
*Výzkumné centrum Data – Algoritmy – Rozhodování*

*Research Centre Data – Algorithms – Decision Making*

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

# Abstracts of Contributions to 4th International Workshop on Data – Algorithms – Decision Making

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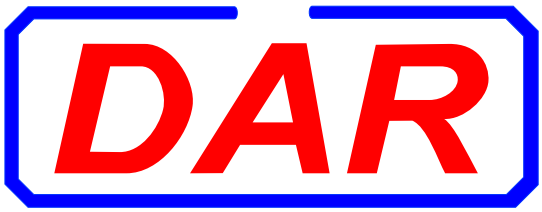
# Content




$4^{th}$ International Workshop on
Data - Algorithms - Decision Making

# Session 1.

## Control under Uncertainty

November 30, 2008, Afternoon

**Chairman:** Miroslav Kárný

# The Impact of Uncertainty on Gene Prognostic Indicators in Automated Cancer Prognosis

[1]David Lowe

Data uncertainty in information processing support environments can be a major factor affecting life-critical decisions.

The use of gene expression values extracted from high dimensional DNA microarrays for patient–specific cancer prognosis has recently led to the proposal that a small subset of special "Prognostic Genes" are capable of discriminating good from poor cancer prognosis. This prognosis is at a patient-specific level and has generated much international and media interest. These studies have now been transferred to clinical use for predicting the likely recovery of breast cancer patients, and commercial companies have been established to provide such analysis of patients' gene expression profiles.

However, by incorporating knowledge of uncertainty, this claim of a unique low-dimensional "Prognostic Gene List' is very probably false, and likely to be the result of a naïve approach to assisted decision support

In this talk I discuss how the existence of a Prognostic Gene List is at first plausible, given the evidence of discriminative models, but that a careful consideration of incorporating *uncertainty knowledge* explicitly in automated machine learning approaches can disrupt this naïve view. I will discuss how the use of uncertainty modifies the decision making process in supervised classification, and how unsupervised topographic visualisation algorithms can be modified to incorporate uncertainty. These modifications produce alternative descriptions of patient-specific data rendering the use of PGL's useless.

The thesis of this talk is that in life-critical areas such as medical applications of cancer prognosis, it is misleading or dangerous to ignore potentially vital knowledge of uncertainty.

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# Validation of the Urban Traffic Control System HRDS and Some Remarks about Queue Length Estimation

[1]Přikryl Jan

After two years of intensive development, the urban traffic control system HRDS approaches the first field testing. The presentation will overview particular stages the development process went through in this year and describe the current state of the project.

The HRDS system uses a state space model to describe the traffic situation in the controlled area. The current control strategy tries to maximise the number of vehicles passing through the traffic network by keeping the length of vehicle queues in the system minimal. The underlaying state-space model is based on so-called Miller's formula that in fact describes the vehicle count conservation law on a single link between two intersections. HRDS can use different kinds of filtering techniques (linear and non-linear Kalman filters, may be extended to particle filters if need aries) to estimate real-world queue lengths, as well as it can use different model and control plugins.

In order to validate the performance of HRDS before actual field testing planned for the fall 2008, the whole system was connected to a commercial microscopic traffic simulator Aimsun [2] via dedicated interface that mimicks behaviour of Siemens C400 intersection controllers. Real measurements of traffic intensity and corresponding signal settings at the planned testing site in Prague (Zličín shopping centre) were used to calibrate Aimsun simulation parameters.

The validation process consisted of repeated performance comparison of two testing scenarios with equal traffic loads:

- simulation of network controlled by stand-alone intersection controllers simulating the current signal settings,
- simulation of network controlled by HRDS coordinating the intersection controllers to minimise queue lengths in the coordinated systems.

The validation of the model revealed a serious inability of the current model to discover abrupt changes in the degree of saturation at an intersection approach, which leads to unreliable queue length estimates. Hence, the final part of the presentation will discuss different models for queue length estimation from intensity and occupancy measurements [1, 3, 4] at a traffic detector placed in certain distance from the stop-bar using different models and their suitability for replacing the current model used by HRDS.

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# Fault Detection for Position Estimation

[1]Punčochář Ivo , [2]Šimandl Miroslav

The global navigation satellite system (GNSS) provides positioning, navigation, and timing services, which are used in many different applications worldwide [1]. It seems reasonable to use the positioning service in traffic control problem. Traffic lights are often controlled by fixed-cycle controllers, but the trend is to develop control strategies that take into account actual traffic situation around a crossroad [2]. Models and light control strategies considered so far are mostly based on measurements from fixed inductive loop detectors placed under surface of road. However, these detectors are prone to mechanical damage and additional source of information is welcomed. A fleet of vehicles equipped with receivers of signals from the GNSS can serve as a net of floating detectors. The data from fixed and floating detectors can be combined and thus provide more accurate information for controlling the traffic flow. Nevertheless, correct function of receivers is mainly conditioned by clear sky view, properly synchronized atomic clocks in satellites, and accurate information about satellites trajectories. Factors that impair these conditions can be regarded as faults because they degrade the overall quality of position estimates [4]. Therefore, these faults should be detected and handled according to requirements of a particular application.

The range of fault detection methods is wide [3] and their applicability depends on the type of available data. If only position estimates from a receiver are available, then it is necessary to develop and use a dynamical model of a vehicle. The fault detection can be based on a simple checking of fit between the dynamical model and position estimates. Such fault detection method can reveal serious faults only, and the quality of detection is heavily dependent on the quality of the dynamical model. A better detection ability can be obtained when raw measurements are available. The raw measurements consist of satellite positions and pseudoranges. These measurements are used for position estimation and fault detection, as well. Again, a dynamical model of a vehicle can be used for position estimation and fault detection [5], but it is not suitable or even allowed in some applications. Mainly, it is because of simplicity, safety, and technical or legal measures. Therefore, the stress is laid on fault detection methods that use only static model of measurement, and the dynamical model of a vehicle is not needed.

The goal is to introduce suitable fault detection approaches and to describe two basic fault detection methods in more details. These two fault detection methods use the same residual generator, but evaluation of residual signals and generation of the decision are different. The first method is based on $\chi^2$ test, and the second one relies on cumulative sum (CUSUM) test. The $\chi^2$ test is simple and easily implementable because it uses only measurements at current time step to make a decision. However, small faults can remain undetected over a period of time. On the other hand, the CUSUM test utilizes measurements from current and past time steps, and therefore, it allows detecting small persistent faults because of their accumulation in sum. Compared to $\chi^2$ test, it suffers from implementation problems. Both methods were evaluated using Monte Carlo simulations for different satellite configurations.

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# Estimation of Models with Uniform Innovations and its Application on Traffic Data

[1]Pavelková Lenka

The contribution summarizes the results achieved by the author in the field of developing of a linear uniform state model (LU model) and its estimation.

The main motivation of this research was the search for a model that is both easily identifiable and suitable for the estimation of the bounded quantities. By the LU model, the state and output innovations are considered to have the uniform distribution. The system states and parameters are estimated on-line with fixed memory on the sliding window. The sliding window as the alternative of the forgetting allows to catch the slow parameter changes. The MAP estimation of the LU model reduces to the linear programming.

The proposed approach provides the following advantages: (i) it allows estimation of the innovation range and (ii) it allows (without excessive computational demands) to respect ,,naturally" hard, physically given, prior bounds on model parameters and states, (iii) it enables the joint estimation of parameters, state, and innovation bounds, whereas the realistic hard bounds on the estimated quantities reduce the ambiguity of the model (arising from estimating a product of two unknowns), (iv) it provides an easy entry of of the partial knowledge on the parameters.

The illustrative example with traffic data will be presented. There, the length of the queues on the controlled intersection will be estimated.

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$4^{th}$ International Workshop on
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# Session 2.

## Multiple-participant Decision-making

November 30, 2008, Afternoon

**Chairman:** Miroslav Kárný

# Uncertainty in Stochastic and Deterministic Control

[1]Herzallah Randa

Modern advances in technology have led to more complex manufacturing processes whose success centers on the ability to control these processes with a very high level of accuracy. Plant complexity inevitably leads to poor models that exhibit a high degree of parametric or functional uncertainty. The situation becomes even more complex if the plant to be controlled is characterized by a multi-valued function or even if it exhibits a number of modes of behavior during its operation. Since an intelligent controller is expected to operate and guarantee the best performance where complexity and uncertainty coexist and interact, we have recently developed new control techniques under the framework of intelligent control to enhance the performance of the controller for more complex and uncertain plants. These techniques are based on incorporating model uncertainty. The new developed control algorithms for incorporating model uncertainty are proven to give more accurate control results under uncertain conditions. In this talk we present some of these approaches that appear to be promising for enhancing the performance of intelligent control systems in the face of higher levels of complexity and uncertainty.

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# Merging of Fragmental Probabilistic Information for a Flatly Structured Cooperation

[1]Miroslav Kárný

Inherent complexity of dynamic decision making (DM) under uncertainty, that precludes implementation of formally optimal strategies, has been primary motivation for the reported research[2]. Distributed DM seems to be only way out of this "curse of dimensionality". A systematic and fully scalable solution has to cope with a flatly organized structures. Otherwise, central decision makers and communication channels to them are either overloaded or information loss is too high.

A cooperation within flat cooperation structures has to rely on combination of fragmental, not fully compatible, probabilistic information pieces. This is a common problem in many application domains. It has been addressed repeatedly, for instance, in connection with probabilistic expert systems [2], knowledge elicitation, [6], cooperation of participants, [1, 5], etc. None of the existing methodologies seems to be complete and automatic enough to serve to the considered purpose.

Flat structures are common in large societal groups: each member of the group has its aims, restricted perceiving, modelling, acting and evaluating abilities. Consequently, he (she/it) interacts with a relatively small number of "neighbors" and modifies his DM elements in inherently selfish way. This fully scalable cooperation model is worth imitation.

This contribution describes a promising methodology [4] based on this model. It formalizes this cooperation structure assuming that the group is formed by Bayesian decision makers who use so called fully probabilistic design of the optimal decision strategy [3]. The group members are supposed to be willing to cooperate with neighbors by providing them probabilistic distributions they use for their DM. At present research stage, interaction and communication structure are assumed to be given. Thus, the group DM is determined by specifying how the offered non-standard (probabilistic) fragmental information pieces is to be exploited.

The exploitation problem is formulated and solved in a strictly Bayesian way. The group member: (i) takes the offered distributions as measured data; (ii) estimates an unknown global distribution describing the cooperating neighbors; (iii) projects this estimate on the domains of interest to the respective neighbors; (iv) approximates each projected distribution by the distribution, which has the form understandable to the decision maker.

The proposed methodology is of an independent interest since it can be used for model and aim elicitation.

