Výzkumné centrum Data – Algoritmy – Rozhodování

Research Centre Data – Algorithms – Decision Making

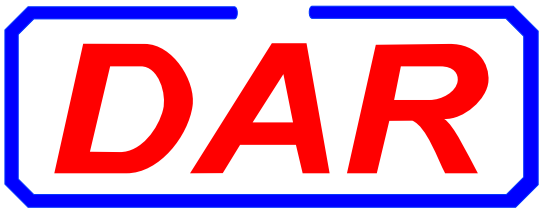
M a r t i n J a n ž u r a – J i ř í I v á n e k (e d s .)

Abstracts of Contributions to 6th International Workshop on Data – Algorithms – Decision Making

December 2, 2010 – December 4, 2010
Jindřichův Hradec, Czech Republic

Interní publikace DAR – ÚTIA 2010/2
Praha, listopad 2010

Content



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

Session 1.

Soft Computing and Fuzzy Modelling

December 2, 2010, Afternoon

Chairman: Vilém Novák

Morphological and Hybrid Morphological/Linear Neural Networks: Lattice-Theoretical Foundations and Applications in Time-Series Prediction

[1]Sussner Peter , [2]Valle Marcos E. , [3]Araújo Ricardo de A.

A morphological neural network (MNN) is generally defined as a type of artificial neural network that performs an elementary operation of mathematical morphology at every node, possibly followed by the application of an activation function. The underlying framework of mathematical morphology can be found in lattice theory.

Morphological and hybrid morphological/linear models have found a variety of applications such as classification, prediction, automatic target recognition, handwritten character recognition, landmine detection, face localization, robot vision, and hyperspectral image analysis. In particular, fuzzy morphological associative memories (FMAMs) and hybrid feedforward neural networks that include a morphological module have recently been successfully applied in the domain of time-series forecasting.

In this talk, we briefly review the mathematical background, the architectures, and the training algorithms of MNNs and some related approaches towards computational intelligence based on lattice theory. Special emphasis is placed on FMAMs and hybrid morphological/linear perceptrons. For these models, we provide some experimental results in time-series prediction. Moreover, we point out the advantages and deficiencies in comparison to other predictors. Finally, we address directions and challenges for further research.

[1]University of Campinas, Department of Applied Mathematics, Brazil, *sussner@ime.unicamp.br*
[2]University of Londrina, Department of Mathematics, Brazil, *valle@uel.br*
[3][gm][2] Intelligent Systems, Information Technology Department, Brazil, *araujora@gmail.com*

F-Transform for Image Fusion Algorithms

[1]Perfilieva Irina , [2]Daňková Martina , [3]Hoďáková Petra , [4]Vajgl Marek

The contribution is focused on the application of F-transform [2] to the problem of image fusion. We propose [1, 3] to decompose an image according to a fuzzy partition of an area, analyze each part, and then aggregate results into a final representation (fusion).

On different examples, we show that the proposed approach can be successfully applied in cases when input images are available as either multi-focus input images or multi-sensor input images. In the first example with multi-focus input images, the fusion algorithm produces an original image. In the second example, the fusion algorithm is applied to channel images taken by sensors with different illumination spectra. We show that our method has better quality than the known benchmark. In the third example, we fuse two brain MRI images and by this, significantly improved the visibility of pathological parts. Last, but not least, a complexity of the proposed algorithm is estimated and a measure of degradation of an image is proposed.

References

[1] M. Daňková and R. Valášek, "Full fuzzy transform and the problem of image fusion," *Journal of Electrical Engineering*, vol. 12, pp. 82–84, 2006.

[2] I. Perfilieva, "Fuzzy transforms: A challenge to conventional transforms," in *Advances in Images and Electron Physics*, P. W. Hawkes, Ed. San Diego: Elsevier Academic Press, 2007, vol. 147, pp. 137–196.

[3] I. Perfilieva and M. Daňková, "Image fusion on the basis of fuzzy transforms," in *Proc. 8th Int. FLINS Conf.*, Madrid, 2008, pp. 471–476.

[1]University of Ostrava, Institute for Research and Applications of Fuzzy Modeling, *Irina.Perfilieva@osu.cz*
[2]University of Ostrava, Institute for Research and Applications of Fuzzy Modeling, *Martina.Dankova@osu.cz*
[3]University of Ostrava, Institute for Research and Applications of Fuzzy Modeling, *Petra.Hodakova@osu.cz*
[4]University of Ostrava, Institute for Research and Applications of Fuzzy Modeling, *Marek.Vajgl@osu.cz*

LFL Forecaster - Time Series Forecasting Software

[1]Pavliska Viktor , [2]Vavříčková Lenka

LFL Forecaster is a specialized software tool for an analysis and forecasting time series created on Institute for Research and Applications of Fuzzy Modeling (IRAFM). It is based on two methods originally developed by members of IRAFM. The first method is based on the notion of fuzzy transform [2] and the second one employs the linguistic rules using fuzzy logic and deduction [1].

The idea of the fuzzy transform is to transform a given function defined in one space into another, usually simpler space, and then to transform it back. The simpler space consist of a finite vector of numbers. The reverse transform then leads to a function, which approximates the original one.

Fuzzy IF-THEN rules can be understood as a specific conditional sentence of natural language of the form

$$\mathsf{IF}\ X_1\ \mathsf{is}\ \mathcal{A}_1\ \mathsf{AND}\ \cdots\ \mathsf{AND}\ X_n\ \mathsf{is}\ \mathcal{A}_n\ \mathsf{THEN}\ Y\ \mathsf{is}\ \mathcal{B},$$

where $A_1, \ldots, A_n$ and B are evaluative expressions (very small, roughly big, etc.). The part of the rule before THEN is called the antecedent and the part after it is called the consequent. Fuzzy IF-THEN rules are usually gathered in a linguistic description

$$\begin{aligned}\mathcal{R}_1 &:= \mathsf{IF}\ X_1\ \mathsf{is}\ \mathcal{A}_{11}\ \mathsf{AND}\ \cdots\ \mathsf{AND}\ X_n\ \mathsf{is}\ \mathcal{A}_{1n}\ \mathsf{THEN}\ Y\ \mathsf{is}\ \mathcal{B}_1,\\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\ \mathcal{R}_m &:= \mathsf{IF}\ X_1\ \mathsf{is}\ \mathcal{A}_{m1}\ \mathsf{AND}\ \cdots\ \mathsf{AND}\ X_n\ \mathsf{is}\ \mathcal{A}_{mn}\ \mathsf{THEN}\ Y\ \mathsf{is}\ \mathcal{B}_m.\end{aligned}$$

Let time series $x_t, t = 1, \ldots, T$ is viewed as a discrete function and let $F_n[x] = [X_1, \ldots, X_n]$ be an fuzzy transform of the function x with respect to the given fuzzy partition. Logical dependencies between components $X_1, \ldots, X_n$ may be described by the fuzzy rules. These rules are generated automatically from the given data and are used for forecasting the next components. Fuzzy transform components as well as their first and second differences are used as antecedent variables.

The inverse fuzzy transform serves for modeling of so called trend-cycle [3]. Trend-cycle serves us to get pure seasonal components. The specific inference method - perception-based logical deduction [1] - is used for the trend-cycle forecast. The seasonal components are forecasted autoregressively. Finally, both forecasted components - trend-cycle and seasonal - are composed together to obtain the time series forecasts.

References

[1] V. Novák, I. Perfilieva. On the Semantics of Perception-Based Fuzzy Logic Deduction. *International Journal of Intelligent Systems*, 19, 1007–1031, 2004.

[2] I. Perfilieva. Fuzzy Transforms: theory and applications. *Fuzzy Sets and Systems*, 157, 993–1023, 2006.

[3] V. Novák, M. Štěpnička, A.Dvořák et al. Analysis of Seasonal Time Series Using Fuzzy Approach. *INT J GEN SYST.*, 39, 305–328, 2010.

[1]University of Ostrava, Institute for Research and Applications of Fuzzy Modeling, *Viktor.Pavliska@osu.cz*
[2]University of Ostrava, Institute for Research and Applications of Fuzzy Modeling, *Lenka.Vavrickova@osu.cz*

Using Fuzzy Approach to Improve Software Support and Maintenance Process

[1]Procházka Jaroslav , [2]Klimeš Cyril

Our work this year elaborates and practically evaluates last year's results. We defined empirical patterns (software support and maintenance) in several problem domains and used best practices derived from standards (Information Systems security) to verify defined model supporting decision making under uncertainty. Mentioned problem domains were chosen based on the fact that vagueness is natural input for rather engineering and/or formal steps. We defined four step general model supporting reasoning. Fuzzy logic is used as mean of expression of vague terms. Model itself comprises of four following steps:

- Selection of relevant data,
- Application of defined rules,
- The mapping for modeling the effects of admissible solutions,
- The mapping for acceptance of the solution itself.

Thanks to the fact, that the described problem areas are pretty complex in term of input variables, we use hierarchical model in LFLC to process more input variables. As a tools support we have chosen LFLC 2000 and Fpn2lfln tool developed in IRAFM (Institute for Research and Applications of Fuzzy Modeling) institute in Ostrava.

This paper summarizes the model, chosen approach, results and next steps.

References

[1] J. Prochazka Agile Support and Maintenance of IT Services. *International Software Development conference proceedings 2010*, Springer 2010, In print.

[2] J. Bartos, J. Prochazka, C. Klimes, et al. FUZZY REASONING MODEL FOR DECISION MAKING UNDER UNCERTAINTY. *International conference proceedings MENDEL 2010*, Brno: Brno University of Technology, 2010. pp. 203-209. ISBN 978-80-214-4120-0

[3] A. Dvorak, H. Habiballa, V. Novak, V. Pavliska. The software package LFLC 2000 its specificity, recent and perspective applications. *Computers in Industry*, Nr. 3/2003, vol. 51, 2003.

[4] J. Knybel, J. Prochazka. Using formal methods for QI information system. *International workshop on Data-Algorithm-Decision Making*, DAR 2005/41, 2005.

[5] J. Knybel, J. Prochazka and C. Klimes. Various Process Wizard for Information Systems. *Proceedings of the 8th International Conference on Enterprise Information Systems*, 2006.

[1]OASA Computers / University of Ostrava, *jaroslav.prochazka@osu.cz*
[2]OASA Computers / University of Ostrava, *cyril.klimes@osu.cz*

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

Session 2.

Knowledge Processing

December 2, 2010, Afternoon

Chairman: Radim Jiroušek

A Characteristic Imset – an Alternative Representative of a BN Structure

[1]Studený Milan , [2]Hemmecke Raymond , [3]Lindner Silvia

First, we recall the basic idea an algebraic and geometric approach to learning a Bayesian network (BN) structure proposed in [1]: to represent every BN structure by a certain uniquely determined vector. The original proposal was to use as an algebraic representative of a BN structure so-called *standard imset*, which is a vector having integers as components. In this paper we propose even simpler algebraic representative, called the *characteristic imset*. It is a vector having only zeros and ones as components, obtained from the standard imset by an affine transformation. In particular, every reasonable quality criterion is an affine function of the characteristic imset. The characteristic imset is much closer to the graphical description: we establish a simple relation to any chain graph without flags that defines the BN structure. In particular, we are interested in the relation to the *essential graph*, which is a classic graphical BN structure representative. In the end, we discuss two special cases in which the use of characteristic imsets particularly simplifies things: learning decomposable models and (undirected) forests.

References

[1] M. Studený, J. Vomlel and R. Hemmecke. A geometric view on learning Bayesian network structures. *International Journal of Approximate Reasoning*, 51:578–586, 2010.

[2] M. Studený, R. Hemmecke and S. Lindner. Characteristic imset: a simple algebraic representative of a Bayesian network structure. In *Proceedings of the 5th European Workshop on Probabilistic Graphical Models* (P. Myllymäki, T. Roos and T. Jaakkola eds.), HIIT Publications 2010-2, pp. 257–264.

[1]ÚTIA AVČR, MTR, *studeny@utia.cas.cz*
[2]TU Munich, Germany, *hemmecke@ma.tum.de*
[3]TU Munich, Germany, *slindner@ma.tum.de*

Probabilistic Troubleshooting: Open Problems and Performance of Heuristics

[1]Lín Václav

In decision-theoretic troubleshooting, we try to find efficient repair strategy for a malfunctioning device described by a formal model. The probabilistic *troubleshooting problem* [1] is given by a set $\mathcal{F} = \{F_1, \ldots, F_m\}$ of possible faults, a set $\mathcal{A} = \{A_1, \ldots, A_n\}$ of available repair steps, and a probabilistic model $P(\mathcal{F} \cup \mathcal{A})$ describing interactions between the elements of $\mathcal{A}$ and $\mathcal{F}$. Each action A_i bears a cost C_i and can either fail ($A_i = 0$) or fix the fault ($A_i = 1$). It is assumed that exactly one fault is present in the modeled system. Let $\pi = \{\pi(1), \ldots, \pi(n)\}$ denote a permutation of indices $1, \ldots, n$; then the repair strategy is a sequence $s = [A_{\pi(1)}, \ldots, A_{\pi(n)}]$ of actions performed until the fault is fixed or all actions are exhausted. Thus, action $A_{\pi(i)}$ will be performed only if all the preceding actions fail, i.e. $A_j = 0$ for $j = \pi(1), \ldots, \pi(i-1)$. To solve the troubleshooting problem, we have to find a repair strategy with the lowest *expected cost of repair*:

$$ECR(s) = \sum_{i=1}^{n} C_{\pi(i)} \cdot P\Big(\bigcup_{j=\pi(1)}^{\pi(i-1)} \{A_j = 0\} \Big).$$

This problem has received a significant attention (see the references in [5, 6, 1, 3]). Brute-force enumeration of the $n!$ sequences is intractable even for small n; however, under certain restrictions the problem is solvable in polynomial time [5, 3]. In other settings it is *NP* hard [6].

In the presentation, we are going to survey the state-of-the-art and the open problems — there are troubleshooting scenarios where the complexity is unknown, and the approximability [4] of known *NP* hard scenarios has not been studied at all. Further, we are going to present results of empirical evaluation of heuristic algorithms proposed in [2, 3].

References

[1] F. V. Jensen et al. The SACSO Methodology for Troubleshooting Complex Systems. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, 15:321–333, 2001.

[2] H. Langseth, F. V. Jensen. Heuristics for Two Extensions of Basic Troubleshooting. *Proceedings of Seventh Scandinavian Conference on Artificial Intelligence*, 80–89, 2001.

[3] T. J. Ottosen, F. V. Jensen. The Cost of Troubleshooting Cost Clusters with Inside Information. *Proceedings of 26th Conference on Uncertainty in Artificial Intelligence*, 2010.

[4] C. Papadimitriou. *Computational complexity.* Addison-Wesley Publishing Company, 1994.

[5] S. Srinivas. A Polynomial Algorithm for Computing the Optimal Repair Strategy in a System with Independent Component failures. *Proceedings of Eleventh Conference on Uncertainty in Artificial Intelligence*, 1995.

[6] M. Vomlelová. Complexity of Decision-Theoretic Troubleshooting. *International Journal of Intelligent Systems*, 18:267–277, 2003.

[1]Academy of Sciences of the Czech Republic, Institute of Information Theory and Automation, *lin@utia.cas.cz*

Independence and Factorization

[1] Jiroušek Radim

In probability theory, the concepts of independence and factorization are closely connected; due to famous Factorization Lemma [1] from some points of view they even coincide. But still under a detailed study they may differ from each other. For example, when considering probabilistic independence complying also with the notion of logical independence (as Coletti, Scozzfava, Vantaggi [4] and some other authors do), one gets an asymmetric notion that manifest different properties from those which hold for factorization. Therefore, it is clear that one has to differentiate which of these two notions is to be used in dependence of the problem solved. The situation becomes even more complicated when one starts considering other than probabilistic theoretical framework. For example, when considering Dempster-Shafer theory of evidence [2] there appear severe problems because one cannot rely upon existence of "density function" and there is no generally accepted notion of "conditional belief function". In spite of this we have succeeded in defining the notion of factorization and so a natural question arises, which will be put to the audience: Are we entitled to take the notion of factorization as a basis for defining the notion of independence?

References

[1] S. L. Lauritzen. *Graphical Models.* Oxford University Press., 1996.

[2] G. Shafer. *A Mathematical Theory of Evidence.* Princeton University Press, New Jersey, 1976.

[3] M. Studený. *Probabilistic Conditional Independence Structures.* Springer, London, 2005.

[4] G. Coletti, R. Scozzafava. Stochastic Independence in a Coherent Setting. *Ann. Mathematics and Artificial Intelligence*, 35:151–176, 2002.

