



Franz Pernkopf

Curriculum Vitae

Contact Information

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Personal Data

Date of birth 28. April, 1975
Citizenship Austria
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Education

- 7/2010 **Habilitation**, *Venia Docendi for Intelligent Systems*, Graz University of Technology, Austria, Thesis: Graphical Models: Discriminative Learning, Inference, and Applications.
- 10/1999–3/2002 **Ph.D. (Dr. mont.)**, University of Leoben, Institute for Automation, Austria, Thesis: Automatic Visual Inspection of Metallic Surfaces, with distinction.
- 10/1994–6/1999 **MSc (Dipl.-Ing., Electrical Engineering/Biomedical Engineering)**, Graz University of Technology, Austria and University of Edinburgh, Scotland (UK), Thesis: Control Software for a 64 by 64 pixel Spatial Light Modulator.
- 9/1989–6/1994 **Technical College**, *Electrical Engineering*, HTBLA Steyr, Austria, with distinction.

Professional Experience

- 9/2019 – present Professor for Intelligent Systems at the Institute of Signal Processing and Speech Communication, Graz University of Technology, Austria.
- 1/2011 – 8/2019 Associate Professor at the Institute of Signal Processing and Speech Communication, Head of the Intelligent Systems Group, Graz University of Technology, Austria.
- 06/2010 – 12/2010 Senior Research Scientist at the Institute of Signal Processing and Speech Communication, Graz University of Technology, Austria.

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- 09/2005 – 01/2006 Research Associate (Erwin Schrödinger fellow) at the University of Washington, Department of Electrical Engineering, Seattle, USA.
- 09/2004 – 05/2010 University Assistant (Assistant Professor level) at the Institute of Signal Processing and Speech Communication, Graz University of Technology, Austria.
- 12/2003 – 8/2004 Research Associate (Erwin Schrödinger fellow) at the University of Washington, Department of Electrical Engineering, Seattle, USA.
- 09/2003 – 11/2003 Research Associate (Erwin Schrödinger fellow) at the Oakland University, Department of Computer Science and Engineering, Rochester, USA.
- 11/2002 – 08/2003 University Assistant (Assistant Professor level) at the Institute of Signal Processing and Speech Communication, Graz University of Technology, Austria.
- 06/2001 – 10/2002 University Assistant at the Institute for Automation, University of Leoben, Austria.
- 10/1999 – 05/2001 Research Assistant at the Institute for Automation, University of Leoben, Austria.

Professional Interests

Machine Learning and Statistical Pattern Recognition; Statistical Data Processing and Modeling; Feature Selection, Graphical Models (Bayesian Networks, Discriminative Parameter and Structure Learning, Belief Propagation); Deep Learning, Bayesian Deep Neural Networks, Particle Filters for Tracking; Data Clustering (Unsupervised Learning and Finite Mixture Models); Intelligent Systems; Medical and Speech Processing Applications.

Job Applications

- 2018 Professorship “Data Science”, University of Innsbruck, position offered.
- 2017 Professorship “Machine Learning”, Graz University of Technology, shortlisted top 3 candidates.

Teaching

- 2011 – 2019 Computational Intelligence (lecture course).
- 2011 – 2015 Einführung in die Wissensverarbeitung (lecture course).
- 2003 – 2019 Speech Communication II (lecture course).
- 2008 – 2019 Verfassen wissenschaftlicher Arbeiten (seminar).

- 2005 – 2019 Advanced Signal Processing Seminar. The following topics have been treated over the years:
- Resource-efficient Neural Networks (WS 2018/2019)
 - Resource-efficient Neural Networks (WS 2017/2018)
 - Signal Processing for Assisted Living (WS 2016/2017)
 - Acoustic Event Detection, Classification, and Keyword spotting (WS 2015/2016)
 - Deep Models and Learning (WS 2014/2015)
 - Speech Information Processing (WS 2013/2014)
 - Fundamental Technologies in Modern Speech Recognition (SS 2013)
 - Signal Processing in Geophysical Problems (WS 2012/2013)
 - Probabilistic Models of Cognition (SS 2012)
 - Convex Optimization for Signal Processing (WS 2011/2012)
 - Graphical Models for Signal Processing (SS 2011)
 - Iterative Decoding Methods and Applications (WS 2010/2011)
 - Kernel Methods (WS 2009/2010)
 - Distributed Signal Processing in Sensor Networks and Applications (WS 2008/2009)
 - Biometrics (WS 2007/2008)
 - Statistical Machine Translation (WS 2006/2007)
 - Graphical Models (SS 2005)
- 2003 – 2019 Speech Communication Laboratory.
- 2003 – 2009 Computational Intelligence (problem class).
- 2005 – 2009 Einführung in die Wissensverarbeitung (problem class).
- 2004 – 2017 Digital Signal Processing Laboratory.
- 2001, 2002 Autonomous Robot Seminar.
- 2001, 2002 Automatic Surface Inspection (lecture course).

