
*Výzkumné centrum Data – Algoritmy – Rozhodování*

*Research Centre Data – Algorithms – Decision Making*

**Martin Janžura – Jiří Ivánek (eds.)**

# Abstracts of Contributions to 5th International Workshop on Data – Algorithms – Decision Making

**November 29, 2009 – December 1, 2009**
**Pilsen, Czech Republic**

*Interní publikace DAR – ÚTIA 2009/3*
*Praha, listopad 2009*

# Content

# Factorization and Multidimensional Models

[1] Jiroušek Radim

It is a generally accepted fact that efficient representation of multidimensional probabilistic models (like Graphical Markov Models, or Compositional Models) is made possible by the properties of the *conditional independence* relation. Nevertheless, it is the property of *factorization*, upon which all these approached are based. We usually say that we employ the properties of conditional independence because in probability theory (under rather general conditions) these two concepts coincide. However, there are several notions of factorization. This becomes to be important especially when one starts considering multidimensional model representation in alternative theories of uncertainty, where factorization lemma need not hold true (or, where several notions of conditional independence relation have been introduced, none of them generally accepted).

In the lecture different notions of factorization will be introduced, first in probability theory and then a possibility to generalize them for Dempster-Shafer theory of evidence will be discussed.

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# Remarks on the Geometric Approach to Learning Bayesian Network Structure

[1]Studený Milan , [2]Vomlel Jiří

The idea of the geometric approach to learning Bayesian network (BN) structure [1] is to represent this graphical structure by a certain integer-valued vector, called the *standard imset*. Then the requirement to maximize a (reasonable) quality criterion over BN structures leads to the task to maximize a linear function over a special polytope. The aim to apply linear programming methods in this area leads to several open (mathematical) question concerning that special polytope. Some of them have been answered recently in [1]. The talk will be a brief overview of the present state of knowledge in this respect.

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# Soft Inference: Reasoning with Second Order Probability Distributions

[1]Gernot D. Kleiter

Imprecise probabilities may be interpreted as (i) intervals (lower and upper probabilities) or as (ii) second order probability distributions. The present contribution uses the distributional approach. We investigate logical connectives and elementary logical inference rules in terms of second order distributions. We do this by using uni- and bivariate beta distributions. A recently proposed family of bivariate beta distributions (Nadarajah, 2007) allows to model correlated uncertainties. Special attention is payed to properties that explain results observed in research on human reasoning and judgment under uncertainty, like the the conjunction fallacy or the difficulties in understanding the modus tollens.

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# Linguistic Approach to Time Series Analysis

[1]Štěpnička Martin , [2]Dvořák Antonín , [3]Pavliska Viktor , [4]Vavříčková Lenka

There is no doubt that the analysis and forecasting of time series have a wide practical use in economy, industry, meteorology, and other parts of life [1]. There are two standard approaches to the analysis and forecasting of time series. The first one stems from the so called *Box-Jenkins methodology* [2]. It consists of autoregressive and moving average models and it has been demonstrated to be very powerful and successful in forecasts.

The second approach, which is called *decomposition*, assumes a given times series to be an additive or multiplicative composition of the *trend, cycle, season*, and a *noise* term. The components of the above mentioned composition have clear meanings, so models decomposing a given time series into these components are very transparent in contrast to complicated autoregressive and moving averages models of the Box-Jenkins methodology.

We combine both approaches to adopt their benefits. First, we decompose the time series into the so called trend-cycle and the seasonal component. The trend-cycle is determined by the *F-transform* [3] of the time series. Autoregressive relationships between successive values in the trend-cycle are then described with help of the linguistic description consisting of fuzzy rules. These are automatically generated by the *linguistic learning algorithm* [4] which is implemented in the LFLC software package [5]. The *perception-based logical deduction* [6] is then used as an inference method to forecast future trend-cycle values.

Seasonal component is analyzed and forecasted separately using the Box-Jenkins methodology and added to the forecasted trend-cycle as in case of the decomposition.

Thanks to the use of both of these methods, the methodology is successfully applicable to robust long time predictions, which has been experimentally justified [7]

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# Linguistic Approach to Associations Mining

[1]Antonín Dvořák , [2]Jiří Kupka , [3]Iva Tomanová

We present a method of data mining which is under development in our institute [2]. The main idea is to evaluate real-valued data by the corresponding linguistic expressions and then search for the corresponding associations using some of the standard data-mining techniques (we have used GUHA method [1]).

Associations, which are mined by this technique have form of sentences of natural language. Hence we call them *linguistic associations*. A typical form of linguistic association is

> *IF profit is high AND cost is rather low THEN productivity is very high AND volume of sale is significantly large.*

Our method captures the genuine linguistic meaning of such associations. This is achieved using a formal logical theory which provides a mathematical model of meaning of evaluating linguistic expressions (a certain class of natural language expressions).

In the first phase of our method, numerical data are replaced by linguistic expressions. It creates a new data table which contains the most suitable linguistic expressions with respect to original numerical data. Then, GUHA method is used on this new data table.

The main outcome of linguistic associations in their easy (or, at least, easier) understandability for the user, in the possibility to use their logical properties for significant reduction of their number, and also in the fact that their vague meaning enables less strict interpretation which complies with the uncertainty of existence of a relation characterized by them.

We tested our method on several data sets from various fields (economy, traffic) using software package LAM (Linguistic Associations Mining) developed at our institute. We will present some theoretical background of this method (evaluating linguistic expressions, GUHA method) and discuss the implementation in LAM and results of this method on various data. We will also mention recent improvements of our method [3] and related method which uses *fuzzy transform* [4].

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# Reasoning in Software Support and Maintenance

[1]Procházka Jaroslav , [2]Klimeš Cyril

Our work this year focuses on modelling and decision making under uncertainty in the context of support and maintenance of IT services. This area is very interesting and has a lot of problems as the complexity of the systems rises. We have experienced problems in a lot of support and maintenance cases we participated in. Most of the cases are in distributed environment, consisting of several teams all over the Europe and India as well. Common problems triggered our research are overloaded people before/after release; lack of architectural knowledge; re-occurring incidents; no or incomplete/outdated documentation; reinventing the wheel (poor knowledge sharing); missing business knowledge (so called big picture); process oriented approach - procedures are very activity oriented, do not care about the customer, only targets matter, e.g. to fulfill the SLA. A lot of problems and lessons learnt in IT industry are gathered in the form of textual patterns. From our expert perspective is relatively easy to identify symptoms and their root cases. But this is very hard for common team leaders or project managers. They usually perform the steps that make the situation much harder. It is caused by hard identification of root cases and acting upon consequences. We have defined the rules and patterns in support and maintenance area to help the teams. Having rules and patterns is one thing, but to implement them and how to implement them is another thing. So we have considered tool usage that can help managers or team leaders to identify root cases and choose practices to improve the situation. Having rules and patterns is one thing, but to implement them and how to implement them is another thing. So, we have considered tool usage that can help managers or team leaders to identify root cases and choose practices to improve the situation.

We have discussed possible approaches that can solve our needs:

- Manual fuzzy IF-THEN reasoning trees,
- Base of IF THEN rules and inference mechanism (Hierarchical base),
- Fuzzy Petri nets.

As a tools support we have chosen LFLC 2000 and Fpn2lfln tool developed in IRAFM (Institute for Research and Applications of Fuzzy Modeling) institute in Ostrava.

This paper discusses approach, issues we are facing and possible solution.

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# Deblurring by Fusion of Images with Different Exposure Times

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We propose a method to remove photo blur due to camera shake, which is a typical problem when taking photos in dim lighting conditions such as indoor or night scenes. We use a pair of images, one of them blurred and the other one underexposed or noisy because of high ISO setting. Existing methods assume convolution model, that is the same blur in the whole image. It is seldom true in practice, especially for wide angle lens photos. We apply a space-variant model of blurring valid in many real situations. Results will be illustrated by a photograph of a night scene.

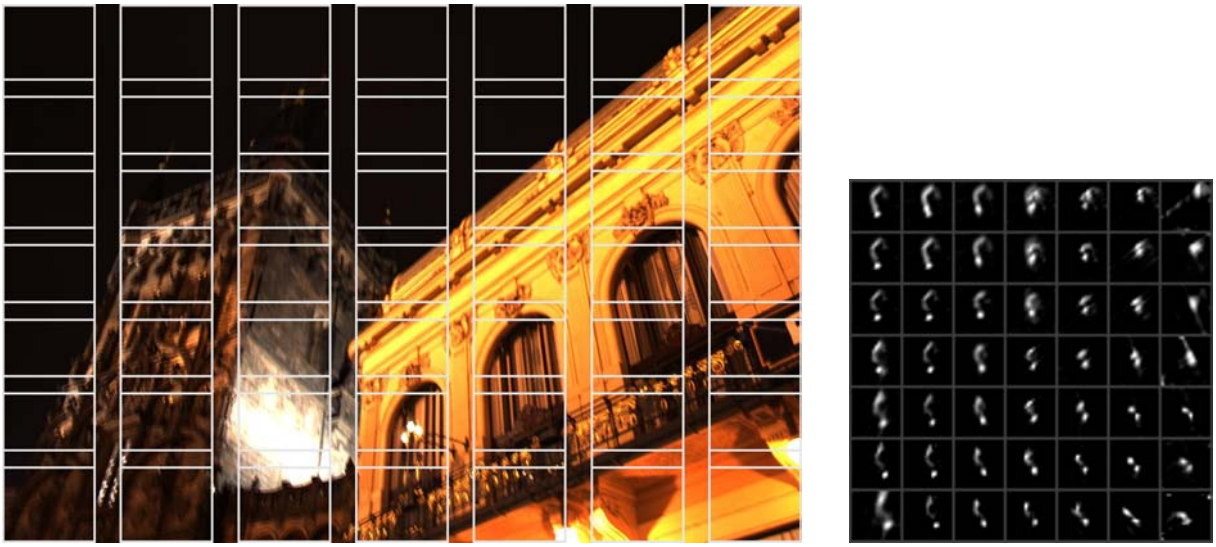

Figure 1: This night photo was taken from hand at ISO 100 and shutter speed 1.3s. Another photo of the same scene was taken at ISO 1600 and 2 stops under-exposure to achieve the hand-holdable shutter time 1/50s. The proposed algorithm combines them to get a low-noise sharp photo. The right image shows PSF's computed within white squares on the left using the proposed algorithm. Short focal length (36mm equivalent) accents spatial variance of the PSF.

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# Time Analysis of 3D Data in Nuclear Medicine

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In research and clinical practice of nuclear medicine there is a demand to compare two tomographic functional images of brain, e.g. PET images. It is useful to combine subtraction of the functional images with an anatomic image, e.g. with MRI. One representative of such methods is the SISCOM method [1]. It can be used, for example, to localize epileptogenic foci (Fig. 2) or to measure development of a tumor in time.

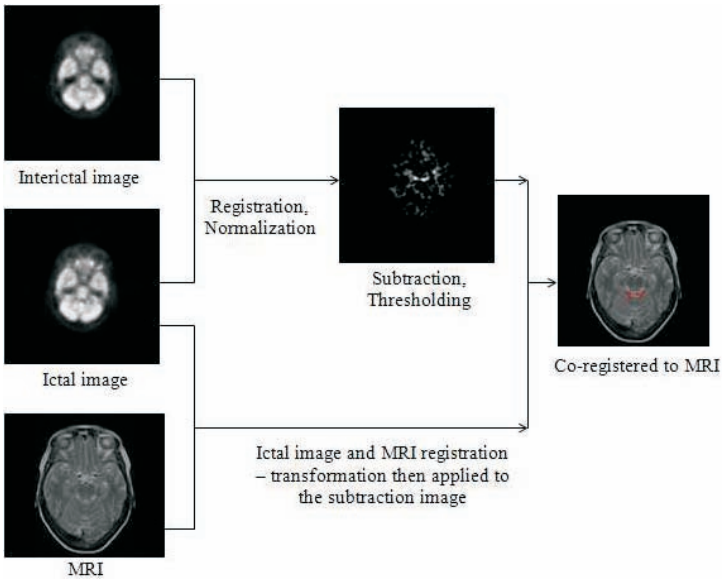


Figure 2: Application of subtraction methods to localization of epileptogenic foci

We have performed a thorough analysis of the relevant published methods [2, 3, 4]. As well, we have performed a research of requirements of the Department of Nuclear Medicine of Na Homolce Hospital, which initiated our work. The resulting procedure, implemented in an intuitive and user friendly software, is today used in research of the hospital.

