Signal and Information Processing Laboratory

Prof. Dr. A. Lapidoth, Prof. Dr. H.-A. Loeliger, Dr. K. Heutschi

ANNUAL REPORT

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Research Period 2002

Teaching Period 2001/2002

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Foreword

It is hard to believe that it is time for me to write another forward to our yearly report, especially since Professor Loeliger and I take turns, so that, in fact, two years have passed since I last wrote one.

2002 brought the International Symposium on Information Theory to Switzerland and with it great excitement but also a fair bit of work. Professor Loeliger was in charge of publications and also a member of the technical program committee, while I co-chaired (with Prof. Telatar) the program committee. We received great help from some of the members of our institute, and in particular from Bernadette Röösli, Matthias Frey, Stefan Moser, Daniel Hösli, Justin Dauwels, and Max Dünki. We seize this opportunity to thank them for their dedicated work.

During this year we also started planning for the Winter School on Coding and Information Theory that will be held in Switzerland in February 2003. It will bring to Switzerland Ph.D. students from all over Europe and, hopefully, will foster interesting discussions and future collaborations. Again, while the workshop is chaired by Prof. Loeliger and myself, various members of the institute have put in great effort into making it a success. We particularly thank Justin Dauwels, Daniel Hösli, and Stefan Moser.

We also are very proud of the achievements of the Ph.D. students in our lab. Three graduated in 2002 with beautiful theses: Dieter Arnold, Ralf Kretzschmar, and Pascal Vontobel. We congratulate them on their achievements and also congratulate Dieter Arnold and Prof. Loeliger for receiving the 2001 IEEE Communication Society Signal Processing for Storage Best Student Paper Award.

We welcome the newcomers to our institute. Natalia Miliou has joined us from Greece, and Maja Ostojic has joined us from Switzerland. We hope that their stay at our institute will be a fulfilling and rewarding experience.

February 2003 Amos Lapidoth

Contents

1. Personnel

Professor for Information Theory:

Prof. Dr. Amos Lapidoth

Professor for Signal Processing:

Prof. Dr. Hans-Andrea Loeliger

Adjunct Lecturer: **Dr. Kurt Heutschi**

Secretaries: **Mrs. Bernadette Röösli**
Mrs. Renate Agotai

Technical Supervisor: **Dr. Max Dünki**

Research Assistants:	**Dieter Arnold**	Dipl.El.Eng.	
	Justin Dauwels	Dipl.Phys.Eng.	
	Matthias Frey	Dipl.El.Eng.	
	Qun Gao	Dipl.El.Eng.	
	Markus Hofbauer	Dipl.El.Eng.	
	Daniel Hösli	Dipl.El.Eng.	
	Volker Koch	Dipl.Eng.	
	Sascha Korl	Dipl.Eng.	
	Ralf Kretzschmar	Dipl.Phys.	left 30.4.02
	Dani Lippuner	Dipl.El.Eng.	left 31.1.02
	Felix Lustenberger	Dipl.El.Eng.	left 30.6.02
	Patrick Merkli	Dipl.Eng. Microtechn.EPF	
	Natalia Miliou	Dipl.El.Eng.	since 1.10.02
	Stefan Moser	Dipl.El.Eng.	
	Maja Ostojic	Dipl.El.Eng.	since 21.10.02
	Pascal Vontobel	Dipl.El.Eng.	left 30.9.02
Technical Staff:	**Francesco Amatore**		
	Thomas Schärer		
	Patrik Strebel	El.Eng.HTL	

Academic Guests:

Prof. Dr. Paul Siegel	University of California, San Diego, USA	17.06.-17.06.02
Prof. Raym. W. Yeung	Chinese University Hong Kong, China	23.06.-24.06.02
Prof. R. Blahut	University of Illinois, Urbana, USA	23.06.-26.06.02
Prof. Dr. M. Tanner	University of Illinois, Chicago, USA	27.06.-30.06.02
Prof. M. Fossorier	University of Hawaii, Honolulu, USA	15.09.-18.09.02
Dr. L. Tolhuizen	Philips Research Laboratories, Eindhoven, The Netherlands	15.10.-18.10.02
Dr. Shraga Bross	Technion Haifa, Israel	28.10.-31.10.02