[1] Ústav teorie informace a automatizace, AV ČR, v.v.i., MTR,, *radim@utia.cas.cz*

Global Classification of Aggregation Functions

[1]Mesiar Radko , [2]Komorníková Magda

Classification of objects considered in any domain is an important tool for the transparentness, better understanding of the considered domain, but also for construction and application of discussed objects. As an example, recall conjunction operators in many–valued logics. They are characterized by the boolean conjunction of propositions "i–th input is greater or equal to the output". Similarly, disjunction operators are characterized by the boolean conjunction of propositions "i–th input is smaller or equal to the output". The aim of this contribution is to open the topic of classification of aggregation functions acting on bounded posets (covering, among others, conjunction and disjunction operators in many–valued logics). In the area of aggregation functions acting on real intervals, such a classification was proposed by Dubois and Prade at AGOP'2001 conference in Oviedo, see also [6]. In Dubois – Prade approach, conjunctive, disjunctive, averaging and remaining aggregation functions were considered, defined by their relationship to Min and Max functions. The class $\mathcal{C}$ of all (n–ary) conjunctive functions (acting on a real interval $[a, b]$) is characterized by the inequality $A \leq Min$, while the inequality $A \geq Max$ is characteristic for the disjunctive aggregation functions. Concerning the averaging aggregation functions, they should satisfy $Min \leq A \leq Max$. To exclude the trivial overlapping of conjunctive and averaging (disjunctive and averaging) aggregation functions, the class $\mathcal{P}$ of pure averaging aggregation functions consists of all averaging aggregation functions up to Min and Max. Denoting $\mathcal{A}$ the class of all aggregation functions (n–ary, on real interval $[a, b]$), $\mathcal{R} = \mathcal{A}\backslash(\mathcal{C} \cup \mathcal{P})$ consists of all remaining aggregation functions, which are neither conjunctive, nor disjunctive nor averaging. Thus this standard classification $(\mathcal{C}, \mathcal{D}, \mathcal{P}, \mathcal{R})$ forms a partition of the class $\mathcal{A}$. In several domains we need to classify the aggregation of more complex objects, which rarely form a chain, but they can be considered as elements of some (bounded) lattice or poset (we will use this abbreviation for a partially ordered set throughout this paper). This is, for example, the case of aggregation of fuzzy sets (intersection, union), of distribution functions (convolution), etc. However, such a classification of aggregation functions on posets is missing in the literature so far. Obviously, we cannot repeat the approach of Dubois and Prade once Min and Max are not defined.

Acknowledgment. The research summarized in this paper was supported by the Grants APVV–0012–07 and VEGA 1/0080/10.

References

[1] G.Beliakov et al. *Aggregation functions: a guide for practitioners*. Springer-Verlag, Berlin, Heidelberg, 2007.

[2] G.Birkhoff. *Lattice theory. Third edition*. American Mathematical Society, Providence, R.I., 1967.

[3] T.Calvo et al. Aggregation operators: Properties, classes and construction methods. *Aggregation operators: Properties, Classes and Construction Methods, Aggregation Operators: New Trends and Applications*, 1–104. Physica-Verlag, Heidelberg, New York, 2002

[4] B.De Baets and R.Mesiar. Triangular norms on product lattices. *Fuzzy Sets and Systems*. 104:61–76, 1999.

[5] G.De Cooman and E.E.Kerre. Order Norms On Bounded Partially Ordered Sets. *The Journal of Fuzzy Mathematics*. 2:281–310, 1994.

[6] D.Dubois and H.Prade. On the use of aggregation operations in information fusion processes. *Fuzzy Sets and Systems*, 142:143–161, 2004.

[7] M.Grabisch et al. *Aggregation functions*. Cambridge University Press, Cambridge, 2009.

[8] S.Jenei and B.De Baets. On the direct decomposability of t-norms on product lattices. *Fuzzy Sets and Systems*. 139(3):699–707, 2003.

[9] F.Karacal and D.Khadjiev. $\bigvee$–distributive and infinitely $\bigvee$–distributive t-norms on complete lattices. *Fuzzy Sets and Systems*. 151(2):341–352, 2005.

[10] R.Mesiar and M.Komorníková. Classification of aggregation functions on bounded partially ordered sets. Proc. SISY'2010, Subotica, September 10 – 11, 2010, 13 – 16, 2010.

[11] S.Saminger-Platz et al. On extensions of triangular norms on bounded lattices. *Indagationes Mathematicae*. 19(1):135–150, 2008.

[12] D.Zhang. Triangular norms on partially ordered sets. *Fuzzy Sets and Systems*. 153(2):195–209, 2005.

[1]SvF STU Bratislava, Department of Mathematics and UTIA CAS Prague, *radko.mesiar@stuba.sk*
[2]SvF STU Bratislava, Department of Mathematics, *magdalena.komornikova@stuba.sk*

Shapley Value: Variations and Applications

[1]Vlach Milan

Recall that basic data specifying a cooperative game with transferable utility are composed of a nonempty set of players and a real-valued function defined on the power set of the set of players. There is a variety of solution concepts for such games. Some solutions consist of sets of payoff vectors, while others are represented by a single payoff vector. An important solution concept of the latter category is the *Shapley value* introduced by Lloyd S. Shapley in 1953.

The Shapley value not only belongs to the most studied and important solution concepts of cooperative game theory but it is also an easily tractable mathematical object with a remarkably wide range of practical applications. In the first part, after necessary preliminaries, we will be looking at basic properties and characterizations of the Shapley value for transferable utility games with a finite number of players. Afterwards, we consider some of the most frequent variations (generalizations and particularizations) of the Shapley value. We conclude with a brief discussion of applications in diverse areas of economics and political science.

References

[1] L. S. Shapley A Value for n-person Games. *Contributions to the Theory of Games II*, H. Kuhn and A. W. Tucker, eds. 307–317, Princeton University Press, 1953.

[2] B. Peleg and P. Sudhölter. *Introduction to the theory of cooperative games, 2nd ed.* Springer, 2007.

[3] S. Moretti and F. Patrone. Transversality of the Shapley value. TOP 16(1):1–41, 2008; DOI:10.1007/s11750-008-0044-5.

[1]Charles University, Department of Theoretical Computer Science and Mathematical Logic; Kyoto College of Graduate Studies for Informatics, *milan.vlach@mff.cuni.cz*

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

Session 3.

Image Fusion

December 3, 2010, Morning

Chairman: Jan Flusser

Disparity Based Hybrid Registration as Background for Substantial Improvement in 3D Subtractive Angiology

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

The lecture will describe an approach designed to improve results in CT based 3D subtractive angiography of lower extremities via better global but locally defined image registration. The principle of subtractive angiography (SA) is simple and routinely used even in its 3D CT-based version; however, still not quite perfect results are generally achieved. The examination consists in first providing natural (pre-contrast) image data of the examined volume, then administering a contrast medium to the patient that fills the vessel structure and finally obtaining the post-contrast CT image data. Assuming that there is no movement of the patient between both CT scans, and also that no imaging distortions are involved, the final 3D vessel structure image is then obtained by subtracting the pre-contrast image data from the post-contrast ones. However, these assumptions are not perfectly valid in practice. The problem of image registration in SA has been addressed in many publications, and presently, the commercially available firmware algorithms are rather sophisticated. Thus, it was a challenging problem, formulated by Philips Nederland, to achieve an improvement that would not only be quantitatively measurable but also appealing to clinical radiologists. The crucial and very demanding step of the procedure is the spatial registration of the acquired 3D volumes of pre- and post-contrast image data. These two sets are not only mutually globally shifted and rotated due to patient movement between pre- and post-contrast image acquisition but generally also geometrically distorted in a complicated way due to time-varying muscle tense and tiny movements of extremities between and during the helical scans. The main problem is thus to achieve the perfect (generally flexible and nonlinear) registration regardless of the unpredictable distortions while taking into account the specific features of the concerned 3D image data. The results (Fig. 11) of the procedure that will be described in the lecture are showing that a real improvement has been achieved compared to what is obtained by standard professional software when applied to the same raw data.

Figure 1: Comparison of the vessel tree reconstruction by commercial firmware of a modern radiological workstation (left) versus results of the presented method (right).

References

[1] Jan,J., Malínský,M., Peter,R., Ouředníček,P. *Improved Disparity Based Image Processing in 3D CT Subtractive Angiography* Proc. 32nd IEEE-EMBC int. conf., Buenos Aires 2010, IEEE, ISBN 978-1-4244-4124-2, DVD issue

[2] Ouředníček,P., Jan,J., Malinsky,M., Peter,R. *Piece-wise rigid registration as a way to improvement of CT angiographic image data* Proc. ESR congress Vienna 2010, Eur. Soc. of Radiology (web issue)

[3] Jan,J., Janová,D. *Disparity analysis for image fusion.* In Proc. ICEE / ICEER 2009 int. conf., Seoul, 2009. pp. 401-404.

[1]Brno University of Technology, Department of Biomedical Engineering, Czech Rep., *jan@feec.vutbr.cz*
[2]Brno University of Technology, Department of Biomedical Engineering, Czech Rep., *xmalin09@stud.feec.vutbr.cz*
[3]Brno University of Technology, Department of Biomedical Engineering, Czech Rep., *roman.peter@phd.feec.vutbr.cz*
[4]Masaryk Univerzity, Faculty of Medicine, Czech Rep.,

Regularized Image Reconstruction in Multimodal 3D Ultrasound Transmission-Tomography

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

The contribution presents the current advance in sound-speed image restoration for 3D ultrasound-transmission tomography. Our research is focused on a fully 3D ultrasound computer tomography (USCT)[1], compared to other research groups working on 2D USCTs (data acquisition and processing in 2D planes moved through the images object). The fully 3D USCT technology results in a better spatialresolution in the third dimension. On the other hand, several additional challenges have to be dealt within 3D USCT: low signal-to-noise ration (SNR), sparsity of the transducer distribution and the need forprocessing of the complete 3D dataset at once.This contribution is focused on reconstruction of sound-speed images, as one possible imaged parameter map obtained from the USCT dataset. Algebraic reconstruction technique is applied and modifiedto enable image reconstruction for the 3D USCT system. 3D regularization is added to the classicalalgebraic reconstruction to deal with the trasducer sparsity and low SNR [2]. Furthermore, 2D synthetic aperture focusing is used to improve the SNR, suppress diffraction andpartly to decrease the level of transducer sparsity. Furthermore, estimation of the SNR in each radiofrequency signal is used to omit low-SNR signals from the reconstruction process. A distributed-computing implementation was designed to make the processing of the complete dataset(20GB) possible. For this purpose, MATLAB Distributed Computing Server toolbox was used on Meta-Centrum computational resources.Tests on synthetic data and measured phantom data are presented. The sound-speed images are alsoapplied to reflectivity reconstruction to compensate for phase front abberation.

References

[1] H. Gemmeke and N.V. Ruiter *3D Ultrasound Computer Tomography for Medical Imaging.* NuclearInstruments and Methods in Physics Research, 550:1057–1065, 2007.

[2] Radovan Jirik, Igor Peterlik, Jiri Jan, Nicole Ruiter, and Michael Zapf. *3d regularized speed-mapreconstruction in ultrasound transmission tomography.* In 2009 IEEE Ultrasonics Symposium, pages 2272–2275. IEEE, November 2009.

[1]Brno University of Technology, Department of Biomedical Engineering, Czech Rep., *jirik@feec.vutbr.cz*
[2]Masaryk University, Brno, Institute of Computer Science, Czech Rep., *peterlik@ics.muni.cz*
[3]Masaryk University, Brno, Faculty of Informatics, Czech Rep, *izaak@mail.muni.cz*
[4]Brno University of Technology, Department of Biomedical Engineering, Czech Rep., *jan@feec.vutbr.cz*
[5]Karlsruhe Institute of Technology, Institute for Data Processing and Electronics, Germany, *Michael.Zapf@ipe.fzk.de*
[6]Karlsruhe Institute of Technology, Institute for Data Processing and Electronics, Germany, *Nicole.Ruiter@ipe.fzk.de*

Monte Carlo Simulation of PET Images for Injection Dose Optimization

[1]Boldyš Jiří , [2]Dvořák Jiří

When a patient is examined by positron emission tomography (PET, [1]), radiotracer dose amount has to be determined. However, the rules used nowadays do not correspond with practical experience. Slim patients are given unnecessary amount of radiotracer and obese patients would need more activity to produce images of sufficient quality.

We have built a model of a particular PET scanner. At the same time, we have approximated human trunk, which is our region of interest, by a cylindrical model with segments of liver, outer adipose tissue and the rest. We have performed intensive Monte Carlo simulations of PET imaging using the simulation package GATE [2].

Under reasonably simplifying assumptions, we have developed curves, which recommend amount of injected activity based on body parameters to give PET images of constant quality. The dependence qualitatively differs from the rules used in clinical practise nowadays. It turns out that it is sufficient for slim patients to be exposed to less radioactivity. On the other hand, for severely obese patients there is limitation inherent to the imaging physics to get an image of sufficient quality.

References

[1] R. Badawi *UW Introduction to PET Physics [online].* last revision January 12, 1999 http://depts.washington.edu/nucmed/IRL/pet intro/

[2] (Full citation due to licence conditions.) S. Jan, G. Santin, D. Strul, S. Staelens, K. Assie, D. Autret, S. Avner, R. Barbier, M. Bardies, P. M. Bloomfield, D. Brasse, V. Breton, P. Bruyndonckx, I. Buvat, A. F. Chatziioannou, Y. Choi, Y. H. Chung, C. Comtat, D. Donnarieix, L. Ferrer, S. J. Glick, C. J. Groiselle, D. Guez, P. F. Honore, S. Kerhoas-Cavata, A. S. Kirov, V. Kohli, M. Koole, M. Krieguer, D. J. van der Laan, F. Lamare, G. Largeron, C. Lartizien, D. Lazaro, M. C. Maas, L. Maigne, F. Mayet, F. Melot, C. Merheb, E. Pennacchio, J. Perez, U. Pietrzyk, F. R. Rannou, M. Rey, D. R. Schaart, C. R. Schmidtlein, L. Simon, T. Y. Song, J. M. Vieira, D. Visvikis, R. Van de Walle, E. Wieers, C. Morel GATE: a simulation toolkit for PET and SPECT. *Phys. Med. Biol.*, 49:4543–4561, 2004.

[1]Ústav teorie informace a automatizace AV ČR, v.v.i., *boldys@utia.cas.cz*
[2]Ústav teorie informace a automatizace AV ČR, v.v.i., *dvorak@utia.cas.cz*

Recent Advances in Forensic Imaging

[1]Mahdian Babak , [2]Saic Stanislav

The art of making image fakery has a long history. But, in today's digital age, it is easily possible to change the information represented by an image without leaving any obvious traces of tampering. Therefore, verifying the integrity of digital images and detecting the traces of tampering without using any protecting pre–extracted or pre–embedded information have become an important research field [3, 1]. This summary represents a categorization of references on blind methods for detecting image forgery. By word blind we refer to those methods using only and only the image function to perform the forgery detection task. Blind methods are mostly based on the fact that forgeries can bring into the image specific detectable changes (e.g., statistical changes).

In this summary we try to design a detailed classification group and fit the existing references into this classification. We mainly will talk about the forensic methods analyzing the followings:

- Near-Duplicated Image Regions [5]
- Computer Graphics and Paintings [6]
- JPEG and Compression Properties [2]
- Interpolation and Geometric Transformations [4]
- Image Splicing [7]
- Color Filter Array and Inter Pixel Correlation [8]
- Local Noise [9]

References

[1] Mahdian, Babak and Saic, Stanislav (2010) A bibliography on blind methods for identifying image forgery, *Image Commun., Vol 25, Num 6, 389–399*, http://dx.doi.org/10.1016/j.image.2010.05.003

[2] Farid, Hany (2009) Exposing Digital Forgeries from JPEG Ghosts, *IEEE Transactions on Information Forensics and Security, Vol. 1, Num. 4, 154–160*

[3] Hany Farid (2009) A Survey of Image Forgery Detection *IEEE Signal Processing Magazine*, Vol. 2, Num. 26, 16–25, www.cs.dartmouth.edu/farid/publications/spm09.html

[4] Babak Mahdian and Stanislav Saic A Cyclostationarity Analysis Applied to Image Forensics IEEE Workshop on Applications of Computer Vision (IEEE WACV), 279–284 December, 2009, Snowbird, UT, USA

[5] B. Mahdian and S. Saic (2007) Detection of copy–move forgery using a method based on blur moment invariants, *Forensic science international*, Elsevier, Vol. 171, Num. 2–3, 180–189,

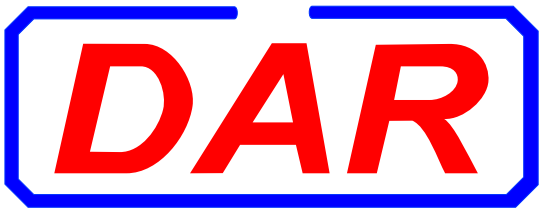
[6] Ng, Tian-Tsong and Chang, Shih-Fu An Online System for Classifying Computer Graphics Images from Natural Photographs, SPIE Electronic Imaging, San Jose, CA, January, 2006

[7] Ng, Tian-Tsong and Chang, Shih-Fu A Model for Image Splicing, IEEE International Conference on Image Processing (ICIP), Singapore, October, 2004

[8] A.C. Popescu and H. Farid (2005) Exposing Digital Forgeries in Color Filter Array Interpolated Images, *IEEE Transactions on Signal Processing*, Vol. 53, Num. 10, 3948–3959, www.cs.dartmouth.edu/farid/publications/sp05a.html

[9] Gou, Hongmei and Swaminathan, Ashwin and Wu, Min (2009) Intrinsic sensor noise features for forensic analysis on scanners and scanned images, *Trans. Info. For. Sec.*, Vol. 4, Num. 3, 476–491, http://dx.doi.org/10.1109/TIFS.2009.2026458

[1]Institute of Information Theory and Automation of the ASCR, *mahdian@utia.cas.cz*
[2]Institute of Information Theory and Automation of the ASCR, *ssaic@utia.cas.cz*



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

Session 4.