There are possible improvements to our method. Using elastic deformation would allow us to better analyse changes causing deformations of their surrounding tissues. In the future, we also plan to focus on other radiotracers and processing of their corresponding images.

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# Assessing the Retinal Nerve Fiber Layer Thickness with Scanning Laser Polarimetry and Optical Coherence Tomography

[1]Tornow Ralf-Peter

Knowledge about the thickness of the retinal nerve fibre layer (RNFL) is of great importance for the early detection of glaucoma and to assess glaucoma progression. The most widely used clinical methods to measure the RNFL thickness are optical coherence tomography (OCT) and scanning laser polarimetry (SLP). Using OCT, circular scans around the optic nerve head (ONH) are acquired and the thickness distribution of the RNFL around the ONH is measured by segmenting the upper and lower boarders of the RNFL in the B-Scan images (see Figure 1). This is a direct measurement of the RNFL thickness. SLP uses the effect that the RNFL is anisotropic and shows birefringence. This means that the refractive

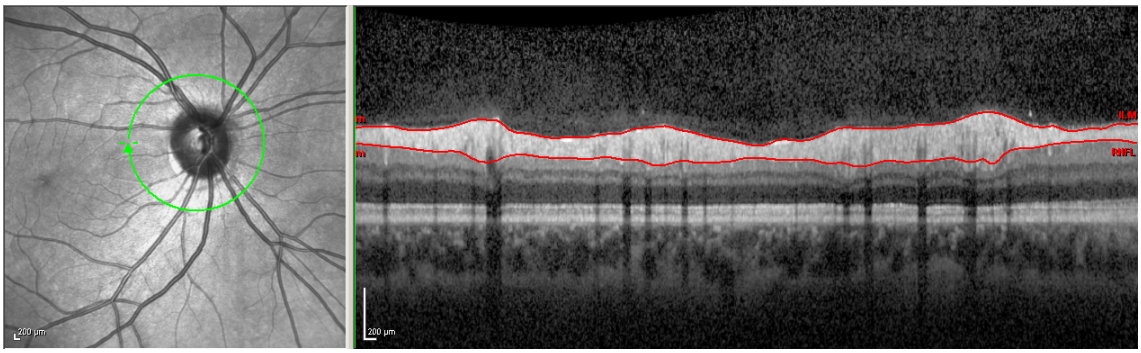

Figure 3: Left: Infra red image of the retina showing the position of the circular scan around the optic nerve head. Right: OCT B-Scan image with the segmented RNFL.

index of the material depends on the direction of the oscillation plane of the light. SLP measures the phase retardation between polarized light illuminating the RNFL at different orientations. The thickness is calculated from the phase retardation assuming a constant birefringence (RNFL thickness = phase retardation / birefringence). However, it was shown that the birefringence of the RNFL is not constant, it changes depending on the position around the ONH [1]. Latest results show that in glaucoma the birefringence is reduced before the thickness of the RNFL decreases and reduced birefringence could be one of the earliest signs of beginning glaucoma. To measure birefringence, both, the thickness and the phase retardation of the RNFL have to be measured (birefringence = phase retardation / thickness). Methods to measure the birefringence of the RNFL could be useful for the early detection of glaucoma. One approach to measure RNFL birefringence is to combine the results of OCT (RNFL thickness) and SLP (phase retardation) with exact local correspondence.

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# Unimodal and Multimodal Registration of Retinal Images

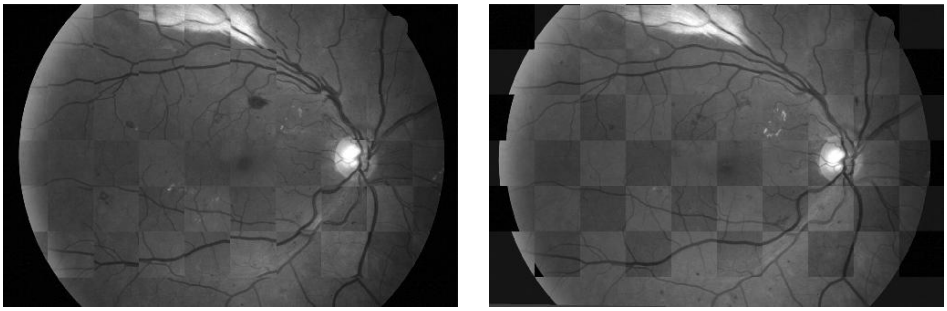
[1]Kolář Radim , [2]Jan Jiří

This paper deals with the registration of retinal images - it concludes three different (multimodal and unimodal) registration approaches with the focus on application of phase-correlation method on color fundus images.

The first approach concludes the registration of confocal scanning laser ophthalmoscope and color fundus images, which is used for glaucoma diagnosis [4].

The second approach concludes the registration of autofluorescent and infrared retinal images, which also found application in glaucoma diagnosis, but in its early stage [1, 2].

The third approach is focused on unimodal registration of color fundus images, which has been studied last year [3]. The images for the last topic were taken by digital color fundus cameras. The proposed method is based on the fast technique using phase correlation. It consists of several steps - global correction of shift and rotation, location of landmarks, their correspondences and image registration using second-order polynomial model using linear set of equations. The method was tested and evaluated from different point of views on two different image sets. The first image set contained images from diabetic patients, where many pathologies and artifacts are visible - hard and soft exudates, hemorrhages, blood-vessels neovascularization, myelinated retinal nerve fibers, retinal scars after laser treatment and clumping of the dark pigment. The second image set was used to test the ability of proposed method to register image pairs without pathologies, but with large shifts or rotations and different and non-uniform illumination conditions (different flash intensity and different time exposure was used during the acquisition). Three different methods were used for evaluation of registration results. The achieved registration accuracy for two image set was 1.89 px and 0.95 px (evaluated for landmarks), respectively.



a) b)

Figure 4: The chessboard images of one pair before registration and after registration.

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# High Through-put Forward Simulation in Ultrasound Tomography for Iterrative 3D Image Reconstruction

[1]Hemzal D. , [2]Jiřík R. , [3]Peterlík I. , [4]Roleček J. , [5]Jan J. , [6]Ruiter N.

In this running-work contribution, our new results are presented for the ultrasound tomography problem. 3D RF tomographic data from an experimental mammography-aimed ultrasound system (cf. Fig. 1) built in Karslruhe Institute for Technology [1] are used with the goal to provide an enhanced reconstruction of the properties of the tissues measured.

The first step used is a reconstruction from projection with edge-preserving regularization [2] and involving focusing. The tissue parameters distribution obtained is then used for a forward simulation of the expected US field according to visco-elastic form of wave equation,

$$\frac{\partial^2 \varrho'}{\partial t^2} - \frac{\sqrt{E}}{\varrho_0}\mathrm{div}(\sqrt{E}\mathrm{grad}\varrho') = \frac{\sqrt{\mu}}{\varrho_0}\mathrm{div}\left(\sqrt{\mu}\mathrm{grad}\frac{\partial \varrho'}{\partial t}\right),$$

via spatial harmonic analysis [3].

The results of this forward simulation are directly comparamble with the RF signals as measured by individual receiving transducers and can, in turn, be used for improvement of the original reconstruction, eg. in terms of non-straight-lined rays involvement. The whole procedure is aimed to become a building block of iterative scheme that would provide the possibility of high-resolution reconstruction.

The particular problems connected with the huge-size FE simulation in 3D [4] are discussed and the solution via utilisation of fine-grain massive parallel hardware by nVidia is outlined.

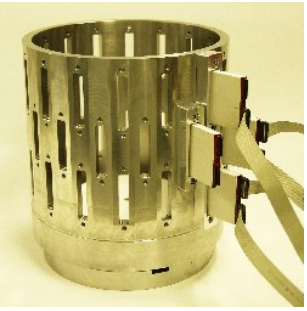

Figure 1.
The examination tank of the generation I ultrasound system revealed, as built in KIT; the protrusions in the tank are to be sealed by the transducers mounts themselves (several brick-shaped mounts with transducer blocks are present).

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# Automatic Artifact Removal from Long-term EEG Recordings

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Blind Source Separation (BSS), which consists in recovering original signals from their mixtures when the mixing process is unknown, and Independent Component Analysis (ICA), were observed as very useful tools in biomedical signal processing [1]. Their aim is to transform multichannel random signals via invertible linear transformation to so called "independent" components. In reality, the separated components are not truly statistically independent, but they are independent "as much as possible" in terms of some criterion. In biomedical processing applications it proved possible to separate responses of different origin, e.g. electrocardiogram (ECG) of a pregnant woman from ECG of her baby [2], or an unwanted interference from the useful signal.

The aim of this presentation is two-fold: (1) compare performance of several successful techniques of the Independent Component Analysis (ICA) [3, 4] with respect to their ability to separate/eliminate artifacts in electroencephalogram (EEG) recordings, and (2) propose novel way of a sequential artifact removal from long-term EEG recordings. The focus is on movement artifacts, eye blinking and unstuck electrode artifacts in neonatal eight channel EEG recordings. The method can be used, for example, as a preprocessing for identification of sleep stages of neonatal babies.

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# Application of a Modified Fay-Herriot Model to Small Area Estimation

[1]Hobza Tomáš , [2]Morales Domingo

Linear mixed models are widely used in applied statistics. Searle et al. (1982) provide a detailed description of linear mixed models and Ghosh and Rao (1994), and more recently Rao (2003) and Jiang and Lahiri (2006), discuss their applications to small area estimation. In this last setup the basic area level linear mixed model was introduced by Fay and Herriot (1979). This model typically assume that the domain random effect have a common constant variance. However, when estimating totals or means we may often find that domains can be divided in two groups where direct estimates behave in a different manner within them; for example they might have different variability. This situation may happen if we are interested in producing estimates by sex. In those cases traditional random intercept models do not fit well to data and some extra parameters are needed in the model.

In this contribution we extend the Fay-Herriot model to an area level linear regression model with random intercepts having one of two possible variances. Estimation procedures for the variance components and regression parameters are considered and empirical best linear unbiased predictors (EBLUP) of domain parameters are derived. The approximation given by Prasad and Rao (1990) and extended to a general class of linear mixed models by Das et al. (2004) is applied to obtain estimators of the mean squared errors of the EBLUP estimates.

Monte Carlo simulation experiments are presented to illustrate the gain of precision obtained by using the proposed model and to get some practical conclusions. A motivating application to Spanish Labour Force Survey data is also given.

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# Bregman Distances in Exponential Families

[1]Stummer Wolfgang , [2]Vajda Igor

This talk is devoted to the study of Bregman distances between probability measures and stochastic processes, which are "extensions" of the Bregman distances between deterministic functions (used e.g. in image processing and related inverse problems, machine learning, etc.). Mainly, we concentrate on models from exponential families. Several examples of statistically and mathfinancially motivated distributions will be given. Some new proposals for associated graphical goodness-of-fit-test procedures (involving colored 3D plots) will also be shown.

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# Optimal Control as a Graphical Model Inference Problem

[1]Kappen Hilbert J.

Stochastic optimal control theory deals with the problem to compute an optimal set of actions to attain some future goal. With each action and each state a cost is associated and the aim is to minimize the total future cost. Examples are found in many contexts such as motor control tasks for robotics, planning and scheduling tasks or managing a financial portfolio. The computation of the optimal control is typically very difficult due to the size of the state space and the stochastic nature of the problem.