Research Projects

- 03/2019 – 02/2022 **Dependable Internet of Things in Adverse Environments, Subproject: Dependable Multi-Agent Systems**, *Funding institution: LEAD Project (excellence programm at TU Graz), 150000 €.*
- 01/2018 – 06/2019 **Artificial Intelligence in Motion Laboratoy (aiMotionLab)**, *Funding institution: Land Steiermark, Total: 390000 €, SPSC: 334000 €, Involvement: joint project with FH Joanneum (project leader) and University of Leoben.*
- 1/2018 – 12/2020 **Smart Accelerated Hardware for Radar Sensors enabling Autnomous Driving**, *Funding institution: FFG, Total: 518.396 €, SPSC: 259.131 €, Involvement: Project leader (joint project with Infineon Technologies Austria AG, Magna Steyr Engineering AG & CoKG).*
- 1/2018 – 12/2019 **Automatic and Reliable Classification of Highly Inline Measured Wafer Edge Defects using Embedded Screeners (ARCHIMEDES)**, *Funding institution: FFG, Total: 689.256 €, SPSC: 147.000 €, Involvement: (joint project with Bright Red Systems GmbH (project leader).*
- 10/2016 – 12/2019 **Resource-Efficient Deep Models for Embedded Systems**, *Funding institution: Austrian Science Fund (FWF), Total: 380000 €, SPSC: 215000 €, I2706-N31, Involvement: Project leader (joint project with University of Heidelberg, H. Fröning).*

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- 01/2017 – 06/2019 **PipeSense**, *Funding institution: Industry, Total: 300000 €, SPSC: 125000 €*, Involvement: Project Leader - Institute of Engineering Geodesy and Measurement Systems, Graz University of Technology, Partners: (joint project with Graz University of Technology, Institute of Engineering Geodesy and Measurement Systems, Österreichische Vereinigung für Gas- und Wasserfach, Energienetze Steiermark GmbH, Linz Gas Netz GmbH, Netz Burgenland Erdgas GmbH, Netz Niederösterreich GmbH, Netz Oberösterreich GmbH, Salzburg Netz GmbH).
- 07/2016 – 09/2016 **Anschubfinanzierung**, *Funding institution: TU Graz, 7000 €*.
- 01/2015 – 12/2019 **Multichannel Acoustic Event Classification and Recognition for Low-resource Platforms**, *Funding institution: Industry, 150000 €*, Involvement: Project Leader, Partner: Ognios GmbH, Salzburg, Austria.
- 01/2016 – 06/2019 **Dependable Internet of Things in Adverse Environments, Subproject: Dependable Composition**, *Funding institution: LEAD Project (excellence program at TU Graz), 150000 €*.
- 07/2015 – 06/2018 **Learning of Bayesian Network Classifiers and Sum-Product Networks**, *Funding institution: Austrian Science Fund (FWF), 260000 €, P27803-N15*, Involvement: Project leader.
- 03/2015 – 07/2015 **Anschubfinanzierung**, *Funding institution: TU Graz, 7300 €*.
- 03/2015 – 02/2017 **Brain, Ears & Eyes - Pattern Recognition Initiative**, *Funding institution: BioTechMed Graz, 120000 €*, Involvement: Project leader at TU Graz (joint project with Medical University Graz, P. Marschik).
- 05/2014 – 07/2016 **Computerunterstützte akustische Diagnostik thorakaler Erkrankungen**, *Funding institution: Land Steiermark, Total: 159000 €, SPSC: 100000 €*, Involvement: Project leader (joint project with Medical University Graz, F.-M. Smolle-Juettner).
- 02/2013 – 08/2016 **Probabilistic Graphical Models For Time-Series Signal Mixtures**, *Funding institution: Austrian Science Fund (FWF), 443000 €, P25244-N15*, Involvement: Project leader.
- 06/2011 – 12/2014 **National Research Network: Signal and Information Processing in Science and Engineering - Part II, Subproject: Nonlinear Dynamics and Machine Learning**, *Funding institution: Austrian Science Fund (FWF), 328000 €, S10610-N13*, Involvement: Project leader.
- 06/2011 – 01/2014 **Discriminative Learning of Graphical Models with Application to Speech and Image Processing**, *Funding institution: Austrian Science Fund (FWF), 302000 €, P22488-N23*, Involvement: Project leader.
- 06/2008 – 05/2011 **National Research Network: Signal and Information Processing in Science and Engineering - Part I, Subproject: Nonlinear Dynamics and Machine Learning**, *Funding institution: Austrian Science Fund (FWF), 270000 €, S10604-N13*, Involvement: Deputy project leader, scientific consultant.
- 10/2007 – 09/2010 **Discriminative Learning of Bayesian Network Classifiers**, *Funding institution: Austrian Science Fund (FWF), 104000 €, P19737-N15*, Involvement: Project leader.