2. Teaching

2.1 Lectures and Practica

Sem.	Instructors	Title	ETH-No.
5th	Prof. H.-A. Loeliger	Stochastic Models and Signal Processing	35-101
8th	Prof. H.-A. Loeliger	Algebra, Codes, and Signal Processing	35-416
5/7th	Prof. A. Lapidoth	Applied Digital Information Theory I	35-417
6th	Prof. A. Lapidoth	Information Transfer	35-104
6/8th	Dr. A. Mittelholzer	Applied Digital Information Theory II	35-418
7th	M. Hofbauer und R. Kretzschmar	Adaptive Filters and Neuronal Networks	35-467
8th	H.P. Schmid	Analog Signal Processing and Filtering	35-468
7th	Dr. K. Heutschi	Acoustics I	35-477
8th	Dr. Heutschi	Acoustics II	35-478
5/ 6th	Practica	Laboratory for "Fundamentals in Electrical Engineering"	35-095/6
2nd/3rd	Prof. H.-A. Loeliger	Cellular Automata	PPS
3rd/4th	Prof. H.-A. Loeliger	Technical Presentations	PPS
3rd/4th	Prof. H.-A. Loeliger	Practical Signalprocessing using a DSP	PPS
2nd/3rd	Prof. H.-A. Loeliger	EMG Biofeedback Device	PPS
3rd/4th	Prof. H.-A. Loeliger	Probability Gates and Analog Decoding	PPS
4th	Prof. H.-A. Loeliger	Introduction to LaTeX	PPS

2.2 Semester Projects and Diploma Theses

During the winter semester 2001/02 and summer semester 2002, 8 Semester Projects (13 candidates) and 4 Diploma Theses (5 candidates) were carried out.

Candidates	Title	Supervisor
Semester Projects WS 2001/02 (7th Semester)		
Mirjam Killer Marco Schurtenberg	Spectral Feature Extraction Using CNNs for Fingerprint Recognition	Gao Merkli
Roman Schilter Maurice Rüegg	Fingerprint Alignment Using Cellular Neural Networks	Gao Merkli
Oskar Berger	Binaurale Ansätze zur Störgeräusch-befreiung in Hörgeräten II	Hofbauer Korl
Semester Projects SS 2002 (8th Semester)		
Jürg Treichler	Simulation of Analog Decoders	Prof. Loeliger Frey, Merkli
Peter Stéphane Oliver Peitz	Klassierung von Verkehrslärm	Kälin, Siemens Schweiz AG
Florian Trösch	Optimizing Antenna Arrays Using Genetic Algorithms	Hösli Stucki, Elektrobit
Erwann Wernli Fabrice Sauterel	Echtzeit-Filter als Cubase VST Plugin	Korl Hofbauer
Felix Bürgin Franziska Pfisterer	QRS-Erkennung zur automatischen Arrhythmie-Analysis	Prof. Loeliger Koch
Diploma Theses WS 2001/02		
Boris Rankov Daniel Lenz	Bounds on the Capacity of Poisson Channels	Moser
Michael Koller	Binaurale Ansätze zur Störgeräusch-befreiung in Hörgeräten	Hofbauer Korl
Gaudenz Koeppel	Entwicklung und Aufbau einer Messeinrichtung zur Bestimmung der Einflüsse von Durchbrüchen auf die Schalldämmung von Trennwänden	Falk/Rieter Auto-motive, Heutschi, EMPA

Diploma Theses SS 2002

Michael Weber	Informationstheorie und neuronale Netze: Bestimmung der Grenzen der lokalen Wetterprognose	Kretzschmar Dauwels

Internal Reports

Dieter Arnold	Computing Information Rates of Magnetic Recording Systems with Media Noise	Prof. Loeliger
Pascal Vontobel	Kalman Filters, Factor Graphs, and Electrical Networks	Prof. Loeliger
Pacal Vontobel	A Generalized Blahut-Arimoto Algorithm	Prof. Loeliger
Markus Hofbauer	Blinde Algorithmen-Uebersicht	Prof. Loeliger

3. Research

3.1 Research Areas

The Signal and Information Processing Lab focusses on research and teaching in the following areas:

Information Theory and Coding

Information theory, error correcting codes, and their application to communication systems. Current topics:

- Bounds on the capacity of fading channels
- The poisson channel at high intensities
- Bounds on the capacity of free-space optical intensity channels
- On multi-access channels (MAC) at high SNR
- On MIMO ricean fading channels
- The capacity region of the poisson multiple-access channel with noiseless feedback
- Optimizing antenna arrays using genetic algorithms
- Capacity of the Gaussian channel with causal side information at the transmitter (“dirty tape” channel)
- Numerical computation of information rates with applications to magnetic recording
- Algebraic coding for iterative decoding

Digital Signal Processing

Current topics:

- Fundamentals of graphical models (“factor graphs”)
- Clock noise and synchronization in communications receivers
- Speech enhancement in hearing aids
- Decomposition of electromyographic signals
- Smart fire alarm devices

Analog Signal Processing

Current topics:

- Decoding and adaptive equalization in analog VLSI
- Fingerprint recognition using cellular neural networks

3.2 Current Research Projects

Information Theory and Coding

Bounds on the Capacity of Fading Channels

The goal of this project is to obtain accurate estimates of the capacity of fading channels, which are typically encountered in mobile wireless communication. The capacity of such channels serves as the ultimate upper bound on the rates at which reliable communication is possible. Moreover, with the advent of Turbo-codes, one can often approach these rates with practical coding schemes.

Since the exact calculation of capacity is intractable, one must resort to upper and lower bounds. To this end we have developed a new technique to derive upper bounds on the capacity of general channels, and we have applied this technique to fading channels. Together with some lower bounds that we have found for such channels, we are now in a position to understand the behavior of the channel capacity for the large family of multi-antenna fading channels with or without memory and with or without side information related to the fading realization.

We have further developed the concept of "capacity achieving input distributions that escape to infinity" and showed how this concept can be used to derive asymptotic estimates of channel capacity. Using this paradigm we were able to derive a high-SNR asymptotic expansion for the capacity of a number of fading models. In particular we have solved the single-input single-output (SISO) case (with memory) as well as the multi-input single-output (MISO) case.

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Professor: Prof. Dr. Amos Lapidoth

Keywords: Channel capacity, high SNR, fading, flat-fading, Ricean fading, Rayleigh fading, MIMO systems, convex programming, duality, fading number, capacity achieving input distributions that escape to infinity.

The Poisson Channel at High Intensities

The study of the Poisson channel has a long history, as it is one of the key models for optical communication. Of special interest is channel capacity, which is the highest rate at which reliable communication is achievable over this channel. Since, the model is highly non-linear (with the output being a Poisson random variable of a mean that is proportional to the input), no closed-form expression for the capacity is known.

In this project we study the asymptotic behavior of channel capacity at high intensities. Our approach is based on a new paradigm - a paradigm based on the notion of capacity achieving input distributions that escape to infinity - that we have introduced for the study of channels at high signal-to-noise ratios.

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Keywords: Channel capacity, fibre optic transmission channels, Poisson distribution, convex programming, duality, capacity achieving input distributions that escape to infinity.

Bounds on the Capacity of Free-Space Optical Intensity Channels

Channel capacity is an extremely important quantity, which is, alas, typically very difficult to compute precisely (even numerically). To address this problem, we have recently developed a new technique which can provide very tight upper bounds on channel capacity. This technique has been employed very successfully to the study of the capacity of fading channels and of phase noise channels.

This project addresses a different channel, namely an optical transmission channel through plain air, the so called "free-space optical intensity channel". Applying our new bounding technique we hope to reach the goal of finding some new upper and lower bounds on the capacity of free-space optical intensity channels.

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Keywords: Channel capacity, optic transmission channel, wireless infrared communication, convex programming, duality, capacity achieving input distributions that escape to infinity.

On Multi-Access Channels (MAC) at High SNR

Multi-access channels model many-to-one communication scenarios, as for example, the uplink in mobile cellular telephony. Contrary to the case of single-user communication via multiple transmit antennae, a multiple-access scenario allows for very limited cooperation among the transmitters, as each transmitter is assumed to be ignorant of the message transmitted by the other users.

In this project we investigate a fading multiple-access channel in the absence of receiver side information. We model the received signal as the sum of two signals, where the first signal is the result of passing the signal transmitted by the first user through a Ricean fading channel, and the second signal defined analogously.