The most common approach to compute the optimal control is through the Bellman equation. For the finite horizon discrete time case, this equation results from a dynamic programming argument that expresses the optimal cost-to-go (or value function) at time $t$ in terms of the optimal cost-to-go at time $t+1$. For the infinite horizon case, the value function is independent of time and the Bellman equation becomes a recursive equation. In continuous time, the Bellman equation becomes a partial differential equation.

For high dimensional systems or for continuous systems the state space is huge and the above procedure cannot be directly applied. A common approach to make the computation tractable is a function approximation approach where the value function is parametrized in terms of a number of parameters. Another promising approach is to exploit graphical structure that is present in the problem to make the computation more efficient. However, this graphical structure is not inherited by the value function, and thus the graphical representation of the value function is an approximation.

In this talk, we introduce a class of stochastic optimal control problems where the control is expressed as a probability distribution $p$ over future trajectories given the current state and where the control cost can be written as a KL divergence between $p$ and some interaction terms. The optimal control is given by minimizing the KL divergence, which is equivalent to solving a probabilistic inference problem in a dynamic Bayesian network (DBN). The optimal control is given in terms of (marginals of) a probability distribution over future trajectories. The formulation of the control problem as an inference problem directly suggests a number of well-known approximation methods, such as the variational method, belief propagation (BP), the cluster variation method (CVM) or generalized belief propagation (GBP) or Markov Chain Monte Carlo (MCMC) sampling methods. We refer to this class of problems as KL control problems.

The class of control problems considered in this paper is identical as in considered by Todorov, who shows that the Bellman equation can be written as a KL divergence of probability distributions between two adjacent time slices and that the Bellman equation computes backwards messages in a chain as if it were an inference problem. The novel contribution of the present paper is to identify the control cost with a KL divergence instead of making this identification in the Bellman equation. The immediate consequence is that the optimal control problem *is identical to* a graphical model inference problem and that the resulting graphical model inference problem can be approximated using standard methods.

The equivalence of certain types of control problems to inference problems is well-known for the linear quadratic Gaussian case and was previously exploited for the non-linear continuous space and time Gaussian case and for the discrete case, [1], [2], [3].

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# Survey of Research Activities at FAV UWB in Identification and Decision Making between 2005-2009

[1]Šimandl Miroslav

The research activities at FAV UWB in identification and decision making between 2005-2009 have focused on three main areas: nonlinear estimation, active fault detection and active dual control.

Within nonlinear state estimation, the point-mass method, particle filtering and derivative-free methods were pursued. The point-mass method was elaborated and the advanced point-mass method [1] was derived which includes anticipative grid design, boundary-based grid placement, thrifty convolution and multigrid design. Within particle filtering, new advances in sampling density design [2] and sample size specification [3] were achieved. A new generation of local filters, the so called derivative-free filters, were analyzed and new derivative-free smoothers and predictors were derived together with numerically-stable versions of the derivative free filters. Moreover, global derivative-free filters were developed [4]. Besides state estimation, also the problem of covariance matrices estimation was analyzed and new techniques for estimation of the matrices were proposed [5]. To support the theoretical results, a software toolbox for nonlinear state estimation was developed as well [6].

A new formulation of active fault detection problem was provided and its general solution was obtained. The basic idea is to apply the closed-loop control strategy for information processing. This formulation makes it possible to specify several special cases, namely active detector with given input signal generator, active detector and input signal generator and active detector and controller. To design a feasible solution, several approximation of the general solution were proposed [7], [8].

The research in the dual adaptive control field was focused on developing explicit dual control methods. First, the classical bicriterial controller was modified to employ a multiple linearization technique. Second, a new dual controller was proposed based on a modification of the cost function to evaluates stochastic characteristics of augmented state and the partial certainty equivalence technique is used to ensure the solvability of the multistage optimization problem [9].

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# DAR and Achievements in the Metal Processing Domain

[1]Ettler Pavel , [2]Puchr Ivan , [3]Štika Jiří , [4]Křen Jaroslav

DAR-related problems solved at COMPUREG during five years of the project duration can be divided into four groups:

**Decision support for operators:** The existing system was upgraded by new versions of algorithms and enlarged to run multiple advisers in parallel. Their outputs were mixed to outperform recommendations of particular advisers. For corresponding publications see [1], [3], [7].

**Parameter estimation from multiple short data records:** This problem arises in relation with pass scheduling for a reversing hot rolling mill. Suggested solution relies on rearrangement of data and engagement of Gaussian mixtures as depicted in [2].

**Control of time-delay systems:** The problem was to be solved within two completely different time scales: minutes and hours for control of annealing furnaces [4] and milliseconds for control of the electromechanical screwdown system [8]. Different means of system model approximation were used in combination with alternating open loop / closed loop control schemes for both cases.

**Mixing of multiple process models:** The effort refers to significant improvement of estimation/prediction of a key process variable for a cold rolling mill. General and simulated results are promising [5], [6]. A starting international project should result in industrially utilizable solution.

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# Vehicle Attitude Estimation with the Aid of GPS/INS Data

[1]Pavelková Lenka , [2]Nagy Ivan

In this presentation, a problem of the vehicle attitude estimation will be introduced. We will present a brief survey of selected methods used for vehicle attitude estimation and afterwards, we propose our solution of this problem.

The attitude of a moving vehicle is determined by means of global positioning system (GPS) but the data set is incomplete because of the big trees, buildings, etc. We aim to estimate the attitude within these GPS data fallouts. For this purpose, we can use an information from the inertial navigation system (INS) that includes a complete noisy information about vehicle velocity, yaw rate and acceleration. We focus on the off-line attitude estimation, i.e. we solve the task of a subsequent reconstruction of the vehicle attitude.

We construct a state model describing the vehicle motion. This model uses kinematics laws, i.e. it is not concerned with the causing forces. It exploits a dependency among the vehicle attitude, velocity and acceleration. The estimation algorithm is based on the Kalman filtering and smoothing.

The presented problem is solved within the framework of the beginning cooperation with the Škoda auto, a.s. This company is interested in cooperation with the research center DAR as of next year.

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# Experience with Implementation of Transportation Control

[1]Přikryl Jan

Every time a new theoretical strategy for signal control in urban transportation network is being implemented in practice, the implementing team faces many challenges of both administrative and technical nature. Using our transportation control system HRSD as an example, we will overview all the main phases of the design and implementation process and mention several important points that have been overlooked in the initial proposal.

We will concentrate on several topics:

*HRSD design, development, and simulation.* The transportation control system is based on the set of discrete models [2, 3] based on the vehicle conservation law [4]. The model provides queue length estimates, and the control block attempts to minimise the queue lengths over the controlled network using linear programming approach. Prior to field-testing the system, the whole system had to be simulated and evaluated. For this purpose a new set of interface libraries for Aimsun traffic micro-simulator [1] has been developed. The final tests took part in May 2009 and provided data for the administrative evaluation of the system.

*Administrative evaluation.* The field test of HRDS had to be approved by all local authorities in charge of any affected part of the transportation system. In our case our proposal was evaluated by the Municipal Department of Transport (ODMHMP), the Prague Public Transit Company (DPP), the municipal road administration agency (TSK Praha) and the Directorate of Transport Police of the Czech Republic. Given that every state body has a legal limit of 30 days to respond, the administrative procedures caused significant delay the whole implementation process.

*Detectors.* A new set of strategic detectors is required by the HRSD algorithm. As we could not afford to place another inductive loops in the road network, cheaper (but also not so reliable) variant using external video-detectors has been chosen. The detectors communicate over wireless link to their particular intersection controllers. Their measurements are collected and transferred to HRSD, they have no direct influence on the local controller.

*Control and communication hardware.* HRSD interfaces to the controlled system over an SQL database that mimics the database used by traffic control centre computers. The data from controllers is collected using a custom-made interface boards converting the controller bus to Ethernet with ability to interpret appropriate commands that would normally come from the traffic control centre. xDSL is used for communication between the controllers. Externeal connectivity is realised over GPRS connection using a modem borrowed from another project. Unfortunately, this severely limits the connection speed and allows just for monitoring the state of the HRSD system, starting it up and shutting it down. All other data (logs, surveillance pictures) have to be downloaded manually on-site.

*Computer hardware.* The whole testing system consists of four computers that have to fit into very confined space inside the intersection controller case. Ideally industrial-grade PCs would have been used – they are small and reliable, but unfortunately also very expensive. Hence, the actual hardware is a mix of notebooks and recycled low-power mini PCs that survived from different other projects.

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# Advances in Pattern Recognition and Modelling

[1]Haindl Michal

Recognition and modelling of multi-dimensional data (or set of spatially related objects) is more accurate and efficient if we take into account all interdependencies between single objects. Objects to be processed like for example multi-spectral pixels in a digitised image, are often mutually dependent (e.g., correlated) with a dependency degree related to a distance between two objects in their corresponding data space. These relations can be incorporated into a pattern recognition process through appropriate multi-dimensional data model. An overview our recent achievements in the area of texture modelling, unsupervised image segmentation, range image segmentation, illumination invariants and multichannel image restoration is briefly outlined.

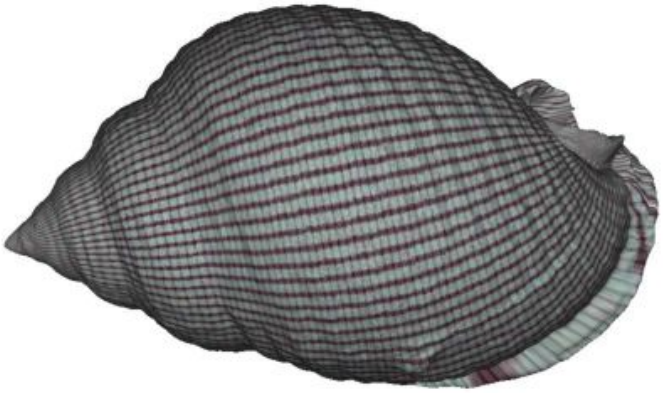

Figure 5: 3D conch model mapped with mixture based synthetic texture.

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# Unsupervised Image Segmentation

[1]Mikeš Stanislav , [2]Haindl Michal

Segmentation is a fundamental process which partitions a data space into meaningful salient regions [5, 4]. Image segmentation essentially affects the overall performance of any automated image analysis system thus its quality is of the utmost importance. Image regions, homogeneous with respect to some usually textural or colour measure, which result from segmentation algorithms [3, 1, 1] are analysed in subsequent interpretation steps. Unsupervised methods which do not assume any prior scene knowledge which can be learned to help segmentation process are obviously more challenging than the supervised ones. The article presents several novel MRF based unsupervised image segmenters together with a solution of the difficult cluster validation problem, and segmentation evaluation methodology [2]. Developed segmentation methods are utilised in various remote sensing, defect detection [5], mammographic [4], and cultural heritage applications.


Figure 6: Selected Berkeley benchmark image, ground truth from the benchmark and the segmentation results from the method (MW3AR) [1] and SWA [7].

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# Visual Perception of Material Appearance - Analysis and Applications

[1]Filip Jiří , [2]Haindl Michal

Accurate appearance representation of textured materials, dependent on illumination and viewing directions, has received significant attention recently. This research area was focused mainly on material appearance measurement, measured data representation, and its compression and modeling [1]. Although past methods achieved important results, they have not taken into account a way we perceive materials. They have measured and processed considerably more data than was actually needed and achieved accuracy that could not be effectively distinguished by our eyes. Moreover, these methods often reached limits of computational speed yielding similar performance. Therefore, one way to obtain higher performance without sacrifying visual accuracy was to measure and analyze the data in a way human visual system do it, and process only the important parts. To achieve this, we have adopted methods of visual psychophysics and performed several controlled experiments on group of volunteers (example in Fig. 1.). Our goal is to identify cognitive mechanism we use when observing textured materials [3]. Our research revealed that different materials require different handling, and achieved considerable improvement of material appearance measurement and compression methods [2].