Multiple-participant Decision-making

December 3, 2010, Morning

Chairman: Miroslav Šimandl

Forgetting-based Estimation of Stationary Parameters in Marginalized Particle Framework

[1]Šmídl Václav

Particle filtering is a popular approximation of Bayesian filtering, i.e. on-line recursive evaluation of posterior distribution of unknown time-varying quantities. Its success is documented by a range of applications in object tracking, navigation, video processing, etc. A known weakness of the particle filtering is its inability to estimate stationary or slowly-varying quantities, which are typically called parameters. Theoretical studies suggest that this task is perhaps impossible as the posterior density degenerates in time [1, 4].

The marginalized particle filtering arise for specific problems that allow analytical marginalization over a part of the unknowns. If the marginalization is over the stationary parameters and the resulting marginal density has sufficient statistics, it is known as particle learning. In effect, each particle carries sufficient statistics of the parameters. This approach was believed to mitigate the problems with stationary parameters [2], however, extensions of the previous analytical results to this case points out the same degeneracy as in the non-marginalized case [3].

A heuristic approach to avoid degeneracy of the posterior density is the use of classical forgetting techniques developed for recursive estimation with sufficient statistics [5]. This approach has been shown to avoid the degeneracy problem in simulation [6]. In this contribution, we will demonstrate the degeneracy problem on some simulated examples. Various forgetting techniques, such as scheduling of the forgetting factor, will be compared. An informal theoretical justification of the use of the forgetting approach will be given as well as its potential limitations. In summary, estimation of the stationary parameters in particle filtering (as well as marginalized particle filtering) is still an open problem. Application of the forgetting technique allows to estimate slowly varying parameters. Its application to stationary parameters is suboptimal, however, it may be sufficient for many practical applications.

References

[1] O. Cappé, R. Douc, É. Moulines, and C. Robert. On the convergence of the Monte Carlo maximum likelihood method for latent variable models. *Scandinavian Journal of Statistics*, 29(4):615–635, 2002.

[2] C.M. Carvalho, M. Johannes, H.F. Lopes, and N. Polson. Particle learning and smoothing. *Statistical Science*, 25(1):88–106, 2010.

[3] N. Chopin, A. Iacobucci, J-M. Marin, K. Mengersen, Ch. Robert, R. Ryder, and Ch. Schäfer. On particle learning. *ArXiv e-prints*, jun 2010.

[4] N. Kantas, A. Doucet, S.S. Singh, and J.M. Maciejowski. An overview of sequential Monte Carlo methods for parameter estimation in general state-space models. 2009.

[5] R. Kulhavý and M. B. Zarrop. On a general concept of forgetting. *International Journal of Control*, 58(4):905–924, 1993.

[6] S. Saha, E. Özkan, V. Šmídl, and F. Gustafsson. Marginalized particle filters for Bayesian estimation of noise parameters. In *Proceedings of the 13th International Conference on Information Fusion*, Edinburgh, UK, 2010.

[1]Institute of Information Theory and Automation, department of Adaptive Systems, *smidl@utia.cas.cz*

Constrained State Estimation

[1]Straka Ondřej , [2]Šimandl Miroslav

State estimation of dynamic stochastic systems is of extreme importance in a range of various fields both technical and non-technical. The goal of state estimation is to find an estimate of a state which is observed through a set of measured quantities. The system is described by a state space model consisting of a difference equation, describing the dynamics of the state, and of an algebraic equation describing the relation between the state and the measurement. Both equations are considered to be stochastic to account for possible uncertainties in the state or measurement.

In some cases also an additional information about the state is known. This information appears as a constraint for the state variable that often describes a physical quantity present within the system. The constraints then arise due to physical laws, technological limitations, kinematic constraints or geometric considerations of the system [1, 2]. Mathematically, the constraints are often given by a set of linear or nonlinear equalities or inequalities. Taking the constraints into account within the estimation problem leads to the constrained state estimation problem.

Within the last decade, several approaches to solve the constrained estimation problem have been proposed. The most notable approaches are: reparametrizing and pseudo-measurement approaches [3, 4], optimization approaches [5], and projection and truncation approaches [6, 7, 8, 9, 10]. The presentation will discuss these approaches to provide a brief survey.

References

[1] YT Chiang, LS Wang, FR Chang, and HM Peng. Constrained filtering method for attitude determination using GPS and gyro. *IEE Proceedings-Radar, Sonar and Navigation*, 149(5):258–264, 2002.

[2] M. Tahk and JL Speyer. Target tracking problems subject to kinematic constraints. *IEEE Transactions on Automatic Control*, 35(3):324–326, 1990.

[3] F.L. Markley. Attitude error representations for Kalman filtering. *J. Guidance, Control and Dynamics*, 26(2):311–317, 2003.

[4] A.T. Alouani and W.D. Blair. Use of a kinematic constraint in tracking constant speed, manouvering targets. *IEEE Transactions on Automatic Control*, 38(7):1107–1111, 1993.

[5] C.V. Rao, J.B. Rawlings, and J.H. Lee. Constrained linear state estimation—A moving horizon approach. *Automatica*, 37(10):1619–1628, 2001.

[6] C. Yang and E. Blasch. Kalman filtering with nonlinear state constraints. In *Proceedings of the 9th International Conference on Information Fusion*, 2006.

[7] B.O.S. Teixeira, J. Chandrasekar, L.A.B. Torres, L.A. Aguirre, and D.S. Bernstein. Unscented Filtering for Equality-Constrained Nonlinear Systems. In *Proceedings of the American Control Conference (ACC'08)*, 2008.

[8] S.J. Julier and J.J. LaViola. On Kalman Filtering With nonlinear Equality Constraints. *IEEE Transactions on Signal Processing*, 55(6):2774–2784, 2007.

[9] D. Simon. *Optimal State Estimation: Kalman, H Infinity, and Nonlinear Approaches.* Wiley-Interscience, 2006.

[10] J. Duník, M. Šimandl, and O. Straka. Multiple-model filtering with multiple constraints. In *American Control Conference (ACC), 2010*, pages 6858–6863. IEEE, 2010.

[1]University of West Bohemia, Department of Cybernetics, *straka30@kky.zcu.cz*
[2]University of West Bohemia, Department of Cybernetics, *simandl@kky.zcu.cz*

Improving Fault Detection Quality by Delaying Decision Making

[1]Punčochář Ivo , [2]Šimandl Miroslav

The problem of decision making under uncertainty arises in many settings ranging from quality control to fault detection [3]. In the case of fault detection, the aim is to design a detector that generates decisions about the occurrence of a fault in an observed system. Depending on a particular application area, the emphasis is usually put on different properties (e.g. the delay for detection, the false alarm and missed detection rates) of the designed detector [5]. Moreover, since some of these properties represent contradictory objectives, a compromise has to be searched for while designing the detector. One of these compromises, that is inherent in all fault detection problems, is the trade-off between the delay for detection and the quality of decisions. The resulting compromise is commonly dictated by the requirements expressed in the terms of the detector properties. By examining a basic premise of fault detection, it is possible to introduce a new level of this compromise.

In the majority of the fault detection problems, each decision refers to a state of the observed system at the current time step. However, there are specific applications in which it may be worthwhile to defer the decision and thus utilize a larger data set. From the estimation point of view, which is an integral part of virtually all decision making processes, it means that smoothing estimates may be employed instead of the filtering ones. Typical examples include: a detector with an event-driven smoothing, a detector with deferred decisions, and a batch data analysis. Although the general idea of delayed decision making can certainly be applied in several fault detection methods, multiple model fault detection is considered as a representative case.

The multiple model approach represents a favorite and successful modeling tool for describing systems that may undergo abrupt changes. Besides fault detection [4], the multiple model approach is widely used in many application areas such as state estimation [7], adaptive control [1] and target tracking [2]. In in this work, the goal is to design a fault detector with delayed decision making in the multiple model framework. The fault detection problem is formulated as a dynamic optimization problem, and the optimal solution is derived using the closed loop information processing strategy (IPS). Additionally, the equivalence of that solution to the solution based on the open loop feedback IPS is demonstrated. To enable deferred decision making, a smoothing algorithm known as the Rauch-Tung-Striebel [6] smoother is employed for obtaining the smoothed estimate of the state. The difference in quality between the immediate and deferred decisions is illustrated by means of a numerical example.

References

[1] M. Athans, S. Fekri, and A. Pascoal. Issues on robust adaptive feedback control. In *Proceedings of the* 16^{th} *IFAC World Congress*, Oxford, UK, June 2006.

[2] Y. Bar-Shalom, X. R. Li, and T. Kirubarajan. *Estimation with Applications to Tracking and Navigation*. John Wiley & Sons, New York, NY, USA, June 2001.

[3] M. Basseville and I. V. Nikiforov. *Detection of Abrupt Changes – Theory and Application*. Prentice Hall, Englewood Cliffs, NJ, USA, 1993.

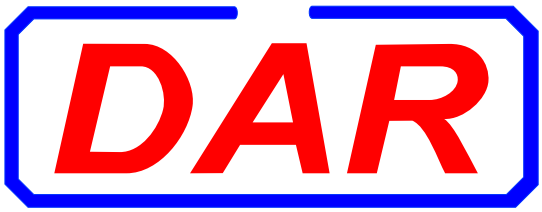
[4] F. Gustafsson. *Adaptive Filtering and Change Detection*. John Wiley & Sons, Chichester, WSX, UK, July 2000.

[5] R. Isermann. Process fault detection based on modeling and estimation methods – A survey. *Automatica*, 20(4):387–404, July 1984.

[6] F. L. Lewis. *Optimal Estimation*. John Wiley & Sons, New York, 1986.

[7] M. Šimandl and J. Královec. Filtering, prediction and smoothing with gaussian sum representation. In *Proceedings of the* 12^{th} *IFAC Symposium on System Identification*, Santa Barbara, USA, June 2000.

[1]University of West Bohemia, Department of Cybernetics, *ivop@kky.zcu.cz*
[2]University of West Bohemia, Department of Cybernetics, *simandl@kky.zcu.cz*



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

Session 5.

Control under Uncertainty

December 3, 2010, Afternoon

Chairman: Miroslav Šimandl

Towards Bounded Estimates of Model Parameters

[1]Ettler Pavel

Model-based prediction is frequently used for industrial control or monitoring purposes. It can be based on recursive Bayesian parameter estimation representing theoretically consistent treatment of uncertainty. In a special case – under the assumption of normal probability distribution of all processed quantities and when restricted to the linear normal autoregressive model with external variables (ARX) – it leads to the very efficient and numerically robust algorithm.

Industrial applications often work with a mathematical model, the structure of which is based, at least to some extent, on a physical model of the process (so called *gray box modeling* – see e.g. [1]). Recursive estimation can track parameter changes caused either by a real change of some physical parameter of the process or compensating imperfect matching of the process and its model. For unrestricted estimation, parameter estimates may occur in regions, which are formally correct but physically unreasonable. Then, especially in the case of an abrupt change of some physical parameter of the process, behavior of a corresponding predictor or controller can become undesirable. Intrinsic application of constraints to the parameter estimates could be beneficial in such cases.

Existence of bounded intervals for acceptable model parameters can be well respected within Bayesian framework. It suffices to restrict support of their prior distribution to this range. For recursive use, this possibility has been theoretically elaborated in [2] for a Gaussian parametric model and in [3] for a uniform parametric model. An alternative, albeit suboptimal solution has been sought to be practically applicable in metal processing industry. Possible solution [4] is based on simultaneous run of two or more proven estimators different in applied process models. Simulated and real data tests outlined potential benefits of the algorithm.

References

[1] T. Bohlin. *Interactive System Identification: Prospects and Pitfalls.* Springer-Verlag, New York, 1991.

[2] M. Kárný. Recursive parameter estimation of regression model when the interval of possible values is given. *Kybernetika*, 18(2), pp. 164–178, 1982.

[3] M. Kárný and L. Pavelková. Projection-based Bayesian recursive estimation of ARX model with uniform innovations. *Systems & Control Letters*, 56(9/10), pp. 646–655, 2007.

[4] P. Ettler and M. Kárný. Parallel Estimation Respecting Constraints of Parametric Models of Cold Rolling. *Proceedings of the 13th IFAC Symposium on Automation in Mining, Mineral and Metal Processing*, Cape Town, pp. 63–68, 2010.

[1]COMPUREG Plzeň, s.r.o., *ettler@compureg.cz*

Nonlinear State Estimation with Missing Observations Based on Mathematical Programming

[1]Pavelková Lenka

The contribution deals with two problems in the state estimation – a bounded uncertainty and missing measurement data – which frequently occur in many practical application. An algorithm for the state estimation of a non-linear discrete-time state-space model with bounded uncertainty (SU model) is proposed here that copes with situations when some data for identification are missing. An estimation of the state and measurement noise bounds is included into the proposed algorithm.

The Bayesian approach is used and maximum a posteriori probability estimates (MAP) are evaluated. As the model uncertainties are supposed to have a bounded support, the searched estimates lie within an area that is described by the system of inequalities. In consequence, the problem of MAP estimation becomes the problem of nonlinear mathematical programming (NLP). The estimation with missing measurements data reduces to the omission of corresponding inequalities in NLP formulation.

The proposed estimation algorithm is applied to the off-line estimation of a moving vehicle position. The position is measured by global positioning system (GPS) but outages occur in the measurements. During these outages, the actual position is estimated using data from the inertial measurement sensors as velocity and yaw rate. A model of the moving vehicle is constructed using kinematics laws. This model can be applied on an arbitrary type of ground vehicle.

The contribution also discusses a setting of initial conditions for the estimation process. To prevent numerical instability of the algorithm based on NLP, a starting point of the optimization has to be set appropriately. Here, we propose its setting in the following way. We construct simplified model of moving vehicle whose states coincide with states of the proposed non-linear SU model. The obtained linear uniform state-space model is estimated and resulting state estimate is set as a starting point for the subsequent NLP.

The proposed algorithm is an alternative to the standardly used Kalman filter based algorithms. It is simple to perform and it need no demanding initial setting. Introduced model uses readily available data.

References

[1] J.O. Berger. *Statistical Decision Theory and Bayesian Analysis.* Springer-Verlag, New York, 1985. ISBN 0-521-83378-7.

[2] R. Fletcher. *Practical Methods of Optimization.* John Wiley & Sons, 2000. ISBN: 0471494631.

[3] L. Pavelková. *Estimation of models with uniform innovations and its application on traffic data.* PhD thesis, Czech Technical University in Prague, Faculty of Transportation Sciences, December 2008. http://simu0292.utia.cas.cz/bibl.

[4] L. Pavelková. Nonlinear state Filtering with missing measurements and its application to vehicle position estimation. *Unpublished - submitted to Kybernetika*, 2010.

[1]Institute of Information Theory and Automation, *pavelkov@utia.cas.cz*

Urban Traffic Control – Field Test and Evaluation

[1]Přikryl Jan

In winter 2010, the final test of our traffic control system HRSD took place in real traffic conditions, controlling two intersections at the Zličín shopping center area in Prague [1].

Numerous data modalities have been collected during the HRDS test and during the reference run of the uncontrolled system. These include data from the ELS Area system (vehicle counts and detector occupancies, signal state changes, requested signal plans), from HRSD (preprocessed counts, occupancies, real phase lengths). Approximately 350GB of video data and some travel times on approaches to one of the tested intersections data have been collected automatically. In addition, manual travel time measurement sessions tool place on two distinct week days during system test.