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[2]Supported partially by a common project IMATI CNR Milano and ÚTIA AV ČR and by GAČR 102/08/0567

# General Interface Supporting Merging of Fragmental Probabilistic Information for Flatly Structured Cooperation

[1]Šmídl Václav

Growing interest in applications of distributed systems, such as multi-agent systems, increases demands on identification of distributed systems from partial information sources collected by local agents. Traditional approach to decentralized systems established by early works [4] is performed by a group of agents with identical description of the state, which is estimated from observations available to each agent [1]. Each agent provides posterior density on the common state variable, which is then combined using various merging techniques. This approach is suitable for applications in distributed target tracking or localization, however, it does not scale well to systems with large distributed state such as traffic networks [3]. Moreover, modeling of the full common state may be unnecessary in situations when only local state of an agent is required to make decisions. In such applications, it is sufficient to improve only posterior density on the local state using information from the neighbors.

We are concerned with fully distributed scenario, i.e. each agent is building posterior density on his local state and can communicate this density with its neighbors. When a neighbor receives such information, it checks if it contains information that is relevant to him, if it does, he merges the message into his own knowledge. A methodology how to uniquely merge local knowledge represented by a probability density function (pdf) was proposed in [2], using non-parametric approach. The resulting pdf, i.e. the merger, can be projected into a parametric class. Projection on discrete pdfs with rectangular grid was given. Such a class may be impractical for pdfs with large support or high-dimensional pdfs. Therefore, we present a projection of the non-parametric pdfs into the class of weighted empirical densities using mixtures of exponential families as proposal densities.

We choose to project the merger into the class of weighted empirical densities. This class has also discrete support, hence we can use previously derived results. We face two challenges in this task: (i) how to choose the points of the support, and (ii) how to evaluate marginal and conditional fragments of the resulting merger. The former challenge is important for computational efficiency of the algorithm, the latter for merging of fragmental pdfs. We address both challenges by choosing a proposal density from the class of exponential family mixtures which is iteratively fitted to the weighted empirical density. The evaluation algorithm iterates as follows: (i) sample support points from the proposal density, (ii) evaluate weights of the merger, and (iii) re-estimate parameters of the mixture. The resulting algorithm is capable of merging wide range of possible fragmental pdfs on continuous support. Performance of the algorithm is illustrated on simple example of distributed estimation.

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# Dual Controller Design Based on Prediction Error Maximization and Partial Certainty Equivalence

[1]Flídr Miroslav , [2]Šimandl Miroslav

In optimal control of linear stochastic systems it is often assumed that the certainty equivalence property holds and thus the well-known and tried LQG approach is used [1]. However, except for few special situations, it is necessary to cope with unknown and possibly even time-varying parameters. In such a case the certainty equivalence property does not hold and it is either difficult or even not possible to solve the dynamic programming problem [2]. Moreover, as pointed by [3], such control pursues two conflicting objectives. It should meet the control objective i.e. to drive the system to a desired state and simultaneously try to improve the quality of estimation of the uncertain parameters. Further, the so called dual control should be cautious with respect to inherent uncertainties and should induce appropriate probing in order to actively support reduction of the uncertainties. This means that the optimal control problem is tightly coupled with estimation and it is also inevitable to find a solution of the nonlinear filtering problem which itself is a very complex task.

Many suboptimal dual control approaches were proposed in the past (see e.g. survey [4]). They all attempt to overcome the difficulties of those two inherent problems and to make it possible to attain the closed form solution and not to lose the dual control properties. Some of the developed dual controllers overcome the problem with solvability by truncating the control horizon to one time step and then supplementing either the criterion or the control with a term that ensures presence of both dual control properties. This truncation of control horizon may, however, induce the myopic behavior and the overall cost of all the control stages may be higher than if the whole multistage control horizon is considered. On the other hand, the dual control approaches that consider the whole control horizon are more complex and computationally demanding.

This contribution presents design of a dual controller which is based on an approximation of probability density functions (pdf's) considered in the solved problem and a modification of the criterion. The pdf's approximation used [5] helps to achieve solvability of the multistage control problem by simultaneous preservation of the cautious feature of the control. In order to ensure the dual features of the resulting controller, the criterion is enhanced by a term maximizing the prediction error of the state augmented by unknown parameters [6]. The advantage of the presented dual controller is that it takes into account the whole multistage control horizon, has straightforward design and practically acceptable computational demands.

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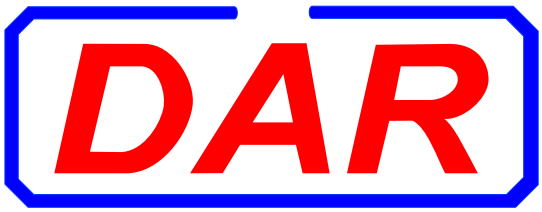


$4^{th}$ International Workshop on
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# Session 3.

## Image Fusion

December 1, 2008, Morning

**Chairman:** Jan Flusser

# An Overview of Image Processing Activities in the DAR Center in 2008

[1]Flusser Jan

The main goal of the talk is to give an overview of the activities of the DAR Image processing group in 2008. We demonstrate the progress achieved on the field of video superresolution, image identification and retrieval, and space-variant image restoration.

Special attention is paid to our two currently running applied projects with a big potential impact on the market. The PIRIS project, partially supported by Profimedia.cz, is aimed to identify modified versions of query images in very large databases. We started this work two years ago. After developing and testing a trial version of the system in Matlab, we are now in the stage of implementing a full version in C. This version is designed for handling a database of 30 millions of photographs.

The second project deals with our recent multi-image deconvolution algorithms. The aim is to simplify and speed-up them while preserving their reasonable performance, such that they could be implemented directly in mobile phones without any off-line processing by computer.

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# 3D Image Registration Based On Phase Correlation

[1]Bican Jakub , [2]Flusser Jan

Image registration plays a major role in multiframe image processing. The purpose of image registration is to geometrically align two or more images differing by the imaging time, viewpoint, sensor modality and/or the subject of the images. We present a new image registration algorithm that employs Phase Correlation Method (PCM) to align rotated and translated 3D images.

Fourier methods form a special group of approaches based on Phase Correlation Method (PCM). PCM was first introduced by Kuglin and Hines [1] as a fast and robust method for estimation of inter image shifts. The method was extended by De Castro and Morandi [2] to register translated and rotated images and later by Reddy and Chatterji [3] to register translated, rotated and scaled images. Keller et al. [4] introduced an algorithm for the registration of rotated and translated 3D volumes based on Pseudopolar Fourier transform.

Our method is based on cylindrical coordinate mapping of image in spatial domain and iterativelly uses PCM to estimate the update of rigid body transform with respect to some transform component: rotation or translation. First, we use PCM and cylindrical coordinate transform to estimate rotation angle that aligns two images that are mutually rotated around known axis. An improvement of this technique is given to eliminate influence of noise and image differences in non-ideal conditions. Finally, an iterative optimization procedure is proposed which uses these techniques in rigid body registration tasks. We experimentally study the method's performace in the case of tomographic brain image registration tasks.

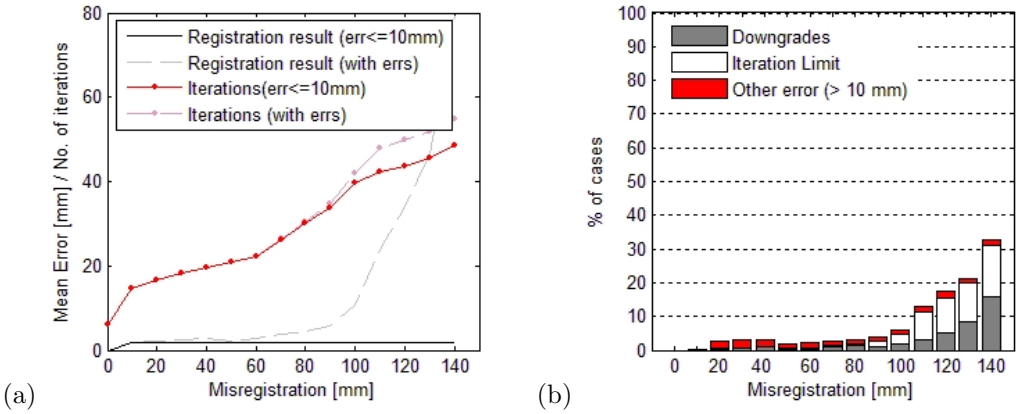


Figure 1: Influence of initial misregistration on the mean error after registration (a), number of iterations (a) and the failure statistics (b): the cases of even increased initial misregistration (Downgrades), the cases of reaching the iteration limit and the rest of the cases when the final misregistration was not decreased below 10 mm. For each bar, one thousand of random transforms were generated.

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# Superresolution and Blind Deconvolution of Video

[1]Šroubek Filip , [2]Flusser Jan , [3]Šorel Michal

Imaging devices, such as camcorders or web cameras, have limited achievable resolution due to many theoretical and practical restrictions. In many real applications traditional superresolution methods fail to provide high-resolution images due to objectionable blur and inaccurate registration of input low-resolution images. We present a method of superresolution and blind deconvolution of video sequences and address problems of misregistration, local motion and change of illumination. The method processes the video by applying temporal windows, masking out regions of misregistration, and minimizing a regularized energy function with respect to the high-resolution frame and blurs, where regularization is carried out in both the image and blur domains.

Recently in [1], we proposed a unifying method that simultaneously estimates the blurs and high-resolution image from multiple low-resolution images. The key idea was to determine subpixel shifts by calculating the blurs. As the blurs are estimated in the high-resolution scale, positions of their centroids correspond to sub-pixel shifts. Therefore by estimating blurs we automatically estimate shifts with sub-pixel accuracy, which is essential for good performance of superresolution.

This work extends our previous results to video and presents remedies for two common problems in superresolution of video: change of illumination and local motion. Apart from robustness to misalignment, including estimation of blurs in the proposed method cancels effects of change of illumination. For warping (registration) of frames, we assume a homography model, which is mostly sufficient even for scenes with significant variations in depth, since change of camera position between neighboring video frames is relatively small. Nevertheless, homography cannot map regions that contain local motion. Thus discrepancies in preregistered images give us regions where local motion is highly probable. Masking out such regions and performing simultaneously blind deconvolution and superresolution, produces naturally looking high-resolution frames. In regions, which are masked out in every frame, interpolation takes place, but in the rest precise superresolution can be calculated.

Figure below shows results of an experiment on a real video sequence with local motion. The left image is one interpolated frame from the original sequence. The middle image was reconstructed using a traditional superresolution method. The right image was obtained by the proposed superresolution method with masking. Masking produces smooth results with the masked-out regions properly interpolated.

