Výzkumné centrum Data – Algoritmy – Rozhodování

Research Centre Data – Algorithms – Decision Making

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Martin Janžura – Jiří Ivánek (eds.)

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Content

3^{rd} International Workshop on
Data - Algorithms - Decision Making

Session 1.

December 9, 2007, Afternoon

Chairman: Radim Jiroušek

On Learning Bayesian Network Structures: Algebraic and Geometric View

[1]Milan Studený, [2]Jiří Vomlel

Bayesian networks are popular models in the area of probabilistic reasoning. They can be viewed as special cases of conditional independence structure models [1].

The presentation will deal with the question of learning Bayesian network structure from data. We will present an algebraic approach which is based on the idea of representing every Bayesian network structure by a certain (uniquely determined) vector, called the *standard imset*. Learning Bayesian network structure consists in maximizing a certain quality criterion, also named a *score*, which is a function of a database and a network structure. There are two neighborhood concepts which can be considered in the search space of network structures. One of them is the *inclusion neighborhood* which comes from conditional independence interpretation, the other is the *geometric neighborhood* which is determined by the mutual geometric position of our vector representatives.

In the end of the talk, we will present the results of preliminary experiments [2] whose aim was to compare our approach with a former analogous method, based on graphical representation of network structures, known as the GES algorithm [3].

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Enumerating the Model Space of Essential Graphs

[1]Gernot D. Kleiter

The contribution describes methods to enumerate labeled and unlabeled essential graphs. To our knowledge this problem has not been solved satisfactorily.

Bayesian networks are the most popular class of models used to represent complex and uncertain knowledge. It is well known, though, that the representation of conditional independence models by Bayesian networks is not one–one, but one–to–many. The principle "one model — one graph" does not hold. Essential graphs avoid this difficulty. They represent conditional independence models by graphs containing both directed and undirected edges.

We describe a method that, for each class of Markov equivalent Bayesian networks, finds a "maximal" linear order of its vertices. The maximal order corresponds to a canonical *representative*. The method is based on two concepts, boundary verteces and symmetric verteces. Boundary verteces generalize the concept of terminal verteces from directed graphs to graphs with directed and undirected edges. Symmetric verteces are defined recursively as verteces having symmetric neighbors. Symmetries can easily be "seen" in the picture of a graph.

For a given unlabeled essential graph, the classes of its symmetric verteces allow to determine the number of its *labelings* by a simple formula. The enumeration of the *unlabeled* essential graphs is more difficult. Combining the methods for labeled and unlabeled essential graphs allows the enumeration of the total set of labeled structures.

Knowledge of the model space is essential for

1. the selection of prior distributions,
2. the identification of competitive models that fit the data,
3. search algorithms, traversal of the model space, Monte Carlo methods,
4. the analysis of the prevalence of different subclasses of models like essential graphs with directed edges only, models with a given number of components only, models that are included in a given graph etc.

Maximally ordered essential graphs may be used to draw models in a standardized way. This facilitates the comparision if different models. The methods are illustrated by examples. A selection of results will be presented.

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Human Reasoning about Uncertain Conditionals

[1]Niki Pfeifer, [2]Gernot D. Kleiter

Traditionally, human conditional reasoning is investigated in the framework of classical logic. The kind of reasoning tasks, the evaluation of the quality of human inferences, and the theory building was dominated by the framework of classical logic. Classical logic alone, however, is an inappropriate framework for investigating human conditional reasoning, since classical logic is not a language for uncertainty. Uncertainty is almost always present in everyday reasoning. Recently, probabilistic approaches to human conditional reasoning emerged [7, 4, 8]. They extend, or go beyond, classical logic and introduce new frameworks in the field.

We investigate human reasoning in a coherence based *probability logic* framework. Our work is based on two theoretical approaches: (i) on the probability theory that is based on coherence [3, 2, 9], and (ii) on the logic of nonmonotonic reasoning, especially on SYSTEM P [6]. Probabilistic semantics of SYSTEM P [1, 5] provide bridges between logic and probability. Common sense conditionals are interpreted as high *conditional probability* assertions. Only information explicitly contained in the premises of an argument enters the model. An immediate consequence is the necessity to work with interval probabilities. *Interval probabilities* (lower and upper probabilities) are psychologically highly plausible and we have empirical evidence that they are actually used when offered as a response mode. E.g., we observed that subjects are especially good in inferring the lower probability bound in probabilistic versions of the MODUS PONENS. Moreover, subjects understand that PREMISE STRENGTHENING (MONOTONICITY) is a probabilistically uninformative argument form. Subjects infer far wider intervals in the PREMISE STRENGTHENING tasks than in the respective probabilistically informative counterparts. Finally, we discuss data on human conditional inferences in probabilistic argument forms like CONTRAPOSITION, TRANSITIVITY, and selected rules of SYSTEM P.

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Finding Solution of Coalition Games by Bargaining Schemes

[1]Dan Butnariu, [2]Tomáš Kroupa

In the framework of n-player games with fuzzy coalitions [1] we introduce a bargaining scheme for the elements of the so-called enlarged core, which generalizes the dynamic theory of Wu [4] in case of the core of classical coalitional games [3]. The *core* is a closed convex set in n-dimensional Euclidean space whose elements can be viewed as possible solutions of the game with fuzzy coalitions. Since the definition of core involves the intersection of uncountably many halfspaces and hyperplanes, the geometrical structure of core need not be easily seen. In particular, deciding nonemptiness of core or whether the n-dimensional vector belongs to the core are rather difficult tasks. In the paper we investigate a concept of the *enlarged core* that is a set of solutions of the game accepted by all but a "negligible" number of coalitions. The enlarged core is always a superset of the core and it is shown that for a large class of coalition games the two sets coincide. By a *bargaining scheme* we mean an iterative procedure that enables to recover an element of the (enlarged) core or to decide the emptiness of the (enlarged) core. In our setting the bargaining scheme is based on the Cimmino-style iterative projection method investigated in [2]. Some sufficient conditions for emptiness of the core and for convergence of the bargaining scheme to an element of the core (provided it is nonempty) are established.

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3^{rd} International Workshop on
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Session 2.

December 9, 2007, Afternoon

Chairman: Miroslav Kárný

Fully Probabilistic Design: Basis and Relationship to Bayesian Paradigm

[1]Miroslav Kárný

There is a wide range of axiomatic formulations of decision making (DM) under uncertainty and incomplete knowledge, e.g. [7]. It seems, however, that none of them fits satisfactorily to closed decision loops in which the selected actions influence distributions describing them, cf. [1], part three. This contribution is an engineering attempt to fill the gap. The adjective "engineering" means that the overall picture is preferred over subtleties like measurability of various mappings.

The contribution serves primarily as a formalized justification of the fully probabilistic design (FPD) of decision-making strategies, [4, 2, 5]. The FPD generates optimal non-anticipative strategy as minimizer of the Kullback-Leibler divergence [6] of the probability density function (pdf), describing behavior of the closed decision loop, on an ideal pdf, describing *desired* behavior of the closed decision loop.

Moreover, the relationship of the FPD to the standard Bayesian DM is established. The FPD extends the Bayesian DM non-trivially. It has the following features: i) any standard DM can be formulated as a special version of the FPD; ii) generic solutions of the FPD are randomized and explicit; iii) realistic, possibly multiple, aims can be quantified by the ideal pdf; iv) hard constraints are quantified by the ideal pdf, too.

Of course, a range of problems remain to be solved. For instance, some standard DM problems a) are expressed in a cumbersome way within the FPD; b) need to deal with a *set* of ideal pdfs and corresponding theory is missing. In spite of this, the FPD is important tool for multiple-participant decision making as it completely reduces cooperation to combination of pdfs modelling both the environment and decision aims. As such, it can exploit knowledge accumulated in connection with so called marginal problem, e.g., [3]. It however reveals that the solution of the marginal problem with incompletely consistent elements is missing.

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Active Change Detection and Control

[1]Ivo Punčochář, [2]Miroslav Šimandl

The change detection problem arises in several applications ranging from time series analysis, and fault detection to automatic control. The main aim is to design a detector that utilizes a model of an observed system, prior information and available measurements to decide whether a change has occurred in the monitored system.

Standard detectors use available measurements for decision-making. They do not generate any signals influencing monitored system and measured data. Therefore, they use open loop feedback information processing strategy and they can be called passive detectors. The quality of decisions can be improved using an active detector that generates auxiliary input signal. It is well known that a properly designed input signal can improve the quality of parameter estimates. Thus, the active change detection approach represents a challenging theoretical problem in signal processing and automatic control, and it can be seen as the special case of general decision-making problem with multiple participants.

Known active change detection methods produce different auxiliary input signals that are optimized with respect to a chosen simple statistical test. These methods usually design the auxiliary input signal for a test period during which it is considered that a change does not occur. Moreover, the simultaneous problem of active change detection and control has not been solved sufficiently so far. In such a case the design is usually based on idea to combine known approaches from automatic control and signal processing.