There is a slight discrepancy in the literature concerning the question what shall be considered as an ultimate performance measure for a traffic control system. Indeed, there are several mutually contradictory aspects that such a system should address: an optimal control system helps to maintain a minimal ecological footprint of the controlled traffic, which means keeping the traffic flow as steady as possible, with minimum number of interruptions. At the same time we need to keep the delay of drivers minimal, as the system-optimal delay from the environmental point of view may be too long for common drivers to accept it. Also, our equipment lacks the ability to provide us with point-to-point travel times, with the exception of one approach were the travel times were measured using RFID technology for the purposes of another project. The following quantities were therefore evaluated in our test:

- travel times (manual, RFID – indicates the total delay or speedup introduced by HRSD)
- detector occupancy (indicates waiting outside or inside the controlled system)
- phase length deviations from the requested values (these indicate how good our model is in predicting the within-cycle phenomena)

Preliminary results show that while in shorted periods our system introduces some delays and causes longer waiting times, from the long-term viewpoint HRSD reaches approximately 5 % reduction in occupancy within the controlled area (see Figure 11).

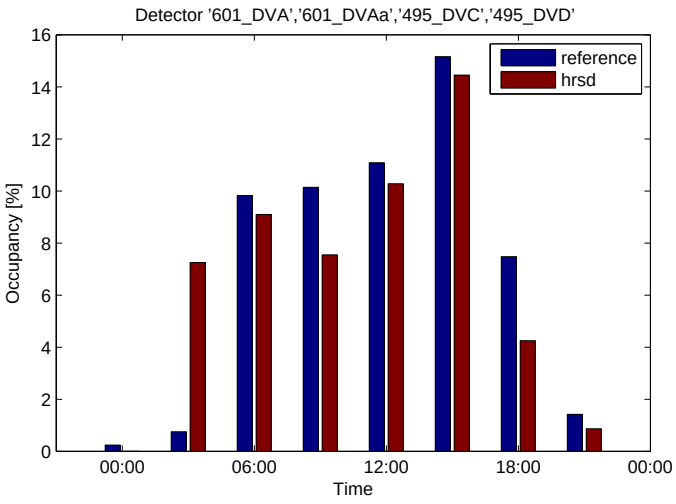
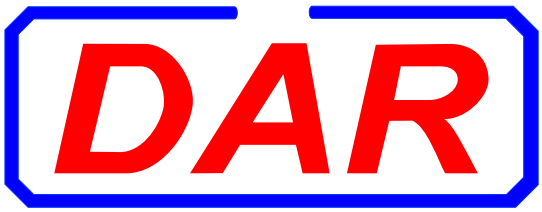


Figure 2: Average occpuancy on a cross-section between intersections 5.495 and 5.601.

References

[1] Tichý T., Musílek P., Zobaník P., Šeps L., Vaněk D., Přikryl J., Pecherková P. Řízení skupiny křižovatek v oblasti OC Zličín – studie. Internal report ÚTIA no. 2271, 2009.

[1]Department of Adaptive Systems, ÚTIA, *prikryl@utia.cas.cz*



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

Session 6.

Decision-making and Classification

December 3, 2010, Afternoon

Chairman: Martin Janžura

Asymptotic Properties and Numerical Comparison Spacings-based Power Divergence Statistics

[1]Boček Pavel , [2]Vajda Igor , [3]van der Meulen Edward

The asymptotic results of [3] are specialized to the case of power divergence statistics, which are generated by the so-called power functions ϕ_α defined for all powers $\alpha \in \mathcal{R}$. Closed form expressions are obtained for the asymptotic parameters of these power divergence statistics for $\alpha \in (-1, \infty)$, and their continuity in α on the subinterval $(-1/2, \infty)$ is proved. These closed form expressions are used to compare local asymptotic powers of tests based on these statistics. Tables of values of the asymptotic parameters are presented for selected representative orders of $\alpha > -1/2$. A program package PODISTAT was developed for the evaluation of several power divergence spacings statistics. These programs are applied to compare three families of spacings-based power divergence statistics for a specific hypothetical distribution and two examples of data sets.

References

[1] I. Vajda and E.C. van der Meulen. *Divergences Between Models and Data under Hypothetical and Empirical Quantiles*. Res. Report No. 2275, Institute of Information Theory and Automation, Prague (*available online at* **http://simu0292.utia.cas.cz/vajda/RR2274**), 2010.

[2] I. Vajda and E.C. van der Meulen. *Goodness-of-fit Criteria based on Observations Quantized by Hypothetical and Empirical Percentiles*. Chapter 23 of *Handbook of Fitting Statistical Distributions with R* (eds. Z.Karian and E.J.Dudewicz), CRC Press, to appear October 2010.

[3] I. Vajda and E.C. van der Meulen. Limit theorems and asymptotic equivalence for a class of spacings-based ϕ-disparity statistics. Abstract, *Prague Stochastics 2010* .

[1]ÚTIA AVČR, Czech Republic, *bocek@utia.cas.cz*
[2]ÚTIA AVČR, Czech Republic,
[3]Katholieke Universiteit Leuven, Belgium, *edward.vandermeulen@wis.kuleuven.be*

Application of a Random Regression Coefficient Model to Small Area Estimation

[1]Hobza Tomáš , [2]Morales Domingo

One of the targets of sampling designs is to produce reliable direct estimates for some given domains. Sample sizes within these planned domains are in general fixed a priori and large enough to achieve the required efficiency conditions. If statisticians are also asked to produce estimates for smaller domains (unplanned domains) the direct estimates are no longer precise as they are based on small sample sizes. The small area estimation approach gives a solution to this problem by introducing models that borrow strength from other areas and variables or from data relationships. The book of Rao (2003), and the reviews of Ghosh and Rao (1994), Rao (1999), Pfeffermann (2002) and Jiang and Lahiri (2006), give nice descriptions of this theory.

Coefficients of auxiliary variables (beta parameters) in the standard nested error model are not allowed to vary across sampling units or domains. This assumption is too rigid in many practical situations. The random coefficient models avoid this problem and give a more flexible way of modelling. This contribution takes the idea of Moura and Holt (1999) of using multilevel models and investigate the application of random coefficient models to the estimation of Spanish household normalized net annual incomes.

References

[1] Ghosh, M. and Rao, J.N.K. (1994). Small area estimation: An appraisal. *Statistical Science*, **9**, 55-93.

[2] Jiang, J. and Lahiri, P. (2006). Mixed model prediction and small area estimation. *Test*, **15**, 1-96.

[3] Moura, F.A.S. and Holt, D. (1999). Small area estimation using multilevel models. *Survey Methodology*, **25**, N. 1, 73-80.

[4] Pfeffermann D (2002). Small Area Estimation. New Developments and Directions. *International Statistical Review*, **70**, 125-143.

[5] Rao, J.N.K. (1999). Some recent advances in model-based small area estimation. *Survey Methodology*, **25**, 175-186.

[6] Rao, J.N.K. (2003). *Small Area Estimation*. John Wiley.

[1]Institute of Information Theory and Automation, Department of Stochastic Informatics, *hobza@fjfi.cvut.cz*
[2]University of Miguel Hernández, Operational Research Center, *d.morales@umh.es*

Canonical Tensor Decomposition and Its Use in Feature Extraction and Signal Classification, and in Blind Separation of Underdetermined Mixtures

[1]Tichavský Petr

Modern applications such as those in neuroscience, text mining, and pattern recognition generate massive amounts of multimodal data exhibiting dimensionality. Tensors (i.e., multi-way arrays) provide a natural representation for such data, and tensor decomposition and factorizations are emerging as promising tools for exploratory analysis of multidimensional data, feature extraction and signal classification. A few examples will be given.

The tensor decompositions can be also used to blindly separate underdetermined instantaneous mixtures of mutually independent nonstationary sources. The adjective *underdetermined* means that the number of sources exceeds the number of channels of the available data. The separation is based on the working assumption that the sources are piecewise stationary with a different variance in each block. It proceeds in two steps: (1) estimating the mixing matrix, and (2) computing the optimum beamformer in each block to maximize the signal-to-interference ratio of each separated signal with respect to the remaining signals. Estimating the mixing matrix is accomplished through a specialized tensor decomposition of the set of sample covariance matrices of the received mixture in each block. It utilizes optimum weighting, which allows statistically efficient (CRB attaining) estimation provided that the data obey the assumed Gaussian piecewise stationary model. In simulations, performance of the algorithm is successfully tested on blind separation of 16 speech signals from 9 linear instantaneous mixtures of these signals.

References

[1] A. Cichocki, R. Zdunek, A.H. Phan and S.I. Amari. *Nonnegative Matrix and Tensor Factorizations: Applications to Exploratory Multi-Way Data Analysis and Blind Source Separation*, Wiley, 2009.

[2] A.H. Phan and A. Cichocki. Tensor decompositions for feature extraction and classification of high dimensional datasets. 2010 International Symposium on Nonlinear Theory and its Applications (NOLTA), Krakow, Poland, September 5-8, 2010.

[3] L. De Lathauwer, J. Castaing. Blind identification of underdetermined mixtures by simultaneous matrix diagonalization. *IEEE Tr. Signal Processing*, 56:1096–1105, 2008.

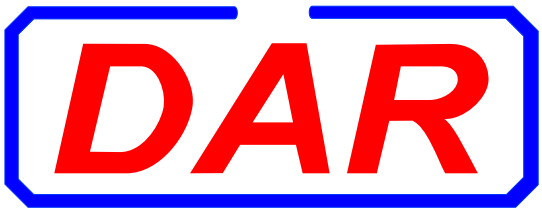
[4] P. Paatero. A weighted non-negative least squares algorithm for three-way 'PARAFAC' factor analysis. *Chemometrics and Intelligent Laboratory Systems*, 38:223–242, 1997.

[5] P. Tichavský and Z. Koldovský. Simultaneous search for all modes in multilinear models. *Proc. ICASSP 2010*, Dallas, TX, March 14-19, 2010, pp. 4114-4117.

[6] P. Tichavský and Z. Koldovský. Weight adjusted tensor method for blind separation of underdetermined mixtures of nonstationary sources. *IEEE Tr. Signal Processing*, to appear.

[7] P. Tichavský. A Matlab p-code for UDSEP, http://si.utia.cas.cz/Tichavsky.html

[1]Institute of Information Theory and Automation, Dept. of Stochastic Informatics, *tichavsk@utia.cas.cz*



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

Session 7.

Multidimensional Signal Processing and Pattern Recognition

December 4, 2010, Morning

Chairman: Michal Haindl

Advances in Image Modelling and Recognition

[1]Haindl Michal

Recent achievements in the area of image modelling and recognition applied to multispectral bidirectional texture function (BTF) synthesis and editing, unsupervised range video segmentation, content-based image retrieval, illumination invariants, multichannel image restoration, and several other applications are briefly outlined. A novel generative colour texture model based on multivariate Bernoulli mixtures [1] was developed for textile materials. Our efficient compound Markov random field model [6] is capable of high quality modelling of real surfaces represented by the multispectral bidirectional texture function. The model combines a non-parametric control random field with analytically solvable widesense Markov representation for single regions. Another method for seamless enlargement and editing of intricate near-regular type of BTF which contains simultaneously both regular periodic and stochastic components was proposed. The algorithm combines our roller method for regular periodic components, while the random part is synthesised from its estimated exceptionally efficient Markov random field based representation. A content-based tile retrieval system [1] was built to ease labourious browsing of tile catalogues. Single tiles are represented by our colour invariant textural features [8, 9]. An unsupervised range video segmentation method based on a spatial Markovian model was published in [4]. The resulting segmentation allows moving objects tracking and simultaneous estimation of their distance and velocity.

References

[1] Filip J., Vacha P., Haindl. M, Green P.R. A Psychophysical Evaluation of Texture Degradation Descriptors. Proceedings of IAPR International Workshop on Structural, Syntactic, and Statistical Pattern Recognition (SSPR & SPR 2010), LNCS 6218, pp. 423-433, Cesme, Izmir, Turkey, August 18-20, 2010

[2] Filip, J., Haindl, M., Chantler, M.J. Gaze-Motivated Compression of Illumination and View Dependent Textures. 20th ICPR, pp. 862-865, IEEE Computer Society CPS, 2010.

[3] M. Haindl, V. Havlíček, and J. Grim, *Colour Texture Representation Based on Multivariate Bernoulli Mixtures*. ISSPA 2010, pp. 578–581, IEEE, 2010.

[4] M. Haindl, P. Žid, and R. Holub, *Range Video Segmentation*. ISSPA 2010, pp. 369–372, IEEE, 2010.

[5] M. Haindl and M. Hatka, *Near-Regular BTF Texture Model*. 20th ICPR, pp. 2114-2117, IEEE Computer Society CPS, 2010.

[6] M. Haindl and V. Havlíček, *A Compound MRF Texture Model*. 20th ICPR, pp. 1792-1795, IEEE Computer Society CPS, 2010.

[7] P. Vacha and M. Haindl. Content-based tile retrieval system. In E. R. Hancock, R. C. Wilson, T. Windeatt, I. Ulusoy, and F. Escolano, eds., *Structural, Syntactic, and Statistical Pattern Recognition*, *LNCS* 6218, pp. 434–443, 2010.

[8] P. Vácha and M. Haindl, Natural Material Recognition with Illumination Invariant Textural Features. 20th ICPR, pp. 858-861, IEEE Computer Society CPS, 2010.

[9] P. Vácha and M. Haindl, Illumination Invariants Based on Markov Random Fields. Pattern Recognition, Recent Advances, ISBN 978-953-7619-90-9, pp. 253–272, In-Teh, Croatia, 2010.

[1]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *haindl@utia.cas.cz*

Feature Selection in Statistical Pattern Recognition

(A Review of UTIA Pattern Recognition Group's Recent Contributions)

[1]Pudil Pavel , [2]Somol Petr

A broad class of decision-making problems can be solved by learning approach. This can be a feasible alternative when neither an analytical solution exists nor the mathematical model can be constructed. In these cases the required knowledge can be gained from the past data which form the so-called learning or training set. Then the formal apparatus of statistical pattern recognition can be used to learn the decision-making. The first and essential step of statistical pattern recognition is to solve the problem of feature selection – or more generally – dimensionality reduction.

The methodology of feature selection in statistical pattern recognition will be presented with respect to results produced within the DAR project framework, particularly in cooperation with our late colleague Jana Novovičová - the renowned expert in statistical modeling and text categorization.

The main aspects of the Feature Selection problem, with direct connection to classification tasks, will be mentioned. The knowledge-based approach has been developed by our group to cover a broader spectrum of situations where feature selection methods are to be used. It includes some already "classical" and highly cited methods and algorithms like floating search methods, adaptive floating search, oscillating search, feature selection based on approximation of probabilistic densities by mixtures, fast branch-and-bound algorithm, dynamic oscillation and flexible-hybrid sequential floating search which will be outlined. Recently discussed topics and related problems will be briefly covered as well, including the problem of feature over-selection, feature selection stability, and automated determination of the suitable feature subset size.

The potential of Feature Selection to improve both the performance and economy of Pattern Recognition systems will be advocated and illustrated on real-world applications.

References

[1] Kudo, M. & Sklansky, J. (2000). Comparison of algorithms that select features for pattern classifiers. *Pattern Recognition*, 33(1), 25–41.

[2] Novovičová, J.; Pudil, P., & Kittler, J. (1996). Divergence based feature selection for multimodal class densities. *IEEE Trans. Pattern Anal. Mach. Intell.*, 18(2), 218–223.

[3] Pudil, P.; Novovičová, J., & Kittler, J. (1994). Floating search methods in feature selection. *Pattern Recogn. Lett.*, 15(11), 1119–1125.

[4] Somol, P.; Novovičová, J., & Pudil, P. (2006). Flexible-hybrid sequential floating search in statistical feature selection. In LNCS 4109 pp. 632–639. Berlin / Heidelberg, Germany: Springer-Verlag.

[5] Somol, P. & Novovičová, J. (2008a). Evaluating the stability of feature selectors that optimize feature subset cardinality. In *Structural, Syntactic, and Statistical Pattern Recognition*, volume LNCS 5342 pp. 956–966.

[6] P. Somol and J. Novovičová, "Evaluating stability and comparing output of feature selectors that optimize feature subset cardinality," *IEEE Trans. PAMI*, vol. 32, pp. 1921–1939, 2010.

[7] Novovičová, J.; Somol, P., & Pudil, P. (2006). Oscillating feature subset search algorithm for text categorization. In *Structural, Syntactic, and Statistical Pattern Recognition*, volume LNCS 4109 pp. 578–587. Berlin / Heidelberg, Germany: Springer-Verlag.

[8] Somol, P.; Novovičová, J.; Grim, J., & Pudil, P. (2008b). Dynamic oscillating search algorithms for feature selection. In *ICPR 2008* Los Alamitos, CA, USA: IEEE Computer Society.