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# Automated Glaucoma Detection with Ophthalmic Imaging Devices

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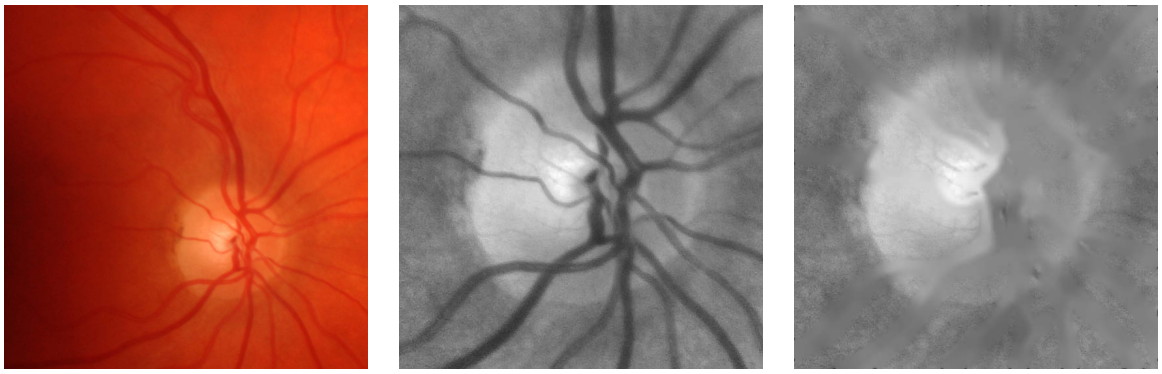
In recent years, research in ophtalmic imaging has taken great leaps forward. New imaging modalities like HRT, GDX and OCT have been introduced and commonly used ones like fundus photography have been improved due to digital imaging. The Chair of Pattern Recognition together with the Ophthalmic Department of the University Erlangen-Nuremberg support these developments by using different imaging devices as a base for automated disease detection. A special focus lies on glaucoma, the second leading cause for blindness in the world. Computer science opens unseen viewpoints on data and diagnosis of ophthalmic images. We use a data driven classification on fundus images for calculating a glaucoma risc index. Disease independent variations are eliminated in a preprocessing step and features for a classification are calculated by a principal component transformation on the resulting image. As a further support for the physician we provide a visualization of the nerve fiber layer thickness on OCT B-Scans and quantitative measurements with DTI imaging.



(a) (b) (c)

Figure 2: Elimination of disease independent variations: (a) cropped original fundus image, (b) illumination corrected input with normalized papilla size, (c) inpainted vessel structures

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# Reconstruction of Attenuation and Sound-Speed Images from 3D Ultrasound Transmission Tomography Data

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

The contribution covers image restoration in ultrasound transmission tomography. This, so far experimental, imaging modality is intended for breast cancer diagnostics. The work is focused on reconstruction of attenuation and sound-speed images from data acquired using a 3D Ultrasound Transmission Tomograph prototype [1]. While the published work in the field has been on 2D ultrasound tomography (transducers in a ring geometry), this project deals with a 3D system (transducers placed on a cylinder wall). The 2D-to-3D transition enables direct 3D acquisitions but it leads to lower number of transducers in a tomographic plane, smaller transducer size, lower signal-to-noise ratio and larger data set size.

Reconstruction within a selected tomographic layer is presented. In the reconstruction of attenuation images, the low number of transducers is taken into account by regularization [2]. A more challenging problem is the low SNR. One possible approach is the synthetic aperture focusing. This is successfully applicable on synthetic data but for processing of real data a correction for sound speed is necessary.

The proposed sound-speed reconstruction is based on the same framework as the attenuation reconstruction, including algebraic reconstruction, formulated as a regularized solution of a linear system of equations.

The image reconstruction is very time-demanding (a full 3D reconstruction corresponds to a system of 3.5 millions of equations, computation time on a single PC is in the range of months).

This raises a strong need for parallelization. Our approach is based Parallel computing Matlab toolbox and the cluster computers of the Czech national project on supercomputing METACentrum.

The image reconstruction algorithms have been tested on data acquired on a self-made attenuation phantom and a breast phantom with known material properties. The image values were in the expected range.

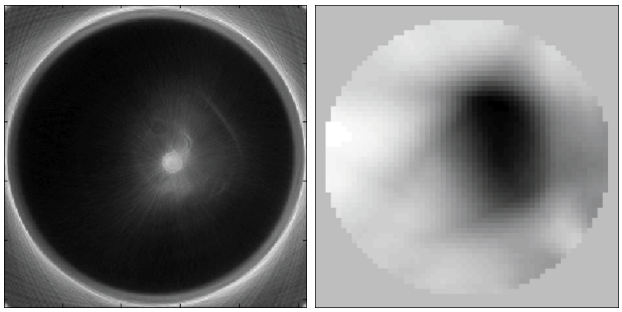

Figure 3: Example of sound-speed image reconstruction. Left: reference reflectivity image. Right: reconstructed sound-speed image.

*Acknowledgement*: Support by the research centre DAR (Ministry of Education, Czech Republic) project no. 1M6798555601, by the DADA grant no. D12-CZ9/07-08 and partially also by the research frame of the FEEC VUT no. MSM 0021630513 is acknowledged.

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# Application of Image Texture Analysis and Pattern Recognition for Retinal Nerve Fibres Classification

[1]Radim Kolář , [2]Jiří Jan , [3]Jiří Roleček , [4]Radovan Jiřík , [5]Jiří Gazárek

This paper deals with the analysis of structure created by retinal nerve fibres (RNF) layer in colour fundus images. The main aim is to find a set of parameters (features), which describe changes in this structure. Therefore, techniques from the texture analysis, features selection and classification are used to find these convenient features.

The RGB images were taken by colour fundus camera Canon CF-60UDi and the mean value from green and blue channels was computed, because the red component doesn't carry any information from RNF reflection. The database of images used in this study contained 30 retinal images: 16 glaucomatous images with RNF layer losses and 14 images of healthy eye. Several square image samples (41 $\times$ 41 pixels) were selected from each retinal image for texture analysis. These were analyzed by first-order, second-order and higher-order statistics, Fourier spectral analysis, Fractal model and by structural-based approach.

Over 30 features were computed using these methods and their *quality* was evaluated by Max-Relevance and Min-Redundancy method [2]. This scheme uses mutual information and is based on two concepts: a *good* feature should have maximum relevance to the target class and minimum redundancy to already selected features.

Two features from statistic-based methods were selected as the most relevant: Texture Homogeneity and Short Run Length Entropy. The feature space is shown in Figure 4. Two clusters represents two classes of different tissues: tissues with RNF layer losses (class B) and healthy tissue (class C). The classification error using leave-one-out cross-validation is below 2% using Ho-Kashyap classifier [1].

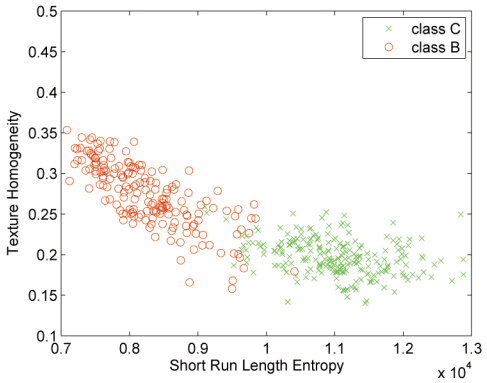


Figure 4: Two clusters represents two classes of different tissues: tissues with RNF layer losses and healthy tissue.

*Acknowledgement*: Support by the research centre DAR (Ministry of Education, Czech Republic) project no. 1M6798555601, by the DADA grant no. D12-CZ9/07-08 and partially also by the research frame of the FEEC VUT no. MSM 0021630513 is acknowledged.

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$4^{th}$ International Workshop on
Data - Algorithms - Decision Making

# Session 4.

## Multidimensional Signal Processing and Pattern Recognition

December 1, 2008, Afternoon

**Chairman:** Michal Haindl

# Structural Poisson Mixtures for Classification of Documents

[1]Grim Jiří , [2]Novovičová Jana , [3]Somol Petr

We consider classification of the text documents in a Bayesian learning framework with a bag-of-words document representation. There are two common models in the representation of text documents (see e.g. [4], [3]). The multivariate Bernoulli model represents each document by a vector of binary feature variables indicating whether or not a certain word occurs in the document. Alternatively, in the multinomial model, the features are defined as frequencies of the related vocabulary terms in the document. In both cases the dimension of document vectors is very high because of a large number of vocabulary terms and therefore different feature selection methods have to be used as a rule. Unfortunately, it is difficult to reduce the size of vocabulary since there are many different classes having different subsets of characteristic terms. An informative subset of features common to all classes often represents a difficult compromise possibly connected with a loss of classification accuracy.

In this paper we propose the use of a structural mixture of multivariate Poisson distributions to learn Bayesian text classifier. By introducing binary structural parameters we can reduce the evaluation of the Bayes formula only to subsets of informative variables which may be different for different classes and even for different mixture components (cf. [1]). In this way we can reduce the number of parameters in the conditional distributions without reducing the number of vocabulary terms.

The proposed method of structural Poisson mixtures represents statistically correct subspace approach to Bayesian decision-making. It is directly applicable to a non-reduced input space of arbitrary dimension and allows for different feature subsets for different classes. We succeeded to improve the classifier performance by relaxing the popular feature independence assumption and using structural mixtures with reduced number of parameters. The advantage of different class-specific feature sets should be more relevant in case of multi-class problems.

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# Evaluating the Stability of Feature Selectors that Optimize Feature Subset Cardinality

[1]Petr Somol , [2]Jana Novovičová

Feature selection (FS) has been a highly active area of research in recent years due to its potential to improve both the performance and economy of automatic decision systems in various applicational fields. It has been pointed out recently that not only model performance but also stability (robustness) of the FS process is important. Domain experts prefer FS algorithms that perform stably when only small changes are made to the data set. Stability (robustness) of feature selection methods is a topic of recent interest and often neglected importance with direct impact on the reliability of machine learning systems. We investigate the problem of evaluating the stability of feature selection processes yielding subsets of varying size.

Recent works in the area of FS methods' stability mainly focus on various stability indices, introducing measures based on Hamming distance, Dunne et al. [2], correlation coefficients and Tanimoto distance, Kalousis et al. [3], consistency index, Kuncheva [4] and Shannon entropy, Křížek et al. [5]. Most of these recent works focus on the stability of single FS methods, while Saeys et al. [7] construct and study an ensemble of feature selectors. Stability of FS procedures depends on sample size, criteria utilized to perform FS and complexity of FS procedure.

To evaluate the stability of feature selectors we propose in this paper several new measures to be called the *consistency measure*, the *weighted consistency measure* and the *relative weighted consistency measure*. Unlike most other measures, these can be used for assessing FS methods that yield subsets of varying sizes. We study in detail the properties of considered measures and demonstrate on various examples what information about the feature selection process can be gained.

We compare the new measures to the generalized form of Kalousis measure [3]. All proposed measures have been used to compare the stability of Sequential Forward Selection algorithm [1] and Sequential Forward Floating Selection algorithm [6] on a set of examples.