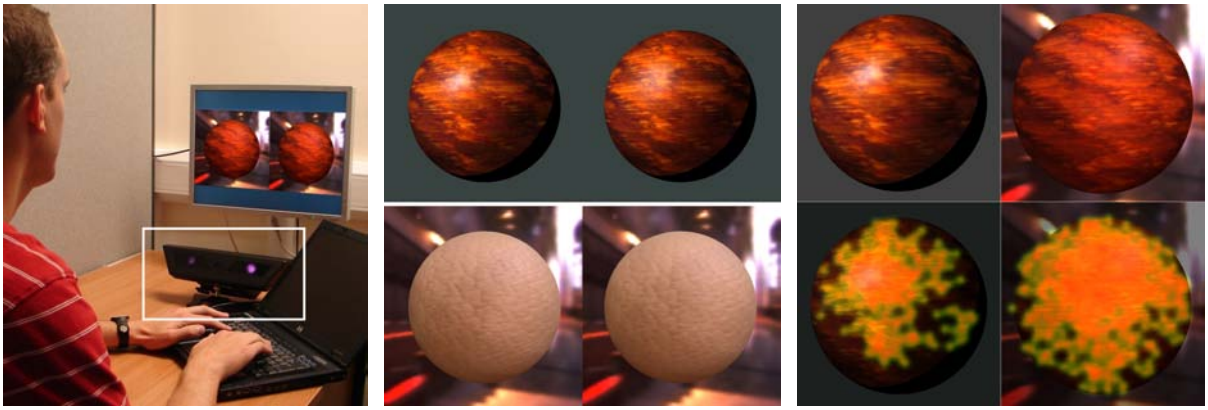

Figure 7: Examples of experimental setup, stimuli, and collected gaze fixations.

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# Markov Point Process for Multiple Objects Detection

[1]Descombes Xavier

We propose a general model based on marked point process for counting a population of objects. The configuration space consists of unordered sets of objects, defined by the location and some marks representing the object geometry. For example, the marks consist of radius in case of disks or minor, major axis and oritentation in case of ellipses. The model is then defined by a Gibbs density with respect to a reference Poisson measure. The Poisson measure allows addressing an unknown number of objects. The density embeds a prior term, penalizing overlaps between objects and a data term computing a distance between grey levels inside and in the neighborfhood of objects. To optimize the model, we consider a simulated annealing scheme based on a multiple birth and death dynamics [1]. An iteration of this algorithm is divided into a birth step and a death step. The birth step consists of adding a set of new objects in the current configuration, independently of both the model and the temperature. The death step consists of removing objects from the current configuration with a probability depending on the difference between energies of the configurations with and without the object under consideration and the temperature. Some results are shown on two applications concerning respectively trees detection [2] and flamingo population counting [3]

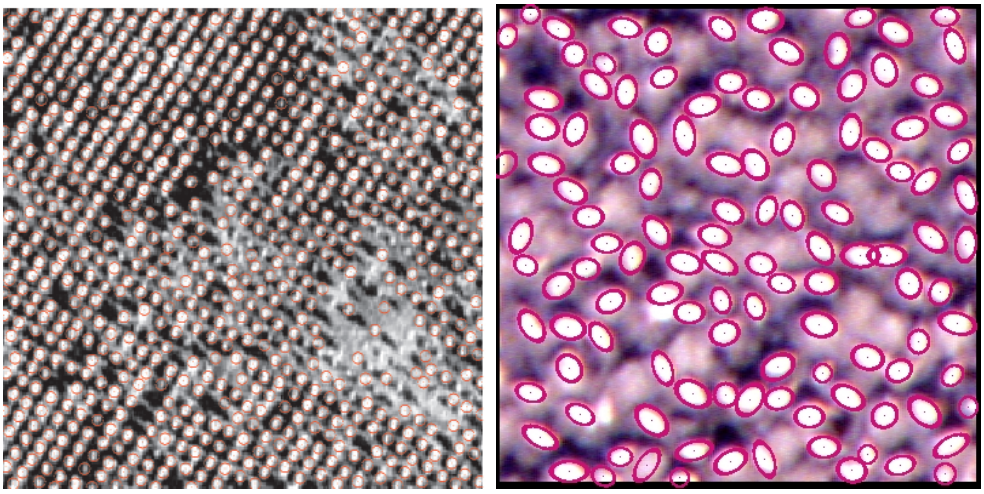

Figure 8: Trees detection (left) and counting of a flamingo colony (right). Images were respectively provided by IFN and La Tour du Valat.

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# Recent Results on Cake and Pie Cutting

[1]Vlach Milan

In the cake cutting models, a *cake* is a measure space, *pieces* of the cake are measurable subsets of the space, and the players *preferences* on the collection of pieces are given by countably additive non-atomic probability measures. Usually no constraints are imposed on the shapes of pieces. However, in applications it is often more appropriate to require the satisfaction of additional conditions. One of restricted models is the interval division problem where the cake is a "non-homogeneous" interval (one-dimensional non-homogeneous and atomless continuum), pieces are subintervals, and divisions are partitions into $n$ subintervals, if there are $n$ players.

In the pie cutting models, a *pie* is viewed as a disk valued along its circumference and pieces are sectors. Thus dividing a pie can be viewed as dividing a circle. Consequently, the difference between interval cakes and pies is topological. This talk is to explain and compare some recent results on cake and pie cutting. The main conclusion is that the difference in topology of these models leads to significant differences in results.

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# Application of Digital Image Processing Methods during Fresco Conservation

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In our work, we present an application of digital image processing algorithms for the process of fresco restoration. Modern methods for image preprocessing and evaluation such as image registration, image fusion, and image segmentation are applied on images of the fresco, obtained in different modalities (visual and ultraviolet spectra) and at different times. Moreover, local chemical analyzes are taken into account during the image analysis. The robustness of proposed algorithms should be high due to the bad state of the fresco. Achieved results can give to art restorers better insight into the evolution of the fresco aging and in this way a proper conservation method can be chosen. Developed methods are illustrated by generated output images.

Proposed solution starts with multi-modal (mutual information) and multi-temporal (it was done semi-automatically) registration. The registered data were fused by means of the PCA transform. For the sampling spots value spread image higher level analysis was realized, including the edge detection (Canny edge detection followed by morphological post-processing) and segmentation.

The work was done in the cooperation with the ALMA, a joint workplace of the Academy of Fine Arts in Prague and the Institute of Inorganic Chemistry of the Academy of Sciences of the Czech Republic. The project has been financed by the Projects of Ministry of Education of the Czech Republic no. 1M0572 and no. MSM6046144603, and by the Project of Grant Agency of the Czech Republic no. 203/07/1324.

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# PET Image Reconstruction Using Prior Information from CT or MRI

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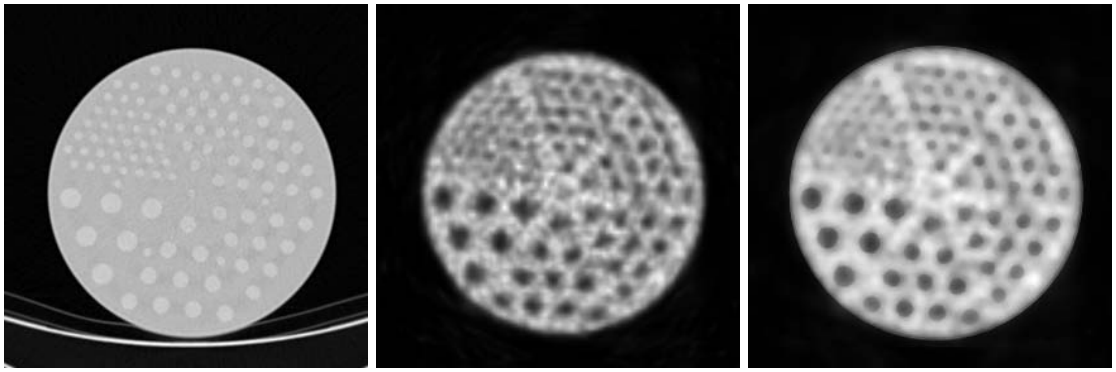
Functional properties of living tissues appear in PET, whereas structural information at significantly higher resolution and better image quality is provided by other modalities, such as CT or MRI. A problem for surgery appears if the existing pathological tissue is not identifiable by MRI/CT but can be seen by PET (as for example in some cases of epilepsy patient). As the PET scans are structurally not precise enough it is difficult for neurosurgeon to identify the brain lesion and there is a need for an invasive exploration of the brain, hence increasing the perioperative morbidity. Making the PET image more focused and less noisy would decrease the risk of surgery.

PET denoising methods based on the wavelet transform have been reported to increase accuracy and precision of PET images in a wide variety of contexts. In order to provide further improvement of PET images, it was acknowledged that the structural information in MRI or CT can be used. Turkheimer *et al.* [1] proposed denoising of PET images in the wavelet domain while using high frequency information from CT or MRI. This is achieved by replacing high-pass bands of PET, which are extremely noisy, with high-pass bands of the structural image, which contain details invisible in PET.

In this work, we formulate PET reconstruction as a blind deconvolution and denoising problem constrained by structural information from MRI/CT. The novelty of the proposed method is in the way how the image prior is built, which consists of total variation seminorm of the MRI/CT data.

An example of one slice of a phantom volume acquired in both modalities (PET and CT) is given below ((a) and (b)). The phantom contains cold rods of different dimensions positioned into triangles oriented around the center. Reconstruction (c) by the proposed method is correctly denoised with contours well localized.

The proposed method provides better focused PET images and it is also robust to misalignment of MRI/CT and PET. We plan to test the method further on clinical data. The primary goal will be to evaluate whether the reconstruction algorithm works also on MRI/PET pairs and if the improved PET images can help to perform surgery.



(a) CT (b) PET (c) PET reconstruction

Figure 9: Example of a phantom volume acquired by a combined PET/CT scanner: (a) CT (512x512x159) image and; (b) corresponding PET (256x256x47) image; (c) reconstructed PET image using prior information from CT.

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# Transmission Tomography Approaches for 3D USCT

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Our ultrasound computer tomograph (***USCT***) for early breast cancer detection uses reflection tomography methods to achieve sub-millimeter images. As has been shown, the reconstruction quality is largely affected by speed of sound variations in the tissue (see [1]). We use transmission tomography for creating speed of sound distributions thus noticeably improving the reflection tomography images.

Due to its cylindrical shape our old setup allowed the use of a 3D cone-beam reconstruction algorithm (FDK, Feldkamp-David-Kress backprojection). The FDK algorithm, however, is heavily dependent on geometric constraints which our new semi-ellipsoidally shaped aperture does not fulfill. To overcome this, different 3D transmission tomography approaches are currently being assessed in terms of quality, geometry independence and algorithmic complexity. Most of the algorithms have been thoroughly studied in 2D but either lack theoretical background or real life image quality evaluation when used in 3D.

In general the problem of inverting the 3D Radon transform has to be solved. Algorithms considered are the algebraic reconstruction technique, ART, as a linear algebra solution, Fourier based approaches and Compressive Sensing in combination with both.

**ART** seeks to reconstruct the speed of sound by solving a large system of linear equations. Attaining high quality reconstructions is difficult as it requires the number of projections to be in the same order of magnitude as the number of voxels in the image. Moreover regularization is favourable to improve the output quality. Special algorithms allow computation in $\mathcal{O}(n^2)$ floating point operations.

**Fourier based** solutions are built upon the idea of filling the spatial 3D Fourier space by applying the Fourier slice theorem on the measured projections. Using dedicated sampling structures and algorithms, a reconstruction in $\mathcal{O}(n^3 \log n)$ time and low memory requirements is possible.

**Compressive sensing** (see [2]) is a means of exploiting the sparsity of a signal to simplify its reconstruction. It may be applied to the methods mentioned in order to relax their memory and processing time requirements. In theory, even undersampling by a factor of 20 should still allow for exact reconstruction.