- 09/2005 – 01/2006, **Shape Description and Classification using Probabilistic Graphical Models**, *Funding institution: Austrian Science Fund (FWF), 50000USD, J2243-N04, Schrödinger Fellowship*, Involvement: Project leader, Partners: University of Washington, Department of Electrical Engineering, Seattle, USA; Oakland University, Department of Computer Science and Engineering, Rochester, USA.
- 12/2003 – 08/2004, 09/2003 – 11/2003
- 03/2001 – 10/2002 **Detection of Surface Defects on Raw Milled Steel Blocks using Range Imaging**, *Funding institution: Industry*, Involvement: Responsible project collaborator, Partner: Voest Donawitz Stahl, Leoben, Austria.
- 11/1999 – 12/2000 **Automatic Inspection System for Detection and Classification of Flaws on Turned Parts**, *Funding institution: Industry*, Involvement: Responsible project collaborator, Partner: Mec.Com, Austria.

Reviewing Activities

- Journals IEEE Transactions on Pattern Analysis and Machine Intelligence, JMLR, IEEE Transactions on Audio, Speech, and Language Processing, JASA, IEEE Transactions on Signal Processing, Machine Learning, Pattern Recognition Letters, IEEE Transactions on Data Mining and Knowledge Engineering, Data Mining and Knowledge Discovery, Artificial Intelligence in Medicine, Machine Vision and Applications, International Journal of Approximate Reasoning, IEEE Signal Processing Letters, IEEE Transactions on Medical Imaging, Artificial Intelligence Review, International Journal of Pattern Recognition and Artificial Intelligence.
- Conferences NIPS-2019, IJCAI-2019, ICASSP-2018, ICASSP-2017, Interspeech-2017, NIPS-2016, MLSP-2016, Interspeech-2016, ICASSP-2016, Interspeech-2015, ICASSP-2015, ICML-2014, ICASSP-2014, ICASSP-2013, ICML-2013, Interspeech-2013, EUSIPCO-2014, EUSIPCO-2010; EUSIPCO-2012; EUSIPCO-2013; ITG-Fachtagung-2012, International Symposium on Chinese Spoken Language Processing (ISCSLP 2012)
- Funding Institutions ERC, Czech Science Foundation, Serbia Innovation Project (2011 - 2018)

Professional Activities and Memberships

- 2020 CHiME 2020 workshop Scientific Committee
- 8/2019 Infineon SummerSchool, Villach, Talk "*Speech Enhancement for ASR using Resource-Efficient Deep Neural Networks*".
- 2019 Session Chair at the Interspeech 2019, Graz, Austria
- 2019 Research Data Management Policy Working Group TU Graz
- 2019 Senior Program Committee Member of IJCAI 2019
- 9/2019 Special Sessions & Challenges Chair, Interspeech 2019.
- 9/2018 Invited Talk, Xilinx, Dublin, Ireland.
- 5/2018 Invited Talk, University of Passau, Germany.
- 2017 – Advisory Board of Swiss Innovation Valley AG.
- 10/2017 Invited Talk, Graz University of Technology, Austria.
- 10/2017 Invited Talk, University of Heidelberg, Germany.
- 2017 Session Chair at the Interspeech 2017, Stockholm, Sweden.
- 6/2017 Invited Talk, University of Innsbruck, Austria.