[9] Somol, P.; Pudil, P.; Novovičová, J., & Paclík, P. (1999). Adaptive floating search methods in feature selection. *Pattern Recogn. Lett.*, 20(11-13), 1157–1163.

[1]Prague University of Economics, Faculty of Management, *pudil@fm.vse.cz*
[2]UTIA, CAS, Dept. of Pattern Recognition, *somol@utia.cas.cz*

Introducing Feature Selection Toolbox 3 – The C++ Library for Subset Search, Data Modeling and Classification

[1]Somol Petr , [2]Vácha Pavel , [3]Mikeš Stanislav , [4]Hora Jan , [5]Pudil Pavel , [6]Žid Pavel

We introduce a new standalone widely applicable software library for feature selection (also known as attribute or variable selection), capable of reducing problem dimensionality to maximize the accuracy of data models, performance of automatic decision rules as well as to reduce data acquisition cost. The library can be exploited by users in research as well as in industry. Less experienced users can experiment with different provided methods and their application to real-life problems, experts can implement their own criteria or search schemes taking advantage of the toolbox framework. In this presentation we first provide a concise survey of a variety of existing feature selection approaches. Then we focus on a selected group of methods of good general performance as well as on tools surpassing the limits of existing libraries, e.g., generalization-improving tools like criterion ensembles, result regularization, etc. We build a feature selection framework around them and design an object-based generic software library. We describe the key design points and properties of the library. The library is published at http://fst.utia.cz.

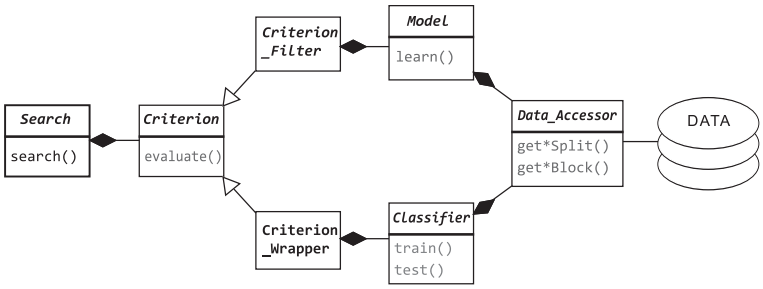


Figure 3: FST3 library architecture – simplified global overview

References

[1] H. Liu and L. Yu, "Toward integrating FS algorithms for classification and clustering," *IEEE Trans. on KDE*, vol. 17, no. 4, pp. 491–502, 2005.

[2] Š. J. Raudys, "Feature over-selection," in *Proc. S+SSPR*, vol. LNCS 4109. Springer, 2006, pp. 622–631.

[3] I. Gheyas and L. Smith, "Feat. sub. sel. in large dimens. domains," *Pattern Recognition*, vol. 43, no. 1, pp. 5–13, 2010.

[4] P. Somol, J. Grim, and P. Pudil, "The problem of fragile feat. subset preference in FS methods and a proposal of algorithmic workaround," in *ICPR 2010*. IEEE Comp. Sc., 2010.

[5] P. Somol and J. Novovičová, "Evaluating stability and comparing output of feature selectors that optimize feature subset cardinality," *IEEE Transactions on PAMI*, vol. 32, pp. 1921–1939, 2010.

[6] M. Hall, E. Frank, G. Holmes, B. Pfahringer, P. Reutemann, and I. H. Witten, "The WEKA data mining software: an update," *SIGKDD Explor. Newsl.*, vol. 11, no. 1, pp. 10–18, 2009.

[7] P. Somol, J. Novovičová, and P. Pudil, *Efficient Feature Subset Selection and Subset Size Optimization.* INTECH, 2010, pp. 75–97. [Online]. Available: http://www.sciyo.com/books/show/title/pattern-recognition-recent-advances

[1]Dept. of Pattern Recognition, UTIA, CAS, *somol@utia.cas.cz*
[2]Dept. of Pattern Recognition, UTIA, CAS, *vacha@utia.cas.cz*
[3]Dept. of Pattern Recognition, UTIA, CAS, *xaos@utia.cas.cz*
[4]Dept. of Pattern Recognition, UTIA, CAS, *hora@utia.cas.cz*
[5]Faculty of Management, Prague University of Economics, *pudil@fm.vse.cz*
[6]Dept. of Pattern Recognition, UTIA, CAS, *zid@utia.cas.cz*

Material Classification with Minimal Feature Sets

[1]Geusebroek Jan-Mark

In this presentation, I will discuss classifying material texture from a single image under unknown viewing and lighting conditions. The current and successful approach to this task is to treat it as a statistical learning problem and learn a classifier from a set of training images, but this requires a sufficient number and variety of training images. We show that the number of training images required can be drastically reduced (to as few as three) by synthesizing additional training data using photometric stereo. Furthermore, we show that natural image statistics can be used to further reduce the feature space to as few as six dimensions. These dimensions correspond to the parameters of a Weibull distribution fitted to the data. We demonstrate the method on the PhoTex and ALOT texture databases.

[1]University of Amsterdam, Faculty of Science, Informatics Institute, Intelligent Systems Lab Amsterdam, *geusebroek@uva.nl*

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

Poster Session

December 2, 2010

Chairman: Jan Flusser

Colour Texture Representation Based on Multivariate Bernoulli Mixtures

[1]Haindl Michal , [2]Havlíček Vojtěch , [3]Grim Jiří

A novel generative colour texture model based on multivariate Bernoulli mixtures [1] is proposed. A measured multispectral texture is spectrally factorised and multivariate Bernoulli mixtures are further learned from single bit planes of the orthogonal monospectral components and used to synthesise and enlarge these monospectral binary factor components. Texture synthesis is based on easy computation of arbitrary conditional distributions from the model. Finally single synthesised monospectral texture bit planes are transformed into the required synthetic multispectral texture. This model can easily serve not only for texture enlargement but also for segmentation, restoration, and retrieval or to model single factors in complex Bidirectional Texture Function (BTF) space models [2]. The strengths and weaknesses of the presented Bernoulli mixture based approach are demonstrated on several colour texture examples. The example on Fig. 4 illustrates properties of our BM model on relatively regular natural gingham texture which is notoriously difficult for some alternative texture models [2].

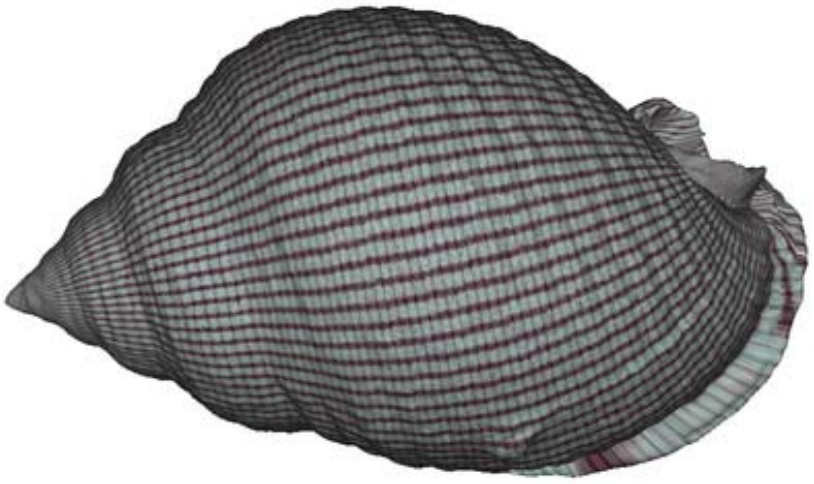


Figure 4: Synthetic gingham texture mapped on a our snail shell model.

References

[1] M. Haindl, V. Havlíček, and J. Grim, *Colour Texture Representation Based on Multivariate Bernoulli Mixtures.* ISSPA 2010, pp. 578–581, IEEE, 2010.

[2] M. Haindl and J. Filip, "Extreme compression and modeling of bidirectional texture function," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 29, no. 10, pp. 1859–1865, 2007.

[1]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *haindl@utia.cas.cz*
[2]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *havlicek@utia.cas.cz*
[3]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *grim@utia.cas.cz*

A Compound MRF Texture Model

[1]Haindl Michal , [2]Havlíček Vojtěch

This paper describes a novel compound Markov random field model [1] capable of realistic modelling of multispectral bidirectional texture function, which is currently the most advanced representation of visual properties of surface materials. The proposed compound Markov random field model combines a non-parametric control random field with analytically solvable widesense Markov representation for single regions and thus allows to avoid demanding Markov Chain Monte Carlo methods for both parameters estimation and the compound random field synthesis. Resulting synthetic more complex textures (such as the ceiling panel on Fig.8) have generally better visual quality (there is no any usable analytical quality measure) than textures synthesised using our previously published (e.g. [2]) simpler MRF models.

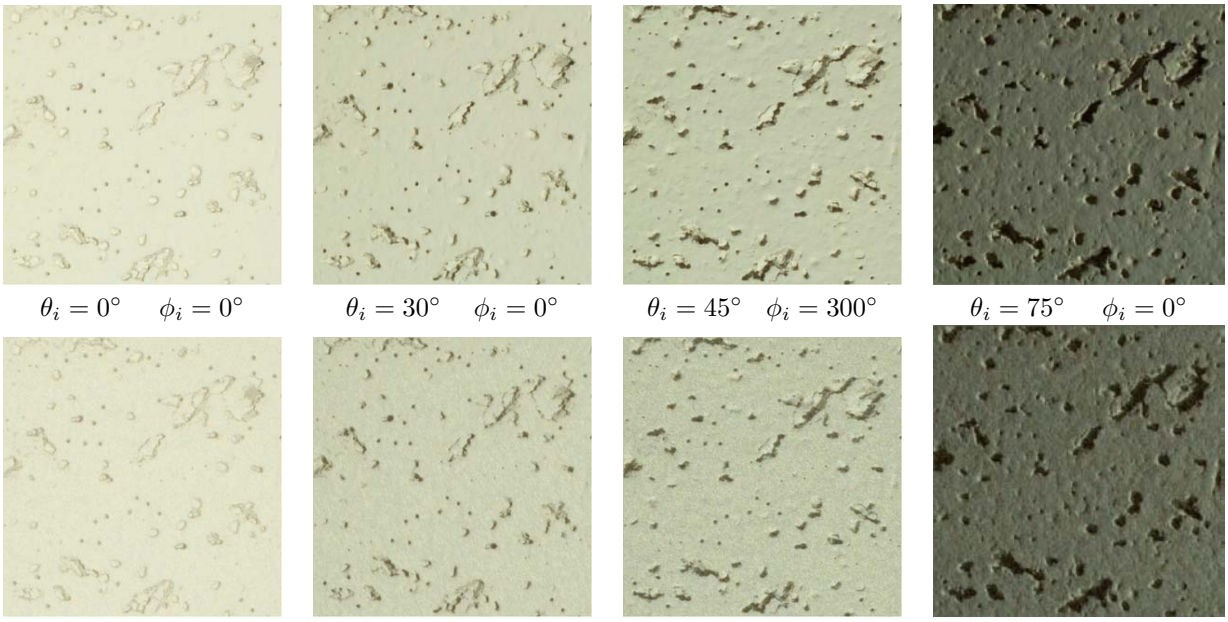


Figure 5: BTF ceiling panel texture measurements (upper row) and their synthetic counterparts for various elevation (θ_i) and azimuthal (ϕ_i) illumination angles.

References

[1] M. Haindl, V. Havlíček, *A Compound MRF Texture Model.* 20th ICPR, pp. 1792-1795, IEEE Computer Society CPS, 2010.

[2] M. Haindl and J. Filip, "Extreme compression and modeling of bidirectional texture function," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 29, no. 10, pp. 1859–1865, 2007.

[1]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *haindl@utia.cas.cz*
[2]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *havlicek@utia.cas.cz*

Content-Based Tile Retrieval System

[1]Vácha Pavel , [2]Haindl Michal

We present a content-based tile retrieval system [1] built to ease laborious browsing of tile catalogues. This computer-aided consulting system retrieves tiles from digital catalogues, so that the retrieved tiles have as similar pattern and/or colours to the query tile as possible.

The system is based on the underlying multispectral Markov random field representation. Single tiles are represented by our approved colour invariant textural features [2] derived from especially efficient Markovian statistics and supplemented with Local Binary Patterns (LBP) features [3] representing occasional tile inhomogeneities. Markovian features are invariant to illumination colour and robust to illumination direction variations, therefore an arbitrary illuminated tiles do not negatively influence the retrieval result. Tile colours are represented by marginal cumulative histograms.

Our system is verified on a large commercial tile database in a psychophysical experiment. Moreover, an interactive demonstration is available online at `http://cbir.utia.cas.cz/tiles/`.

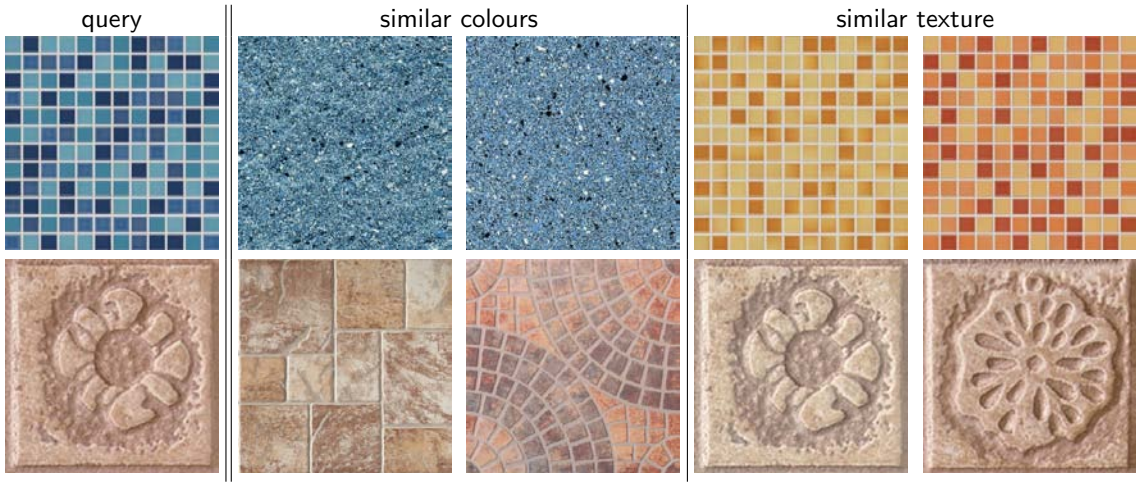


Figure 6: Examples of similar tiles retrieved by our system. The query image, on the left, is followed by two images with similar colours and texture. The images are from the internet tile shop `http://sanita.cz` .

Acknowledgement
The authors thank all and every volunteer of the psychophysical experiments.

References

[1] P. Vacha and M. Haindl. Content-based tile retrieval system. In E. R. Hancock, R. C. Wilson, T. Windeatt, I. Ulusoy, and F. Escolano, eds., *Structural, Syntactic, and Statistical Pattern Recognition*, *LNCS* 6218, pp. 434–443, 2010.

[2] P. Vacha and M. Haindl. Illumination invariants based on Markov random fields. in *Proc. of the 19th International Conference on Pattern Recognition, ICPR 2008*, pp. 1–4, 2008.

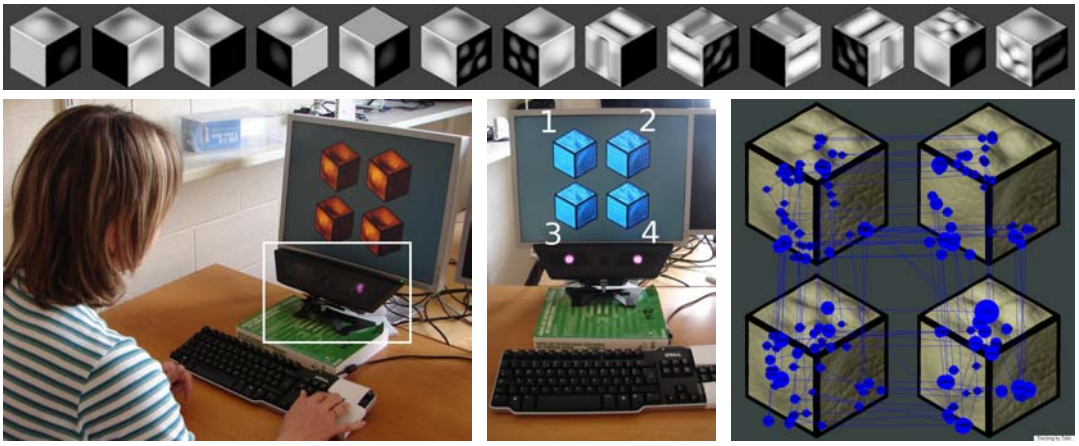
[3] T. Ojala, M. Pietikäinen, and D. Harwood. A comparative study of texture measures with classification based on feature distributions. *Pattern Recognition*, 29(1):51–59, 1996.