The aim of research at Department of Cybernetics, University of West Bohemia is to evaluate known approaches to active change detection and propose a unified formulation, which allows to design active detector and controller using closed loop information processing strategy. The design of active detector and controller is stated as an optimization problem over a finite detection horizon and the unified formulation provides a theoretical framework that allows to study several special cases. The first special case deals with active detector design where a part of the active detector generating input signal is given in advance. The second special case deals with the problem of active detector design where the detector generating decisions and input signal improving change detection should be designed. The third special case deals with an active detector and controller design problem. The unified formulation is applied in multiple model framework and its contribution is also illustrated in simple numerical examples.

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Nuclear Medicine, Treatment of Thyroid Cancer and Mathematical Modelling

[1]Ladislav Jirsa, [2]Ferdinand Varga

Nuclear medicine operates with *open sources* od ionizing radiation. Practically, a chemical substance with a radioactive element is applied into human organism. Radioactive atom has the same chemical properties as a stable atom, except its nucleus is unstable, *i.e.* it undertakes, with some probability, a structural change accompanied by emission of ionizing particles. Nuclear medicine takes advantage of selective accumulation of a particular element/molecule in a particular organ. Radiation emitted by the accumulating area can be either detected and processed for diagnostic imaging or used for radiodestruction of the target tissue.

Radioactive iodine, accumulated in thyroid, is used in diagnostics and therapy of thyroid diseases.

The only information about distribution of a radioactive element in the organism are counts of detected particles over the body or ROI in some time interval. Radioactive decay is a random process and these counts are Poisson-like distributed. Particles of the source are mixed with particles of the radioactive background which is always present. Unknown activity is estimated by comparison of counts from a known (standard) and the unknown radiation source (*e.g.* thyroid). To handle these data correctly, adequate mathematical methods must be adopted.

As examples, Bayesian estimation of unknown activity and time integral of activity sequence will be demonstrated [1], [2].

Another problem is *how much* activity is to be administered to a particular patient for therapy, so that the tumour is reliably destroyed and, at the same time, secondary radiation risks are minimal. This task is solved as a control problem. The administered activity is set to optimize the treatment marker with respect to the requirement of minimal possible value of the activity. As a model of the organism response, a large set of historical data has been analyzed for a multidimensional probabilistic mixture. Based on this mixture and probabilistic control design with users' aims, an advisory system was designed to recommend an individual therapeutic activity using the patient's diagnostic data.

The initial version of the advisory system is based on processing of dosimetric data. It was tested on 101 patients undergoing iodine therapy after a diagnostic (low activity) administration. Therapeutic activities, recommended by the system, were compared with those decided by physicians. Relative difference below 15% was observed in 46% of the cases and evaluated by the physicians as satisfactory. A difference below 10% was observed in 31% of the cases, difference above 50% in 15% of the cases. The recommended values were lower, in general, than those set by the physicians.

Currently, the data space is being extended by biochemical data together with improved data processing. The first results are expected soon.

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Decision Support Principles Applied to Model Mixing

[1]Pavel Ettler

Decision support principles have been employed to solve an interesting problem - continuous selection of a simple model or models among several models available. The task is based on the assumption that a process to be modelled or controlled is governed by several physical laws at once which is the case of the metal rolling. That implies several simple models which should match measured data. Nevertheless, due to imperfect measurements and other uncertainties being involved, predictions based on particular models are often unreliable or inaccurate. This motivated search for methods which utilize all available models at once and mix their outputs with the aim to get better results. Several alternatives were developed and tested on industrial data. For the case which was investigated, the favourite method clearly outperformed application of a single complex model.

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3^{rd} International Workshop on
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Session 3.

December 10, 2007, Morning

Chairman: Jan Flusser

Image Analysis – Progress in 2007

[1] Jan Flusser

The main goal of the talk is to give an overview of the activities of the DAR Image processing group in 2007. We demonstrate the progress achieved on the field of image fusion, superresolution imaging, space-variant restoration, and object recognition. Special attention is paid to the invariant recognition of objects undergoing unknown elastic deformations.

Apart of the theoretical results we describe also our two image database projects – NEPHELE, which deals with a database of microscopic samples taken from old paintings, and PIRIS, which is aimed to identify modified versions of query images in very large databases.

At the end of the talk we present an outlook for the future and we explain what topics we plan to deal with in the second half of the existence of the DAR Research Center.

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Multichannel Restoration of Images with Space-Variant Blur

[1]Michal Šorel, [2]Jan Flusser

This contribution covers the progress achieved by DAR image processing group in the area of space-variant restoration.

We proposed a solution of the related problems of image restoration and depth map estimation from two or more space-variantly blurred images of the same scene in situations, where the extent of blur depends on the distance of scene from camera. This includes out-of-focus blur and the blur caused by camera motion. The latter is typical for low-light conditions.

Both out-of-focus blur and camera motion blur can be modeled by convolution with a spatially varying point spread function (PSF). There exist many methods for restoration with known PSF. In our case, the PSF is unknown as it depends on depth map and camera trajectory during the motion. Solution of such a problem is highly ambiguous if only one degraded image is available. Therefore we assume that at least two images of the same scene are available, which gives us additional information that makes the problem tractable.

Our approach belongs to the group of variational methods that estimate simultaneously sharp image and depth map, based on the minimization of a cost functional. Compared to other existing methods, it works for much broader class of PSFs. In case of out-of-focus blur, the algorithm is able to consider known optical aberrations. As for camera motion blur, we are concerned mainly with the special case where the camera moves in one plane perpendicular to the optical axis without any rotations. In this case the algorithm needs to know neither camera motion nor camera parameters.

The proposed method can be extended to color images. We exploit correlations between color channels to improve robustness with respect to noise.

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Calibration of an Ultrasonic Computed Tomography System

[1]Adam Filipík, [2]Jiří Jan, [3]Igor Peterlík , [4]Dušan Hemzal , [5]Radovan Jiřík

A 3D setup for USCT has been developed at Forschungszentrum Karlsruhe (FZK), Germany. The system (Fig. 1) consists of 384 senders and 1536 receivers mounted on 48 transducer array systems (TAS). The cylinder which holds the TASes can be rotated in 6 steps to achieve a total of 11,520 virtual transducers, which can produce approximately 3.5 million A-scans. The transducers' mean frequency is 2.7 MHz. A complete system scan produces about 20 GB of data per measurement.

For the reconstruction of tomographic images, it is crucial to know the positions of individual transducers within error in the order of the wavelength magnitude. An estimate of the positions can be made based on the dimensions of the TASes and the cylinder. But even small positioning errors (in the range of tenths of millimeters) can lead to significant degradation of image quality. With respect to the number of transducers in the system, it is unfeasible to measure the geometry manually.

An auto-calibration technique, which utilizes only the internal ultrasonic signals used by the system to solve the problem, has been designed and tested. The technique is based on time-of-flight principle, similar to GPS navigation. Particularly, the time-of-flights of individual ultrasonic pulses are used for a triangulation, formulated as a minimization problem, where the to-be-minimized quantity is the sum of squares of differences between measured and estimated pulse arrival times. The unknown minimization parameters are the positions and the individual time-delays of transducers.

The main extension over GPS is that no transducers or receivers are assumed to be in known positions and all are calibrated at once. The calibration is self-contained—no additional calibration phantoms, high precision positioning devices, etc, are needed. The accuracy of the calibration is primarily limited by the accuracy of the signal detection. Recently, the method was successfully tested on real USCT data.

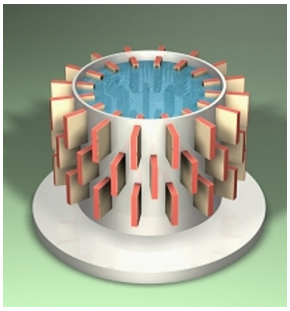

Fig.1 A 3D USCT System

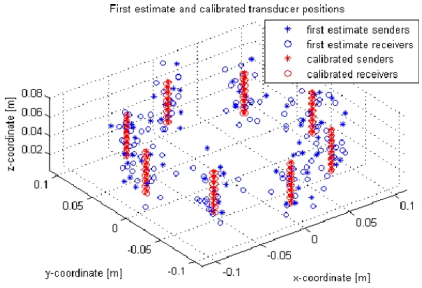

Fig.2 A 3D scatter plot of individual transducers before and after calibration

Authors sincerely acknowledge the contribution of Dr Nicole Ruiter and Dr Rainer Stotzka Forschungszentrum Karlsruhe Germany, who initiated the project and enabled providing the needed data.

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Ultrasound Computer Tomography for Breast Cancer Diagnosis

[1]Nicole Ruiter

Early breast cancer diagnosis is still a major challenge. The standard screening methods often detect cancer in a state when metastases have already developed. The presence of metastases decreases the probability of survival significantly. A more sensitive tool for breast cancer diagnosis could lead to diagnoses in an earlier state, i.e. before metastases are generated.