- 2017 Habilitation Committee of Pejman Mowlaei Beikzadehmahaleh, Graz University of Technology.
- 6/2016 Talk, "Efficient Probabilistic Models for Cochlea Implants", Med-El, Innsbruck.
- 2016 Substitute member of the works council for academic personnel, Graz University of Technology.
- 2016 Program Committee for the IEEE Workshop on Machine Learning for Signal Processing (MLSP).
- 2016 Scientific Committee of 4th CHiME Workshop.
- 1/2015 Invited Talk, "Efficient Probabilistic Models: Learning and Reduced-Precision Analysis", Technical University Munich, Germany.
- 2015 Scientific Committee of Interspeech.
- 2014 Signal Processing Theory and Methods (SPTM) Technical Committee of the IEEE Signal Processing Society.
- 2014 Senior Member of the IEEE.
- 2013 Coordination Team of the Doctoral School *Information and Communications Engineering* at Graz University of Technology.
- 2013 Session Chair at the European Conference on Machine Learning (ECML 2013), Prague, Czech Republic.
- Invited Tutorial, "Probabilistic Graphical Models", Academic Press Library in Signal Processing, Vol. 1, Ch. 18, pp. 989-1064, 2014.
- 2008, 2012 Program Committee for the International Conference on Signal and Image Processing (SIP).
- 06/2011 Invited Talk, "Discriminative Learning of Bayesian Networks and Applications", Machine Learning Technical Meeting, Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Vienna.
- Editorial Board of ISRN Artificial Intelligence.
- 04/2011 Invited Talk, "Discriminative Learning of Bayesian Network Classifiers", University of Bonn, Bonn.
- 10/2010 Invited Talk, "Discriminative Learning of Bayesian Network Classifiers", Austrian Research Institute for Artificial Intelligence, Vienna.
- 10/2009 Invited Talk, "Machine Learning for Speech Processing", ITG Fachgruppe, Graz.
- 2008 Session Chair at the International Conference on Computer Vision and Computer Graphics Theory and Applications (VISIGRAPP 2008), Madeira, Portugal.
- 2/2007 Invited Tutorial, "Discriminative learning of Bayesian networks for classification", Tutorial on Pattern Recognition, FTW Forschungszentrum Telekommunikation Wien GmbH, Vienna.

Awards and Scholarships

- 2016 Finalist of best student paper, *DNN-based Speech Mask Estimation for Eigenvector Beamforming*, ICASSP, 2016.
- 2016 Finalist of best student paper, *A Robust Multichannel Lung Sound Recording Device*, BIODEVICES, 2016.

- 2012 Kardinal-Innitzer-Förderungspreis (Kardinal-Innitzer Young Investigator Award), Vienna, Austria.
- 2010 Young Investigator Award of the Province Styria (Förderungspreis des Landes Steiermark), Graz, Austria.
- 2010 Finalist of best student paper, *A Factorial Sparse Coder Model for Single Channel Source Separation*, Interspeech, 2010.
- 2003 Fahrzeugverband-Jubiläumsstiftung Forschungspreis (Fachverband der Fahrzeugindustrie), Wien, Österreich.
- 2002 Erwin Schrödinger Fellowship, Vienna, Austria.
- 2002 Erwin-Wenzel-Preis, Linz, Austria.
- 2002 Fred-Margulies Preis, Vienna, Austria.

Academic Cooperation Partners (Selected)

- Sebastian Tschitschek, Microsoft Research Cambridge, UK.
- Robert Peharz, University of Cambridge, UK.
- Philipp Aichinger, Medical University Vienna, Austria
- Holger Fröning, University of Heidelberg, Germany.
- Pedro Domingos, Jeff Bilmes, University of Washington, USA.
- Peter Marschik, Freyja-Maria Smolle-Jüttner, Horst Olschewski, Medical University Graz, Austria.