We seek the asymptotic expansion of the rate-sum at high SNR.

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Keywords: MAC, Gaussian fading, sum-rate, high SNR, convex programming, duality.

On MIMO Ricean Fading Channels

In this project we study the capacity of a multiple-transmit multiple-receive system operating over Ricean fading channels. The transmitter is assumed to

employ spatially and temporally white Gaussian inputs, and the receiver is assumed to possess perfect knowledge of the realization of the fading process.

We prove that the mutual information corresponding to such scenarios is componentwise monotonic in the vector of the singular-values of the mean matrix. The dependence on the variance of the fading is under current investigation.

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Keywords: Ricean fading, MIMO systems, capacity, mean.

In Collaboration with: Young-Han Kim, Information Systems Laboratory, Stanford University

The Capacity Region of the Poisson Multiple-Access Channel with Noiseless Feedback

The Poisson multiple-access channel (MAC) models a many-to-one optical communication system. Its capacity region has recently been computed by Lapidoth & Shamai. The purpose of the present research is to investigate the gains (in capacity) afforded by noiseless delayless feedback from the receiver to the transmitters.

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Keywords: Poisson channel, multiple-access, capacity region, feedback.

In Collaboration with: Shraga Bross, Technion Israel Institute of Technology

Optimizing Antenna Arrays Using Genetic Algorithms

Antenna arrays can be deployed at the receiver of a communication system to retain desired signals from particular directions while rejecting undesired components from other directions. Different array geometries lead to different array patterns (also called beamformers), which yield the antenna gain as a function of the incident angle. In this project different array geometries (1 and 2-dimensional) with isotropic element patterns have been investigated. The hardware complexity of full regular arrays can be reduced by thinning them out. At the same time some specifications regarding the array pattern have to be fulfilled. For example, a high ratio of the mainlobe level to the sidelobe level is desired. Since the number of possible array configurations increases exponentially with the number of antenna elements, an exhaustive search for the best configuration is not feasible. As an alternative genetic algorithms have been employed in order to find optimum solutions with respect to the specifications. In particular, classic GA's have been compared to so-called micro GA's with very small populations. MATLAB has been used for the simulations. This project was initiated by Elektrobit AG, Bubikon (Switzerland).

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Professor: Prof. Dr. Amos Lapidoth

Keywords: antenna arrays, array patterns, beamforming, genetic algorithms

Supported by: Andreas Stucki, Elektrobit AG, Bubikon (Switzerland)

In Collaboration with: Florian Trösch

Capacity of the Gaussian Channel with Causal Side Information at the Transmitter ("Dirty Tape" Channel)

In many communication scenarios the channel is time-varying and can be modeled with a state-dependent channel law. If only the transmitter has some knowledge about the underlying state process the calculation of the channel capacity usually requires the consideration of an extended input alphabet and seems to be a hard problem in general. A particular case of such a scenario is the so-called dirty tape channel. Apart from the often employed additive noise component this model assumes that the current state is determined by another additive interference that is known causally at the sender. In this project we considered the problem of finding the capacity-cost function of this channel, i.e., the capacity given that the sender is allowed to use at most a given average cost. Different aspects like for instance discretisation of the alphabets and in particular the capacity per unit cost have been investigated.

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Keywords: channel capacity, time-varying channels, side information, equivalent channels, capacity per unit cost

Computation of Information Rates with Applications to Magnetic Recoding

The information rate and the channel capacity (in the sense of Shannon) are key properties of any communications channel. However, for many important channels with memory, it is not known how to compute these quantities with sufficient accuracy.

Since 2001, we have made significant progress with such numerical methods. In particular, the information rate of any finite-state source/channel model (with up to a few thousand states) can now be computed accurately. Upper and lower bounds on the information rate of very general (non finite-state) channels can be computed either by finite-state approximations or by reduced-state trellis computations.

In collaboration with A. Kavcic, we have also been studying an extension of the Blahut-Arimoto algorithm to optimize the information rate over finite-state Markov sources with a fixed number of states.

This work was motivated mainly by applications in magnetic recording, but the results have a much wider scope.