We are developing a new imaging method for breast cancer diagnosis, ultrasound computer tomography (USCT), which allows recording of reproducible 3D images with high spatial resolution and tissue contrast. Additionally, quantitative measurements of physical parameters, i.e. sound speed and attenuation, which are known to be different in cancer tissues, are possible.

Our experimental 3D setup consists of a water filled cylinder (18 cm diameter and 15 cm high) and contains 384 sending and 1536 receiving transducers, grouped in three rings on the cylinder surface, each 5 cm high. The cylinder can be rotated by a motor to 6 different motor positions, emulating a complete covering of the cylinder with transducers. Sequentially, each emitter sends an unfocused wave front (center frequency 3 MHz, bandwidth 1 MHz, opening angle 25°).

In this talk the setup and the first results of a 3D demonstration system are presented. The challenges of building such are system and the current limitations are discussed and possible solutions are proposed. The currently applied reconstruction algorithms will be presented together with first 3D images and alternative approaches are discussed.

Biosketch

Nicole Ruiter studied Medical Informatics at the University of Heidelberg (Dipl. Inform. Med. 2000). She received the Ph.D. degree (Dr. rer. nat.) in 2004 from University of Mannheim on registration of MR volumes and X-ray mammograms by biomechanical models. She is currently research scientist at Forschungszentrum Karlsruhe and leads a small research group on the subject of ultrasound computer tomography.

Her research interests are breast cancer diagnosis, ultrasound computer tomography, image registration and biomechanical models of the breast.

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Registration Framework for the Autofluorescence and Infrared Images

[1]Radim Kolář , [2]Jiří Jan

Image Data

The images, for which the algorithms have been designed, were acquired at Department of Ophthalmology, Friedrich-Alexander University of Erlangen-Nrnberg (Germany). The laser scanning ophthalmoscope used for acquisition was Heidelberg Retina Angiograph (HRA2), which serves for angiographic examination of human retina.

In **autofluorescence** (AF) mode, the retina is illuminated by a narrow blue light laser beam (488 nm) in a raster manner. This beam excites the lipofuscin that consequently emits light with a longer wavelength (around 500 nm). The emission intensity depends on the amount of lipofuscin accumulation in retinal pigment epithelium (RPE).

In **infrared** (IR) mode, HRA2 device uses infrared laser light with wavelength 820 nm to illuminate the tissue in raster manner. During scanning, the reflections from tissue are acquired. The IR image has the same size and resolution as the AF image.

Registration framework

1. Image preprocessing—for both images, AF and IR, the filtering by anisotropic diffusion is performed and gradient images are computed.
2. Optimization strategy—two levels multiscale approach with controlled random search algorithm is used for registration.
3. Optimization criterion—the normalized cross correlation is utilized in spite of the multimodality. This was possible because of the high correlation of the infra-red and autofluorescence gradient images, particularly on the edges of the vessels.
4. Transform of both images into common coordinates—it has turned out that rigid transform is suitable - rotation, scaling and translations in x, y directions are considered.

Results

The proposed approach with the above parameters was tested on our database of 131 ophthalmologic image pairs (AF and IR image). The CRS optimization was run 5 times for 30 images to test the sensitivity to random initialization. No visible changes among these particular results were observed. Each registered pair was classified to: 'poor', 'moderate', 'good' and 'excellent'.

The possible pixel misalignments were examined primarily in the area around the optical disc. Two experts (A, B) evaluated independently the registration results based on the edge and mosaic images simultaneously. The weighted mean score was determined for each expert. Results are presented in table below.

Class Expert	1	2	3	4	Mean Score	Class 1,2,3
A	107 (81.7%)	15 (11.4%)	6 (6.4%)	3 (2.3%)	1.27	128 (97.7%)
B	98 (74.8%)	21 (16.0%)	4 (3.1%)	8 (6.1%)	1.41	123 (93.9%)

Table 1: Registration results

Class 2 and 3 includes images where the misalignment errors were visible mainly at the periphery of the images. The central part (OD with its surroundings) was registered without significant errors. Therefore, the percentage of successfully registered images can be considered 97.7 % and 93.9 %, respectively (including Class 1, 2 and 3) for applications, where good registration only around the OD is crucial.

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Topological Spaces of Rough Set Theory

[1]Milan Vlach

The theory of rough sets introduced by Pawlak [3] deals with situations in which knowledge about elements of a given nonempty set U is provided by a binary relation or a collection of binary relations on U. The basic idea is to use the available knowledge for introducing the notion of a definable subset and to approximate every undefinable subset through definable sets. A number of modifications and generalizations of original Pawlak's approach have been proposed and studied, and several notions and facts known in various branches of mathematics have been rediscovered and introduced under different names by the rough set community.

The main purpose of this paper is to elaborate on the observation of several authors that there is an intimate connection between the operators used for approximation of undefinable sets and operators commonly met in topological spaces; see, for example, [4, 5, 6]. In particular, it will be showed that the collection of Pawlak's definable sets forms a uniformity whose topology is a partitioned topology in U, and that the lower and upper approximation operators are actually the interior and closure operators with respect to this special topology. Moreover, it will be demonstrated that similar relations hold in more general context. Furthermore, given that the approximation operators commonly used in applications of rough set theory are isotonic set-valued set-functions, they are also closely related to operators of the system of extended topology introduced and studied in detail by Preston Hammer in the early 1960's [1, 2].

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3^{rd} International Workshop on
Data - Algorithms - Decision Making

Session 4.

December 10, 2007, Afternoon

Chairman: Michal Haindl

Multiresolution Satellite Image Segmentation by H-MMC Model-based Algorithm

[1]Giuseppe Scarpa

In this talk we present a new algorithm for the unsupervised hierarchical segmentation of multiresolution optical images. Such data are collected by a single system that provides both a low-resolution multispectral image and a high resolution single-band "panchromatic" image; in this way, the bulk of data to be acquired, transmitted and stored is much reduced w.r.t. a high-resolution multispectral data cube while most of the information of interest is retained. To segment such images, one must perform a "data fusion" between the two pieces of information so as to obtain a map with the same (high) resolution of the panchromatic image but the reliability associated with the richer multispectral data.

The segmentation of multiresolution images is often addressed by running in sequence two independent algorithms, first a pan-sharpening of the data, which provides a datacube at the highest spatial resolution, and then a standard segmentation algorithm for multispectral data. Needless to say, the segmentation performance is affected by all errors introduced in the pan-sharpening phase, and its complexity, quite significant for the most sophisticated algorithms, increases sharply when dealing with the new high-resolution multispectral datacube.

The few papers focusing on the direct segmentation of multiresolution images share a common approach, based on a two-step (in the case of two resolutions) procedure where a first large-grain segmentation is carried out on the multispectral data, to be later refined in a second step based on the high-resolution panchromatic data. In these approaches, the spectral information has the priority w.r.t. the spatial resolution, since it is the first to be taken into account, while the panchromatic data are used in a later moment only to refine spatially the coarse segmentation obtained in the previous step. Intuitively, one expects such algorithms to provide good results when the spectral information is "more relevant" than the spatial one, that is, when the spatial resolution of the objects in the image to be segmented is sufficiently low w.r.t. the resolution of the data. However, when the original image is very rich in fine details (think of urban areas), the initial low-resolution segmentation of the multispectral data, working on spectrally mixed cells, is likely to output quite often incorrect results, producing a strong bias hard to recover in subsequent steps, and leading ultimately to significant errors, like the loss of entire regions.

Based on this observation, we proposed in [1] to follow the opposite path, and proposed an algorithm that works first on the high-resolution panchromatic data, performing an over-segmentation aimed at preserving fine details, and then takes into account the spectral information contained in the low-resolution multispectral data to further process this basic information. The initial over-segmentation produces a large number of elementary regions, most of them very small, which are then clustered and progressively merged, based on both spectral and spatial properties, in order to reveal progressively the textured image segments and to reduce the map to a small number of meaningful classes. The merging process proceeds accordingly with an underlying discriminative model, referred to as *Hierarchical Multiple Markov Chain* (H-MMC) model [2, 3], which gives a hierarchical multiscale description of any texture based on multiple (spatially oriented) Markov chains describing the textural spatial interactions at different scales. The goal of the merging process is to reconstruct the underlying hierarchy, that is achieved by means of a properly defined metric, namely the *region gain*, for relating the regions and delivering a sequence of nested segmentation maps at different levels of detail, that provide a very rich description of the image in terms of its component regions. Experiments on IKONS data show the effectiveness of the technique.