Soft Skills

- 2017 Nichts Neues ohne Innovation, Graz University of Technology, Austria.
- 2017 Psychologische Ansätze zur Personalführung, Graz University of Technology, Austria.
- 2015 - 2016 Advanced Leadership Program, Graz University of Technology, Austria.
 - Hochschuldidaktik für Führungskräfte
 - Erfolgreich führen und kommunizieren mit Konzepten der Transaktionsanalyse
 - Führungskompetenz kompakt
 - Sich und andere verändern
 - Strategieentwicklung für Führungskräfte
 - Arbeitsrecht für Führungskräfte
 - Wie wir uns unsere Probleme selber machen
- 2015 Management von Forschungsprojekten, Graz University of Technology, Austria.
- 2014 Forschungsprojekt- und Programmmanagement für Projektauftraggeber/innen, Graz University of Technology, Austria.
- 2010 – 2011 Management Development Program at Graz University of Technology, Austria.
 - 2011 Leading Technical Teams, Graz University of Technology, Austria.
- 2010, 2011 Didaktik 1,2,3: Durchführen von Lehrveranstaltungen im akademischen Bildungsbereich, Graz University of Technology, Austria.
- 2010 Erfolgreich in die Öffentlichkeit: Dos and Don'ts für den Umgang mit Medien, Graz University of Technology, Austria.

2009 Führen, Delegieren, Motivieren, Graz University of Technology, Austria.

Supervised PhD Students

- 2010 Stefan Petrik, Phonetic Similarity Matching of Non-Literal Transcripts in Automatic Speech Recognition.
- 2010 Michael Stark, Source-Filter Model Based Single Channel Speech Separation.
- 2012 Michael Wohlmayr, Probabilistic Model-Based Multiple Pitch Tracking of Speech.
- 2013 Christina Leitner, Speech Enhancement using Kernel PCA.
- 2014 Sebastian Tschatschek, Maximum Margin Bayesian Networks: Asymptotic Consistency, Hybrid Learning, and Reduced-Precision Analysis.
- 2014 Dietmar Schabus, Audio-visual Speech Synthesis Based on Hidden Markov Models, external PhD Candidate at FTW Forschungszentrum Telekommunikation Wien GmbH, Vienna.
- 2015 Robert Peharz, Foundations of Sum-Product Networks for Probabilistic Modeling.
- 2019 Matthias Zöhrer, Speech Enhancement Using Deep Neural Beamformers.
- running Christian Knoll, Fixed Point Analysis of Belief Propagation (Expected Graduation: 2019).
- 2019 Elmar Messner, A Holistic Approach to Multi-Channel Lung Sound Classification.
- running Lukas Pfeifenberger, Multichannel Acoustic Event Classification and Recognition for Low-resource Platforms (Expected Graduation: 2020), external PhD Candidate funded from Ognios (industry partner), Salzburg.
- running Wolfgang Roth, Bayesian Deep Neural Networks (Expected Graduation: 2020).
- running Martin Trapp, Bayesian Non-Parametric Models and Sum-Product Networks (Expected Graduation: 2020), external PhD Candidate at Austrian Research Institute for Artificial Intelligence (OFAI), Vienna.
- running Kimtruc Nguyen, Acoustic Scene Classification and Event Detection (Expected Graduation: 2020).
- running Johanna Rock, Resource-efficient Deep Neural Networks (Expected Graduation: 2021).
- running Alexander Fuchs, Neural Networks for Wafer Edge Defect Classification (Expected Graduation: 2021).

Supervised Master Students

- 2007 Christoph Böhm, Unsupervised Speaker Segmentation in One-Channel Speech Data.
- 2007 Christian Wallinger, A Flexible Sender-Based Packet Loss Recovery Method.
- 2008 Christoph Schmauder, Schwingungsanalyse für Störstoffdetektion und Schnittspalteinstellung einer Müllzerkleinerungsmaschine, joint project with Komptech.
- 2008 Michael Wiesenegger, Wavelet-Based Speaker Change Detection in Single Channel Speech Data.
- 2010 Robert Peharz, Single Channel Source Separation using Dictionary Design Methods for Sparse Coder.
- 2012 Gregor Pirker, A Speech Database for Pitch Determination.