[1]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *vacha@utia.cas.cz*
[2]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *haindl@utia.cas.cz*

A Psychophysical Evaluation of Texture Degradation Descriptors

[1]Filip Jiří , [2]Vácha Pavel , [3]Haindl Michal , [4]Green Patrick R.

Delivering digitally a realistic appearance of materials is one of the most difficult tasks of computer vision. Accurate representation of surface texture can be obtained by means of view- and illumination-dependent textures. However, this kind of appearance representation produces massive datasets so their compression is inevitable. For optimal visual performance of compression methods, their parameters should be tuned to a specific material. We propose a set of statistical descriptors motivated by textural features, and psychophysically evaluate their performance on three subtle artificial degradations of textures appearance. We tested five types of descriptors on five different textures and combination of thirteen surface shapes and two illuminations. We found that descriptors based on a two-dimensional causal auto-regressive model, have the highest correlation with the psychophysical results, and so can be used for automatic detection of subtle changes in rendered textured surfaces in accordance with human vision.



Tested combinations of shapes and illumination directions, setup of the psychophysical experiment, example stimuli image, and recorded gaze fixation pattern.

References

[1] Filip J., Vacha P., Haindl. M, Green P.R. A Psychophysical Evaluation of Texture Degradation Descriptors. Proceedings of IAPR International Workshop on Structural, Syntactic, and Statistical Pattern Recognition (SSPR & SPR 2010), LNCS 6218, pp. 423-433, Cesme, Izmir, Turkey, August 18-20, 2010

[1]ÚTIA AV ČR, Pattern Recognition Department, *jiri.filip@utia.cz*
[2]ÚTIA AV ČR, Pattern Recognition Department, *vacha@utia.cz*
[3]ÚTIA AV ČR, Pattern Recognition Department, *haindl@utia.cz*
[4]School of life sciences, Heriot-Watt University, Scotland, *P.R.Green@hwu.ac.uk*

The Problem of Fragile Feature Subset Preference in Feature Selection Methods and A Proposal of Algorithmic Workaround

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

We point out a problem inherent in the optimization scheme of many popular feature selection methods. It follows from the implicit assumption that higher feature selection criterion value always indicates more preferable subset even if the value difference is marginal. This assumption ignores the reliability issues of particular feature preferences, over-fitting and feature acquisition cost. We propose an algorithmic extension applicable to many standard feature selection methods allowing better control over feature subset preference. We show experimentally that the proposed mechanism is capable of reducing the size of selected subsets as well as improving classifier generalization.

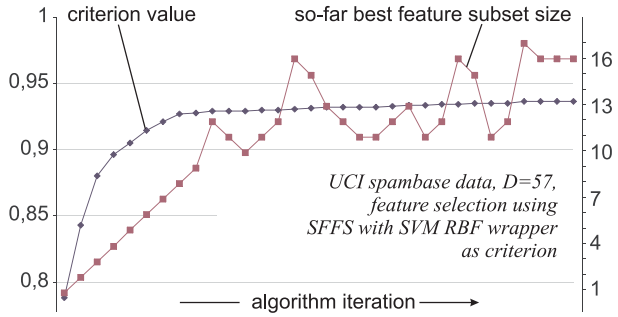


Figure 7: In many FS tasks very low criterion increase is accompanied by fluctuations in selected subsets; both in size and contents

References

[1] I. Guyon and A. Elisseeff. An introduction to variable and feat. sel. *J. Mach. Learn. Res.*, 3:1157–1182, 2003.

[2] F. Hussein, R. Ward, and N. Kharma. Genetic algorithms for feature selection and weighting, a review and study. *icdar*, 00:1240, 2001.

[3] A. Kalousis, J. Prados, and M. Hilario. Stability of feature selection algorithms. *Knowledge and Information Systems*, 12(1):95–116, 2007.

[4] R. Kohavi and G. H. John. Wrappers for feature subset selection. *Artif. Intell.*, 97(1-2):273–324, 1997.

[5] Š. J. Raudys. Feature over-selection. In *Proc. S+SSPR, LNCS 4109*, pages 622–631. Springer-Verlag, 2006.

[6] J. Reunanen. A pitfall in determining the optimal feature subset size. In *Proc. 4th Int. Workshop PRIS*, pages 176–185, Porto, Portugal, 2004.

[7] J. Reunanen. Less biased measurement of feature selection benefits. In *SLSFS 2005, Revised Selected Papers*, volume LNCS 3940, pages 198–208. Springer, 2006.

[8] F. Sebastiani. Machine learning in automated text categorization. *ACM Computing Surveys*, 34(1):1–47, March 2002.

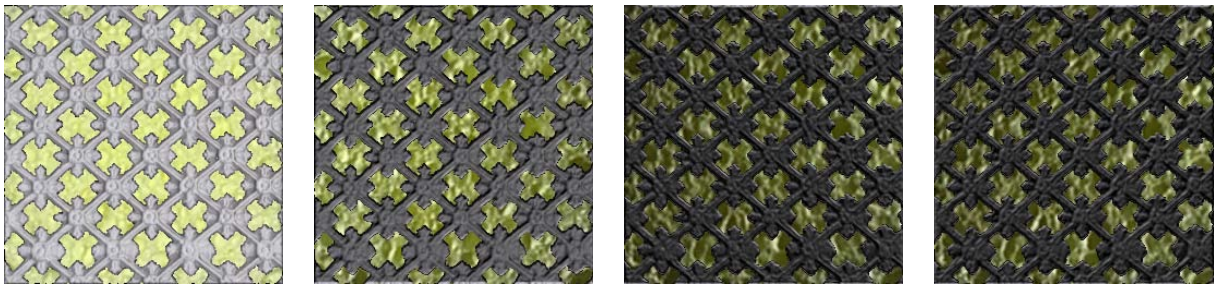
[9] P. Somol, J. Novovičová, J. Grim, and P. Pudil. Dynamic oscillating search algorithms for feature selection. In *Proc. ICPR*. IEEE Computer Society, 2008.

[1]Dept. of Pattern Recognition, UTIA, CAS, *somol@utia.cas.cz*
[2]Dept. of Pattern Recognition, UTIA, CAS, *xaos@utia.cas.cz*
[3]Faculty of Management, Prague University of Economics, *pudil@fm.vse.cz*

Near-Regular BTF Texture Model

[1]Haindl Michal , [2]Hatka Martin

In this paper we present a method for seamless enlargement and editing of intricate near-regular type of bidirectional texture function (BTF) which contains simultaneously both regular periodic and stochastic components. Such BTF textures cannot be convincingly synthesised using neither simple tiling nor using purely stochastic models. However these textures are ubiquitous in many man-made environments and also in some natural scenes. Thus they are required for their realistic appearance visualisation. The principle of the presented BTF-NR synthesis and editing method is to automatically separate periodic and random components from one or more input textures [1]. Each of these components is subsequently independently modelled using its corresponding optimal method. The regular texture part is modelled using our roller method, while the random part is synthesised from its estimated exceptionally efficient Markov random field based representation. Both independently enlarged texture components from the original measured textures representing one (enlargement) or several (editing) materials are combined in the resulting synthetic near-regular texture. Fig.8 demonstrates a BTF editing application, where the foreground iron texture was detected from one non-BTF image while the background texture was estimated from the BTF measurements.



$\theta_i = 0^\circ \quad \phi_i = 0^\circ$ $\theta_i = 60^\circ \quad \phi_i = 162^\circ$ $\theta_i = 75^\circ \quad \phi_i = 15^\circ$ $\theta_i = 75^\circ \quad \phi_i = 345^\circ$

Figure 8: BTF sponge textures with grille for various elevation (θ_i) and azimuthal (ϕ_i) illumination angles.

References

[1] M. Haindl, M. Hatka, *Near-Regular BTF Texture Model.* 20th ICPR, pp. 2114-2117, IEEE Computer Society CPS, 2010.

[2] J. Filip and M. Haindl, "Bidirectional texture function modeling: A state of the art survey," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 31, no. 11, pp. 1921–1940, 2009.

[1]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *haindl@utia.cas.cz*
[2]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *hatka@utia.cas.cz*

Range Video Segmentation

[1]Haindl Michal , [2]Žid Pavel , [3]Holub Radek

An unsupervised range video segmentation method based on a spatial probabilistic model for intended vehicle-based safety and warning system applications is introduced. Statistical range data discontinuities are represented by a wide-sense Markov model [1] which guides the subsequent line-based region growing process [2]. Single frame segmentations [3] are mutually corrected using the continuity constraint. The resulting segmentation allows tracking moving objects and estimating their distance and velocity. The method is illustrated on synthetic range video data. The algorithm can be easily paralleled to reach real time performance on recent multiple-core processors. Estimated car distances for single frames in meters are denoted in Fig.9 their precision was always better than 8 centimeters in every frame.

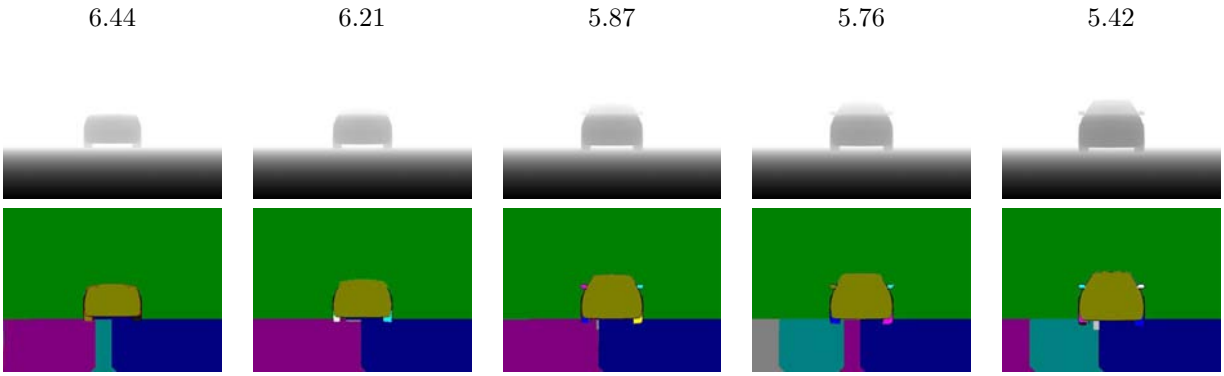


Figure 9: Range video frames (odd image rows) their corresponding segmentation and estimated car distances from range camera in meters.

References

[1] M. Haindl, P. Žid, and R. Holub, *Range Video Segmentation.* ISSPA 2010, pp. 369–372, IEEE, 2010.

[2] M. Haindl and P. Žid, *Fast segmentation of range images.* Lecture Notes in Computer Science, no. 1310, pp. 295–302, 1997.

[3] M. Haindl and P. Žid, *Fast segmentation of plannar surfaces in range images.* 14th ICPR, pp. 985–987, IEEE CS, 1998.

[1]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *haindl@utia.cas.cz*
[2]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *zid@utia.cas.cz*
[3]Institute of Information Theory and Automation of the ASCR, Department of Pattern Recognition, *rh@utia.cas.cz*

Fast Moment Computation Based on Block Decomposition

[1]Suk Tomáš , [2]Flusser Jan

A new method of moment computation based on decomposition of the object into rectangular blocks is presented. The decomposition is accomplished by means of incremental distance transform. The method is compared with earlier morphological methods, namely with erosion decomposition to squares. All the methods are also compared with direct computation by definition.

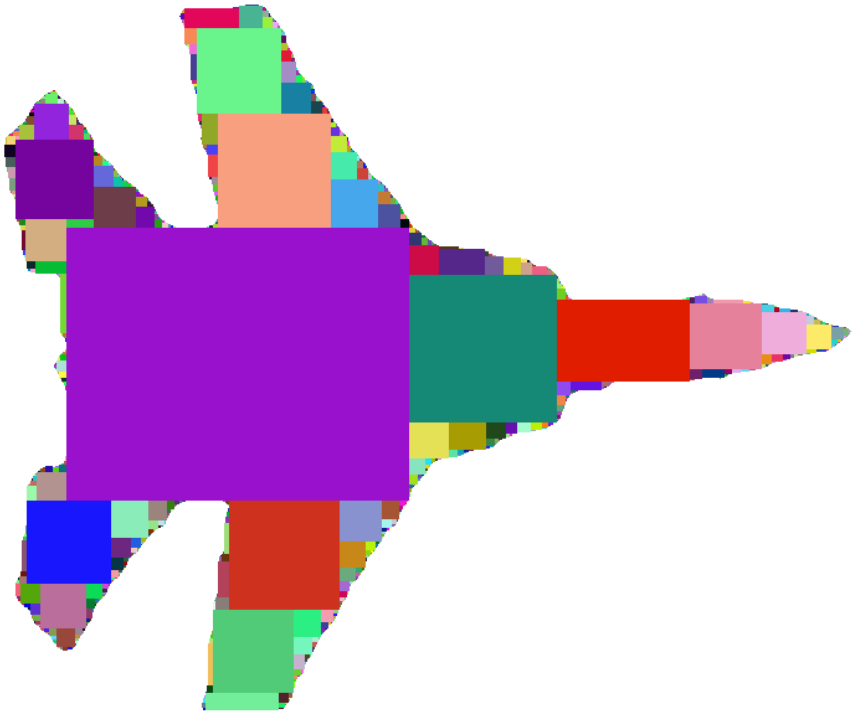


Figure 10: Example of decomposition

References

[1] Jan Flusser, Tomáš Suk, and Barbara Zitová, *Moments and Moment Invariants in Pattern Recognition*, Wiley, Chichester, 2009.

[2] Tomáš Suk and Jan Flusser, "Refined morphological methods of moment computation," in *20th International Conference on Pattern Recognition ICPR'10*. August 2010, pp. 966–970, IEEE Computer Society.

[3] Juan Humberto Sossa-Azuela, Cornelio Yáñez-Márquez, and Juan Luis Díaz de León Santiago, "Computing geometric moments using morphological erosions," *Pattern Recognition*, vol. 34, no. 2, pp. 271–276, 2001.

[1]Institute of Information Theory and Automation of the ASCR, Image Processing Department, *suk@utia.cas.cz*
[2]Institute of Information Theory and Automation of the ASCR, Image Processing Department, *flusser@utia.cas.cz*

Multi-market Trading Problem

[1]Zeman Jan

The trading task is challenging problem for most mathematics and economists [3]. The problem is based on price speculation, where the speculator tries to buy cheep commodity contract, wait for price increase and then earn money by reselling the contract. Nowadays, the approaches provided by exchanges allows to speculate on increase and also decrease of the commodity price. Thus, the speculation on market changes in stochastic game, when speculator bets whether the price increase or decrease.

To design the trading strategy, speculators use various methods. The main streams are the fundamental analysis and the technical one. The fundamental analysis assumes that actual price does not reflect the real price, therefore bases predictions on analysis of the market state, actual news and activities of institutions. In contrast, the technical analysis deals primary by price curves to predict the further price behavior.

Classical investing methods based on fundamental analysis (e.g. value investing [2] or indexing [1]) serve primary for stock trading and the for long-time investment in terms of decades. The methods of technical analysis [6], unlike the fundamental one, provides profit in short-time, as it recommends actions more often, i.e. one action per week or month. However, there is no method of technical analysis, which results in profitable strategy working for decades. The viability of these approaches is about a year. Then, it should be completely revised. Beside, the successful methods, if any, are not advertised everywhere and are kept in strict confidence. So up to the author's best knowledge, there is no known methodology how to design optimal strategy for speculators.

Our previous research can be classified as technical analysis, because we work with the price sequences and design the speculator strategy [4, 7]. Moreover, we extend the price sequence by additional channels [5]. But our previous approaches worked with infinite capital to invest and with a single market, because with infinity capital, the multiple market trading can be solved separate market by market.

The paper deals with extension the task for constrained capital and multiple markets, but the task grows exponentially with the number of markets. Therefore the another representation of the task must be searched. We present the representation by participants, where each participant works with one market and communicates with other participants by asking and bidding the capital. The basic experiments and comparing with the original task are presented.

References

[1] J. Bogle *The First Index Mutual Fund: A History of Vanguard Index Trust and the Vanguard Index Strategy.* Bogle Financial Center.

[2] B. Graham *Security Analysis.* McGraw Hill Book Co., 1934.

[3] J. Hull *Options, futures, and other derivatives.* Pearson/Prentice Hall, 2006.

[4] M. Kárný, J. Šindelář, Š. Pírko, J. Zeman. Adaptively optimized trading with futures *Research report, UTIA*, 2009.

[5] J. Šindelář Study of BVAR(p) process applied to U.S. commodity market data. *International Conference on Operations Research and Financial Engineering, ICORFE'09*, 159:951–955, 2009.