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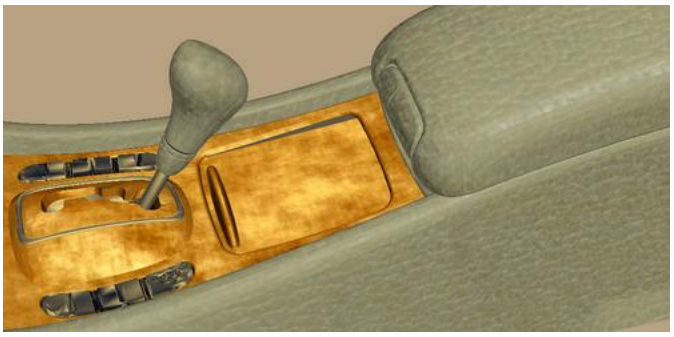
Model-Based Pattern Recognition and Modeling

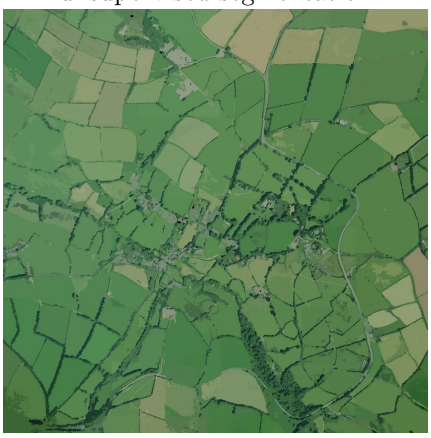
[1]Michal Haindl

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

BTF model



unsupervised segmentation



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Are Better Feature Selection Methods Actually Better ?

[1]Petr Somol, [2]Jana Novovičová

One of the hot topics discussed recently in relation to pattern recognition techniques is the question of actual performance of various modern feature selection methods – especially with respect to classification accuracy.

Feature selection 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. The number of available methods and methodologies has grown rapidly while promising important improvements. Yet recently many authors put this development in question, claiming that simpler older tools are actually better than complex modern ones – which, despite promises, are claimed to actually fail in real-world applications.

The talk will address this question – various approaches to feature selection will be overviewed and several illustrative examples will be given, showing both the pitfalls and advantages of applying more advanced methods.

The problem of overfitting will be discussed from the feature selection point of view. The impact of overfitting on classifier generalization ability will be demonstrated. The problem of limited data size and its impact on overfiting in the feature selection process will be discussed. Standard and less widely used techniques of classification performance evaluation will be reviewed and demonstrated. Some conclusions and recommendations regarding feature selection expectable performance will be drawn.

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Texture Defect Detection

[1]Michal Haindl, [2]Jiří Grim, [3]Stanislav Mikeš

This paper presents a fast multispectral texture defect detection method based on the underlying three-dimensional spatial probabilistic image model. The model first adaptively learns its parameters on the flawless texture part and subsequently checks for texture defects using the recursive prediction analysis. We provide colour textile defect detection results that indicate the advantages of the proposed method. The presented method was successfully tested on the set of artificially damaged colour textile textures, so the ground truth for every pixel is well known and cannot be influenced by a subjective evaluation. Another application is to evaluate a skin disease treatment progress. Fig. 1 illustrates a patient with pemphigus vulgaris skin disease and its automatically detected regions which are subsequently compared with previous checking to monitor a disease treatment efficiency.

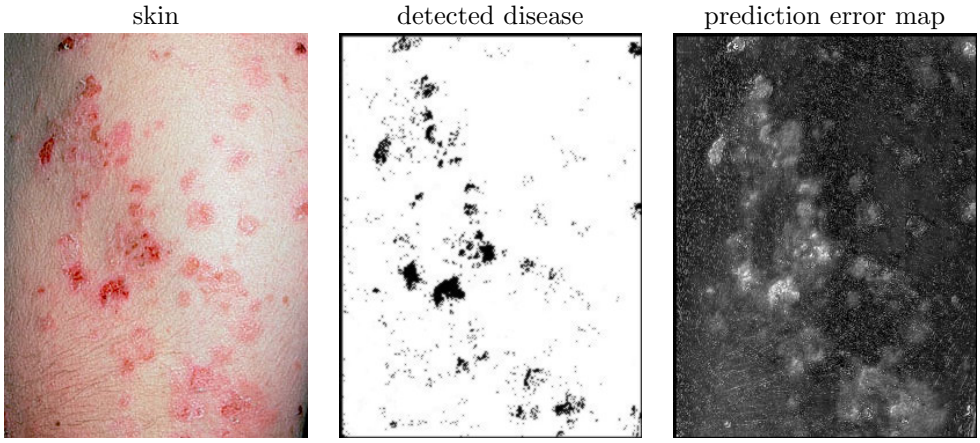

Figure 1: Monitoring of the pemphigus vulgaris skin disease progress.

Most published texture defect detection methods [2, 3] does not use the multispectral information. Our method takes advantage of both multispectral as well as the spatial information. The method is simple, extremely fast and robust in comparison with these alternative methods.

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3^{rd} International Workshop on
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Session 5.

December 10, 2007, Afternoon

Chairman: Igor Vajda

Bregman Distances, $\phi-$divergences, Finance and Censoring

[1]Wolfgang Stummer, [2]Igor Vajda

Bregman distances between *functions* play an increasingly important role in the treatment of industrial inverse problems, e.g. in image reconstruction and in finance. As a potential extension, following [1] we first introduce Bregman distances between *general probability measures*, and discuss some links with $\phi-$divergences; we also present some correspondingly derived bound on particular Bregman distances between non–lognormally distributed financial diffusion processes (which generalizes some result on bounds in [3]).

Following [2], we secondly introduce modified $\phi-$divergences of general finite measures. Special cases like the modified power divergences of measures, modified information divergence of measures, and modified total variation of measures are discussed. For the latter two, we show a generalized Pinsker's inequality. Some situations are presented where the evaluation of ϕ-divergences of finite non-probability measures represents an important step of statistical inference. Special emphasis is put on applications to randomly right-censored models (which in general are e.g. used in medical and biological statistics). In particular, we derive Bayesian results on data-observation-based risk reductions for optimal model decisions.

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Blind Source Separation Methods Based on Approximate Joint Diagonalization Algorithms

[1]Petr Tichavský, [2]Tomáš Marek

Blind inversion of a linear and instantaneous mixture of source signals is a problem often found in many signal processing applications of biomedical signal processing, speech processing and in wireless communications.

Three routes exist towards the solution of the blind source separation problem, each of them assumes a different model of the data: (1) "non-Gaussianity", (2) "spectral diversity" and (3) "non-stationarity" of the original (unmixed) sources. The route (1) assumes that all the sources can be well-modeled as independent and identically distributed (i.i.d.) non-Gaussian processes; at most one source is allowed to be Gaussian. Recently we have proposed an algorithm Efficient FastICA (EFICA) [1] to solve the problem. In the route (2), all the sources are modeled as Gaussian Autoregressive (AR) processes, assuming that the sources have distinct power spectra. Finally, in the route (3), all sources are modeled as Gaussian, block-wise stationary, with varying variances in different blocks. All three routes can be combined together. For example, the first two routes were combined in papers [4] and [5].

The latter two routes to the blind source separation problem lead to an approximate joint diagonalization (AJD) problem. In the route "spectral diversity", the set of lagged covariance matrices is jointly diagonalized. In the route "non-stationarity", set of covariance matrices of different signal blocks is jointly diagonalized.

In the seminar we present a review of existing AJD algorithms together with the criteria that they use for the diagonalization. A particular attention will be paid to a criterion that use a block diagonal weight matrix. The optimal weight matrix can be estimated from partially separated data.

The resultant algorithm for the spectral diversity model is called the Weights Adjusted Second Order Blind Identification (WASOBI) [3], [6]. It was shown to be asymptotically efficient, achieving the corresponding Cramér-Rao bound [2]. A similar solution will be proposed for the "non-stationarity" route to the blind source separation.

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New Estimation Results in Regression

[1]Tomáš Hobza

A median estimator of the logistic regression parameters is introduced. It is defined as the classical L_1-estimator applied to continuous data $Z_1, ..., Z_n$ obtained by a statistical smoothing of the original binary logistic regression observations $Y_1, ..., Y_n$. Some results concerning consistency and asymptotic normality of this estimator are presented. A method called enhancement is introduced which in some cases increases the efficiency of this estimator. Sensitivity to contaminations and leverage points is studied by simulations and compared with the sensitivity of some robust estimators previously introduced to the logistic regression.

Zavedeme mediánový odhad parametrů modelu logistické regrese, který je definován jako klasický L_1-odhad aplikovaný na spojitá data $Z_1, ..., Z_n$ získaná statistickým vyhlazením původních binárních pozorování $Y_1, ..., Y_n$. Budou prezentovány některé výsledky týkající se konzistence a asymptotické normality tohoto odhadu. Dále bude představena metoda zvaná "vylepšení", která v některých případech zvyšuje eficienci mediánového odhadu. Citlivost tohoto odhadu na kontaminaci dat bude na základě simulační studie porovnána s citlivostí některých robustních odhadů uvažovaných v literatuře.