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- 2012 Christoph Klug, RTBlocks: A Cross-Platform Algorithm Design Framework for Real-Time Audio Processing on Android.
- 2013 Nikolaus Mutsam, Maximum Margin Hidden Markov Models.
- 2013 Klaus Dobbler, Vibroakustisches Monitoring in Smart Homes.
- 2013 Florian Pokorny, Detection of Negative Emotions in Speech Signals Using Bags-of-Audio-Words.
- 2013 Lukas Pfeifenberger, Evaluation, Simulation and Implementation of a Multi-Channel Speech Enhancement System.
- 2013 Andreas Zehetner, Keyword Spotting for Emergency.
- 2014 C.E. Cancione Chacón, On Belief Propagation and Higher Order Power Methods.
- 2014 Erwin Nindl, Traffic Flow Reconstruction on Motorways by Data Fusion.
- 2014 Georg Kapeller, Speech Enhancement with Sum-Product Networks.
- 2015 Michael Rath, Message Scheduling in Loopy Belief Propagation.
- 2015 Wolfgang Roth, Hybrid Generative-Discriminative Training of GMMs.
- 2015 Christopher Walles, Segmental Conditional Random Fields for Phone Recognition.
- 2016 Johannes S. Innerbichler, Cloud Storage Performance Analysis.
- 2016 Markus Feuerstein, Refractory Wear Modelling Using Statistical Methods.
- 2016 Michael Peitler, Acoustic Event Detection of General Sounds.
- 2017 Fridtjof Sterna, Real-time Automatic Recognition of Spoken Digits on an Embedded System using Deep Recurrent Neural Networks.
- 2018 Christoph Aigner, Requirements Specification of a Systems-Engineering Tool: Example on Effort Estimation using Neural Networks.
- 2018 Florian Kulmer, Self-Confident Belief Propagation.
- 2018 Johanna Rock, Change-point Detection in Smartphone Usage.
- 2018 Andreas Wöhrer, 16 Channel USB 2.0 Sound Card for Digital MEMS Microphones.
- 2018 Andreas Wurm, Predicting the Latency of MQTT Brokers Using Deep Learning.
- 2019 Hannes Unterholzner, Channel Selection for Distant Automatic Speech Recognition.

Key Publications

Most of my research relates to the area of machine learning, statistical modeling, and artificial intelligence. In particular, the focus is on developing innovative methods and techniques for extraction of information and modeling of data including the empirical verification of the methods. In the sequel, some key publications (ordered by year) including a short summary are listed.

1. E. Messner, M. Zöhrer, F. Pernkopf, "*Heart Sound Segmentation - An Event Detection Approach using Deep Recurrent Neural Networks*", IEEE Transaction on Biomedical Engineering (TBME), Vol. 65, No. 9, pp. 1964–1974, 2018.

We accurately detect the state-sequence first heart sound (S1) - systole - second heart sound (S2) - diastole, i.e. the positions of S1 and S2, in heart sound recordings. We propose an event detection approach, without explicitly incorporating a priori information of the state duration. This renders it also applicable to recordings with cardiac arrhythmia and extendable to the detection of extra heart sounds (third and fourth heart sound), heart murmurs, as well as other acoustic events. Methods: We use data from the 2016 PhysioNet/CinC Challenge, containing heart sound recordings and annotations of the heart sound states. From the recordings, we extract spectral and envelope features and investigate the performance of different deep recurrent neural network (DRNN) architectures to detect the state-sequence. We use virtual-adversarial training (VAT), dropout and data augmentation for regularization. Results: We compare our results with the state-of-the-art method and achieve an average score for the four events of the state-sequence of $F_1 \hat{=} 96\%$ on an independent test set.

2. C.Knoll, D. Mehta, T.Chen, F. Pernkopf, "*Fixed Points of Belief Propagation - An Analysis via Polynomial Homotopy Continuation*", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 40, No. 9, pp. 2124–2136, 2018.

Belief propagation (BP) is an iterative method to perform approximate inference on arbitrary graphical models. Whether BP converges and if the solution is a unique fixed point depends on both the structure and the parametrization of the model. To understand this dependence it is interesting to find all fixed points. In this work, we formulate a set of polynomial equations, the solutions of which correspond to BP fixed points. To solve such a nonlinear system we present the numerical polynomial-homotopy-continuation (NPHC) method. Experiments on binary Ising models and on error-correcting codes show how our method is capable of obtaining all BP fixed points. On Ising models with fixed parameters we show how the structure influences both the number of fixed points and the convergence properties. We further assess the accuracy of the marginals and weighted combinations thereof. Weighting marginals with their respective partition function increases the accuracy in all experiments. Contrary to the conjecture that uniqueness of BP fixed points implies convergence, we find graphs for which BP fails to converge, even though a unique fixed point exists. Moreover, we show that this fixed point gives a good approximation, and the NPHC method is able to obtain this fixed point.