So far, all algorithms have been implemented using only basic optimization and compared using artificial data as well as real life measurements. ART without regularization has proven to be sensitive to varying signal quality and projection count. First comparisons to the FDK algorithm clearly showed inferior image quality even when including all available projections at a low resolution. The Fourier based solution as proposed in [3] turned out to be difficult to implement fast and reliably when only regarding the inversion step – essentially a matrix regularization problem – one initially wanted to omit.

A viable alternative to this step could be the use of sophisticated interpolation in the Fourier domain, even though this would increase the algorithmic complexity. While geometry independence has been shown for all methods, to deliver comparable and robust results, their implementations have to be improved with regularization and proper application of compressive sensing in mind. First compressive sensing tests have not been very promising since the results on real data have been far worse than indicated in the original papers.

Diffraction tomography may also proof a feasible choice for reconstruction but is still subject to extensive research. Our implementation is currently work in progress and as such not yet fit for a comprehensive and tenable comparison.

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# GridMate – The Grid Matlab Extension

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During the last years the complexity of computational problems has increased constantly. Thus, their local computation got more time consuming and expensive. E.g. at Karlsruhe Institute of Technology is a group working on a novel approach for medical imaging, the Ultrasound Computer Tomography [1]. The aim of this project is to detect breast cancer in a very early stage. Ultrasound signals, sent into the breast tissue, are taken by a device called Ultrasound Computer Tomograph, the visualization of results is realized by reconstructing the female breast, using millions of measured ultrasound amplitude scans. Therefore, the local computation of a single reconstruction, feasible for diagnosis, takes several days on a single workstation computer.
The reconstruction algorithm is implemented in Matlab [2], which is a powerful tool for rapid prototyping, algorithm development and application in various scientific fields. In the meanwhile Matlab is even able to run functions in parallel on a network of machines, but it is still difficult to run Matlab functions on Grid resources. For this purpose GridMate [3] was developed at the Institute for Data Processing and Electronics of Karlsruhe Institute of Technology. The aim of GridMate is to run arbitrary Matlab functions in parallel without struggling with special extensions or licenses. On the one hand, GridMate uses the Matlab Runtime Environment to run Matlab functions remotely integrated in WSRF-compliant web services. Existing Matlab functions are compiled, using the Matlab Builder for Java [4], deployed dynamically on the Grid infrastructure and are available immediately.
On the other hand GridMate offers a Matlab toolbox to integrate the access to the infrastructure seamlessly into the users application. It allows parallel access to deployed functions and hides the technological complexity. The user only has to outsource the parallelized part of the application to the GridMate servers and replace the relevant code by calls to GridMate functions. Afterwards, data conversion, data transfer and execution are performed fully transparent in parallel. For evaluation purposes the USCT reconstruction as well as another applications from the field of material science [5] were adapted to be able to use GridMate.
During first tests on a homogeneous Grid infrastructure GridMate was able to scale for both applications almost linear, depending on the number of utilized machines and the applications characteristics. Achieved speedup rates were remarkable and could reach a factor of ten if using 16 Grid nodes.
A drawback of the current approach is that all the data is transferred from the users machine to the Grid, which results in a bottleneck. Hence, current related work deals with tieing distributed storage solutions to GridMate.

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# Recent Developments in Exploitation of Data Assimilation in Early and Late Phase of Radiation Accident

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The paper gives a comprehensive summary on developments achieved in years 2006-2009 in exploitation of the data assimilation (DA) in the field of radiation protection. Radiation accident followed by an aerial release of radionuclides into the environment has the two successive phases: the early and the late phase [3]. In order to ensure efficiency of introduced countermeasures it is necessary to predict spatio-temporal distribution of the released radionuclides and its evolution. DA is the optimal way how to exploit information from both the measured radiological data and expert-selected (modeled) prior knowledge to obtain reliable estimates of radiation situation. The palette of available DA methods spans from the simple ones bases on pure interpolation to the advanced Bayesian methods [1]. We apply the Bayesian methodology for assimilation in both the phases.

In the early phase, movement of radioactive cloud over the terrain is modeled [8]. During this process, measurements available from the Early warning network of the CR are used for correction of selected initial conditions (magnitude of release, meteorological conditions etc.) entering used atmospheric dispersion model in the form of prior distributions [10]. The developed method based on particle filters [2] gives us assimilated (improved) estimate of the radiation situation on terrain and a way how to easily extend the estimate to prediction on an arbitrary time horizon.

In the late phase, propagation of radionuclides deposited on terrain thought the environment is modeled. This phase lasts until the radiation levels resume to background values. We use linearized model of radionuclides removing due to radioactive and environmental decay processes and a parametrized form of model error covariance structure [6] for estimation of radiation situation on terrain in time horizon of several month or years [9]. The developed DA methodology is based on marginalized particle filter [5].

Specific DA algorithms are tested on scenarios simulating different reactor accidents in a power plant. The objective is to integrate DA subsystem into the decision support system HARP localized for the conditions of the CR [7]. This work is supported by grants GAČR 102/07/1596 and MŠMT 1M0572.

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# Model Predictions Using More Precise Meteorological Data, Basic Comparison for Available Data Formats in ČR

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In order to test an atmospheric dispersion model based on a more sophisticated computational algorithm, the HYSPLIT modeling system [1] has been adapted and applied in a case study of radioactive plume release from the Temelin nuclear power plant.

The HYSPLIT model uses a lagrangian approach where a pollutant dispersion is described within the moving coordinate system and is simulated by tracking the movement of puffs or a large number of particles representing quantity of the air pollutant. Using three dimensional gridded meteorological data together with terrain description inside desired domain, the HYSPLIT model is capable of calculating pollutant deposition and dispersion even in a complex terrain. The model displays a trajectory of the plume center as well as a concetration field in user defined vertical levels.

Meteorological data fields for the model simulations were obtained from the MM5 model (The PSU/ NCAR Mesoscale Model v.5) being operated by UI AV ČR. According to the weather data we selected three time periods for the HYSPLIT model calculations representing three different meteorological conditions - calm situation with low wind speeds, situation with normal stability conditions and unstable situation during storm.

The wind speed and direction data from MM5 model for these cases in the first hour of release were compared with meteorological data from another prognostic model - Aladin (Czech Hydrometeorological Institute) and with measurements. Unfortunately considerable differences between these data sources were observed, especially under light wind conditions. The inconsistence of the input meteorological data sugests that the data assimilation in the first hours of the release will be necessary for proper prediction of the pollutant dispersion.

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# Iterative Formulation of Control Aims in Fully Probabilistic Design

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A control design converts knowledge about the controlled system, constraints and control aims into the controller. Control aims must be quantified in the way compatible to the design. A systematic quantification of the control aims, called aim elicitation, is the least supported step of the design process. We present a solution of this problem within the framework of a fully probabilistic design (FPD) [1].

Any controller modifies the closed-loop behaviour to reach the control aims. The controller is chosen in order to minimize a given loss function. The FPD selects the controller that minimizes the Kullback-Leibler divergence of the joint probability density function (pdf) describing closed-loop behaviour to the ideal pdf. The ideal pdf expresses both the desired closed-loop behaviour and constraints on system inputs. Thus within the FPD, the aim elicitation reduces to the choice of the ideal pdf.

For complex multidimensional systems, the task to construct the ideal pdf may represent a nontrivial problem requiring an expert experienced both in practical treatment of the system and theory as well.

The poster proposes a conservative construction of the ideal pdf. Similarly as the popular "windsurfer" approach to control design [2], it iteratively modifies intermediate control aims according to gradually learnt model of the observed closed loop. The proposed methodology is applied to normal pdfs. In this case, the FPD algorithmically coincides with linear-quadratic control design. Thus, the methodology simplifies use of this practically important control design and exploits better its potential. This statement is illustrated by numerical examples.

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# Joint Estimation of Gaussian and Multinomial States

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The present work is devoted to the joint estimation of mixed-type (continuous and discrete-valued) state variables. This problem is often solved via stochastic approximations used sampling methods (such as particle filters). However, exploitation of particle filters is rather expensive in a computational sense and often require large capacity of data sets. It can be unsuitable to a range of application areas. The present paper considers an entry-wise approach to Bayesian filtering. With its help the joint mixed-type state filtering is solved with an easy computational approximation of the posterior probability density function. In case of independent continuous and discrete data the solution is quite analytically tractable.

The main advantage of the proposed entry-wise approach is a possibility to consider entries of the state vector described by different models. The present work describes a special case with some restrictions: a discrete-valued entry should be placed at the end of the state vector. Extension of the proposed filtering up to the general non-restricted form of the vector is planned to be presented later.

General probabilistic solution is proposed as the filtering, which provides the estimates of entries of a state vector, updated entry-wise. The state-space model is factorized via the chain rule.

Specialization to a series of models was necessary before application of the filtering to the mixed data. For continuous variables and linear Gaussian models the entry-wise updating of the state estimate is reached with the help of decomposition of precision matrices. The proposed factorized version of Kalman filter covers the state estimation in this case. An analytically tractable filtering with a discrete state-space model is shown for multinomial distribution. The joint filtering of mixed states combines both algorithms with approximation of a posterior pdf via minimization of the Kerridge inaccuracy. Illustrative experiments demonstrate application of the filtering to simulated traffic control data.

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# State Estimation with Nonlinear Constraints

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Recursive state estimation of discrete-time nonlinear dynamic systems from noisy measurement data has been a subject of considerable research interest for the last four decades. The general solution to the state estimation problem is given by the Bayesian approach in the form of Bayesian recursive relations (BRR). The closed form solution to the BRR can be found in a few special cases only and in other cases an approximate solution is in focus.

There are three main approximate approaches to the BRR solution: the analytical approach based on model linearization and Gaussian sum approximation of probability density functions (pdf's), the numerical approach based on numerical solution of the integral in BRR and simulation approach using Monte Carlo approximation.

The state variables of physical systems are often tied due to technological limitations or physical laws [1] and lead to a state constraint which is usually not taken into account within these estimation approaches.

Within the Kalman filtering framework, which consists of the famous Kalman filter (KF) solving the BRR analytically and local nonlinear filters based on the KF, there are several methods to constrained state estimation.

They can be classified into three groups: reparametrization, pseudo-observation and projection methods. The reparametrization methods integrate the constraint into the system description by reparametrizing the system, which in effect leads to classical unconstrained estimation [2] and therefore this method will not be considered further. The pseudo-observation methods transform the constraint into a deterministic measurement equation which is appended to the system description [3]. The projection methods propose a projection operator that transforms the estimate [4] onto the constraint surface.

Although both the pseudo-observation and projection methods have clear interpretation if the constraints are in the form of linear algebraic equations, they are not usually successful for constraints given by nonlinear algebraic equations. The reason is that they assume that if a probability density function (pdf) obeys the nonlinear constraint, the corresponding point estimate obeys the constraint as well, which is not usually true, especially for nonlinear constraints. To overcome these difficulties, a two-step projection method was proposed in [5] based on first constraining the filtering pdf obtained from the Kalman filtering framework and then constraining the point estimate to obey the nonlinear constraints.

The aim of the paper is to show possibilities of taking nonlinear constraints into account within global filters, among which the filter based on Gaussian sum approximation is chosen as a suitable approach. The reason is that it naturally generalizes the Kalman filtering framework and preserves analytical solvability of the BRR. Among the approaches for applying the constraint, the two-step projection method is chosen.

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# Estimation of Noise Covariances for Periodic Systems

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The state estimation and optimal control design methods require complete knowledge of the functions in the system equations and of the statistics of the noises affecting the system and the measurement. However, from practical viewpoint of usage of the methods, the knowledge of the noise statistics is questionable in many cases. The incorrect description of the noise statistics can cause a significant worsening of estimation or control quality.