[6] StockCharts. *(http://www.stockcharts.org/school/).*

[7] J. Zeman. Futures Trading: Design of a Strategy. *International Conference on Operations Research and Financial Engineering, ICORFE'09*, 159:951–955, 2009.

[1]Institute of Information Theory and Automation, Adaptive systems, *janzeman3@seznam.cz*

Bicriterial Dual Control for Time Variant Stochastic System Using Neural Networks

[1]Král Ladislav , [2]Šimandl Miroslav

Goal of the paper is to design a bicriterial dual control for slowly time variant nonlinear stochastic multivariable systems and thus to provide an extension of authors previous works [1] and [2].

Modelling of unknown nonlinear functions describing a multivariable system is approached via functional approximator represented by multilayer perceptron neural networks. Unknown parameters of the neural networks are considered as time variant and are described by Wiener process. Dependence of output of the model on the parameters of the neural network is nonlinear. Therefore, it is advisable to exploit nonlinear estimation method for finding the unknown parameters [3]. Parameters of the model are estimated by the extended Kalman filter because it is practical, computationally moderate and represents an effective alternative to optimization methods as quasi-Newton, Levenberg-Marquardt, or conjugate gradient techniques [4].

For determination of the control action, a suboptimal dual cost function based on the bicriterial approach is considered [5]. The cost function exploits two separate criterions where each of this criterion introduces one of the conflicting aspects between estimation and control; caution and probing. The first criterion evaluating the control quality and the second criterion expresses the learning effort of the control because it forces an increase of the prediction error to obtain richer information for the parameter update. It should result in an improvement of control quality in a future. Final control law is obtained in an analytical form based on a subsequent minimization of the defined criteria.

The quality of the proposed functional adaptive controller is illustrated in two numerical examples [6]. The proposed approach is compared with adaptive non-dual controller based on the certainty equivalence principle [7]. It is shown that the proposed bicriterial dual adaptive controller is suitable for special time variant non-linear stochastic multivariable systems, and that it is possible to achieve better control quality in comparison with non-dual adaptive controller based on the certainty equivalence principle.

References

[1] Šimandl, M., Král, L., and Hering, P. (2005). Neural network based bicriterial dual control of nonlinear systems. *In: Preprints of the 16th IFAC World Congress.* Prague: IFAC.

[2] Král, L. and Šimandl, M. (2008). Functional adaptive control for multi-input multi-output systems. *In: Preprints of the 17th IFAC World Congress.* Seoul: IFAC.

[3] Chen, F.C. and Khalil, H.K. (1995). Adaptive control of a class of nonlinear discrete-time systems using neural networks. *IEEE Transaction on Automatic Control*, 40(5), 791–801.

[4] Haykin, S. (1999). *Neural Networks: A comprehensive foundation.* Prentice-Hall, Upper Saddle River, NJ, 2nd edition.

[5] Filatov, N.K. and Unbehauen, H. (2004). *Adaptive Dual Control.* Springer-Verlag.

[6] Bugeja, M.K. and Fabri, S.G. (2008). Multilayer perceptron adaptive dynamic control of mobile robots: Experimental validation. *European Robotics Symposium 2008*, 44, 165–174.

[7] Fabri, S.G. and Kadirkamanathan, V. (2001). *Functional Adaptive Control: An Intelligent Systems Approach.* Springer-Verlag.

[1]University of West Bohemia, Department of Cybernetics, *ladkral@kky.zcu.cz*
[2]University of West Bohemia, Department of Cybernetics, *simandl@kky.zcu.cz*

Bayesian Soft Sensing in Cold Sheet Rolling

[1]Dedecius Kamil , [2]Jirsa Ladislav

We are concerned with the theory of soft sensing in industrial applications, namely the cold sheet rolling. In comparison to the classical sensing, the generally cheaper soft sensors provide the ability to process large amounts of measured data, used for building predictive models [1]. To achieve robustness of these sensors, their main purpose – prediction of variables which are not directly measurable – is often accompanied by other important tasks, e.g., the fault detection and diagnosis, control, graceful degradation mechanisms etc. [2].

There are three main approaches to soft sensors: physical modelling, multivariate statistics and artificial intelligence modelling [1]. Some selected approaches comprise the methods using the Kalman filter [3], neural networks [4, 5], statistical methods [6, 7] and many others. We present a Bayesian approach to the statistical soft sensing in the data-driven paradigm. Our goal is to predict a physical variable, which is crucial for the rolling process, but which can be measured only with a high traffic delay. Fortunately there exists a set of other variables measured during the process, which are more or less correlated with the quality of interest. Using a class of several different Bayesian regressive models, determining the predicted value with a reliability generally unknown at the particular time instant, the high predictive performance of the sensor is achieved by their combination in a way inspired by Bayesian model averaging [8]. The approach allows fast adaptivity of the sensor and its graceful degradation if measurements dropouts or hardware failures occur.

References

[1] Fortuna, L. et al. *Soft sensors for monitoring and control of industrial processes*, Springer Verlag, 2007.

[2] Venkatasubramanian, V. et al. *A review of process fault detection and diagnosis*, *Computers & Chemical Engineering*, Elsevier, 27:293–346, 2003.

[3] Joseph, B. and Brosilow, C. *Inferential control of processes*, *AIChE Journal*, Wiley Online Library, 24:485–509, 1978.

[4] Qin, S.J. and McAvoy, T.J. *Nonlinear PLS modeling using neural networks*, *Computers & Chemical Engineering*, Elsevier, 16:379–391, 1992.

[5] Radhakrishnan, V.R. and Mohamed, A.R. *Neural networks for the identification and control of blast furnace hot metal quality*, *Journal of process control*, Elsevier, 10:509–524, 2000.

[6] Park, S. and Han, C. *A nonlinear soft sensor based on multivariate smoothing procedure for quality estimation in distillation columns*, *Computers & Chemical Engineering*, Elsevier, 24:871–877, 2000.

[7] Lin, B. et al. *A systematic approach for soft sensor development*, *Computers & Chemical Engineering*, Elsevier, 31:419–425, 2007.

[8] Hoeting, J.A. et al. *Bayesian model averaging: A tutorial*, *Statistical science*, 14:382–401, 1999.

[1]ÚTIA AV ČR, Department of Adaptive Systems, *dedecius@utia.cas.cz*
[2]ÚTIA AV ČR, Department of Adaptive Systems, *jirsa@utia.cas.cz*

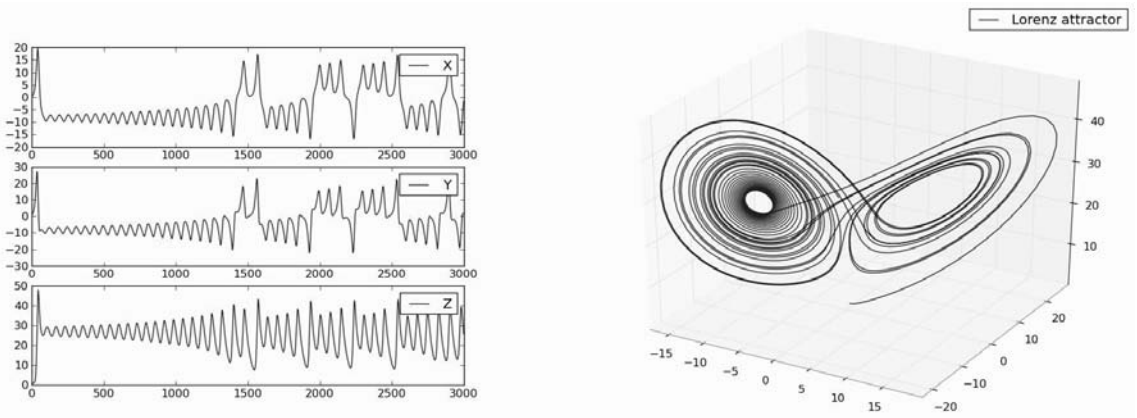
A Hybrid Filtering Methodology for Nonlinear Estimation

[1]Hofman Radek , [2]Dedecius Kamil

We are concerned with Bayesian estimation of a discrete stochastic process governed by a nonlinear model. We employ marginalized particle filter (MPF, [5])—which is also known as Rao-Blackwellised particle filter, [2]—for on-line tuning of nuisance parameters of analytical filters.

Particle filtering [1] is a general filtering methodology applicable to nonlinear and non-Gaussian systems. However, intensive sampling is in high-dimensional spaces computationally prohibitive. MPF arises when the structure of the model allows marginalization over a subset of state variables [5]. Selected state variables are then estimated with an analytical filter and the rest is treated using particle filter. The marginalization substantially reduces the dimension of the space we sample from. This is of particular significance in high-dimensional estimation problems emerging, e.g., in geoscientific applications.

The methodology is demonstrated on estimation of a three-dimensional chaotic nonlinear system given by the Lorenz attractor [4]. We use the extended Kalman filter (EKF, [3]) for estimation of the three coordinates of the attractor and the particle filter for adaptive tuning of model error covariance in EKF. EKF is the nonlinear version of the Kalman filter [6]. It uses linearized version of a nonlinear differentiable state transition function to propagate posterior covariance matrix. Jacobian of the Lorenz attractor is approximated at each time step using forward differences. Observations are simulated by the attractor, which is integrated forward with the fourth-order Runge-Kutta scheme, and perturbed with a Gaussian noise. Satisfactory accuracy of estimation was achieved even with a small number of particles.



References

[1] A. Doucet, N. De Freitas and N. Gordon. *Sequential Monte Carlo methods in practice.* Springer Verlag, 2001.

[2] A. Doucet, N. De Freitas, K. Murphy and S. Russell. *Rao-Blackwellised particle filtering for dynamic Bayesian networks. Proceedings of the Sixteenth Conference on Uncertainty in Artificial Intelligence*, 176–183, 2000.

[3] S. S. Haykin. *Kalman filtering and neural networks.* Wiley Online Library, 2001.

[4] E. N. Lorenz. *Deterministic nonperiodic flow. J. Atmos. Sci.*, 20: 130–141, 1963.

[5] T. Schön, F. Gustafsson and P. J. Nordlund. *Marginalized particle filters for mixed linear/nonlinear state-space models. IEEE Transactions on Signal Processing*, 53:2279–2289, 2005.

[6] D. Simon. *Optimal state estimation: Kalman, H_∞ and nonlinear approaches.* John Wiley and Sons, 2006.

[1]ÚTIA AV ČR, Department of Adaptive Systems, *hofman@utia.cas.cz*
[2]ÚTIA AV ČR, Department of Adaptive Systems, *dedecius@utia.cas.cz*

Variational Bayes Approximation for Distributed Fully Probabilistic Design

[1]Šmídl Václav , [2]Tichý Ondřej

Variational Bayes is a well known technique of approximate Bayesian estimation, [3]. It is based on approximation of the true multivariate posterior density by a product of conditionaly independent densities defined on disjoint parts of the parameters space. The approximate posterior is found by minimization of the Kullback-Leibler divergence between a conditionally independent density and the true posterior. The solution is typically found iteratively using moments of one density to find shaping parameters of the others. This is sometimes known as message passing [5]. Fully probabilistic design of control strategy is an alternative formulation to the classical dynamic programming, [1, 2]. It is based on the use of Kullback Leibler divergence as loss function in dynamic decision-making. The resulting control strategy is found explicitely in the form of probability density function.

In this contribution, we investigate application of the Variational Bayes idea in fully probabilistic design. We are concerned with multi-input multi-output systems, where we seek conditionally independent approximation of the multivariate control strategy. Application of the Variational Bayesian theorem is straightforward. What results is an iterative algorithm in which the conditionally independent startegies are computed in parallel. As typical for Variational Bayes approximations, each startegy needs moments generated withing design of the remaining startegies. The resulting scheme corresponds to the scheme of distributed control where autonomous desision-making units exchange messages with the neighbours. In this particular case, the messages are in the form of conditional probability density functions.

The approach is studied in simulation on a simple 2-input 3-output example. Results are compared with other techniques of distributed fully probabilistic control schemes [4].

References

[1] M. Kárný. Fully probabilistic design: Basis and relationship to Bayesian paradigm. In Ivánek J. Janžura M., editor, *3rd International Workshop on Data - Algorithms - Decision Making*. ÚTIA, 2007.

[2] M. Kárný and T.V. Guy. Preference elicitation in fully probabilistic design of decision strategies. In *Proceedings of the 49th IEEE Conference on Decision and Control*. IEEE, 2010.

[3] V. Šmídl and A. Quinn. *The Variational Bayes Method in Signal Processing*. Springer, 2005.

[4] V. Šmídl. On adaptation of loss functions in decentralized adaptive control. In *Proceedings of the 12th IFAC symposium on Large Scale Systems*, Villeneuve d'Ascq, France, 2010.

[5] J. Winn and C.M. Bishop. Variational message passing. *The Journal of Machine Learning Research*, 6:661–694, 2005.

[1]Institute of Information Theory and Automation, department of Adaptive Systems, *smidl@utia.cas.cz*
[2]Institute of Information Theory and Automation, department of Adaptive Systems, *otichy@utia.cas.cz*

Multimodal Comparison of the Retinal Nerve Fibre Layer

[1]Kolář Radim , [2]Gazárek Jiří , [3]Odstrčilík Jan , [4]Jan Jiří

Glaucoma is characterized by retinal changes, particularly in the region of the optic nerve head and progressive atrophy changes in the retinal nerve fiber layer (RNFL). There is a high effort to diagnose the RNFL analysis using fundus-camera images since the 1980 [1], but until now, there is no routinely used method allowing automated RNFL diagnosis using only fundus camera images. The texture-based approaches provide a promising tool for qualitative RNFL thickness analysis. Nevertheless, the quantitative analysis is also possible using the optical coherent tomographic (OCT) slices, which can visualize retinal layers including nerve fiber layer.

We have used 62 texture parameters using different approaches to investigate the correlation between particular parameter and nerve fibre layer thickness. Due to limited possibilities of acquisition of the high quality color fundus images and the OCT retinal volumes from the same subject, we used only 3 healthy subjects. The texture parameters and nerve fiber layer thickness were evaluated for several retinal positions (and variable RNFL thickness) in each subject. This gave us 225 image patches for analysis. An example of 'very short run' feature obtained from gray-level run length texture analysis is shown in Fig.1 as a dependence on RNFL thickness. The correlation coefficient for this feature is 0.58.

Most of the tested features were correlated with RNFL thickness (correlation coefficient nearly 0.6). We are going to include more subjects to make this analysis more valuable and we will also employ a preprocessing step to increase the correlation between texture features and RNFL thickness.

figure example

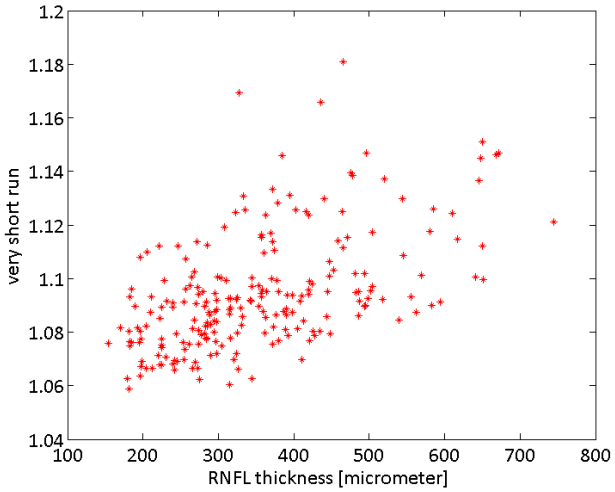


Figure 11: Example of selected texture parameter as a function of RNFL thickness.

References

[1] M. Lundström, O.J. Eklundh Computer Densitometry of Retinal Nerve Fibre Atrophy - a pilot study. *Acta Ophthalmologica*, 58:639–644, 1980.

[1]Brno University of Technology, Department of Biomedical Engineering, *kolarr@feec.vutbr.cz*
[2]Brno University of Technology, Department of Biomedical Engineering, *xgazar03@stud.feec.vutbr.cz*
[3]Brno University of Technology, Department of Biomedical Engineering, *xodstr02@stud.feec.vutbr.cz*
[4]Brno University of Technology, Department of Biomedical Engineering, *jan@feec.vutbr.cz*

Retinal Nerve Fiber Layer Texture Analysis via Markov Random Fields

[1]Odstrčlík Jan , [2]Kolář Radim , [3]Jan Jiří , [4]Gazárek Jiří

Texture analysis of the retinal nerve fiber layer (RNFL) in colour fundus images is a promising tool for early glaucoma diagnosis. This contribution describes model-based method for detection of changes in the RNFL. The method utilizes Gaussian Markov random fields (GMRF) and the least-square error (LSE) estimate for the local RNFL texture modelling. The model parameters are used as a texture features and non-linear Bayesian classifier [2] is used for supervised classification of healthy and glaucomatous RNFL tissue. The proposed textural features are applied for segmentation of RNFL defects in a high-resolution colour fundus-camera images (3504×2336 pixels). The results are qualitatively compared with the Optical Coherence Tomography images regarded us as a gold standard due to the possibility of quantitative RNFL thickness measurement.