3. R. Peharz, R. Gens, F. Pernkopf, P. Domingos, "*On the Latent Variable Interpretation in Sum-Product Networks*", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 39, No. 10, pp. 2030–2044, 2017.

One of the central themes in Sum-Product networks (SPNs) is the interpretation of sum nodes as marginalized latent variables (LVs). This interpretation allows the application of the EM algorithm and to efficiently perform MPE inference. In literature, the LV interpretation was justified by explicitly introducing the indicator variables corresponding to the LVs' states. However, as pointed out in this paper, this approach is in conflict with the completeness condition in SPNs and does not fully specify

the probabilistic model. We propose a remedy for this problem by modifying the original approach for introducing the LVs, which we call SPN augmentation. We discuss conditional independencies in augmented SPNs, formally establish the probabilistic interpretation of the sum-weights and give an interpretation of augmented SPNs as Bayesian networks. Based on these results, we find a sound derivation of the EM algorithm for SPNs, which was presented mistaken in literature. Furthermore, the Viterbi-style algorithm for MPE proposed in literature was never proven to be correct. We show that this is indeed a correct algorithm, when applied to selective SPNs, and in particular when applied to augmented SPNs.

4. S. Tschitschek and F. Pernkopf, "On Bayesian Network Classifiers with Reduced Precision Parameters", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 37, No. 4, pp. 774–785, 2015.

For Bayesian network classifiers (BNCs) we performed reduced-precision analysis and published several papers. In this paper, we present novel theoretical results and extended empirical results for BNCs with finite precision fixed-point parameters. All our results are based on the assumption that parameters are learned in full-precision and rounded to the desired precision for classification. We derive three types of bounds on the classification performance after parameter precision reduction and compare these in experiments. Additionally, we empirically compare the classification performance and robustness of BNCs with respect to precision reduction for different learning paradigms.

5. M. Zöhrer, R. Peharz, and F. Pernkopf, "Representation Learning for Single-Channel Source Separation and Bandwidth Extension", IEEE Transactions on Audio, Speech, and Language Processing, Vol. 23, No. 12 pp. 2398–2409, 2015.

In this paper, we use deep representation learning for model-based single-channel source separation (SCSS) and artificial bandwidth extension (ABE). Both tasks are ill-posed and source-specific prior knowledge is required. In addition to well-known generative models such as restricted Boltzmann machines and higher order contractive autoencoders two recently introduced deep models, namely generative stochastic networks (GSNs) and sum-product networks (SPNs), are used for learning spectrogram representations. For SCSS we evaluate the deep architectures on data of the 2nd CHiME speech separation challenge and provide results for a speaker dependent, a speaker independent, a matched noise condition and an unmatched noise condition task. GSNs obtain the best PESQ and overall perceptual score on average in all four tasks. Similarly, frame-wise GSNs are able to reconstruct the missing frequency bands in ABE best, measured in frequency-domain segmental SNR.

6. M. Zöhrer, F. Pernkopf, "General Stochastic Networks for Classification", Neural Information Processing Systems (NIPS), 2014.

In this work, we introduce a new training procedure for supervised learning of representations. In particular we define a hybrid training objective for general stochastic networks, dividing the cost function into a generative and discriminative part, controlled by a trade-off parameter. We are able to obtain state-of-the-art performance on the MNIST dataset, without using permutation invariant digits and significantly outperform baseline models on sub-variants of the MNIST and rectangle database.

7. M. Wohlmayr and F. Pernkopf, "Model-Based Multiple Pitch Tracking Using Factorial HMMs: Model Adaptation and Inference", IEEE Transactions on Audio, Speech, and Language Processing, Vol. 21, No. 8, pp. 1742–1754, 2013.