In the last five decades, various methods for estimating the noise covariance matrices have been published. Among others the following can be mentioned: Bayesian estimation, covariance matching methods, correlation methods, subspace methods, prediction error methods or the Kalman filter working as a parameter estimator. The short characterisation of these noise covariance matrices estimation methods with their properties, advantages, and disadvantages can be found in e.g. [1, 2, 3]. It should be mentioned that some methods for direct estimation of the filter gain instead of estimation of the noise covariance matrices have also been proposed [4].

Some of the above mentioned methods are suitable for time-invariant systems or Gaussian systems only or do not allow to estimate all elements of the noise covariance matrices. Moreover, all the methods were derived under no assumption on periodicity of the system. However, periodic systems often occur in many different areas such as communication systems, economics and aerospace applications [5] and periodicity of the system may substantially simplify the estimation method design.

This contribution is thus devoted to the introduction of the multi-step prediction based correlation method for estimation of whole state and measurement noise covariance matrices for linear non-Gaussian time-variant stochastic periodic systems. The proposed method is essentially based on two steps; first, the covariance and cross-covariance matrices of the measurement prediction error sequence are computed, second, the noise covariance matrices are estimated by means of the standard least-squares method. The resulting estimates of the noise covariance matrices are proved to be unbiased and consistent.

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# Recent Advances in Software for Nonlinear Estimation

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Nonlinear estimation of discrete-time stochastic dynamic systems is a rapidly developing field of study which plays a crucial role in many areas. It is thus beneficial to have a suitable tool at hand which can facilitate the development and testing of new estimation techniques as well as provide an easy-to-use tool offering a broad family of estimation techniques to researchers and application engineers.

There are several software packages dealing with nonlinear state estimation. Most of the packages are very powerful tools, which provide extensive support for all the currently well-known local estimation methods and at least elementary particle filter. Unfortunately, not so many of them also provide a complex framework suitable for application to variety of system models. One of the packages that offers such a framework is NFTools [1]. The main strength of NFTools is its suitability even for casual user who is spared from unnecessary details while offering the knowledgeable user full control over the experiments, which is indicated by more than 150 users worldwide.

In spite of its advantages, the NFTools toolbox has two main drawbacks. First, it does not offer other means for specification of the system besides the structural description, which is a limiting factor especially for particle filters. Also description of time-varying systems is not possible. This was the motivation for a new complete redesign of the nonlinear estimation framework that builds on the best ideas and practices gained from the development and use of NFTools and implements a fully probabilistic specification of the system together with generalization of the structural system description which includes time-variance.

These deficiencies of NFTools led to development of new software package the Nonlinear Estimation Framework (NEF) [2]. The framework was designed with the aim to facilitate implementation, testing and use of various nonlinear state estimation methods in mind. The main strength of the framework is its versatility due to the possibility of either structural or probabilistic description of the problem and can be advantageously employed for vast variety of tasks. It simplifies description of the time-varying systems and simultaneously makes it more powerful. It is currently feature-wise (from the point of implemented estimation techniques) on par with NFTools. Besides the well-known basic nonlinear estimation methods such as the extended Kalman filter, the divided difference filters and the unscented Kalman filter, the framework implements particle filter with advanced features as well. As the framework is designed on the object oriented basis, its further extension by user-specified nonlinear estimation algorithms is extremely easy. The latest version of the software package is available at `http://nft.kky.zcu.cz/`.

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# Prediction and Optimal Trading in U.S. Commodity Markets

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In the presentation we show a way of modelling the evolution of price of a financial instrument (here we apply the model to a price of U.S. commodity futures contract, but other financial instruments could be modelled including shares of stock) with a linear stochastic process - here namely the vector auto-regressive proces of order $p$ [2]. The process is fitted to the data using Bayesian statistics [4], so that the parameters are considered to be random variables. In the first part of the presentation a detailed description of modelling and used approximations is given. Approximate forecast of the price evolution up to a horizon $h$ is made using Monte Carlo sampling from posterior parameter distribution and model with log-normal innovations is considered. At the end of the first part few results are shown, comparing the predictive power of such model to benchmark models usually used in todays Financial Mathematics.

In the second part we introduce possible ways of optimal control of a trading process, involving price evolution according to the model described in the first part, where the agent tries to optimize his wealth, possibly also considering the risk involved in investing into a risky financial asset. Such an optimization task can be solved in many cases [1],[3], but in the presented model, where future prices are not independent from one time moment to the next, the parameters are random and transaction costs are present, approximate sloutions of the optimal control are proposed.

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# Presentation of Bayesian Decision Making Toolbox (BDM)

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The Bayesian Decision Making Toolbox is a next generation of software tools developed at the department of adaptive systems. As the name suggests, its main purpose is to serve development of algorithms for Bayesian Decision making and their implementation in practical applications.

**Design considerations** The toolbox is designed using object oriented approach, where mathematical objects—such as probability density functions (pdfs), and estimators—are represented by corresponding software classes [2]. These objects form a tree-like structure, where the root classes represent the most general forms of the mathematical object and each inheritance level represents a specific specialization of the object. For example, the most general class for probability density functions is called `pdf`. The exponential family of pdfs is a special case, with specific properties, therefore, its software class `eEF` is inherited from `pdf` which it extends by appropriate methods. The Gamma density is a special case of the exponential family pdf, hence it is inherited from `eEF`.

**Implementation** The toolbox is implemented in two parts: (i) C++ library, and (ii) Matlab toolbox. The library consists of basic classes of decision-making: pdfs, Bayesian estimators, decision strategy designers. These classes are created from user-specified information in hierarchical way. Numerical computation is implemented through the IT++ library, which maps fast routines (e.g. MKL) into clean C++ API which is reminiscent of Matlab syntax. The Matlab toolbox consists of mex files of prepared scenarios for the use of the classes from the library. These scenarios work as follows: (i) they read user configuration and create the requested decision-making objects, (ii) a predefined algorithm is performed on these objects. For example, the `estimator` scenario is a general algorithm of sequential Bayesian estimation (Bayesian filtering). All scenarios can be also compiled as standalone application.

**Open Development Model** The toolbox (and the library) is developed as an open-source project with homepage: `http://mys.utia.cas.cz:1800/trac/bdm`. The code is available under the terms of GNU General Public License (GPL) allows to use code from other GPL software projects (e.g. R language). This license entitles anyone to modify and distribute the code under the condition that the changes are also available under this license. The project is managed on-line via open-source system Trac. Anyone is allowed to create a ticket (bug report or feedback) and discuss development of the toolbox. Furthermore, simulations and algorithms published in journal papers or conferences are maintained within the project so that the published results can be reproduced and examined publicly.

**What is Implemented** The basis of Bayesian calculus is algebra on pdfs. Many specific pdfs are implemented with methods for evaluation of their values and moments. Special purpose classes representing the chain rule of pdfs, or the ratio of pdfs are also available. The Bayes rule is implements for a range of approximations, e.g. Mixtures of exponential family members (EM and QB algorithms), Bayesian filtering (Kalman, particle and marginalized particle filters). Advanced algorithms for merging of fragmental pdfs are also available for various approximations. Various algorithms from Mixtools [1] are being ported to the new system.

We believe that open nature of development and availability of the code for multiple-platforms are sufficient motivators for interested readers to try the toolbox and provide feedback to the authors.

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# Futures Trading: Task Analysis

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Futures contracts (so-called futures) are financial derivatives traded at exchanges (see [4]). Financial speculators are interesting in the futures as well as stocks and funds.

The speculator predicts the price's increase or decrease in order to buy or to sell the given instrument. The origin of the speculator's profit is in the price's change. However the clear profit depends also on transaction costs and taxes, which makes the speculator's task more difficult, than it seems at the first sight.

The design of profitable strategy is challenging and speculators use various methods to that. Two main streams are: the fundamental analysis and the technical one. The fundamental analysis assumes the actual price does not reflect the real price. Therefore it bases predictions on the analysis of the market state, actual news and activities of the institutions involved. In contrast, the technical analysis deals primary with price's curves to predict the further price's behavior.

Classical investing methods based on the fundamental analysis (e.g. value investing [3] or indexing [2]) serve primary for a stock trading and for the long-time investment in terms of decades. The technical analysis [5], may provide a short-time profit, as the actions are recommended more often, i.e. one action per week or month, but most of methods of technical analysis are designed only for stocks. The futures contracts are special type of investment instruments, therefore their prices do not behave similarly to stocks prices: there are no strong long-time trends, the possible trends are usually short-time, if any.

Up to the author's best knowledge, none of the fundamental analysis or technical analysis methods is profitable at futures. Beside, if even exists any, it is not advertised everywhere and is kept in a strict confidence.

The presented approach belongs to the technical analysis, because the main information, used to design the buying/selling strategy, originates from the price. The original task is reformulated as decision-making problem and is solved via dynamic programming (see [1]). The presented approach analyzes the task, because is has been shown that the futures trading has a lot of specific properties generally not respected by dynamic programming.

The main contribution of the article is based on a comparison of: (i) the speculator's strategy designed with the knowledge of the *whole* future price sequence and; (ii) the partial strategy designed with the knowledge of only a *part* of the future price's sequence. The comparison leads to an analysis of changes in the enlarging sequence of the speculator's actions with time. Two special indexes were designed for the comparison of two sequences of a different length.

This prepares a systematic background for a new approach in estimating the Bellman function [6] and to the design of the speculator's decision strategy for futures trading [7].

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# Texture Editing Using Frequency Swap Strategy

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A fully automatic colour texture editing method [1] is proposed, which allows to synthesise and enlarge an artificial texture sharing anticipated properties from its parent textures. The edited colour texture maintains its original colour spectrum while its frequency is modified according to one or more target template textures (Fig.10). Edited texture is synthesised using a fast recursive model-based algorithm. The algorithm starts with edited and target colour texture samples decomposed into a multi-resolution grid using the Gaussian-Laplacian pyramid. Each band pass colour factors are independently modelled by their dedicated 3D causal autoregressive random field models (CAR) [4]. We estimate an optimal contextual neighbourhood and parameters for each of the CAR submodel. The synthesised multi-resolution Laplacian pyramid of the edited colour texture is replaced by the synthesised template texture Laplacian pyramid. Finally the modified texture pyramid is collapsed into the required fine resolution colour texture. The primary benefit of these multigrid texture editing models is their ability to produce realistic novel textures with required visual properties capable of enhancing realism in various texture application areas.

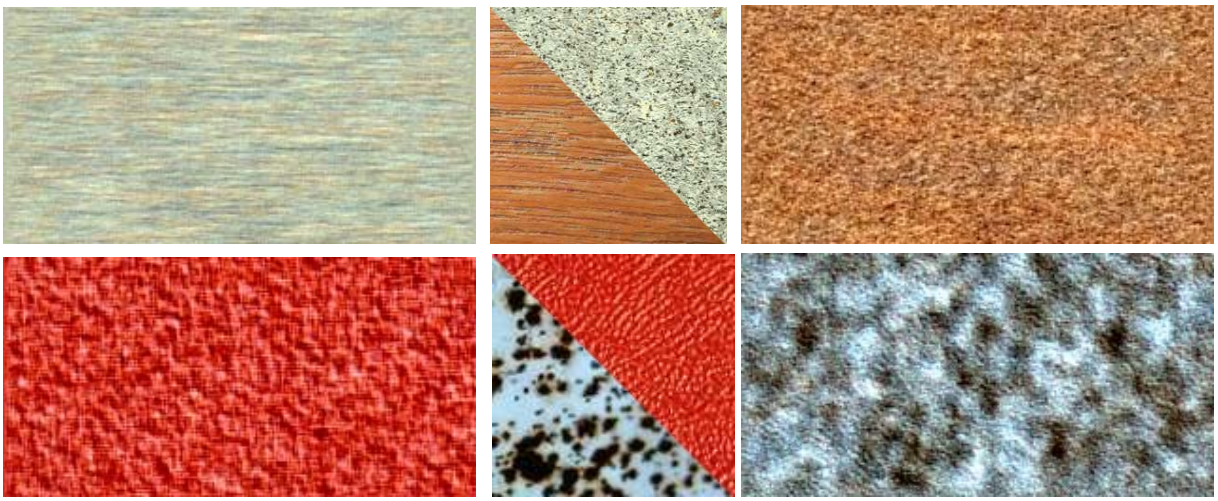

Figure 10: Wood, tile, lichen, and leather natural textures (middle column) and their resynthesised edited counterparts using the 3D CAR models (left and right).