Markov random fields texture modeling is an efficient tool enabling description of a probability of spatial interactions in a textural image. The GMRF models an image texture $y(s)$, which is represented by a set of zero mean observations for a rectangular image lattice. The GMRF model is a stationary non-causal two-dimensional autoregressive process assuming that the individual observations are governed by the following difference equation [1]:

$$y = \sum_{r \in N_s} \phi_r y(s+r) + e(s),$$

where N_s is a neighborhood set centered at pixel s, ϕ_r is a model parameter of a particular neighbor r, and $e(s)$ is a stationary Gaussian noise process with zero mean and known variance σ [1].

A neighborhood structure depends directly on the order and the type of the model. We assume a fifth-order symmetric rotation-invariant neighborhood structure on rectangular lattice.

According to this we have 6 parameters (textural features): five parameters describe influence of the neighbors to the central pixel and one Gaussian parameter σ describes model noise variance. These 6 features can be estimated in the least square error (LSE) sense [1].

Manually selected textural regions (97×97 pixels) characterizing three classes of retinal tissue, assuming glaucomatous thickness changes in the RNFL, were used for training three-state Bayesian classifier: Class A - $_{(141)}$ RNFL pattern of glaucomatous patients, Class B - $_{(142)}$ RNFL losses, Class C - $_{(283)}$ RNFL pattern of healthy patients.

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

References

[1] R. Porter, N. . Canagarajah, *Rotation-invariant texture classification: wavelet, Gabor filter and GMRF based schemes*, IEEE Proc. Vis.-Image Signal Processing, vol. 144(3), pp. 180-188, 1997.

[2] P. Paalanen, J. Kamarainen, J. IIonen, H. Kalviainen. *Feature representation and discrimination based on Gaussian mixture model probability densities-Practices and algorithms*, Pattern Recognition, vol. 39(7), pp. 1346-1358, 2006.

[1]Brno University of Technology, Department of Biomedical Engineering, *xodstr02@stud.feec.vutbr.cz*
[2]Brno University of Technology, Department of Biomedical Engineering, *kolarr@feec.vutbr.cz*
[3]Brno University of Technology, Department of Biomedical Engineering, *jan@feec.vutbr.cz*
[4]Brno University of Technology, Department of Biomedical Engineering, *xgazar03@stud.feec.vutbr.cz*

Bimodal Comparison of Retinal Nerve Fibre Layer Thickness: Fundus Camera versus Optical Coherence Tomography

[1]Gazárek Jiří , [2]Jan Jiří

In this paper, preliminary comparisons of the segmentation results from the retinal nerve fibre layer (RNFL) in digital fundus camera (DFC) photo with Optical Coherence Tomography (OCT) results have been done. Early detection of changes in the texture caused by nerve fibres atrophy in DFC images is important for diagnosis of glaucoma. Therefore, the main purpose of this work is focused on the analysis of texture representing RNFL in DFC images. Three local approaches [1] (directional local spectral analysis, edge-evaluation approach and difference of local brightness based approach) have been successfully tested for automatic detection of RNFL. The features provided by these three approaches were used for texture classification and the results compared with the information of thickness obtained by OCT.

In our study five glaucomatous DFC images and corresponding OCT B-scans of the same eyes were considered. Each of the DFC images was labelled by a medical expert. DFC images has been matched together with corresponding OCT B-scans.

The total set of 18 375 measurements were chosen. Three above described features were derived from each area in DFC images. Neural network with binary output (healthy tissue/atrophy) was created for the classification of RNFL thickness. One related feature (RNFL thickness) from the OCT B-scans was derived. After setting the minimum threshold for healthy tissue reliability was calculated for the neural network classification. The 30m threshold classifier gives the best results: specificity 88.85% and sensitivity 88.59%.

A comparison of RNFL segmentation by DFC analysis with OCT results was proposed and realised as an initial attempt in this paper. A correlation between results of the three local texture analysis approaches in DFC images and the objectively measured RNFL thicknesses in OCT results has been found.

References

[1] Gazárek J., Jan J., Kolář R. *Bimodal Comparison of Retinal Nerve Fibre Layer Atrophy Evaluation.* Proc. BIOSIGNAL10, Brno, Czech Republic, CD issue, 2010.

[1]Brno University of Technology, Department of Biomedical Engineering, Czech Rep., *exgazar03@stud.feec.vutbr.cz*

[2]Brno University of Technology, Department of Biomedical Engineering, Czech Rep., *jan@feec.vutbr.cz*

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

Forward Simulation in Ultrasonic Tomography

Hemzal Dušan , Jiřík Radovan , Fousek Jan , Ruiter Nicole

The numerically demanding task of forward simulating the temporal propagation of a spatial ultrasonic pulse given the parameters of the system itself as well as those of the measured sample is complicated by the high frequencies of the ultrasound used (in orders of MHz). Even in linear approximation, the Helmholtz equation requires for its solution several spatial elements for each spatial cycle of the wave. In result, only few cubic centimeters of the volume near the transmitting transducer can be simulated using the available hardware.

Combining a suitable reformulation of the wave equation and an adaptive mesh technique, we were able to simulate a true measurement from an experimental USCT setup (KIT, Karlsruhe, Germany).

Masaryk Univerzity, Faculty of Science, *hemzal@physics.muni.cz*
Brno University of Technology, Department of Biomedical Engineering, Czech Rep., *jirik@feec.vutbr.cz*
Masaryk Univerzity, Faculty of Informatics, *izaak@mail.muni.cz*
Karlsruhe Institute of Technology, Institute for Data Processing and Electronics, Germany, *Nicole.Ruiter@ipe.fzk.de*

Parallelization Efforts and Results in USCT Reconstruction and Simulation

Fousek Jan , Peterlík Igor , Jejkal Thomas

There are currently three main projects ongoing in the ultrasound transmission tomography on the The Faculty of Electrical Engineering and Communication Brno University of Technology. It is the 3D regularized speed-map reconstruction [2], simulation of the propagation of ultrasound using the Finite Element Method [1] and simplified simulation used to generate testing input data for the reconstruction. All three projects are computationally demanding and it was necessary to employ parallel processing in order to speedup the computation or even make in possible.

The reconstruction software needs to process large input data to assemble the overdetermined system of linear equations which is consequently solved. As it is written in Matlab we have made use of the Matlab Distributed Computing Toolbox to distribute the assembly over a larger group of workers. Simple checkpoint system improves the robustness of this solution and caching system eases the data transfer load.

The FEM simulation requires very large mesh and the equation system assembly and its solving are both time and memory consuming. For the sake of performance it uses GetFEM++ [4] written in C++ to assembly the system. This system was too large to be solved on single machine, therefore we have used MUMPS [5] which is a parallel direct solver for the systems of linear equations. Next to the distributed approach, we have also tried out-of-core variant on single SMP node, which have performed similarly.

The simplified simulation constructs a virtual phantom and with the help of raytracing algorithm produces testing data in same format as the real prototype. It is written in Matlab and we are currently working on its parallelization in the collaboration with the Institute for Data Processing and Electronics in Karlsruhe using their grid middleware for Matlab called GridMate [3]. It is a first application to use GridMate on the resources of MetaCentrum and its purpose is to test the potential of GridMate for other projects.

References

[1] D. Hemzal, I. Peterlik, J. Rolecek, J. Jan, N. Ruiter, and R. Jirik. 3D simulation of diffraction in ultrasonic computed tomography. In *Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE*, pages 454–457. IEEE, 2008.

[2] R. Jirik, I. Peterlik, J. Jan, N. Ruiter, and M. Zapf. 3D regularized speed-map reconstruction in ultrasound transmission tomography. In *Ultrasonics Symposium (IUS), 2009 IEEE International*, pages 2272–2275. IEEE, 2010.

[3] T. Jejkal. GridMate–The Grid Matlab Extension. *Managed Grids and Cloud Systems in the Asia-Pacific Research Community*, pages 325–339, 2010.

[4] Y. Renard and J. Pommier. Getfem finite element library. http://home.gna.org/getfem.

[5] P. R. Amestoy, I. S. Duff, J. Koster, and J.-Y. L'Excellent. A fully asynchronous multifrontal solver using distributed dynamic scheduling. *SIAM Journal on Matrix Analysis and Applications*, 23(1):15–41, 2001.

Masaryk Univerzity, Faculty of Informatics, *izaak@mail.muni.cz*
INRIA Lille – Nord Europe, *Igor.Peterlik@inria.fr*
Karlsruhe Institute of Technology, Institute for Data Processing and Electronics, *thomas.jejkal@kit.edu*

Robust Bayesian Auto-regression Model

Šindelář Jan

The problem of estimating parameters of an auto-regression model in a Bayesian paradigm has been solved before, when the model has innovations coming from exponential family [3]. The main reason for choosing exponential family was the simplicity of computation and the fact that Gaussian distribution, often found in nature due to existence of limit theorems, is also a member of this family.

Applications of modeling to data, where the distribution of innovations is known to be heavy-tailed calls for a method, more robust with respect to possible outliers. Such methods have been developed in the past [1],[2] often using a likelihood with Huber loss function in the exponent or similar approximations. With the use of such methods a constant specifying the position of the tails has to be chosen, which is often difficult.

Intead, we choose the 1-D innovations of the model to be Laplace distributed, choose a Bayesian conjugate prior to such a model distribution and try to compute the resulting filtration, when new data of a realization of an adjacent random process arrive.

The computation of the resultant posterior distribution of the parameters of the model is still computationally tractable as will be shown [4]. The computation is slower than the classical solution at a ratio $1 : N^k$, where N is the number of data used for computation and k is the dimension of the parameter space. An immediate guess would be to use a moving window estimation of the parameters, making the estimation faster and the model adaptive. An efficient algorithm has been proposed to solve the presented problem [5].

References

[1] P. J. Rousseeuw, A. M. Leroy *Robust Regression and Outlier Detection* Wiley, 2003.

[2] P. J. Huber *Robust Statistics.* Wiley, 1981.

[3] M. Kárný, J. Böhm, T. V. Guy, L. Jirsa, I. Nagy, P. Nedoma, L. Tesař *Optimized Bayesian Dynamic Advising, Theory and Algorithms* Springer, 2005.

[4] J. Šindelář Bayesian vector auto-regression model with Laplace errors applied to financial market data *Conference on Mathematical Methods in Economics, MME2010.*

[5] J. Šindelář Algorithm for splitting and merging complexes of convex polyhedra according to given hyperplanes in general dimension *11th International PhD Workshop on Systems and Control a Young Generation Viewpoint 2010.*

Department of Adaptive Systems, Institute of Information Theory and Automation ASCR, *jan.sindelar@utia.cas.cz*

Recursive Hybrid Filter for Systems with Mixed Observations

Suzdaleva Evgenia , Nagy Ivan

The presented work deals with online state estimation for dynamic hybrid systems with mixed continuous and discrete observable and non-observable variables. Dynamic systems that show both continuous-time and discrete-valued behavior are met in many fields (target tracking, image processing, speech recognition, traffic control, etc.) Modeling and especially adaptive control of such hybrid systems is a difficult task. Fast online state estimators for hybrid systems are desired in some of these areas.

Many algorithms exist for state estimation of such systems. The well-known approach is the interactive multiple model (IMM) algorithm [1], which performs Kalman filter [2] for each model and then computes a weighted combination of updated state estimates produced by all the filters. The IMM filter is close to that proposed in this paper. A difference is that the presented method takes the state-space model in a general form for both the normal and discrete states along with mixed observations and control inputs.

The proposed solution is based on a decomposed version of the state-space model and Bayesian filtering [3]. The general solution is universal in the sense of exploited distributions. The provided specialization shows usage of the approach with normal and multinomial models. The proposed algorithm performs a joint estimation via Kalman filter and multinomial state estimation.

A part of the proposed work concerned with the estimation of discrete multinomial state is also close to hidden Markov models (HMM) theory [4]. However, the algorithms mentioned run mostly offline and are supported by Monte Carlo computations. The presented paper aims at online state estimation and analytical solution as far as possible. It means that it applies numerical procedures only in that parts, which cannot be computed analytically. The paper exploits a decomposition of state estimate, which enables to consider state as a product of various (here specialized) distributions that is convenient for computations with exponents. An online filter for discrete multinomial state based on fully analytical solution is proposed. The state-space model is taken as the probability (density) function in more general (not reduced) form, including control variables for corresponding distributions.

The presented approach was tested on traffic data with real intensities measured at one of the controlled microregions in Prague. A queue length of awaiting cars was estimated as the normally distributed state jointly with the discrete multinomial level of service (LoS) of the microregion. LoS reflects a degree of traffic saturation in the sense how easy the cars can pass through the microregion with 4 possible values from 1 (the best) to 4 (the worst). The fast online estimation of these states can influence the adaptive control of the intersection via the green light time.

References

[1] Yaakov Bar-Shalom, Thiagalingam Kirubarajan, and X.-Rong Li, *Estimation with Applications to Tracking and Navigation*, Wiley, New York, NY, USA, 2002.

[2] M.S. Grewal and A.P. Andrews, *Kalman Filtering: Theory and Practice Using MATLAB. 2nd edition*, Wiley, 2001.

[3] M. Kárný, J. Böhm, T. V. Guy, L. Jirsa, I. Nagy, P. Nedoma, and L. Tesař, *Optimized Bayesian Dynamic Advising: Theory and Algorithms*, Springer, London, 2005.

[4] M. J. Beal, Z. Ghahramani, and C. E. Rasmussen, "The infinite hidden markov model," in *Advances in Neural Information Processing Systems*, 2002, vol. 14.

Institute of Information Theory and Automation of the Academy of Sciences of the Czech Republic, Department of Adaptive Systems, *suzdalev@utia.cas.cz*

Czech Technical University, Faculty of Transportation Sciences, *nagy@utia.cas.cz*

List of Authors

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). Je tvořeno těmito subjekty:

- Ústav teorie informace automatizace AV ČR, v.v.i.
- Ostravská univerzita v Ostravě, Ústav pro výzkum a aplikace fuzzy modelování
- Vysoké učení technické v Brně, Fakulta elektrotechniky a komunikačních technologií, Ústav biomedicínského inženýrství
- Západočeská univerzita v Plzni, Fakulta aplikovaných věd
- Empo Praha, spol. s r. o.
- Compureg Plzeň, s. r. o.
- ELTODO, dopravní systémy, s. r. o. (do 31.12.2009)
- OASA COMPUTERS, s. r. o.
- DELTAX Systems, a. s. (od 1.8.2009 Telefónica O2 Business Solutions, spol. s.r.o.)
- ŠKODA AUTO, a.s. (od 1.1.2010)

Ediční řada **Interní publikace DAR** je určena pro rychlé předávání poznatků vznikajících v rámci činnosti Výzkumného centra Data – Algoritmy – Rozhodování. Obsahuje rukopisy článků a příspěvků na konference, výzkumné zprávy, dokumentaci pořádaných odborných akcí a další pracovní materiály s omezenou distribucí. Autoři plně odpovídají za obsah jejich textů.

Research Centre Data – Algorithms – Decision Making

Research Centre Data – Algorithms – Decision Making was established in 2005 due to support program of Ministry of Education, Youth and Sports. It is created by following institutions:

- Institute of Information Theory and Automation of the Academy of Sciences of the Czech Republic
- University of Ostrava, Institute for Research and Applications of Fuzzy Modelling
- Brno University of Technology, Faculty of Electrical Engineering and Communication, Department of Biomedical Engineering
- University of West Bohemia, Faculty of Applied Science
- Empo Praha, spol. s r. o.
- Compureg Plzeň, s. r. o.
- ELTODO, dopravní systémy, s. r. o. (till 31.12.2009)
- OASA COMPUTERS, s. r. o.
- DELTAX Systems, a. s. (from 1.8.2009 Telefónica O2 Business Solutions, spol. s.r.o.)
- ŠKODA AUTO, a.s. (from 1.1.2010)

Reports series **Interní publikace DAR** is intended for a quick transfer of knowledge produced by activites of Research Centre Data - Algorithms - Decision Making. It includes manustripts of papers and conference contributions, research reports, documentations of organised scientific events and other working prints with limited distribution. The autors are fully responsible for contents of their texts.

Ústav teorie informace a automatizace AV ČR, v.v.i.
Pod vodárenskou věží 4
182 08 Praha 8

Tel: 266 052 265
Fax: 286 890 378
e-mail: dar@utia.cas.cz

Internet: http://dar.site.cas.cz