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# Texture Segmentation Benchmark

[1]Mikeš Stanislav , [2]Haindl Michal

Unsupervised or supervised texture segmentation is the prerequisite for successful content-based image retrieval, scene analysis, automatic acquisition of virtual models, quality control, security, medical applications and many others. Although more than 1000 different methods were already published [8, 3, 6, 7, 5, 1, 2, 4], this ill-defined problem is still far from being solved and even cannot be solved in its full generality. In addition to that, very little is known about properties and behaviour of already published segmentation methods and their potential user is left to randomly select one due to absence of any counseling. This is among others due to missing reliable performance comparison between different techniques because very limited effort was spent to develop suitable quantitative measures of segmentation quality that can be used to evaluate and compare segmentation algorithms.

The Prague texture segmentation data-generator and benchmark is a web based ( http://mosaic.utia.-cas.cz) service designed to mutually compare and rank different texture segmenters, and to support new segmentation and classification methods development. The benchmark verifies their performance characteristics on monospectral, multispectral, bidirectional texture function (BTF) data and enables to test their noise robustness, scale, and rotation or illumination invariance. It can easily be used for other applications such as feature selection, image compression, and query by pictorial example, etc. The benchmark functionalities are demonstrated on five previously published image segmentation algorithms evaluation.

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# Illumination Invariants Based on Markov Random Fields

[1]Vácha Pavel , [2]Haindl Michal

Textures are important clues to specify objects present in a visual scene. Unfortunately, the appearance of natural textures is highly illumination and view angle dependent. As a consequence, most recent realistic texture based classification or segmentation methods require multiple training images [1] captured under all possible illumination and viewing conditions for each class. Such learning is obviously clumsy, probably expensive and very often even impossible if required measurements are not available.

We propose textural features, which are invariant to illumination spectrum and extremely robust to illumination direction. They require only a single training image per texture and no knowledge of illumination direction or spectrum. Hence, these features are suitable for content-based image retrieval (CBIR) of realistic scenes with colour textured objects and variable illumination. The illumination invariants are derived from Markov random field based texture representations. Our illumination invariant features are favourably compared with frequented features in this area - the Local Binary Patterns, steerable pyramid and Gabor textural features, respectively. The superiority of our new invariant features is demonstrated in the illumination invariant recognition of the most advanced representation for realistic real-world materials - Bidirectional Texture Function (BTF) textures.

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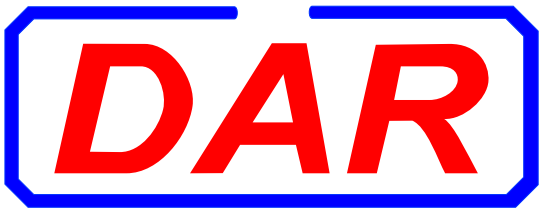


$4^{th}$ International Workshop on
Data - Algorithms - Decision Making

# Session 5.

## Decision-making and Classification

December 1, 2008, Afternoon

**Chairman:** Igor Vajda

# On Optimal Decisions in Continuous Models Achieved by Discrete Methods

[1]Vajda Igor

Quantizations of continuous data $X_1, ..., X_n$ are commonly used in algorithmizations of decision functions $\delta_n = \delta_n(X_1, ..., X_n)$. This means that the real data space $\mathbb{R}$ of each decision argument $X \in \{X_1, ..., X_n\}$ is replaced by the discrete digit

$$d(X) = \mathbf{\Sigma}_{j=1}^{m}\ j.\boldsymbol{I}_{A_j}(X) \in \{1, ..., m\} \stackrel{\Delta}{=} \mathbb{D}$$

indicating the quantization cell from a partition $\mathcal{P} = \{A_1, ..., A_m\}$ of $\mathbb{R}$. Thus in practical applications the decisions $\delta_n$ are based on the discrete arguments

$$(Y_1, ..., Y_n) \stackrel{\Delta}{=} (d(X_1), ..., d(X_n)) \in \mathbb{D}^n.$$

The quantization transforms the original continuous model $\mathcal{CM} = \{\langle \mathbb{R}, P_\theta \rangle : \theta \in \Theta\}$ of the i.i.d. data $X_1, ..., X_n$ into the discrete model

$$\mathcal{DM} = \{\langle \mathbb{D},\ p_\theta = [p_\theta(1) \equiv P_\theta(A_1), ..., p_\theta(m) \equiv P_\theta(A_m)] \rangle : \theta \in \Theta\}$$

generating the i.i.d. data $Y_1, ..., Y_n$.

The lecture deals with the special decisions $\delta_n = \theta_n(X_1, ..., X_n)$ about the unknown true value of $\theta \in \Theta$ (estimation of the parameter $\theta$). It presents conditions under which some esimates $\theta_n(Y_1, ..., Y_n)$ available in the $\mathcal{DM}$ are optimal in the sense of the asymptotic consistency and efficiency in the $\mathcal{CM}$. Similar conditions guaranteeing the achievability of the theoretical statistical optimality by means of the practically used discrete methods were not found in the previous literature.

The lectured results are based on the paper [1] supported by the DAR and not reported so far in the DAR seminars or workshops. They will include also an application in a concrete situation with estimation of a security risk in an open battlefield.

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# New Results on Bregman Distances

[1]Wolfgang Stummer , [2]Igor Vajda

Bregman distances between *general probability measures* were shortly introduced in [1] in a merely conceptual way. In this talk, we first present fully rigorous foundations for them, including some connections with the class of $\phi-$divergences. Furthermore, we carry out a systematic study on Bregman distances for exponential families on Euclidean as well as path spaces (cf.[3]). Several examples are shown in order to illuminate the corresponding theory, and to indicate its potential use for a wide range of areas in statistics and financial econometrics. Finally, we discuss some possible way of obtaining bounds for Bregman distances in models beyond (but vaguely related to) exponential families, generalizing some results of [2].

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# An Application of Linear Model with Both Fixed and Random Effects in Small Area Estimation

[1]Hobza Tomáš , [2]Morales Domingo

Battesse et al. (1988) proposed for the first time a nested-error regression model in the setup of small area estimation. Since then, Empirical Best Linear Predictors (EBLUP) based on unit-level linear mixed models are commonly used to estimate domain linear parameters. These models typically assume that the regression parameter is constant but the intercept is random with realizations on the domains. Random intercept linear models grossly assign a regression line to each domain with the same slope but different intercept. The intercept variance refers to the variability across domains of the line heights at the origin. Searle et al. (1982) provide a detailed description of these models and Ghosh and Rao (1994), and more recently Rao (2003) and Jiang and Lahiri (2006), discuss their applications to small area estimation.

More specifically, if we are interested in estimating domain means we may often find that there exist a small subset of them that have a different behavior because the superpopulation model changes to have another structure. For example, it may happen that model intercept is much higher in the mentioned domains than in the rest of them. In these cases traditional random intercept models do not fit well to data because some domains are responsible for producing an overestimated intercept variance affecting negatively the EBLUP estimates. We may also consider the case of being interested, because of administrative or political reasons, to increase the precision of estimates of means for some given domains. It is thus necessary to introduce EBLUP estimators of means based on a linear mixed model with one factor having both fixed and random levels.

A general theory for a case where a factor has both fixed and random effect level was developed under a one-way ANOVA model by Njuho and Milliken (2005). In this paper their model is extended to a linear regression model with an intercept being fixed in a part of the domains and being random in the rest of the domains. Estimation procedures for the fixed effects, variance components and regression parameters are considered and EBLUP estimators of domain means are derived as well as estimators of the mean squared errors of the EBLUP estimates. To illustrate the gain of precision obtained by using the proposed model a Monte Carlo simulation experiment is presented. A motivating application to Spanish Labour Force Survey data is also given.

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# Blind Separation of Convolutive Mixtures in the Time Domain - Separation of Speech Signals

[1]Koldovský Zbyněk , [2]Tichavský Petr

We present a novel time-domain method for blind separation of convolutive mixture of audio sources (the cocktail party problem). The method allows efficient separation with good signal-to-interference ratio (SIR) and signal-to-distortion ratio (SDR) using short data segments only. It proceeds in three or four steps, see Figure 1.
1) An independent component analysis (ICA) algorithm is applied to a data matrix formed by mutually time-delayed received signals.
2) The components obtained in step 1 are grouped using a clustering algorithm and a criterion of similarity of the components.
3) Inverse of the ICA decomposition is used to reconstruct the contribution of each source on each microphone. The contributions can be combined together to estimate each source separately.

In practice, we are able to separate simultanous speech of 2-4 speakers from audio recording of the length less than 6000 samples, which is less than 1 s in the 8 kHz sampling. The average time needed to process the data with filter of the length 20 was 2.2 seconds in Matlab v. 7.2 on an ordinary PC with 3GHz processor.

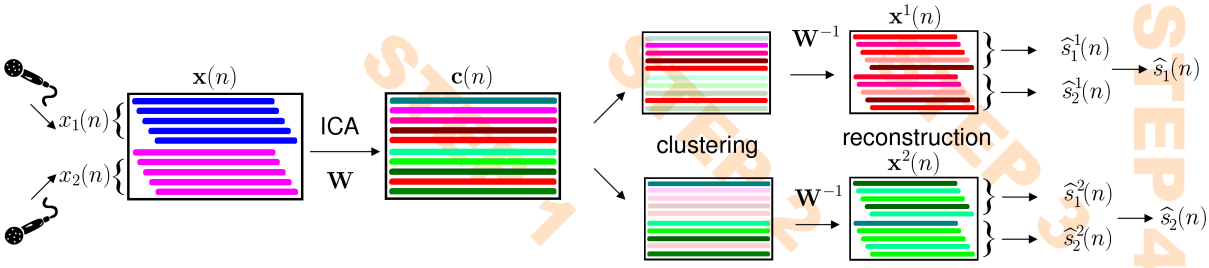


Figure 5: Workflow of the proposed separation algorithm for two speakers and two microphones.

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$4^{th}$ International Workshop on
Data - Algorithms - Decision Making

# Session 6.

## Knowledge Processing

December 2, 2008, Morning

**Chairman:** Milan Mareš

# Copulas: a Tool for Modeling the Stochastic Dependence

[1]Mesiar Radko

Due to Sklar's theorem [15], each joint distribution $F_Z$ of a random vector $Z = (X_1, \ldots, X_n)$ can be written in the form

$$F_Z(x_1, \ldots, x_n) = C\left(F_{X_1}(x_1), \ldots, F_{X_n}(x_n)\right),$$

where $F_{X_i}$, $i = 1, \ldots, n$, are 1-dimensional distribution functions and $C\colon [0,1]^n \to [0,1]$ is a copula ($C$ is unique if $Z$ is continuous). For more information on copulas we refer, e.g., to the monograph by Nelsen [12]. Copulas allow to discuss the rank-dependent properties of $Z$, e.g., the rank correlation (Spearman's rho), lower and upper tail dependencies, etc. We will discuss the characterization of copulas, especially of 2-dimensional ones (2-copulas, for short), some of their classes and some construction methods. A special attention will be paid to the case when only the diagonal section of a copula is known. Statistically this means that the distribution of the maximum of marginal random variables is known, assuming that they are uniformly distributed over the interval $[0, 1]$. In the case of associative 2-copulas, their $n$-ary extension need not be a copula, in general. We will characterize all associative 2-copulas yielding an $n$-copula for each $n \geq 2$. Finally, some possible applications will be indicated.