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# Influence of Sender Focusing in USCT

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The process of steering and focusing the acoustic pulses is known as beamforming. Focusing limits the useful near field depth, because beam converges rapidly beyond the focal zone. The focal zone is defined as the region where intensity has the value with in 3 db of maximum. Presently the work has been limited to 2D and up to sender elements focusing only and later it can be tested for the receiver focusing also. Presently only up to three sender elements were used for focusing to demonstrate the effect of focusing. The focusing of USCT (Ultrasound Computer tomography) transducer was done by introducing the calculated delay on the basis of the geometry of the system. The author tried the various combinations focusing on a particular receiver and number of transmitters to estimate the optimal number of transducer elements that can give better focusing results. Presently the trial of algorithm is limited to synthetic data with added noise. For the present work only time of flight has taken as the parameter for the estimation of the pulse. It is found that for sender focusing the root mean square error with comparison to the calculated time of flight was lesser than the error without focusing. The root mean square for the calculation of the time of flight (TOF) for focused and unfocused data was calculated. The author is also trying to analyze the effect of increasing the number of transducers.

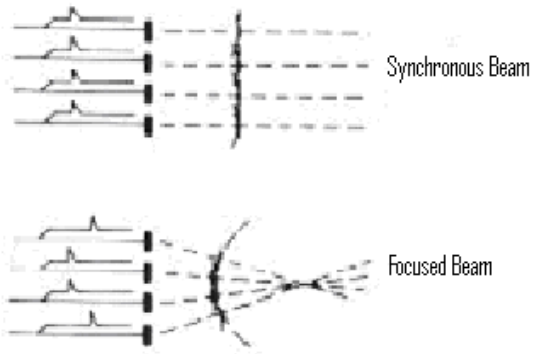


Figure 11: Focusing of Ultrasound Transducer

*Acknowledgement: This work has been supported by the national research center DAR (Data, Algorithms and Decision making) project no. 1M0572 coordinated by the Institute of Information Theory and Automation, Academy of Science, Czech Rep. and partly also by the institutional research frame no. MSM 0021630513; both grants sponsored by the Ministry of Education of the Czech Republic.*

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# Improvement of Textural Analysis Method Aimed to Detection of Neural Fibre Layer Loss in Retinal Images

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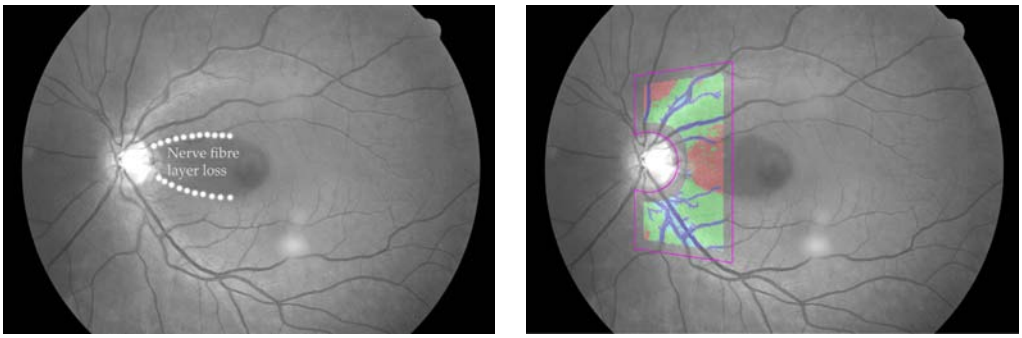
The contribution deals with analyzing the classical fundus camera retinal images, although a more quantitative method for measuring the retinal neural fibre layer (RNFL) - the optical coherence tomography (OCT) appeared recently. However, the OCT examination is still expensive and not generally available, hence an effort have been made for estimation of the RNFL presence from the fundus camera images. This analysis is a difficult task even for an experienced ophthalmologist; thus it is even tougher for an automated process. Several publications concerning this problem have been published, but the problem remains not solved satisfactorily.

Three texture analysis approaches have been successfully tested for automatic detection of RNFL in a few available images [1]: a directional local spectral analysis, an edge-evaluation approach and a difference-of-brightness based approach. These three approaches were implemented in a software package for automatic detection of RNFL loss and the final decision was based on a heuristically estimated linear combination of the three features.

To improve the classification, a neural network (NN) was implemented that was trained on features derived from 232 manually selected local areas in 6 fundus camera images (92 areas lacking the NFL, 140 healthy areas). The NN was then tested on 100 other manually selected local areas (50 areas lacking the NFL, 50 healthy ones) with the classification error of 10%. These results can be considered an improvement in comparison with heuristically based classification in [1]. Presently, more extensive statistical evaluation is under way.

In the next phase, the classification reliability might be improved by adding more textural approaches as features for automatic detection of RNFL. The OCT is expected to be used as a golden standard providing RNFL thickness maps to be compared with the conclusions based on fundus camera images.




a) b)

Figure 12: a) original fundus camera image labeled by a medical expert, b) result of fully automatic recognition (the RNFL loss areas are marked red)

*Acknowledgement: This work has been supported by the national research center DAR (Data, Algorithms and Decision making) project no. 1M0572 coordinated by the Institute of Information Theory and Automation, Academy of Science, Czech Rep. and partly also by the institutional research frame no. MSM 0021630513; both grants sponsored by the Ministry of Education of the Czech Republic.*

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# Near-Regular Texture Synthesis

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This paper describes a method for seamless enlargement or editing of difficult colour textures containing simultaneously both regular periodic and stochastic components. Such textures cannot be successfully modelled using neither simple tiling nor using purely stochastic models. However these textures are often required for realistic appearance visualisation of many man-made environments and for some natural scenes as well. The principle of our near-regular texture synthesis and editing method [5] is to automatically recognise and separate periodic and random components of the corresponding texture. Each of these components is subsequently modelled using its optimal method. The regular texture part is modelled using our roller method [2, 5], while the random part is synthesised from its estimated exceptionally efficient Markov random field based representation [4]. Both independently enlarged texture components from the original measured texture are combined in the resulting synthetic near-regular texture. In the editing application (Fig.17) both enlarged texture components can be from two different textures. The presented texture synthesis method allows large texture compression and it is simultaneously extremely fast due to complete separation of the analytical step of the algorithm from the texture synthesis part. The method is universal and easily viable in a graphical hardware for purpose of real-time rendering of any type of near-regular static textures.

Figure 13: Near-regular texture editing. Measured textures (three leftmost) and edited textures (three rightmost).

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# Illumination Invariant Unsupervised Segmenter

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A novel illumination invariant unsupervised multispectral texture segmentation method [1] with unknown number of classes is presented. Multispectral texture mosaics are locally represented by illumination invariants derived from four directional causal multispectral Markovian models recursively evaluated for each pixel. Resulted parametric space is segmented using a Gaussian mixture model based unsupervised segmenter. The segmentation algorithm starts with an over segmented initial estimation which is adaptively modified until the optimal number of homogeneous texture segments is reached. The performance of the presented method is extensively tested on the large illumination invariant benchmark Fig.17 from the Prague Segmentation Benchmark [2] using 21 segmentation criteria and compares favourably with alternative segmentation methods [3, 4].

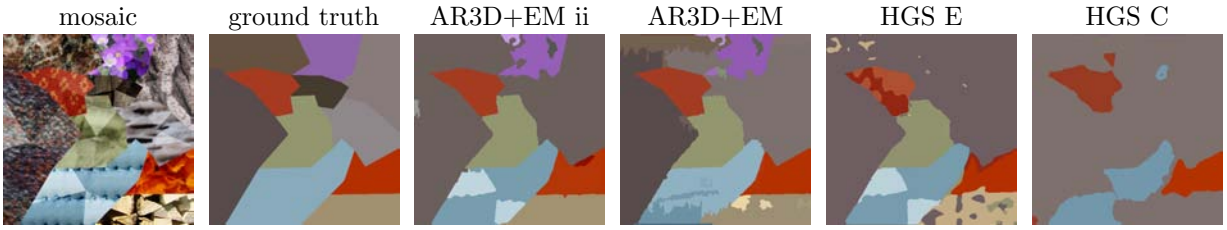


Figure 14: Selected experimental texture mosaics, ground truth from the benchmark [2] and the corresponding segmentation results.

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# Illumination Invariant and Rotational Insensitive Textural Representation

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We propose an illumination invariant and rotation insensitive texture representation [1] based on a Markovian textural model. A texture is aligned with its dominant orientation and illumination invariant textural features [2] are derived from fast analytical estimates of Markovian statistics. We do not require any knowledge of illumination direction or spectrum. This makes our method suitable for a computer analysis of real scenes, where the appearance of materials depends on their orientation towards the illumination source.[3]

Our method is favourably tested on the most realistic visual representation of natural materials - the bidirectional texture function (BTF). We use CUReT texture database [3], which consists in 61 real-world materials, each acquired with 92 different illumination and viewpoint directions. According to the experiments displayed in Fig 17, the proposed method outperforms leading rotation and illumination invariant methods: Local Binary Patterns (LBP) and texton MR8 methods [4].

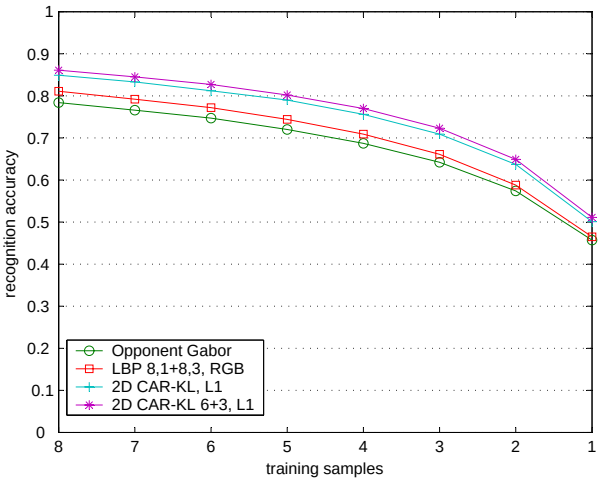


Figure 15: Correct classification for different numbers of random training images per material. The values are averages over 1000 random selections of training images. Two variants of the proposed method are denoted with "2D CAR-KL" prefix.

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# Dynamic Oscillating Search as a Tool for Feature Selection and Feature Subset Size Optimization

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In feature selection (FS) the search problem of finding a subset of $d$ features from the given set of $D$ measurements, $d < D$, with the aim to improve various properties of pattern recognition systems (i.e., to maximize a suitable criterion function) has been of interest for a long time. Since the optimal methods (exhaustive search or the Branch-and-Bound [2]) are not suitable for non-monotonic criteria nor high-dimensional problems, research has focused on sub-optimal search methods (for recent overviews see [5], [9]). While many approaches to sub-optimal FS are possible (e.g., using evolutionary [3] or Relief-type methods [9]) the family of sequential search methods [2] [9] has been particularly popular due to their good compromise between speed and optimization efficiency, as well as usability with wide variety of criterion functions.

In this presentation we describe a new method extending the principle of Oscillating Search (OS) [10]. While OS requires $d$ to be specified by user (as is the case with most sequential FS methods), the new method determines the best subset size automatically, with preference put on smaller subsets. This ability makes it particularly suitable for Wrapper [4] [5] type of FS, which has recently gained lots of interest. Moreover, the new method has better optimization ability, yielding more often results closer to optimum. Although stronger optimization is naturally accompanied by higher risk of feature over-selection [8], the new method is capable of improving classifier generalization as well.