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Testing Hypotheses in Exponential Families of Stochastic Processes

[1]Fajfrová Lucie, [2]Vrbenský Karel

There are three points which could be mentioned in this contribution.

I. We describe a concept which we use for statistical inference of stochastic processes. It is based on information divergences D_r, $r \in \mathbb{R}$, called Rényi divergences [2]:

$$D_r(P_1, P_0) = \frac{1}{r(r-1)} \ln \int f_1^r f_0^{1-r} \, d\mu,$$
$$D_1(P_1, P_0) = D_0(P_0, P_1) = \int f_1 \ln \frac{f_1}{f_0} \, d\mu,$$

for $r \neq 1, r \neq 0$, where $f_1 = \frac{\mathrm{d}P_1}{\mathrm{d}\mu}$, $f_0 = \frac{\mathrm{d}P_0}{\mathrm{d}\mu}$ are densities with respect to a reference measure μ. We are interested in exponential families $\{P_{\theta,t}\}$ of random processes or random fields, see [1], [3]. Our aim is to test hypotheses about parameter θ. The hypotheses testing employs statistics derived from Rényi divergences and the most important part of the statistic procedure is an optimization based on test powers. It leads to a choice of one from the Rényi statistics, which is used for the final decision.

II. The second part is devoted to particular models which are suitable for this concept and which are implemented in the prepared software. Among them Levy processes, regression models and random fields.

III. The final word could belongs to a confrontation of our approach with other developments in the theory of statistical inference for stochastic processes.

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3^{rd} International Workshop on
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Session 6.

December 11, 2007, Morning

Chairman: Jiří Močkoř

On Arithmetic Fuzzy Models

[1]Martin Štěpnička, [2]Bernard De Baets, [3]Lenka Nosková

Systems which use a fuzzy rule base and an inference mechanisms are quite frequently used in many applications. Fuzzy rules and inference mechanisms can be described by a system of fuzzy relation equations.

Consider arbitrary universes X and Y. The classes of fuzzy sets on X and Y are denoted by $\mathcal{F}(X)$ and $\mathcal{F}(Y)$, respectively. Then all information available in a given fuzzy rule base is contained in pairs of input-output fuzzy sets i.e. in $(\mathbf{A}_1, \mathbf{B}_1), \ldots, (\mathbf{A}_n, \mathbf{B}_n)$, telling us that, for $i = 1, ..., n$, the fuzzy set $\mathbf{A}_i \in \mathcal{F}(X)$ is assigned the fuzzy set $\mathbf{B}_i \in \mathcal{F}(Y)$.

A solution to a given system of fuzzy relation equations can serve us as a proper model of fuzzy rules (fuzzy model for short). But only the two following particular solutions,

$$\hat{\mathbf{R}}_*(x, y) = \bigwedge_{i=1}^{n} \left(\mathbf{A}_i(x) \to_* \mathbf{B}_i(y)\right), \tag{1}$$

$$\check{\mathbf{R}}_*(x, y) = \bigvee_{i=1}^{n} (\mathbf{A}_i(x) * \mathbf{B}_i(y)), \tag{2}$$

let us call them the conjunctive and the disjunctive fuzzy model, respectively, have been mainly studied so far.

The contribution will aim at new solutions of systems of fuzzy relation equations. The first one - additive fuzzy model - which is derived from the disjunctive fuzzy model was motivated by several methods often used in practice. The second one — multiplicative fuzzy model — which is derived from the conjunctive fuzzy model was neglected up to now. We investigate both new solutions and describe existence of a direct connection between systems of fuzzy relation equations and different fuzzy models. The crucial role of the Ruspini partition is proved and also visually demonstrated.

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Solving ODE with Fuzzy Initial Condition using Fuzzy Transform

[1]Irina Perfilieva, [2]Dagmar Plšková

We investigate ordinary differential equations with fuzzy initial conditions. We formulate a modification of the Cauchy problem when the initial condition is fuzzy and characterize theoretical solution of this problem.

The problem is numerically solved by the fuzzy transform method which was developed by I. Perfilieva, see in [1]. the method was successfully used to solving the classical Cauchy problem, see for example [4]. The approximated solution of the problem can be found as a solution of the fuzzy relation equation, see [2].

The modification of the Cauchy problem will be illustrated on simple examples.

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Abstract Components for Process Modelling using Information Systems

[1] Jaroslav Procházka

This paper describes methodical-applicational abstract framework. Such a framework serves as a support for business process automation using information system. Abstract components use strictly defined syntax and semantics (based on Colored Petri nets), helps users to perform the business processes, to document them, and support them using information systems functions. For business process identification and documentation purposes is the ProSci methodology extention used. This methodology uses abstract components and gives also advices for their implementation. The methodology is defined by meta-model and describes several phases, their inputs, outputs, roles and workflows.

Applicational part of a framework is represented by two abstract components called Process Modelling Tool (PMT) and Process Wizard (PW). PMT has own defined visual notation called UN (User Notation) that is transformed onto Colored Petri net. Colored Petri net definition is read by PW and according this definition are system functions called. So we can support business process by information system and automate their parts. This model is also easily extensible (and contains mechanisms) with generation of a new information systems functions. All components are abstract, not implemented, so it could be realized in different object oriented information systems.

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3^{rd} International Workshop on
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Chairman: Miroslav Kárný

Simulation Results of Urban Traffic Control Algorithm

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Every urban traffic control strategy has to undergo several steps of simulated testing prior to experimental real-life deployment. These tests are used to identify possible problems and provide supporting data for the administrative process at municipal authorities.

We will start with a brief overview the physically-based state-space model that forms the base of our algorithm for signalised intersection control [2]. The model is based on a simple conservation law and its detailed form reads

$$\begin{aligned} \xi_{i,k+1} &= \delta_{i,k}\xi_{i,k} - \left[(1-\delta_{i,k})\, I_{\mathrm{in},i,k} + \delta_{i,k} S_i\right] z_{i,k} + I_{\mathrm{in},i,k}, \\ O_{i,k+1} &= \kappa_i \xi_{i,k} + \beta_i O_{i,k} + \lambda_i, \end{aligned}$$

where $\xi_{i,k}$ and $O_{i,k}$ are the state variables, namely queue length and occupancy at the i-th arm of the traffic network, S_i denotes the saturation flow (maximum number of vehicles that could travel through the arm in a unit of time), $I_{\mathrm{in},i,k}$ is the input intensity (number of cars entering the arm), $z_{i,k}$ is the length of the green signal, $\delta_{i,k}$ is a saturation flag of i-th arm, and $\kappa_i, \beta_i, \lambda_i$ are constants depending on the position of the measuring detector at the given arm. The output equations

$$\begin{aligned} I_{\mathrm{out},j,k} &= \sum_{i \in \mathbf{A}_j} \alpha_{ij} \left[(1-\delta_{i,k})\xi_{i,k} + \left[(1-\delta_{i,k})\, I_{\mathrm{in},i,k} + \delta_{i,k} S_i\right] z_{i,k}\right], \\ O_{i,k} &= O_{i,k}. \end{aligned}$$

describe the output of the intersection using constant turning rates α_{ij}. Measurements of output intensities $I_{\mathrm{out},j,k}$ and occupancies $O_{i,k}$ are used to filter the state predictions.

We will show results of several experiments based on micro-simulation of real life situation using Aimsun micro-simulator [1] coupled with our interfacing library to Matlab [3, 4]. Our simulations strongly suggest that $\forall i : \beta_i = 0$, and that while in cases of strongly differing traffic demands the proposed UTC method provides very encouraging results, in border cases under near-optimum fixed control strategy the algorithm drives the system to the complete saturation of one of the conflicting intersection arms.

Analysis of possible reasons and ways out of it will be presented.

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State Estimation with Unknown Noise Covariance Matrices

[1] Jindřich Duník, Miroslav Šimandl

The successful design and application of an arbitrary state estimation technique is conditioned by knowledge of a sufficiently exact model of a real system. However, in many cases the system is not described exactly and unknown parameters occur in the model, namely in the "deterministic part" including the functions in the state and measurement equations and in the "stochastic part" including statistical properties of the system initial state and state and measurement noises. As an example of a model with unknown parameters, the linear and nonlinear state space model of traffic system can be mentioned which contains unknown covariance matrices in the state and measurement equations. The noise covariance matrices cannot be determined from the physical properties of the traffic system and have to be estimated somehow.

The methods for estimation of the state and measurement noise covariance matrices can be generally divided into two groups, namely on-line and off-line estimation methods. The off-line estimation can be performed by e.g. the subspace methods [5] or the prediction error methods [2]. These methods are, however, suitable mainly for linear t-invariant systems or for special types of nonlinear systems only.