**Acknowledgement**.
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# Algebra and Geometry for Coalition Game Theory

[1]Kroupa Tomáš

A coalition game can be described by a set of players, a set of plausible coalitions, and a characteristic function of the game. In general the set of players can be infinite and the coalitions enable only a partial membership of the players [1]. This situation is captured by an algebraic structure called lattice ordered Abelian group [3]. A solution for a large class of games on these structures is then constructed by using the concept of subdifferential [2].

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# Arithmetic Circuits of the Noisy-or Models

[1]Vomlel Jiří , [2]Savický Petr

Arithmetic circuits can be used to represent the process of probabilistic inference in Bayesian networks using methods for which the structure and complexity of the process does not depend on the evidence. The size of the circuit corresponds to the time complexity of the inference algorithm if the method of the downward pass is fixed. For example, for the well-known junction tree methods, there is an arithmetic circuit which represents calculation with the same complexity [3]. However, arithmetic circuits are more flexible and also allow representation of calculations using different types of computational savings, for example when the conditional probability tables of the Bayesian network have a certain local structure [2].

We use the size of arithmetic circuits to compare the effect of preprocessing BN with noisy-or gates using parent divorcing and tensor rank-one decomposition. For this purpose, we use the inference methods implemented in Ace [1] by Chavira and Darwiche for several examples of two-layered networks with noisy-or gates (BN2O type networks) in two situations. First, we use Ace on the original network directly, which means that a kind of parent divorcing is used. Second, before the application of Ace the network is preprocessed using a noisy-max decomposition, originally proposed by Díez and Galán [4] and generalized as the tensor rank-one decomposition by Savicky and Vomlel [6]. The size of the resulting circuits depends mainly on the size of the largest clique in the triangulated graph of the network. The treewidth of the optimally triangulated graph of the transformed model is provably never larger than the treewidth of the model preprocessed using parent divorcing. Hence, one may expect that tensor rank-one decomposition produces circuits which are usually not larger than the ones from parent divorcing, even if heuristic triangulation is used. Our experiments with Ace confirm this conclusion on average. There are cases where the transformed network provides a significantly larger circuit; however, using a better triangulation computed by Hugin [5] instead of the one computed by Ace we reduced the deterioration factor in our experiments to at most 3. This is much smaller than the best improvement factors, which exceed 100.

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$4^{th}$ International Workshop on
Data - Algorithms - Decision Making

# Session 7.

## Soft Computing and Fuzzy Modelling

December 2, 2008, Morning

**Chairman:** Milan Mareš

# Implicational Interpretation - the Continuity Issue

[1]Štěpnička Martin , [2]Bodenhofer Ulrich , [3]Daňková Martina , [4]Novák Vilém

A summary containing a more detailed description of the presentation and its main results. The length of the presentation summary including references should not exceed **one page**. Please do not use any personal macros.

A finite set

$$\mathcal{R} = \{\mathcal{R}_1, \ldots, \mathcal{R}_n\} \tag{1}$$

of fuzzy rules of the form

$$\mathcal{R}_i := \mathsf{IF}\ x \text{ is } \mathcal{A}\ \mathsf{THEN}\ y \text{ is } \mathcal{B} \tag{2}$$

is called a *linguistic description* [5]. Variables $x$ and $y$ take values from universes $X$ and $Y$, respectively. Symbols $\mathcal{A}$ and $\mathcal{B}$ stand for specific linguistic expressions and they are basically interpreted by fuzzy sets $A \underset{\sim}{\subseteq} X$ and $B \underset{\sim}{\subseteq} Y$. Interpretation of the whole linguistic description $\mathcal{R}$ is then a fuzzy relation $R \underset{\sim}{\subseteq} X \times Y$.

There are two main approaches how to interpret the linguistic description, the $M$amdani-Assilian interpretation (also sometimes called conjunctive interpretation) and the $i$mplicational interpretation. The latter one respects the conditional IF-THEN form of rules (2) and employs a genuine fuzzy implication. The first one was motivated by a successful experiment [4] and it is very often used in practice, which is not true in case of the implicational interpretation.

What are the reasons for neglecting implicational interpretation in applications? Some of the often recalled arguments against it are not theoretically substantiated [1], but some of them definitely deserve further investigation. One of the problems worth of investigation is the continuity of the output after an appropriate defuzzification. The Mamdani-Assilian inference is usually connected with the COG (*Center of Gravity*) defuzzification. If $X, Y$ are sets of real numbers and all fuzzy sets are continuous then Mamdani-Assilian interpretation with the COG inference assures continuity. This is sometimes misinterpreted as an advantage of this kind of interpretation.

However, its careless application may lead to erroneous results because possible inconsistencies can be hidden by the continuity of the output.

We will show, how quickly and effectively we may proceed checking the consistency (*coherence*, see [3]) of linguistic description (1) in case of the implicational interpretation. An analogous process is much more complicated in case of the Mamdani-Assilian interpretation [2]. We may then restrict our focus only to those linguistic descriptions which are consistent. After all we may introduce some sufficient conditions for the continuity of the implicational interpretation after the MOM (*Mean of Maxima*) defuzzification.

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# Fuzzy Transform in Image Processing

[1]Perfilieva Irina , [2]Vajgl Marek , [3]Pavliska Viktor

Since fuzzy transform has already proved its ability to be used in *image compression* and reconstruction, there is always a room to improve quality of compressed and reconstructed images, as well as ability to usage *fuzzy transform* at another image processing application, e.g. *image fusion*. On the basis of preserving monotonicity an improved algorithm of image compression and reconstruction can be proposed. The algorithm is based on partitioning the range of the function $f_I$ which corresponds to an image $I$.

The key idea of the technique proposed in this overview is a fuzzy partition of the universe into fuzzy subsets (factors, clusters, granules etc. [4]). In the theory of fuzzy transforms [2, 3] (F-Transform for short), for a sufficient representation of a function it is sufficient to know the function's average values over fuzzy subsets from the fuzzy partition of its domain [1]. Then, the function can be associated with a mapping from the set of fuzzy subsets to the set of its average values. In brief, this is an idea of direct fuzzy transform of a function and is the basis of the algorithm used in our image processing research.

In image processing we work with image divided in discrete values, by pixels. Therefore we need *discrete* F-Transform. The (direct) discrete F-Transform of $f$ is introduced in [1] too.

Those F-Transform methods are used in image compression. Each image is divided into pixel arrays, represented in R/G/B image model. A direct fuzzy transform is applied on these arrays, as a result the array of components is returned. Moreover, this array is compressed by any standard compression algorithm (Huffman, Deflate) into final image file. Number of resulted components or number of pixels used as a base for one component can be selected before algorithm – those two variables are dependent and mainly affect the size of compressed and quality of reconstructed image.

Lower number of components cause small compressed image, but fuzzy reconstructed result – fuzzy effect depends on number and direction of dimensions of fuzzy transform. Higher number of components cause higher quality of reconstructed image, but does not offer good compression quality. Therefore some more improvements have been made. Most significant ones are variable number of components (means variable number of pixels used as a source for one component) and replacing R/G/B model with Y/Cb/Cr representation. Those two enhancements rapidly improve overall quality of F-Transform apply in image compression processing.

Another target of an application of represented F-Transform is image fusion. Initial request is to have a set of images-photos capturing the same scene with different focus. Each image is focused on different distance, which causes the another part of image is fuzzy. The basic thing is use F-Transform to find and resolve sharp and soft steps in image. Sharp changes in the part of an image mainly means higher quality of this part of image – image is probably focused right there. The F-Transform is recursively applied on image trying to find biggest component changes. This changes are used as the base in reconstruction of final image.

For both presented procedures there were simple applications made, offering to check and compare improvements of the methods.

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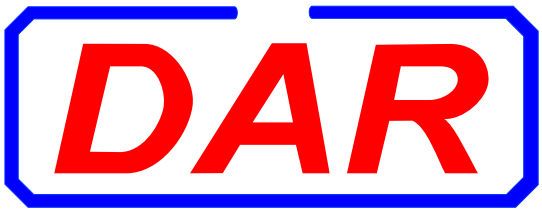


# $4^{th}$ International Workshop on Data - Algorithms - Decision Making

## Poster Session

December 1, 2008, Evening

**Chairman:** Jan Flusser

# Nonlinear Filtering for Estimation of State Noise Covariance Matrices

[1]Duník Jindřich , [2]Straka Ondřej , [3]Šimandl Miroslav

State estimation techniques are important for applications in control, signal processing, and fault detection. The techniques require complete knowledge of the functions in the system equations and of the probability density functions (or statistics, at least) of the noises affecting the system and the measurement.

The Kalman filter and its counterparts for nonlinear systems, the extended Kalman filter or the sigma-point Kalman filters [1], are well-known and, due to their relative simplicity, widely used state estimators. Their design is conditioned by a sufficiently exact knowledge of the first and second order statistics of the state and measurement noises. However, from practical viewpoint of usage of the methods, the knowledge of the noise statistics is questionable in many cases. Incorrect description of the noise statistics can cause significant worsening of estimation quality or even divergence of a filter [2]. Therefore, the methods for estimating the covariance matrices of the state and measurement noise have been a subject of research interest.

The noise covariance matrices estimation is a generally nonlinear estimation task. In the last decade, several novel methods for noise covariance matrices estimation have been proposed. These methods can be divided into two groups: methods reformulating the nonlinear estimation task as a pseudo-linear estimation [3] and methods estimating noise covariance matrices by means of nonlinear state estimation techniques [4].

The first group of the methods are based on complete knowledge of the "deterministic" part of the system description. Such assumption allows to reformulate the nonlinear noise covariance estimation into a pseudo-linear form, where second-order statistics of a measurement prediction error sequence, given by a linear filter, are computed from measured data and then, the computed statistics are used for noise covariance matrices estimation. These methods are thus suitable mainly for linear time-invariant systems.

The second group of the methods, suitable also for nonlinear systems, is based on augmenting the state vector with the parameter vector (so called joint estimation) and their simultaneous estimation by nonlinear filters. However, the joint estimation has been originally intended for estimating parameters in the "deterministic" part of system description and its straightforward application for noise covariance matrices estimation does not necessarily lead to a convergent nonlinear filter. This fact, which is sometimes overlooked by authors, e.g. [1], was shown in [4], where the modified joint estimator allowing the noise covariance matrices estimation was proposed. Unfortunately, the explanation why the standard formulation of the joint estimation is not suitable for noise covariance matrices estimation was given by means of a simple scalar example without general substantiation.