Robustness against noise and interfering audio signals is one of the challenges in speech recognition

and audio analysis technology. One avenue to approach this challenge is single-channel multiple-source modeling. Factorial hidden Markov models (FHMMs) are capable of modeling acoustic scenes with multiple sources interacting over time. While these models reach good performance on specific tasks, there are still serious limitations restricting the applicability in many domains. In this paper, we generalize these models and enhance their applicability. In particular, we develop an EM-like iterative adaptation framework which is capable to adapt the model parameters to the specific situation (e.g. actual speakers, gain, acoustic channel, etc.) using only speech mixture data. Currently, source-specific data is required to learn the model. Inference in FHMMs is an essential ingredient for adaptation. We develop efficient approaches based on observation likelihood pruning. Both adaptation and efficient inference are empirically evaluated for the task of multipitch tracking using the GRID corpus.

8. R. Peharz, S. Tschitschek, F. Pernkopf, "*The Most Generative Maximum Margin Bayesian Networks*", International Conference on Machine Learning (ICML), 2013.

This paper introduces hybrid parameter learning of Bayesian networks (BNs). BNs represent distributions and are therefore well-suited for generative learning. Even when the conditional distribution obtained by discriminative training of BNs is unique, the representation as a BN might be not unique. A natural approach is to use this degree of freedom to improve the generative aspect of the model, i.e. to select the representation with highest likelihood. This describes a domain of likelihood-aware discriminative models, justifying a generative usage, such as sampling new examples, versatile inference scenarios, and consistent treatment of missing features during test time. We use a large margin formulation for discriminative training, introducing a likelihood-weighted ℓ^1 -norm. This simultaneously optimizes the data likelihood and therefore partly maintains the generative character of the model. For many network structures, our method can be formulated as a convex problem, guaranteeing a globally optimal solution.

9. F. Pernkopf, M. Wohlmayr, S. Tschitschek, "*Maximum Margin Bayesian Network Classifiers*", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 34, No. 3, pp. 521–532, 2012.

We present a maximum margin parameter learning algorithm for Bayesian network classifiers using a conjugate gradient (CG) method for optimization. In contrast to previous approaches, we maintain the normalization constraints on the parameters of the Bayesian network during optimization, i.e., the probabilistic interpretation of the model is not lost. This enables us to handle missing features in discriminatively optimized Bayesian networks. In experiments, we compare the classification performance of maximum margin parameter learning to conditional likelihood and maximum likelihood learning approaches. Discriminative parameter learning significantly outperforms generative maximum likelihood estimation for naive Bayes and tree augmented naive Bayes structures on all considered data sets. Furthermore, maximizing the margin dominates the conditional likelihood approach in terms of classification performance in most cases. Margin-optimized Bayesian network classifiers achieve classification performance comparable to support vector machines (SVMs) using fewer parameters. Moreover, we show that unanticipated missing feature values during classification can be easily processed by discriminatively optimized Bayesian network classifiers, a case where discriminative classifiers usually require mechanisms to complete unknown feature values in the data first.

10. F. Pernkopf and D. Bouchaffra, "*Genetic-based EM Algorithm for Learning Gaussian Mixture Models*", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 27, No. 8, pp. 1344–1348, 2005.

We propose a genetic-based expectation-maximization (GA-EM) algorithm for learning Gaussian mixture models from multivariate data. This algorithm is capable of selecting the number of components of

the model using the minimum description length (MDL) criterion. Our approach benefits from the properties of Genetic algorithms (GA) and the EM algorithm by combination of both into a single procedure. The population-based stochastic search of the GA explores the search space more thoroughly than the EM method. Therefore, our algorithm enables escaping from local optimal solutions since the algorithm becomes less sensitive to its initialization. The GA-EM algorithm is elitist which maintains the monotonic convergence property of the EM algorithm.

Publications

I contributed to more than 135 refereed conference papers (some at UAI, ICML, AISTATS, NIPS, ECML, AAAI, and ICASSP), 38 refereed journal papers (some at IEEE TPAMI, IEEE TSALP, PLOS One, IEEE TBME, JMLR, Pattern Recognition), and 1 book chapter. These papers received >2100 citations on Google Scholar and my h-index is 23. The publication focus for journals is on IEEE Transactions, where e.g. the IEEE TPAMI journal has an impact factor of 9.455 (2017).

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9. W. Roth, R. Peharz, S. Tschitschek, F. Pernkopf, *"Hybrid Generative-Discriminative Training of Gaussian Mixture Models"*, Pattern Recognition Letters, Vol. 112, pp. 131–137, 2018.
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