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Professor: Prof. Dr. Hans-Andrea Loeliger

Keywords: magnetic recording, channel capacity, information rates, hidden Markov models, Monte Carlo methods

In Collaboration with: IBM Zurich Research Lab., Prof. A. Kavcic, Harvard University, Cambridge, MA, USA

Algebraic Coding for Iterative Decoding

Error correcting codes and/or coded modulation schemes are essential to most modern telecommunications schemes. Due to recent breakthroughs ("turbo coding", "low-density parity check codes"), practical coding schemes now achieve reliable data transmission at rates extremely close to Shannon's fundamental limit. While classical coding theory ("BCH codes", "algebraic geometric codes") is deeply rooted in abstract algebra, these new coding schemes rely on codes that are "randomly" selectly within a class of codes with a structure suitable for iterative "probability propagation" decoding.

Despite this happy state of affairs, the "random" coding schemes do not satisfy all wishes. E.g., there is a lack of analytical results on the error probability below the level that can be seen in simulations. We hope that such additional wishes can be satisfied with suitable algebraic code constructions. A variety of such constructions can be obtained either from finite geometries or from the Cayley graphs of certain matrix groups. Several such codes have been shown to be at least as good as "random" codes.

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Keywords: error correcting codes, algebraic coding, low-density parity check codes, factor graphs, Ramanujan graphs, finite geometries.

In Collaboration with: Prof. J. Rosenthal, University of Notre Dame, IN, USA, Prof. M. Tanner, University of Illinois at Chicago, IL, USA

Digital Signal Processing

Clock Noise and Synchronization

This project is concerned with the following two related topics: - Phase synchronization in communication receivers. - Effects of nonideal clocks in communication receivers. These topics are of central, and growing, importance to digital communications, but not well understood.

We are beginning to study these topics from several sides: physics and circuit theory; information theory; and signal processing. We heavily rely on modeling by factor graphs and signal processing by the summary-product algorithm.

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Keywords: synchronization, clock jitter, factor graphs.

Decomposition of EMG Signals

All muscular activity is triggered by electrical pulses in the nerve cells that control individual groups ("motor units") of muscle fibres. The measurement and the analysis of such electrical signals is of significant interest to physicians.

Our laboratory has a long tradition in the processing of such electromyographic (EMG) signals. The signals as measured by various types of electrodes consist of the linear superposition of (the signals corresponding to) many motor units. The main signal processing task is to identify the "signatures" of the individual motor units and to decompose the measured signal into the corresponding components.

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Keywords: EMG, signal decomposition, source separation, factor graphs.

In Collaboration with: Dr. T. Läubli, Institut für Hygiene und Arbeitsphysiologie (IHA), ETH Zurich

Speech Enhancement in Hearing Aids

In noisy environments, the perceived quality of speech signals in hearing aids is often unsatisfactory. We are studying the enhancement of such speech signals in two separate approaches.

1. Use of two microphones. Here we focus on the "blind" identification of linear filters for noise reduction. A first goal is to understand the achievable speech quality by "optimal" linear filtering under a variety of conditions.

2. Model-based nonlinear filtering. We use factor graphs to specify a variety of generalized hidden Markov models and we explore many versions of the summary-product algorithm to clean up the signals.

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Keywords: speech enhancement, noise reduction, beamforming, hidden Markov models

Supported by: KTI, Phonak AG, Stäfa

Analog Signal Processing

Decoding and Adaptive Equalization in Analog VLSI

Error correcting codes may be represented by "factor graphs", and iterative "probability propagation" decoding operates by "message passing" along the edges of the graph. Back in 1998, we discovered that the factor graph of many error correcting codes (including trellis codes, turbo codes, and low-density parity check codes) can be translated directly into analog transistor circuits that operate in continuous time and in parallel. Such analog decoders are composed of "probability gates", where currents represent probabilities and voltages represent logarithms of probabilities (or of probability ratios). We have built a collection of such "probability gates" as individual integrated circuits, which has allowed us to put together and to study several decoders on the breadboard level. We hope that such analog decoders will allow the use of error correcting codes in applications where digital decoders would be too slow or would consume too much power. We are also extending this approach to joint decoding and adaptive equalization.