The on-line algorithms for the noise covariance matrices estimation can be roughly divided into two groups, namely adaptive and minimax filtering methods. As far as the adaptive filtering algorithms are concerned, they can be classified into various groups [4] such as Bayesian estimation, maximum likelihood estimation, correlation methods, and covariance matching methods. These methods can be further modified into the form where, instead of computation of the noise covariance matrices, the filter gain is directly computed [1, 3]. As an alternative to the adaptive filtering methods directly computing the filter gain the methods based on the minimax approach can be mentioned [6]. The common disadvantage of the adaptive and the minimax filtering methods is that these methods have been designed for the linear systems only.

The contribution is therefore focused on the introduction of a novel technique for estimation of the system noise covariance matrices intended for either linear or nonlinear systems [7]. The proposed method is based on the analysis of statistical properties of innovation sequence of a filter and allows to determine a sufficient number of independent equations to estimate all elements of unknown noise covariance matrices. The proposed method is conditioned by sufficiently exact knowledge of system initial condition and by a possibility to measure a few first data repeatedly. These conditions are in accord with the formulation of the traffic problem.

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Emulation of ELS3 Traffic Controller in TSS Aimsun Simulation Environment

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During the last two years, research work at the research centre Data-Algorithms-Decision Making at ELTODO dopravní systémy s.r.o. was focused on creation of complex environment for traffic control simulation. The aim of the contribution is to introduce structure of traffic control loop and its implementation in simulation environment with emphasis to software implementation of industry standard traffic controller ELS3 and its integration into TSS Aimsun in the form of GETRAM Extension module.

Created simulation environment is presently exploited for hierarchical transport controller algorithm testing before its final on-site testing in Prague-Zličín traffic area (5 crossings situated on the Řevnická street).

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3^{rd} International Workshop on Data - Algorithms - Decision Making

Poster Session.

Approximate Estimation of the Linear Uniform State-Space Model

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The aim of this presentation is to give an insight into the problem of the on-line estimation of the linear uniform (LU) state model. This model stems from the state space model known from the Kalman filtering theory [3], but it differs in the type of innovations. The LU model was introduced in [1]. Here, the model is extended by assuming of the time-varying model matrices and offset terms. It is described by the following state and output equation

$$x_t = A_t x_{t-1} + B_t u_t + F_t + {}^{x}e_t$$
$$y_t = C_t x_t + D_t u_t + G_t + {}^{y}e_t$$

where

$t = 1, 2, \ldots, T$ labels discrete time;

x, u, y are state, input and output vectors respectively;

A_t, B_t, F_t, C_t, D_t, G_t are model matrices of appropriate dimensions; the unknown entries of the model matrices are collected into the parameter θ;

${}^{x}e_t$, ${}^{y}e_t$ are the vectors of the state and output innovations respectively; they are assumed to be zero mean with constant variances, mutually conditionally independent and uniformly distributed on the box with the center 0 and boundaries $(-{}^{x}r, {}^{x}r)$ and $(-{}^{y}r, {}^{y}r)$.

The Bayesian estimation of the states $x^{1:T} \equiv [x_1, x_2, \ldots, x_T]$, parameters θ and innovation boundaries ${}^{x}r$, ${}^{y}r$ exploits the conditional probability density function (pdf) $f(d^{1:T}, x^{1:T}|x_0, {}^{x}r, {}^{y}r, \theta)$ of the data $d^{1:T}$, $d_t = (y_t, u_t)$, $t = 1, 2, \ldots, T$ and states $x^{1:T}$ and the prior pdf $f(x_0, {}^{x}r, {}^{y}r, \theta)$, see [2].

For the real-time applications, we need to perform the estimation in each time step t. The on-line Bayesian estimation with fixed lag $\partial > 0$ integrates out the superfluous state $x_{t-\partial-1}$ in each time step. With increasing t this operation soon becomes unmanageable because of the increasing complexity of the support of the corresponding posterior pdf. Therefore, the posterior pdf have to be approximated.

This presentation compares two approaches to the approximation of the posterior pdf: (i) the ,,cutting" of the superfluous states and (ii) the replacement of the non-uniform terms (arising by the integration) by the uniform ones.

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New Approach to the Switching of State

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Intelligent traffic control is one possible way how to improve capacity of light controlled network. Basic principle of the traffic-flow control is based on minimization of total queue lengths in a micro-region [6, 4]. Measurement of the queue lengths is difficult, so it is necessary to estimate them. The traffic micro-region can be described by a linear state space model (SSM) [6] where state is just formed by queue lengths. The SSM includes some unknown parameters which need to be estimated together with the states. Such the estimation requires the use of non-linear estimation techniques [2, 5, 1, 3].

The traffic model is based on traffic flow conservation principle: the queue at time k is equal to the sum of the previous queue at time $k-1$ and the arrived cars, given by the intensity and the sample period, minus the number of cars which pass through the intersection.

The number of cars depends on the existence of queue. In cases that the previous queue exists, the number of passing cars is limited by saturation flow and actual green-time. Otherwise, the number of passing cars depends on both the input intensity and green-time. It causes switching of the model with respect to the previous queue length and it is performed by parameter considered as Kronecker function (0,1). It is the serious point of estimation.

For that reason, the another two approaches was developed: (i) an approximation of the Kronecker function by hyperbolic tangent (HT) and (ii) multi-model approach (MM) [7].

Another approach is based on principle of continuous δ function. The Kronecker function is replaced by Gauss error function (GEF) taking its value between 0 and 1. The shape of GEF depends on the time-variant state covariances. This variability of GEF causes independence of the current value of parameter δ on relation between queue and road capacity. On the other hand, dependence on model accuracy is given with respect on measurement.

The mentioned approaches were compared with respect to efficiency and accuracy. The worst results were obtained in case of Kronecker function. The MM approach gave the best results but it was time consuming. The most efficient were HT and GEF approaches. GEF is more general and more adapted on current state than HT.

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Jobcontrol - Software Tool for System Identification and Control

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The purpose of software package Jobcontrol is to integrate algorithms present in Mixtools and Designer Matlab packages to simplify its usage for end user. It splits the task of model identification and process control into logical steps.

The main structure of Jobcontrol package was presented in [7, 8]. The Jobcontrol system was already applied in several real applications.

Kaolin production line identification and control. Control system introduction in this process of kaoline (china-clay) dehydration allows for production quality improvement because the temperature and humidity started to be controlled [3]. Target user of this application was the kaolion production factory in Ostrov nad Ohří.

Control of the biotechnology process for biodegradable polymers production. This application made in co-operation with Bulgarian Academy of Science, war targetted to biologically degradable polymers production using bio-reactors [4, 5]. Control of this process improves effectiveness of the production, hence competitiveness of this environmentally-friendly product is increased.

Diagnostics in Lymphoscintigraphy. Early phases of secondary lymphedems in are difficult to diagnose. Our system helps physician in the early diagnosis, making the medical therapy more human friendly [2, 1]. This appliceation was developed with the co-operaqtion of FN Motol.

Application for stock market futures trading. In the co-operation with Colosseum company, an application for futures trading is currently being developed [6].

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Decentralized Adaptive Control via Merging of Multi-Step Predictors

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This work represent a specific scenario in the area of multiple-participant decision-making [1]. The task is to control 2x3 (two-input, three-output) system, S, with two controllers, C_1 and C_2, each designed using 1x2 model (Fig. 1). A naive approach would be to use adaptive control design independently for each controller. We seek an improvement of the control performance in the class of adaptive controllers that can exchange information about the common output, y_2. The task is to find what type of information should be exchanged and how it can be utilized.

The starting point is fully probabilistic design of adaptive control strategy for centralized control. In this approach, the control law is designed in each step as follows: 1) update model parameters in the light of observed data, 2) design control strategy using dynamic programming with receding horizon, and 3) apply the optimum control strategy. The same algorithm is performed in naive approach to decentralized control for each controller. Since we assume that the same observations of $y_{2,t}$ are available to both agents, we conjecture that no improvement can be made in estimation of model parameters. However, individual models generate distinct predictions of future outputs which are used dynamic programming. These discrepancies can result in conflicting action design. We propose to harmonize the future predictions using probabilistic merging [2].

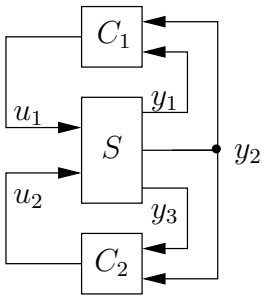

Figure 2: Example of decentalized adaptive control of 2x3 sytem.