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# Combining Multiple Feature Subset Evaluation Criteria in Feature Selection

[1]Petr Somol , [2]Jiří Grim , [3]Pavel Pudil

A common practice in multidimensional classification methods is to apply a feature selection (FS) procedure as the first preliminary step. The aim is to avoid overfitting in the training phase since, especially in the case of small and/or high-dimensional data, the classifiers tend to adapt to some specific properties of training data which are not typical for the independent test data. The resulting classifier then poorly generalizes and the classification accuracy on independent test data decreases. By choosing a small subset of "informative" features we try to reduce the risk of overfitting and to improve the generalizing property of the classifier. Moreover, FS may also lead to data acquisition cost savings as well as to gains in processing speed.

In most cases a natural way to choose the optimal subset of features would be to minimize the probability of classification error. As the exact evaluation of error probability is usually not viable, we have to minimize some estimates of classification error (wrapper methods) or at least some estimates of its upper bound, or even some intuitive probabilistic criteria like entropy, model-based class distances, distribution divergences, etc. (filter methods) [3]. In order to avoid biased solutions the chosen criterion has to be evaluated on an independent validation set. Nevertheless, the problem of overfitting applies to FS criteria and FS algorithms as well [6] and cannot be fully avoided by means of validation. It is well known that different optimality criteria may choose different feature subsets. The resulting feature subsets may differ even if one and the same criterion is applied to differently chosen training data. In this respect the "stability" of the resulting feature subsets becomes a relevant viewpoint [4].

It has been shown repeatedly in literature that classification system performance may be considerably improved in some cases by means of classifier combination [2]. In multiple-classifier systems FS is often applied separately to yield different subsets for each classifier in the system [1]. Another approach is to select one feature subset to be used in all co-operating classifiers [5].

In contrary to such approaches we utilize the idea of combination to eventually produce one feature subset to be used with one classifier. We propose to combine FS criteria with the aim to obtain a feature subset that has better generalization properties than subsets obtained using single criteria. In the course of FS process we evaluate several criteria simultaneously and, at any selection step, the best features are identified by combining the criteria output. In the presentation we show that subsets obtained by combining selection criteria output using voting and weighted voting are more stable and improve the classifier performance on independent data in most cases.

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# Conservative Particle Systems as Models for Traffic Flow

[1]Fajfrová Lucie

We study models of conservative particle systems, which generalise a well known zero range process (introduced in [1]). In this generalisation (considered also in [2, 3]), jumps of more than one particle in one moment are allowed. We describe such systems in the context of modeling a traffic flow since the generalisation in sense of multiple jumps fits on the traffic interpretation - it brings a new possibility of splitting the columns.

In our study, we are interested first of all in a construction of the Markov process, a characterisation of its stationary states and in giving conditions for the attractiveness of the process.

The presentation illustrate how particle systems (zero range process, exclusion process and misanthrope process) could be understood as models of a traffic flow. Particle systems with zero range or exclusion interactions have been already used as models of traffic flow e.g. in [4] (and references therein). Czech readers could find interesting a paper [5] in which the use of models of statistical physics for description of traffic jams is popularised.

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# Vessel Segmentation by Matched Filtering in Colour Retinal Images

[1]Odstrcilik J. , [2]Jan J. , [3]Kolar R.

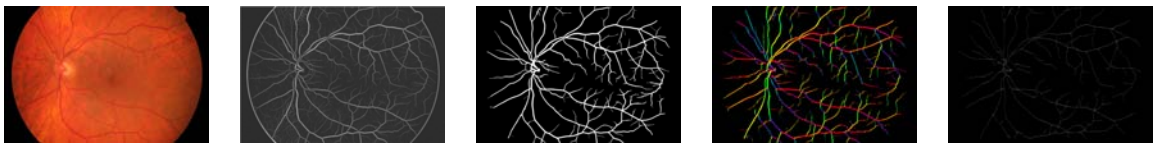
The paper deals with the method for segmentation of vessel structure in high resolution colour retinal fundus images, based on 2D matched filtering.

The RGB image data were taken by digital fundus camera CANON CF-60UVi with the attached digital camera CANON EOS-20D, with 60° field of view, and 3504 x 2336 pixel resolution (Fig. 1a).

The approach utilizes correlation between the local image areas possibly containing a vessel segment and 2D masks obtained via averaging of brightness profiles of vessels for several different vessel widths. Each of the basic masks is rotated in twelve different directions; this way, 60 2D convolution kernels for 5 different widths, each with 12 orientations are produced. Compared to the previously published results [1], the segmentation has been improved primarily in two directions: the width resolution has been increased from 3 to 5 width classes, and the orientation information is now utilized to provide vessel direction maps (Fig. 1d) that are used to complementing the missing vessel segments and also for generating skeleton of the blood-vessel tree (Fig. 1e). The parametric maps representing the maximum responses of the filters are then combined (Fig. 1b) and finally thresholded thus obtaining binary vessel maps to be morphologically cleaned in order to remove the artefacts due to noise and also to complement the obviously missing parts of vessels (Fig. 1c).

The method was designed and tested using the high-resolution fundus camera images provided by a cooperating ophthalmological clinic, and also statistically tested based on the standard public image database DRIVE, although provided worse results due to lower pixel resolution.

These results will be used as a preprocessing step in a texture analysis of the retinal nerve fibre layer and also for generating skeleton of the blood-vessel tree. These skeletons might be also used for landmark-based registration of temporal images in order to support the diagnosis of diabetic retinopathy and glaucoma [2].



a) b) c) d) e)

Figure 16: a) Original fundus image; b) Example of a fused parametric image containing the maxima of all 60 partial filter responses; c) Overall segmentation result; d) Colour labeling of vessel pixels according to detected vessel orientation (spectral scale: 0° red- 165° violet); e) Skeleton of the blood-vessel tree.

*Acknowledgement: This work has been supported by the national research center DAR (Data, Algorithms and Decision making) project no. 1M0572 coordinated by the Institute of Information Theory and Automation, Academy of Science, Czech Rep. and partly also by the institutional research frame no. MSM 0021630513; both grants sponsored by the Ministry of Education of the Czech Republic.*

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# Time of Flight Detection in 3D Ultrasound Computed Tomography

[1]Roleček Jiří , [2]Jan Jiří , [3]Hemzal Dušan

3D Ultrasound Computed Tomography is a new medical diagnostic imaging modality, relying on a system built-up of a cylinder container with ultrasonic transducer arrays. The container is filled with water, in which the imaged tissue is submerged. The data set is captured from all possible combinations of transducer and receiver transducers. This huge data set (20 GB) serves then as the input to reconstruction algorithms. The quality of image reconstruction crucially depends on geometry accuracy of the set-up as well as on the precise detection of the ultrasound pulse time of arrival.

Some basic methods based on the first peak detection in the A-scans (in expected time position) were proposed in [1]. The accuracy of the results obtained by these methods turns out insufficient because of changes in the received pulse shape. Therefore, another approach is suggested in this contribution. Our approach introduces chirp signals and their matched filtering detection, which moreover is variable, adapted to changes in angularly dependent signal characteristics. For every combination of transducer receiver, characterized by mutual angular properties, a particular chirp matched filter must be designed, which is then used for more precise time-of-flight detection. For signals corresponding to all transducer - receiver combinations in an appropriate angle range, the correlation matrix is evaluated. Pulses with correlation coefficient (corresponding to comparison with a certain preliminarily chosen standard pulse) higher than a chosen threshold are averaged to obtain the standard received chirp signal to be used as the impulse response of the detecting filter for the appropriate angle.

For a better accuracy in the detection process, both the chirp signals and the received A-scans are re-sampled from the original 10 MHz sampling frequency to 20 MHz. This way, additional time resolution of detection is obtained. The designed method ensures better signal to noise ratio then the previous approaches and consequently more accurate time of flight detection. However, the achieved higher precision is only just minimally sufficient and for an acceptable reliability of USCT system calibration still an improvement will have to be sought.

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# Automated 3D Registration in CT Subtraction-angiography

[1]Peter Roman , [2]Malínský Miloš , [3]Jan Jiří , [4]Ouředníček Petr

The paper describes a novel method of vessel structure extraction from the 3D CT angiography data, possibly improving the results compared to the common standards. Our approach is based on more precise volume registration of corresponding individual bones obtained from the precontrast and postcontrast phases followed as usually by final subtraction. In order to eliminate vessel distortion we use the postcontrast phase image as the reference one in the process of registration. Based on the fact that each individual bone is a rigid body, for the registrationof these objects the rigid transform is used (albeit with generally different parameters for each individual bone). In principle, the almost ideal registration of the bone should consequently enable to remove the bone from the difference image perfectly thus leaving only the desirable pre/post-contrast information, even if the bones are moved mutually between the pre- and post-contrast acquisitions. For the application of the individual rigid transforms of the bone data, thebones must be segmented out individually very reliably, which is not always possible perfectly - in some cases the bones might become connected either by imaging artefacts or by cartilage material indistinguishablefrom the bone material (thoughusually only in a range of a few pixels).

In contrast to the above initial assumption, the hypothesis of bone rigidity might be sometimes violated due to the patient movement during the image acquisition, thus a minor flexible post-registration of bones is needed. In case of the soft tissue volume registration, the rigid parameters derived from each bone are used as the initial approximations. This approach provides a number of subtraction possibilities due to overlapping of the partial areas. The final subtracted volume is then created in two steps. Each bone area is defined by individual difference of corresponding registered bone while the area of soft tissue is defined by minimal value from all the previously obtained subtractions. Using this approach, we are presently able to provide rather good isolated 3D vessel structures without important traces of other tissues.When compared by an experienced radiologist to images provided by commercial software belonging to the CT unit, clearly more detailed vessel structure can be traced in our results.

**Acknowledgement**

The project has been supported by Philips Nederland and partly also by the research frame no. MS0021630513 of the Ministry of Education, Czech Republic

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# Regularization of Sound-Speed Image Reconstruction in Ultrasound Transission Tomography

[1]Jiřík Radovan , [2]Peterlík Igor , [3]Fousek Jan , [4]Jan Jiří , [5]Zapf Michael , [6]Ruiter Nicole

**Background, Motivation and Objective** Ultrasound transmission tomography is a potentially promising alternative to standard X-ray imaging in medical diagnosis, especially in breast cancer diagnosis. Sound of speed (SOS) is one of diagnostically significant parameters related to tissue pathology. Sound speed images could be directly used for diagnosis or for correction of reflectivity imaging applied to the same data.

**Statement of Contribution/Methods** Reconstruction of SOS maps from data recorded with a 3D ultrasound transmission tomograph is investigated. Algebraic reconstruction technique is used. Large overdetermined system of linear equations is formed from line integrals corresponding to each sender-receiver combination. The equation system is regularized by edge preserving regularization [1] and solved as non-linear least-squares problem.

**Results** The method has been tested on synthetic data and on real data measured with a 3D ultrasound transmission tomography prototype using a human breast phantom. The resulting spatial SOS map followed the object shape and the estimated velocity values were in accordance with the expected range.

**Discussion and Conclusions** To reconstruct a reasonable image, the use of regularization was essential due to sparse transducer distribution and noise. In the classical approach of filtered backprojection with heavily interpolated projections, the neighboring projection samples would be assumed to be related. Here, the transducer sparsity is approached by assuming neighboring voxels of the reconstructed image to be related. This is a more realistic assumption. Furthermore, the character of the used regularization leads to preserved edges, to some extent.

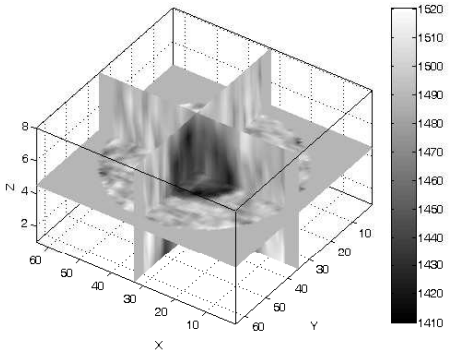


Figure 17: 3D Reconstruction of breast phantom

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