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Professor: Prof. Dr. Hans-Andrea Loeliger

Keywords: analog decoder, nonlinear circuits, factor graphs, joint decoding and equalization

3.3 Completed Research Projects

KRETZSCHMAR Ralf

A Survey of Neural Network Classifiers for Local Wind Prediction

ETH-Diss. Nr. 14538 (Referee: Prof. Dr. F. Eggimann)

This thesis generally discusses the topics of class overlap and class imbalance for real-world applications with focus on the application of local wind speed and wind gust prediction.

To improve the handling of class overlap and class imbalance, variance controlled neural networks (VCNN) are introduced and class-specific correction (CSC) is applied. Both methods produce classifiers that are more reliable in presence of class overlap and class imbalance than those produced by well-established methods for certain problems.

The application of local wind prediction is formulated as a data-based classification task. The experiments involve the selection of appropriate input features, classifiers, and post-processing methods. The resulting forecast system is benchmarked on statistically significant testing sets for several sites. Multilayer perceptrons involving class-specific correction are found to lead to most accurate predictions, especially for severe winds. The experiments also indicate that samples from other stations can be used to reduce the involved class imbalance in a local training set. As a conclusion, two recipes for local wind prediction are formulated from which a sketch for further work can be derived.

ARNOLD Dieter

Computing Information Rates of Finite-State Models with Application to Magnetic Recording

ETH-Diss. Nr. 14760 (Referee: Prof. Dr. H.-A. Loeliger)

The topics of this thesis are mathematical models of the read-back channel in magnetic recording systems and their ultimate information-theoretical limit, the capacity.

Source and channel of the read-back channel can be modelled as a single finite-state model (FSM). The joint source/channel FSM is fully specified by the state transition probabilities of the source model and the output probability distribution function. In our case, this distribution is a parameterized Gaussian density. We focus on a-periodic and irreducible FSMs whose state and observation process are stationary and ergodic. Thus by the Shannon-McMillan-Breiman theorem, the entropy rates of the state and the observation process are determined by the probability of a typical sequence of those processes.

A new and practical method for computing lower and upper bounds (information rates) on the capacity of such finite-state channel models is presented. The pivotal observation behind the method is that the entropy rate of the channel output can be computed by standard forward sum-product trellis processing of simulated or (in principle) measured channel output data.

The method is applied to various FSMs of the read-back channel in magnetic recording systems with additive white Gaussian noise (AWGN), continuous mixture noise including medium noise, and discrete medium noise with memory. These models comprise (generalized) partial-response polynomials, sources with run-length limit constraints, FSMs that are trained on synthetically generated waveforms (microtrack model), and the binary jitter channel.

Keywords: Finite-state models, Shannon-McMillan-Breiman theorem, sum-product algorithm, information rate, channel capacity, magnetic recording, medium noise.

VONTOBEL Pascal

Algebraic coding for Iterative Decording

ETH-Diss. Nr. 14961 (Referee: Prof. Dr. H.-A. Loeliger)

Since the publication of Shannon's 1948 paper “A Mathematical Theory of Communication“ the quest has been on to find practical channel coding schemes that live up to the promises given by Shannon. Traditionally, coding theory focused on finding codes with arge minimum distance and then to find an efficient decoding algorithm for such a code. In the realm of iterative decoding the picture is reversed: given an iterative decoding algorithm, one has to look out for codes that are suitable for this algorithm.

To understand iterative decoding algorithms, it is advantageous to have a basic knowledge of factor graphs and the sum-product algorithm. Therefore, in a first step we show how the detection problems in a data transmission system can be very naturally modeled by factor graphs and solved with the help of the sum-product algorithm. We also show how different iteratively decodable channel codes fit very naturally into this picture.

For loopless factor graphs the sum-product algorithm gives back the desired results; for loopy factor graphs the results are only approximations to the desired ones. As we do not want that the sum-product algorithm becomes prohibitively computationally intense, we have to bound the local state space sizes. Under these circumstances, it seems favorable in our applications at hand to perform a sub-optimal algorithm on a loopy factor graph than to perform an optimal algorithm on a loopless factor graph. One reason for this phenomenon lies in the fact that under the above restriction much stronger codes can be achieved when allowing factor graph with cycles than without cycles. In order to apply the sum-product algorithm successfully, experimental evidences seem to indicate that it is advisable that the factor graph looks locally tree-like, i.e.~that there are no short cycles. This helps the messages of the sum-product algorithm to be as independent as possible. To be able to construct factor graphs of codes having these desirable properties, our next step is therefore to consider constructions of graphs having large girth, i.e. graph whose length of the shortest cycle is large. We then unify different constructions of graphs that have a large girth and we propose some extensions.