Probabilistic merging is a method that seeks the closest joint distribution to the given (possibly inconsistent) distributions. For example, each controller is able to generate one-step-ahead predictor, $f_1(y_{1,t+1}, y_{2,t+1}|P_{1,t})$ and $f_2(y_{2,t+1}, y_{3,t+1}|P_{2,t})$, where P_i stands for all observations available to C_i up to time t. Optimal centralized controller would be designed using joint density $f(y_{1,t+1}, y_{2,t+1}, y_{3,t+1}|P_{1,t}, P_{2,t})$. In order to approach globally optimal control, we seek an approximation $\tilde{f}(y_{1,t+1}, y_{2,t+1}, y_{3,t+1}|P_{1,t}, P_{2,t})$ that is constructed from available f_1 and f_2. Using [2],

$$\tilde{f}(y_1, y_2, y_3) = f_1(y_1|y_2) f_2(y_3|y_2)(\alpha f_1(y_2) + (1-\alpha) f_2(y_2)), \tag{1}$$

where conditioning on P_i and time indexes were dropped for brevity. Note that y_1 and y_3 are conditionally independent in (1). Marginal densities, $\tilde{f}(y_1, y_2)$ and $\tilde{f}(y_2, y_3)$ can be generateed in ith controller if it knows the marginal density of its neighbour, $f_{1-i}(y_2)$. Therefore, we propose to modify step 2) above as follows: 2a) design control strategy using predictors based on own model; 2b) generate multistep predictor of common output $f(y_{2,t+1}, y_{2,t+2}, \ldots)$ and send it to the neighbours; 2c) merge marginal on y_2 from the neighbours with own predictor using (1), 2d) design control strategy using the merged predictors.

An experiment was performed to study the approch in simulation. For a selected system, value of the control criteria for two controllers using merged predictors was about 20% lower that that for two naive adaptive controllers. Of course, this positive result needs to be verified by further experiments.

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Polar and Radon's Transforms for Affine Invariant 2D Recognition

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Image moments enable the construction of basic affine transform, which ensures the invariance to translation, scaling, first rotation and stretching of the image. Let $\mathrm{f}_{\mathrm{AFF}}$ be such image after basic affine transform. Two proposed methods take advantage of knowledge from the paper of Suk and Flusser [1], which proposed the method based on moments for object recognition, even if they are symmetric. There is a problem to ensure the invariance to the second rotation. New methods use modified images obtained via polar or Radon's transform and so they enable realization of the affine invariant recognition system with the numerical stable elimination of the second rotation.

The first approach is called Affine Invariant Polar Matching (AIPM). Defining maximum radius as $\rho_{\mathrm{f}} = \max\{\|\overline{x}\|_2 \mid \mathrm{f}_{\mathrm{AFF}}(\overline{x}) > 0\}$ we can apply polar transform to obtain alternative binary image $\mathrm{f}_{\mathrm{POL}}(r,\varphi) = \mathrm{f}_{\mathrm{AFF}}(\rho_{\mathrm{f}}\, r\cos\varphi, \rho_{\mathrm{f}}\, r\sin\varphi)$. The affine invariant pattern matching for unknown pattern f is based on dissimilarity of $\mathrm{f}_{\mathrm{POL}}$ and fixed pattern images after polar transform. The second approach is called Affine Invariant Radon's Matching (AIRM). Denoting Radon's transform as Ra we can obtain alternative gray image $\mathrm{f}_{\mathrm{RAD}}(s,\vartheta) = \frac{\mathrm{R}(s,\vartheta)}{M_{\mathrm{AFF}}}$, where $\mathrm{R}(s,\vartheta) = \mathrm{Ra}\left(\mathrm{f}_{\mathrm{AFF}}(\rho_{\mathrm{f}}\, x, \rho_{\mathrm{f}}\, y)\right)$ and $M_{\mathrm{AFF}} = \max\limits_{s,\vartheta} \mathrm{R}(s,\vartheta)$. The affine invariant pattern matching for unknown pattern f is based on dissimilarity of $\mathrm{f}_{\mathrm{RAD}}$ and fixed pattern images after Radon's transform.

These two approaches were used for binary object classification. They were tested on patterns with known classification. Twenty four classes of binary 2D images were chosen. Every class was represented by one original pattern and one hundred of its affine deformed images. The complete process of recognition is demonstrated in the Fig. 3. Original and affine transformed images (the first column) were transformed via basic affine transform (the second column). All images from one class have after basic affine transform (almost) identic size and shape but alas they are rotated. Such images were transformed by polar (the third column) or Radon's (the fourth column) transform and their dissimilarities were calculated. The classification error was less then 0.2%. More information can be found in [2], [3].

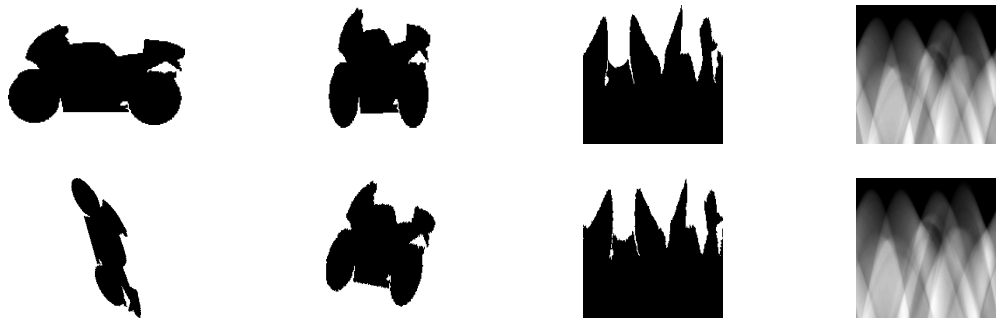

Figure 3: Classification steps for unknown pattern

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Importance Functions in Particle Filtering

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Particle filtering (PF) [1] is currently a rapidly evolving method used for state estimation of discrete-time nonlinear non-Gaussian systems. One of the key parameters affecting estimation quality in PF is the importance function (IF). Many IF proposals based on various ideas have appeared recently in literature and therefore, the goal of the poster is to provide an IF survey and to discuss their properties.

In PF, a discrete-time system given by the state transition pdf $p(\mathbf{x}_k|\mathbf{x}_{k-1})$ and the measurement pdf $p(\mathbf{z}_k|\mathbf{x}_k)$ is considered and the aim is to find the filtering pdf $p(\mathbf{x}_k|\mathbf{z}^k)$ conditioned by every measurement up to time k.

The idea of PF in nonlinear state estimation is to approximate the filtering pdf by the empirical filtering pdf which is given by random samples of the state and associated weights. The general PF algorithm can be decomposed into two principal steps. The former is to draw samples from an IF and the latter is to compute the corresponding weights so that the empirical pdf given by the samples and weights approximates the filtering pdf. The weights computation exploits the IF, transition and measurement pdf's. Obviously, the choice of the IF significantly affects quality of the state estimate.

Development of IF design techniques [2] proceeds using two main approaches. The first approach develops the original concepts of the IF design and proposes the prior IF [3] enhancements; e.g. in [4] the auxiliary particle filter was developed. Thus, the approach will be called the *direct* approach. The latter approach to IF design comes out of utilization of another filtering technique producing a filtering pdf which is used as the IF. Therefore, it will be called the *composite* approach. The following table contains a list of the most frequently used IF's within the direct approach with their key aspects.

IF	characteristics
optimal	high estimate quality, available in a few cases only
prior	simple, given by the transition pdf, does not utilize current measurement
fixed	freely explores state space, poor estimate quality
auxiliary	appends primary weights respecting current measurement
likelihood	simple, given by the measurement pdf
gradient-based	same as prior but moves particles to high-likelihood regions

The IF's of the composite approach use for samples generating for example the extended Kalman filter, Gaussian sum filter, sigma-point filter, Gaussian sum sigma-point filter or H_∞ filter.

Utilization of the composite approach in the IF design brings quality increase in terms of both the point estimates and the filtering pdf estimates. The direct approach may also provide high quality results but it is necessary to respect the system characteristics and to use a suitable IF. Higher computational demands are drawback of the composite approach IF's as they may be almost an order higher than for the direct approach IF's. Also utilization of another estimator as the IF generator poses higher theoretical requirement to the composite approach IF.

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Image Retrieval Measures Based on Illumination Invariant Textural MRF Features

[1]Pavel Vácha, [2]Michal Haindl

Content-based image retrieval (CBIR) systems target image databases using feature similarities with respect to the query. We introduce fast and robust image retrieval measures that utilise novel illumination invariant features extracted from three different Markov random field (MRF) based texture representations. These measures allow retrieving images with similar scenes comprising colour textured objects viewed with different illumination brightness or spectrum.

The proposed illumination insensitive measures are compared favourably with the most frequently used features like the Local Binary Patterns, steerable pyramid and Gabor textural features, respectively. The superiority of these new illumination invariant measures and their robustness to added noise are empirically demonstrated in the illumination invariant recognition of textures from the Outex database [1].

Moreover, we have developed the demonstration, which utilises the proposed illumination invariant features and which enables to search through a texture database for similar textures [3].