Therefore, the aim of the contribution is to give a regular explanation why the standard formulation of the joint state and parameter estimation does not lead to a convergent estimator of noise covariance matrices. The explanation comes out of the Bayesian recursive relations. Also the novel noise covariance matrices estimation methods are briefly described and their important aspects are highlighted.

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# Queue Length Estimation in Urban Traffic Networks

[1]Duník Jindřich , [2]Flídr Miroslav , [3]Pecherková Pavla

Majority of large cities suffer from traffic congestion, which results in both higher economic cost (e.g. travel times, fuel consumption, traffic accidents, injuries) and degradation of the environment (e.g. air pollution, noise). The traffic congestion forms because of insufficient capacity of a traffic network or its incomplete exploitation. Intelligent traffic control represents a possibility to preserve or to improve the capacity of the current light controlled network.

In most of the cities, the traffic control is based on a principle of static control of intersections where the control is performed by a fixed time plan. Because the type of the control cannot adapt to the actual traffic situation, a various dynamic traffic control methods have been designed. Around the world, several types of dynamic traffic control strategies are used or developed, e.g. TRANSYT, SCOOT, SCATS, MOTION, and TUC [1]. Most of the previously introduced dynamic control strategies are commercial tools with all associated advantages and disadvantages. The main advantage is in availability of full service. The main disadvantage is problematic adaptation of such product to the needs of a particular customer. These commercial strategies are usually geared to traffic control of big cities where the traffic network consists of the multilanes and the capacity of traffic network is huge. In the historical cities, such as Prague, these control strategies cannot be employed without problems (for example, description off application of the traffic control system MOTION in Prague [2]). For this reason a new control strategy is being designed [3]. This traffic control strategy has been designed especially for historical urban areas, characteristic by a traffic network formed by many narrow one-way roads which are equipped mainly by the inductive detectors.

The designed traffic control strategy uses a nonlinear state-space model [3] of the traffic flow derived by means of the widely-used traffic flow conservation principle and the control strategy is based on the principle of sum of queue lengths minimisation. Unfortunately, the queue lengths, which represent the actual traffic situation pretty well, are not directly measurable by the fixed detectors and thus, they have to be estimated. Therefore, an essential part of the traffic control system is a subsystem for queue length estimation.

The queue length estimation subsystem is based on the nonlinear state estimation techniques. The nonlinear state estimation techniques can be generally classified into the two groups: local and global methods. The local methods are often based on the approximation of nonlinear functions in the state-space model so that the technique of the Kalman filter design can be used also for nonlinear systems. These methods provide results with local validity within some neighbourhood of a point estimate only, but they are computationally efficient. On the other hand the global methods provides results valid in almost whole state-space, but they are very computational demanding. In this contribution, the local derivative-free estimators are considered, namely the unscented Kalman filter and first and second order divided difference filters [3].

The aim of this contribution is following. First, to introduce the technique for design of traffic system model. Second, to briefly discuss the local nonlinear state estimation methods suitable for traffic problem. Third, to apply the estimation methods and designed traffic model for queue lengths estimation on the basis of real data coming from Prague district Smíchov.

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# Windsurfer, Fully Probabilistic Control Design and the Jobcontrol Package

[1]Jirsa Ladislav , [2]Tesař Ludvík

A control design converts knowledge about the controlled system, constraints and control aims into the controller. In fully probabilistic control design (FPD), the desired system behaviour (ideal) is expressed by a probability density function of respective quantities and the controller is selected to minimize the Kullback-Leibler divergence of probability density functions describing actual and ideal closed-loop behaviour. The ideal is chosen to meet the control aim.

However, ideal behaviour of the closed loop must be realistic. Therefore, the ideal is adapted according to the observed behaviour and gradually modified towards the desired control aim. This iterative process, called *windsurfer* approach, results in reaching of the control design respecting properties of the controlled system and ability to control it using the given means and constraints.

The *windsurfer* approach to control aim elicitation was integrated into the Jobcontrol package, a software tool for system identification and control. This package is a user interface for the Mixtools toolbox and library for identification and control of complex systems and their modelling by normal probabilistic mixtures.

In the experiments, a MIMO system was simulated and adaptively controlled. A normal ideal probabilistic density function was chosen, which leads to algorithmic coincidence of FPD with the LQ design. The presented approach was compared with other adaptive controllers. Decrease of adaptation time in case of the *windsurfer* is demonstrated.

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# Functional, Non-functional and Regression Testing using Simula Language

[1]Procházka Jaroslav

Our work focuses on process oriented (process driven) information system, where errors in functionality can cause problems in the whole business process or even in the whole enterprise because business processes are supported and automated by information system. This is the reason why development, maintenance and support of information system are important aspects of business. Every change (enhancement) needs to be assessed, designed and implemented to avoid affecting already implemented features. Testing (besides others) of the new enhancement as well as preceding features (so called regression testing) is obviously one of the critical aspects. By testing of information system we mean verification of the product against requirements specification done by testers. Acceptance testing done by customers (so called validation) is omitted. Requirements serving as a basis for testing can be split in two basic categories:

- Functional requirements stating the expected behavior of the future information system from the user point of view,
- Nonfunctional requirements defining needed performance, robustness, reliability, security.

Why we use Simula. The main reason is the need of nesting of two (possibly of more) world viewings. In order to separate the different world viewings but to let them a possibility to a rational (logically consistent) interaction, locality of classes (of representations of concepts) should be at disposal [2, 5]. So SmallTalk, C++ and the object-oriented versions of Pascal are not of use. There are three object-oriented programming languages that admit local classes, namely Java, Beta and Simula. The Java object-oriented tools are very poor, its simulation possibilities cause a non-deterministic program run and the locality of Java classes is rather inconsequent so that a small programming error can cause a chaotic mixing of several world viewings with ending by computer collapse. Beta is extremely obscure both from the view of popularity and namely from the view of its syntactical rules. Thus we use Simula.

This paper clarifies the need for additional testing using nested discrete simulation. Next it summarizes defined simulation approach and proposed model suitable for testing the behaviour of information system and its regression.

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# BTF Roller

[1]Hatka Martin , [2]Haindl Michal

A realistic physically correct visualization of virtual objects with real material surfaces require to map 3D shapes with genuine nature-like colour textures. However, the appearance of real materials dramatically changes with illumination and viewing variations. Thus the only reliable way for a material visual properties representation is to capture its reflectance in as wide range of light and camera position combinations as possible. This is the principle of the recent most advanced texture representation the Bidirectional Texture Function (BTF) [1].

This paper describes a generalization of our previously published simple roller method for seamless enlargement of colour textures such as natural bidirectional texture functions (BTF) that realistically represent appearance of given material surfaces. The generalized roller allows automatic detection of major texture periodicity directions which do not need to be aligned with coordinate axes. The roller texture synthesis method is based on the overlapping tiling and subsequent minimum error boundary cut. One or several optimal double toroidal BTF patches are seamlessly repeated during the synthesis step. While the method allows only moderate texture compression it is extremely fast due to complete separation of the analytical step of the algorithm from the texture synthesis part. The method is universal and easily implementable in a graphical hardware for purpose of real-time rendering of any type of static or dynamic textures.

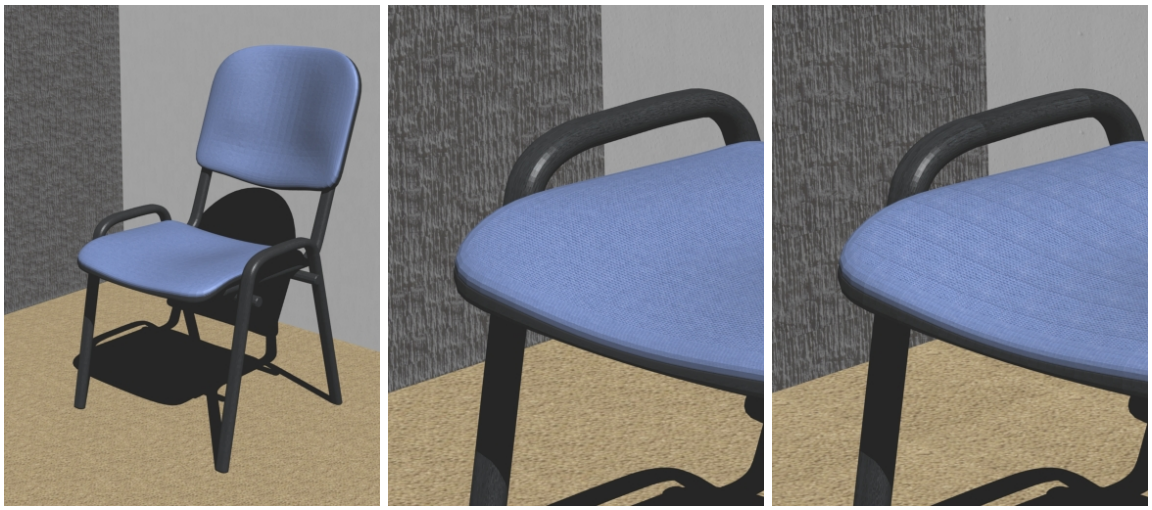

Figure 6: Chair retreat with several synthesized textures (left), detail (middle), and detail with tiled textures (right), respectively.

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# Census Results Publication by Means of a Statistical Model

[1]Hora Jan , [2]Grim Jiří

In the last years we presented a method for interactive presentation of census results by means of the probabilistic expert system. The method is based on approximating statistical properties of the original data by a discrete distribution mixture of product components. Statistical information is derived from the estimated model without any touch to original data, therefore, it can be distributed without any risk of disclosure of individual respondents.

Here we present results of our method applied on the real data set containing all the collected question forms from Czech census in 2001, which we recently managed to get from Czech Statistical Office.

On these data we show that our method is comparable to method based on distributing small subset of the original data set, which is considered to be currently the most powerful method of census results publication.

