequent image analysis strategy for automated root detection. Five wavelengths in the visible (VIS) and near-infrared (NIR) spectrum are used to enhance living roots by a multivariate grouping of pixels based on differences in reflectance; background noise is suppressed by a vesselness enhancement filter. The system was tested against manual analysis of grid intersections for both spring barley (Hordeum vulgare L.) and perennial ryegrass (Lolium perenne L.) cultivars at two time-points. The images of living roots were captured in wet subsoil conditions with dead roots present from a previous crop. Results: Under the soil conditions used in the study, NIR reflectance (940 nm), provided limited ability to separate between rhizosphere components, compared to reflectance in the violet and blue light spectrum (405 nm and 450 nm). Multivariate image analysis of the spectral data, combined with vesselness enhancement and thresholding allowed for automated detection of living roots. Automated image analysis largely replicated the root intensity found during manual grid intersect analysis of the same images. Although some misclassification occurred, caused by elongated structures of dew and chalkstone with similar reflectance pattern as living root, the system provided similar or in some cases improved detection of genotypic differences in the total root length within each tube. Conclusion: The multispectral imaging system allows for automated detection of living roots in minirhizotron studies. The system requires considerably less time than traditional manual recording using grid intersections. The flexible training strategy used for root segmentation offers hope for the transfer to other rhizosphere components and other soil types of interest.

General information
Publication status: Published
Organisations: Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, University of Copenhagen
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Pages: 657-672
Publication date: 1 Aug 2019
Peer-reviewed: Yes

Publication information
Journal: Plant and Soil
Volume: 441
Issue number: 1-2
ISSN (Print): 0032-079X
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
Original language: English
Keywords: Automated, Imaging, Minirhizotron, Multispectral, Root, Soil
DOIs: 10.1007/s11104-019-04132-8
Source: Scopus
Source ID: 85068149700
Research output: Contribution to journal -> Journal article -> Annual report year: 2019 -> Research -> peer-review

An Efficient Storage of Infrared Video of Drone Inspections via Iterative Aerial Map Construction

In this letter, we present a novel compression algorithm of infrared video sequences captured during drone inspections based on iterative aerial map construction. In our approach, we first apply a stitching algorithm to construct a map of an inspected area assuming that a drone is flying at the same altitude by trajectory close to meander, so that each frame can have a partial overlap with other frame captured much earlier or later. Then, we extract position and rotation angle within the map for each frame and use them as a side information for the video coding. In order to compress an input video sequence, we utilize a multi-view H.265/HEVC with two views. First view is a virtual view generated utilizing the decoded frames of the second view and the side information, whereas the input video is considered as the second view, which is encoded utilizing the virtual view as a reference for the inter-view prediction. The proposed approach has two main benefits. First, the aerial map is generated during decoding utilizing the side information, i.e., the map is not embedded into a bit stream. Second, the inter-view prediction allows to exploit an additional redundancy, which is typical for a drone video. Experimental results show that the proposed algorithm provides 1.4%-2.4% bit rate savings comparing to H.265/HEVC. The maximum possible bit rate savings are estimated from 15.5% to 18.9% assuming that the drone is repeatedly flying many times at exactly the same trajectory.
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.

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.

General information
Publication status: Published
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Number of pages: 10
Publication date: 1 Aug 2019
Peer-reviewed: Yes

Publication information
Journal: Science of Nature
Volume: 106
Issue number: 7-8
Article number: 45
ISSN (Print): 0028-1042
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
Original language: English
Keywords: Geolocator, Protandry, Red-backed shrike, Songbird migration
DOIs:
10.1007/s00114-019-1637-6
Source: Scopus
Source ID: 85068764947
Research output: Contribution to journal > Journal article – Annual report year: 2019 > Research > peer-review

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 N_{en} 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).

General information
Publication status: Published
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Pages: 202-210
Publication date: 1 Aug 2019
Peer-reviewed: Yes

Publication information
Journal: Journal of Process Control
Volume: 80
ISSN (Print): 0959-1524
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%.
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.

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.

**General information**
Publication status: Published
Organisations: Fiber Sensors & Supercontinuum, Department of Photonics Engineering, University of Sydney, Macquarie University
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Pages: 21420-21434
Publication date: 22 Jul 2019
Peer-reviewed: Yes

**Publication information**
Journal: Optics Express
Volume: 27
Issue number: 15
ISSN (Print): 1094-4087
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
Original language: English
Electronic versions:
oe_27_15_21420.pdf
DOIs:
10.1364/OE.27.021420
Source: Scopus
Source ID: 85069858180
Research output: Contribution to journal › Journal article – Annual report year: 2019 › Research › peer-review

**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.

**General information**
Publication status: Published
Organisations: Department of Electrical Engineering, Acoustic Technology, Department of Mechanical Engineering, Solid Mechanics
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Number of pages: 6
Publication date: 22 Jul 2019
Peer-reviewed: Yes

**Publication information**
Volume: 115
Issue number: 4
Article number: 041903
ISSN (Print): 0003-6951
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
Original language: English
Electronic versions:
1.5110296.pdf
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.
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
Publication status: Published
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Number of pages: 17
Publication date: 2 Jul 2019
Peer-reviewed: Yes

Publication information
Journal: Sensors (Switzerland)
Volume: 19
Issue number: 14
Article number: 3091
ISSN (Print): 1424-8220
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
Original language: English
Keywords: Blockchain, Digital rights management, Game theory, Smart contract

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%.

General information
Publication status: Published
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Pages: 339-353
Publication date: 1 Jul 2019