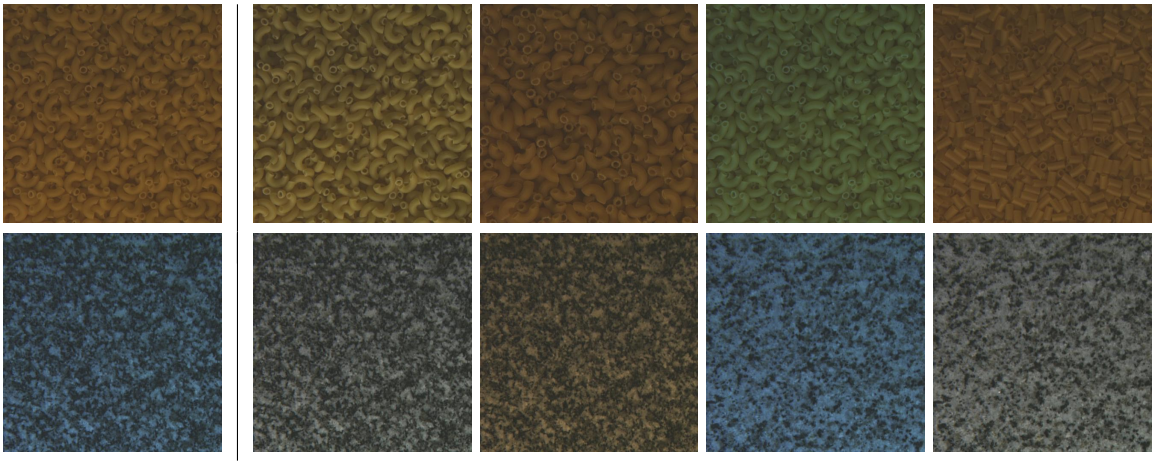

Figure 4: Examples of illumination invariant retrieval on textures from OuTex database. The images in the first columns are query images, followed by retrieval results in the next columns.

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Attenuation Imaging Using Ultrasound Transmission Tomography

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The contribution presents the current state of the project aimed at attenuation imaging using ultrasound transmission tomography. The target application field of this imaging modality is breast cancer diagnosis. It is intended as an alternative to the conventional B-mode ultrasound or X-ray imaging. The transmission-tomography setup provides a high amount of data and information, while keeping the advantage of non-ionizing character of ultrasound.

The imaged object is immersed in a water tank, with the inside wall covered by ultrasound transducers. Two experimental devices have been developed in Forschungszentrum Karlsruhe. In the two-dimensional (2D) tomograph [1], the transducers are arranged in a ring, while in the three-dimensional (3D) tomograph [2] the transducers cover the whole tank surface. One transducer is in the emitter mode, while all other transducers record the received radiofrequency signals. The recording is repeated until all transducers have been used as emitters.

So far, our attenuation imaging methods have been successfully tested on 2D synthetic data (generated using Huygens' principle of wave propagation) [3]. On real data measured from phantoms, only qualitative images could be estimated. To find possible sources of errors, a more realistic data simulation tool was designed, based on a commercial simulation software Wave 2000 (CyberLogic, USA). The major source of errors seems to be diffraction. To suppress the phenomenon, synthetic-aperture focusing on transmitting and receiving was proposed.

Furthermore, the image reconstruction algorithm was extended by including regularization. Namely, the reconstructed attenuation-coefficient image is expected to consist of smooth regions with sharp edges. Hence, the total variation (TV) regularization was incorporated in the algebraic reconstruction technique (ART).

Results on synthetic and measured phantom data sets show positive effects of the modifications. Evaluation of the results will be given in the presentation.

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Texture Analysis of Retinal Nerve Fiber Layer in Color Fundus Images

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Introduction

The loss of the retinal nerve fiber layer (RNFL) in retinal structure is connected with glaucoma disease and therefore its quantification plays an important role in diagnosis. There has been a high effort to use color retinal photography to evaluate a RNFL thickness since 1980, e.g. [1]. But until now, there is no routinely used method for RNFL quantification. This work is focused on the selection of the parameters obtained from the gray level run length matrix to distinguish the loss of the RNFL.

Data

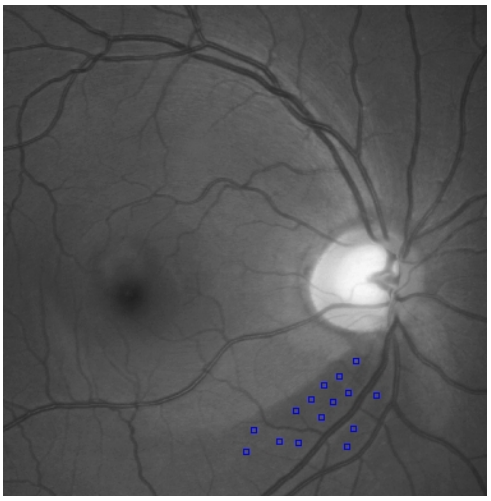

Fig.1. Several square samples taken from the fundus image from area of loss of RNFL (class A)

Green and blue channel were extracted from the JPG fundus camera (Canon CF-60UDi with digital camera Canon D20) images with low compression. The mean value (GB channel) was computed, because spectrum of the reflection light shows a local maximum on corresponding green-blue wavelength. The size of the images was 3504×2336 with field of view $60°$.

For texture analysis, the small square samples (41x41 pixels) were selected from the tissues with RNFL (165 samples, class A) and tissues without RNFL (160 samples, class B) from patients with glaucoma (see Fig. 1). The control group of samples was selected from healthy patients (310 samples, class C).

Texture Analysis

The gray-level run length (GLRL) method is a way of extracting a higher order statistic features. The GLRL matrix is a two dimensional matrix in which each elements gives a total number of occurrences of runs with defined length at given gray level and given direction. A large number of scalar texture features can be computed from GLRL matrix. In our study we used: short run emphasis, long run emphasis, gray level non-uniformity, run length non-uniformity, run percentage, low gray level run emphasis, high gray level run emphasis. Definitions can be found in [2].

Results and Conclusions

For all classes, the above-mentioned parameters were computed and t-tests were performed to compare the means for each parameter between classes A-C, B-C and A-B. We observed that all parameters can be used as a feature for tissue discrimination except high and low gray level run emphasis at a significant level $p = 0.05$.

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Simulation of Forward Task Solution in 3D USCT

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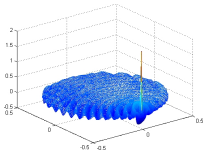
Introduction



We are developing a new software for experimental ultrasound equipment (3D USCT at Forschungszentrum Karlsruhe Germany), which enables high-resolution three-dimensional ultrasound imaging of the female breast. The aim is to provide the female breast diagnosis with the tomographic image reconstruction of higher quality. In its first stage, the procedures based on solution of (stationary) Helmholtz equation $\Delta p' + k^2 p' = 0$ for the pressure deviation due to ultrasound wave propagation will be treated in the forward problem with appropriate boundary conditions of Robin type. Subsequently, the main idea will stand on inverse wave equation solution. A simulation software for wave equation within 2D USCT was developed during the last year based on the real geometry of the equipment. Advancing now the model to 3D, lot more demanding procedures and of course much more computational performance is to be treated as well as new phenomena brought out by the more complex geometry. For the real system, more than 2.109 nodes would be needed to achieve ten nodes per wavelength and, hence, the parallelization of the procedures wil be unavoidable.

Model

In our calculation, FEM techniques will be used with tetrahedron elements. We are able to design the precise model of ultrasound tank, which was constructed by FZK: based on the real system geometrical data, a 3D model can be designed in AutoCAD and then imported into meshing software, which will design whole FEM net. Output from meshing software is a list of all nodes and elements, where every node has information, if it is a boundary node and which part of volume (kind of tissue, tank fluid, ...) it belongs to. Format of input data is folowing:

- **matrix V** nodes; each row contains coordinates x, y, z of a node and its ID.
- **matrix E** elements; each row contains the numbers of its four vertice-nodes ID.

Computation

As a first step in constructing the weak solution of the Helmholtz equation, the momentum integrals

$$M_J(k,l,m) = \iiint_J x^k y^l z^m dxdydz$$

with J denoting the element, have to be evaluated explicitely as functions of the element nodes coordinates. As far as ODEs of second order are considered, only moments with $k+l+m \leq 2$ are needed, of course the lowest moment $M(0,0,0)$ being the element volume

$$M_J(0,0,0) \equiv V_{ABCD} = \iiint_J dxdydz = \frac{1}{6} \begin{vmatrix} x_A - x_B & x_B - x_C & x_C - x_D \\ y_A - y_B & y_B - y_C & y_C - y_D \\ z_A - z_B & z_B - z_C & z_C - z_D \end{vmatrix}$$

Incorporating consequently the linear approximation functions, using the Galerkin minimization method, a (sparse) linear system of equtions is obtained, that is to be solved for the unknown values of the nodal pressure displacement.

Results and Conclusions

The first results are at hand, at the conference we aim to show the first 3D simulation figures.

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Výzkumné centrum Data – Algoritmy – Rozhodování

Výzkumné centrum Data – Algoritmy – Rozhodování (DAR) bylo založeno v roce 2005 v rámci programu MŠMT Výzkumná centra PP2 – DP01 (č. p. 1M6798555601; CEP 1M0572) těmito subjekty:

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