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# Gray-Scale Image Recognition in Frequency Domain

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The research is oriented to affine invariant recognition of 2D gray-scale images via 2D Fourier spectrum [1]. The moments of second order were used to obtain affine invariant spectrum from translation invariant amplitude spectrum. The square of 2D spectrum $\Psi$ was analyzed on circular paths with radius omega. Harmonic analysis of samples on the path enabled to study harmonics. It is easy to prove that the system of squared absolute values of Fourier coefficients

$$C_n(\omega) = \left| \frac{1}{\pi} \int_0^{\pi} \Psi(\omega \cos\varphi, \omega \sin\varphi) e^{-2in\varphi} d\varphi \right|^2 \quad (1)$$

is affine invariant and able to recognize sufficiently large objects. In discrete case we get only good approximation of affine invariant features. The COIL–100 image database [2] from Columbia University was used in experimental part. Original color images of objects in basic position were convert to gray-scale images. The method was tested on 100 image classes, which consist of various affine transforms of corresponding etalon. For affine transforms were used random parameters of translation, no scaling, $\alpha \in \{0, \frac{\pi}{6}, \frac{\pi}{5}, \frac{\pi}{4}, \frac{\pi}{3}\}$ as angle of first rotation, $\delta \in \{\frac{3}{2}, 2, \frac{5}{2}\}$ as parameter of stretching, and $\beta \in \{\frac{\pi}{5}, \frac{\pi}{3}\}$ as angle of second rotation. So each class consists of 30 images. The 1-NN classifier was used for classification of affine transformed images to correct classes and number of misclassified objects was measured for determination of method efficiency. The results were very optimistic. The methodology is useful for object recognition in biomedicine and industry. More information can be found in [3], [4].

Figure 7: Examples of harmonics for two etalons

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# The Material Description and Classification in *NEPHELE* System for Artwork Restoration

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We present a comprehensive information system for processing and archiving material analyses data produced during art restoration process - *Nephele*. The *Nephele* is a database system extended with image analyzing modules - image registration, segmentation, and object description and classification - designed for archiving and working with material analyses reports. The aim of the material analyses of paintings is to identify inorganic and organic compounds using microanalytical methods, and to describe painting layers and their morphology. Archiving all these data, *Nephele* can act as a knowledge base and an expert system for future advanced analyses.

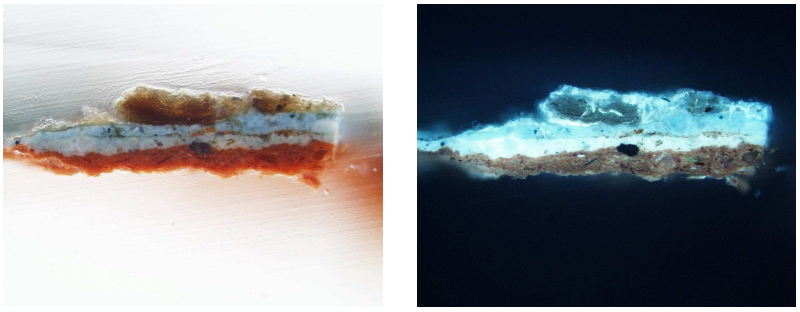

Figure 8: The images of the artwork cross-section in the visible (left) and ultraviolet (right) spectra.

Image-type data of the archived reports are taken in several modalities (see figure 8) and then they are pre-processed, analyzed, and described for further evaluation. The UV and VIS images are geometrically misaligned due to the manipulation errors during the acquisition process. Therefore, they must be registrated, which is done by means of *mutual information*. The image segmentation module separates the background of images and also distinguishes the color layers of the cross-section.

Moreover, next to the classical text-query database search *Nephele* supports report retrieval based on the similarity of the sample image to the archived image data, which can notably facilitate selection of relevant records to the current restoration case. In the near future, the *Nephele* system will be extended by the module for automatic painting material classification, based on neural network architecture and newly designed material taxonomy using object descriptors, capturing the layers morphology, their homogeneity or heterogeneity, and their color properties.

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# Clustering of Dependent Components in fMRI Data

[1]Martin Havlíček , [2]Jiří Jan

In ordinary independent component analysis (ICA), the components are assumed to be completely independent, and they do not have any particular order, or other relationship. The lack of an inherent order of independent components is related to the condition of complete statistical independence [1]. In practice, when we use ICA for analysis of data obtained by functional magnetic resonance (fMRI), we can observe very clearly violation of the independence assumption. It is possible to find, for example, couples of components that are clearly dependent on each other. This dependence structure is often very informative, and it would be useful to estimate it.

For this purpose, we tried to perform clustering analysis on resulting independent components in order to reveal their residual, mutual dependence, and to group related components. As an input for clustering algorithm we used matrix of symmetry that was represented by matrix of mutual information among all components - calculated pairwise. We tested two clustering algorithm, k-means and linkage, when both provided very similar results. Even though, we were mostly successful to cluster components into the correct group, it happened very often that e.g. one component in particular group had absolutely different character than the others. Therefore, we concluded this relatively direct procedure as an insufficient and proposed a little bit different approach.

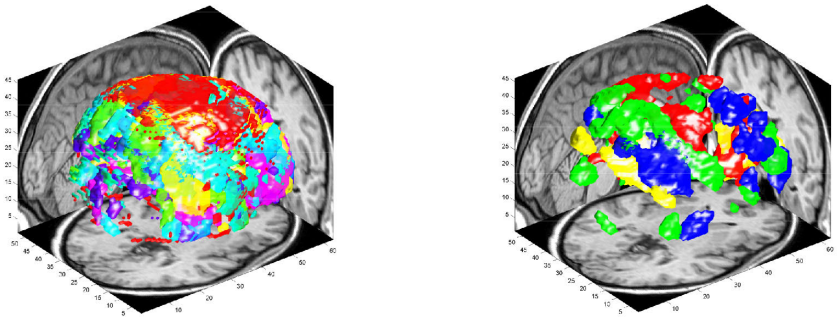

Figure 9: Illustration of the clustering result. On the left there are all components (activated regions) that enter to the clustering algorithm, and on the right there are components, which belong to the particular cluster (cluster with artifacts is not depicted).

We suppose that the main drawback of previous procedure is partial loss of spatial structure, because in order to calculate mutual information between components, we had to break down 3-D representation of component into 1-D vector. Thus, the principal aim of our new approach is to describe in detail spatial organization of detected brain activation in components by means of suitable attributes. We have calculated greater set of descriptive attributes, mostly based on geometric configuration of activated objects, i.e. coordinates of activated voxels, centers of gravity, distances from common origin, three principal axis of usually non-symmetric objects, their spatial symmetry, volume, roundness, etc.

Based on this kind of descriptors, we believe that we can obtain more accurate results by using clustering methods. Moreover, because we have characterized relatively big volume of voxels by apparently smaller number of attributes, it enables us to perform our analysis also by fuzzy clustering methods that seem to be more convenient for our case. Final results will be presented in the form of poster at the conference.

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# Modified Time-of-Flight Based Calibration Approach for Ultrasonic Computed Tomography

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The contribution describes a novel modification of the method for geometrical and transducer-time-delay auto-calibration of an ultrasonic computed tomography (USCT) system utilizing the particular USCT system concept [1]: the exactly known spatial relations among transducers grouped in each of the transducer array systems (TASes). The algorithms used for the calibration remain based on the principles similar to the global positioning system (GPS) navigation, however, the positions and orientations of complete TASes are calibrated, rather than individual positions of transducers (ITE approach) as in the previous work [2]. This way, the number of unknowns is substantially reduced while the number of available equations remains unchanged. Consequently, a solution substantially more robust with respect to measurement noise can be obtained based on this highly overdetermined equation system. The method is capable of calibrating the individual positions of all ultrasonic transducers via their positions in TASes as well as their individual time delays at once during sc. empty measurement, without a need for any particular arrangements, e.g. calibration phantoms.

Extensive simulations have been run in order to evaluate the efficiency of the TAS approach compared to the ITE approach based calibration. The results are quite convincing, particularly with respect to convergence analysis. First, the sizes of region of convergence (sensitivities to initial estimates) were compared. The initial estimate values were derived from the ground-truth positions and delays by introducing random errors of various variance. Noiseless cases (i.e. with faultless TOF measurements) are presented on fig. 5, showing surprising insensitivity to initial errors. Secondly, sensitivity of the resulting calibration precision as dependent on the TOF measurement errors was investigated by multiple simulations. These started all from medium erroneous random initial estimates ($\sigma$ = 1cm) but the TOF measurements were differently imprecise, with the characteristic error $10^{-5}$ to $10^{-9}$s. As it is clearly seen on fig.6, the TAS approach is far superior: not only it provides substantially faster convergence but primarily it is capable of providing the needed spatial calibration precise within a fraction of a millimetre even with realistic TOF errors (in the range of $2*10^{-7}$s) while the required time precision in ITE approach is rather unfeasible (under $10^{-9}$s).

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# 3D Simulation of Diffraction in Ultrasonic Computed Tomography

[1]Dušan Hemzal , [2]Igor Peterlík , [3]Jiří Roleček , [4]Jiří Jan , [5]Nicole Valerie Ruiter , [6]Radovan Jiřík

The poster presents new results in developing the exact means for simulating the realistic situation in the USCT (ultrasonic computed tomography) imaging system [1], aiming both at evaluating the approximations used in the existing USCT image reconstruction methods as to their precision and also (in a longer perspective) at iterative improvement of the obtained images via continuum mechanics based feedback. The mathematical models, generalised in comparison with [2], emerging from the transparent physical background, are presented for inhomogeneous media incorporating both the object tissue and the surrounding fluid. The equations are already general enough to employ complex nonlinear phenomena in three-dimensional space; and linearised 3D simulations giving rise to wave equation (WE) have been performed enabling some conclusions on the feasibility of this approach with respect to the available computing resources. Some of the results of the numerical solution of the WE in 3D by means of the finite-element method show in local detail the diffraction phenomena on acoustic-impedance inhomogeneities. The spatial extent of the simulations is basically limited only by the available computing resources. The hardware requirements and related practical limitations are mentioned together with a few examples of presently available results.

The contribution reflects present state of a long term project on detailed US field simulation in the USCT imaging system. The theoretical development concerns formulation of the relevant mathematical models including higher order phenomena; the experimental computations using so far intentionally simplified models aim at verifying the feasibility of the approach with respect to the size of the numerical formulation and its solvability by available means. The further perspective of the work, encompassing the time dimension and complex physical phenomena potentially non-linear, is in parallelization of the algorithms and utilization of powerful grid-based hardware structures.

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# Segmentation of Vessel Structure in Retinal Images by Matched Filtering

[1]Jan Odstrčilík , [2]Jiří Jan , [3]Radim Kolář

This contribution deals with an approach to segmentation of vessels in colour photographic images of retina, based on multiple use of matched filtering. The results of filtering, which is matched to short segments of vessels of different orientation and width, are consequently thresholded and the partial binary images combined into the resulting description of the vessel structure. Segmentation of vessels is an important phase in analysis of retinal images; providing the vessel system description may be both important for diagnostic purposes directly and useful as a step preceding the segmentation of the optical disc (the terminal of the sight nerve bundle) or macula (yellow spot); different alternatives methodologies have been published, e.g. [13].

The presented approach evaluates the correlation between local image areas, possibly containing a vessel segment, and the matched filter masks describing approximately typical vessel segments. The masks have been designed based on typical vessel brightness profiles perpendicular to vessel axes, measured in retinal images, then averaged in groups of similar profiles, and suitably approximated. Three ranges of the vessel width were considered: thin, medium and thick, which turns out sufficient for effective matched detection. The profile for thick vessels respects also the axial reflection of light this was one of the reasons for using more profiles of different widths. Filtered (parametric) images were obtained for each of the three vessel-width ranges, which yield local evaluation of the presence of a vessels section (of a particular width and orientation) for each pixel of the image, and fused for each width.

Each of the three fused images is consequently thresholded using the threshold value determined by the algorithm [1] utilising the local entropy. In the next step, the complete vessel structure image is combined of these partial three binary images. The final processing step consists of cleaning small artefact objects, appearing due to image noise and non-vessel structures in the input image, by means of morphological opening, and missing pats are also filled in by conditional morphological operators.

The statistical evaluation of the algorithm as the reliability of the vessel segmentation concerns, based on comparison with expert manual segmentations, is a part of the full paper.

In further development, a more sophisticated method for (possibly non-linear) fusion of the binary images will be searched, as well as a better compromise between cleaning the artefacts and preserving very thin vessels. In frame of the morphological processing, also connecting the separate sections of obviously interrupted vessels would be desirable.

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# Calibration of Geometry for Three dimensional Ultrasonic Computed Tomography

[1]Pawan Kumar Pathak , [2]Jiří Roleček , [3]Jiří Jan

The purpose of this work is to estimate and calibrate the position of the transducer for three dimensional USCT according to various parameters to attain better reconstructed images. The experiment was performed with empty measurement and angular delay has been taken as the parameter for estimation and calibration of the TASs. The calibrated geometry is made independent in space . In the present work only first TAS layer is taken. Finally a comparison has been made between the real geometry and calibrated geometry. The comparison is made on the basis of the distances of opposite pair of transducers the TASs.

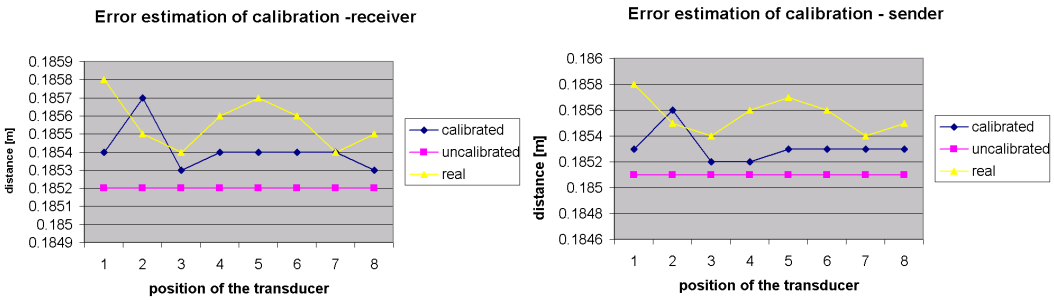


Figure 10: The error between the calibrated,uncalibrated and real measured distance of the opposite pair of transducers

The present work is limited to the only one layer of TAS. Calibration performed here can be more optimized by using higher tolerance limit.the maximum distance error for the present setup for sender is 0.4 mm and for receiver is 0.35 mm.

*Acknowledgement*: Support by the research centre DAR (Ministry of Education, Czech Republic) project no. 1M6798555601, by the DADA grant no. D12-CZ9/07-08 and partially also by the research frame of the FEEC VUT no. MSM 0021630513 is acknowledged.

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# Simulation of Parameter Influence in Ultrasonic Computed Tomography

[1]Jiří Roleček , [2]Dušan Hemzal , [3]Igor Peterlík , [4]Jiří Jan

We are dealing with physically based computational modelling of the real ultrasonic field in the USCT (ultrasonic computed tomography) imaging system. Finite element method discretising the volume of the USCT tank is used for solving the Helmholtz equation as a presently simplified model. We are at this stage able to run simulations of ultrasound field with two kinds of spatial variant parameters involved, the attenuation coefficient and the speed of ultrasound.

Currently, for most of the basic simulations, which are aimed to verify the model including its boundary conditions and volume regions definition for attenuation and speed of sound phenomena, a system of 107 374 equations is to be solved. In this case, sufficient configuration for computation used is 1GB RAM and Intel Celeron CPU@1,6 GHz. Solving the system of equations by the means of GMRes method with a prescribed residual value of $10^{-4}$ takes from one up to five minutes depending on the values of coefficient b (the grater value of coefficient the faster computation).

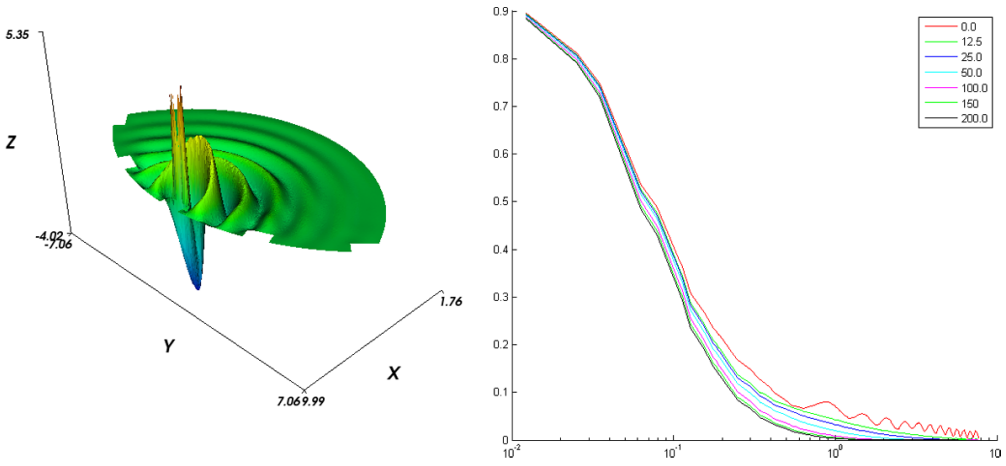


Figure 11: a) Beam intensity in log x coordinate, b) Layer intensity for value of attenuation coef. 25 $m^2s^{-1}$

Present computations are limited by the available computing resources and by the used solving algorithms. The work to follow is aimed to set up parallelized linear solver on a powerful cluster hardware, which will enable simulation of the ultrasound field in real dimensions covering whole volume model of USCT tank. Also, a much finer mesh will be needed to obtain simulation results for realistic geometrical dimensions and actual values of physical parameters.

*Acknowledgement*: Support by the research centre DAR (Ministry of Education, Czech Republic) project no. 1M6798555601, by the DADA grant no. D12-CZ9/07-08 and partially also by the research frame of the FEEC VUT no. MSM 0021630513 is acknowledged.

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# Detection of Neural Fibre Layer in Retinal Images via Textural Analysis

[1]Gazárek J. , [2]Jan J. , [3]Kolář R.

Weakening or local disappearance of the neural layer on retina indicates serious sight damage, possibly also beginning or advanced glaucoma. The analysis of the neural layer status is a difficult task even for an experienced ophthalmologist as its appearance is rather indistinct; the more it is uneasy for an automated process. Several publications concerning this problem have been published, however, the problem is still not satisfactorily solved.

The aim of the work was design, evaluate and compare few different approaches that should enable automatic detection of a possible damage to the retinal neural layer. Three of them showed an acceptable correlation with the medical expert conclusions - the directional spectral approach, the edge based approach and the difference local brightness. Colour photographic images of retina of 18 eyes, both healthy and with a different degree of the neural layer degradation, were analysed. The JPEG low compression images, provided by the fundus camera Canon CF-60UDi with an attached reflex camera Canon EOS 20D, covering 60 viewing angle, had the resolution 3504 x 2336 pixels. The images were mostly taken through the blue-green filter BPB 45 that is a part of the fundus camera.

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# Heuristic Improvement of Vision Under Aberrated Imaging

[1]Hemzal D. , [2]Kolář R. , [3]Jan J.

**1. diffraction as precursor to aberrated imaging**

The physical basics of imaging are contained in a model of diffraction at perforated opaque screen. This covers utilization of Huygens-Fresnel principle with coherent secondary light-sources defined over a wavefront across the screen opening. A familiar result of the usual simplification of Fraunhofer diffraction (which requires plane incoming waves) is that the directional amplitude of scattered light is a Fourier integral of the screen transmission function [1]. This result needs, however, a slight generalization for, in classical Fraunhofer approximation, the (point shaped) light source is allowed to lie on the optical axis only; we give the integral for generally settled point source. In the case of extended source, one has to keep in mind that its points are not coherent and hence first the intensity of each diffraction is calculated an only consequently these intensities from different points are summed up. We provide the correct solution and the discussion concerning the convolution shifting.

**2. PSF of the eye, and its scaling**

The optical transfer function (OTF) of an eye can be obtained via straight generalization of the opaque screen model. It can be decomposed into two factors: an amplitude, which comprises the Stiles-Crawford effect describing the opacity of the lens and a phase function, which can be described by Zernike coefficients [2]. Definition of PSF from OTF is given with particular care devoted to PSF correct scaling. We also show why the diffraction integral can be used in the case of non-zero lens vergency.

**3. problems with the inverse filtering**

We demonstrate that a method of inverse filtering cannot be applied straightforwardly as it would require negative intensities of light to improve the vision. To remove these values shift and crop of the intensity values can be employed which, however, reduce significantly the image contrast. We demonstrate both the issues on particular examples of aberrated imaging.

**4. heuristic model of astigmatism improvement**

The PSF of astigmatism can, in the simplest model, be treated as a straight line oriented according to astigmatism axis. In correspondence with the usual subjective reports we study the sharp edges between light and dark parts of the source. A good measure of the image quality is the contrast of such a light edge. We use the slope of its light-darkness gradient over several last lit pixels. We show that the slope is a linear function of both the PSF values and the intensity of appropriate pixels within the source. As a linear function does not have local extremes all source pixels can be fully lit or fully dim (this brings the black and white imaging as sufficient - a welcome reduction of size of transferred and/or calculated data allowing possibly for real-time processing). In case of pure astigmatism we show that no vision improvement is possible. We also show that in the case of astigmatism combined with other aberrations the vision improvement becomes possible.

**5. conclusions and future work**

In the previous paragraph we have demonstrated that the aberrated vision can in principle be improved using pre-filtering. An important remark is that to what extent (or even whether at all) is given by the particular aberration taken into account (as also shown). To step further from the heuristic treatment as presented here for the sake of brevity the following procedure will be applied: after definition of suitable sources (say, simple geometrical objets or latin alphabet letters) a measure will be appointed first of the original and aberrated image distance. For each particular aberration, a set of pre-aberrations of the source will be treated in which the optimal one will be (based on the distance rule) found. To this end a classification of typical aberrations for every particular group of eyes (say, LASIK treated) needs to be found. Both the tasks are already in progress by authors.

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