Finally, we come to the heart of our thesis, viz. the algebraic construction of codes suitable for iterative decoding. Based on graphs with large girth, we propose various algebraic constructions of regular and irregular low-density parity-check codes and turbo codes. Especially by using more complicated subcodes than simple parity-check subcodes and by using bit nodes of different degrees, one can obtain a rich class of codes.

Apart from this main line, we treat several topics that are still within the subject at hand. Viz., we discuss why codes whose Tanner graphs are trees cannot be asymptotically good; we give a shorter and more intuitive proof of this fact than available in the literature. We unify different algorithms that can be used to perform the sum-product update rule for an indicator function of a subcode, namely the BCJR algorithm, the one-sweep algorithm, and decoding on the dual

code. Finally, we propose some variations of a lower bound first given by Tanner on the minimum distance of some codes.

Keywords: Digital data transmission, channel coding, iterative decoding, factor graphs, sum-product algorithm, low-density parity-check codes, turbo codes, graphs with large girth, finite geometries, algebraic code constructions.

3.4 Completed Dissertations

KRETZSCHMAR Ralf — A Survey of Neural Network Classifiers for Local Wind Prediction

ETH Diss. Nr. 14538

Referee:	Prof. Dr. F. Eggimann
Co-referee:	Prof. Dr. H. Richner, Atmosphärenphysik Prof. N. Karayiannis, University of Houston, USA Dr. P. Eckert, MeteoSuisse Dr. D. Cattani, MeteoSuisse

ARNOLD Dieter — Computing Information Rates of Finite-State Models with Application to Magnetic Recording

ETH Diss. Nr. 14960

Referee:	Prof. Dr. H.-A. Loeliger
Co-Referee:	Dr. E. Eleftheriou, IBM, Switzerland Prof. A. Kavcic, Harvard University, Cambridge, USA

VONTOBEL Pascal — Algebraic Coding for Iterative Decording

ETH Diss. Nr. 14961

Referee:	Prof. Dr. H.-A. Loeliger
Co-Referee:	Prof. R. M. Tanner, University of California, Santa Cruz, USA Prof. J. Rosenthal, University of Notre Dame, Indiana, USA

4. Congresses, Meetings and Committees

4.1 Congress Organization

Prof. Lapidoth

Co-Chair of the Program Committee for the 2002 ISIT, Lausanne, Switzerland.

Co-Chair of the 2003 Winter School on Coding and Information Theory, Monte Verità, Switzerland.

Member of the Program Committee for the 2004 International Zurich Seminar, Zurich, Switzerland.

Prof. Loeliger

Publications Committee, 2002 IEEE International Symposium on Information Theory, Lausanne, Switzerland.

Co-Chair of the 2003 Winter School on Coding and Information Theory, Monte Verità, Switzerland.

Chairman of the 2004 International Zurich Seminar, Zurich, Switzerland.

4.2 Participation in Congresses and Meetings

Arnold Dieter	INTERMAG Conference, Amsterdam, The Netherlands, 28.4. – 5.2.2002.
Arnold Dieter	GLOBECOM 2002, Taipei, Taiwan, 17. – 21.11.2002.
Arnold Dieter Dauwels Justin Frey Matthias Merkli Patrick Vontobel Pascal	ISIT 2002, IEEE International Symposium on Information Theory, Lausanne, Switzerland, 30.6. - 5.7.2002.
Frey Matthias Merkli Patrick	Miniaturisierte Elektronik mit modernen Aufbautechniken, Entwicklung und Einsatz, ETH Zuerich, Switzerland, 19. – 20.3.2002.
Frey Matthias Merkli Patrick	Analog Decoding Workshop, TU Munich, Germany, 26.6.2002.
Gao Qun Lustenberger Felix	ISCAS'2002, IEEE International Symposium on Circuits and Systems, Phoenix, Arizona, USA, 26. – 29.5.2002.
Hofbauer Markus	SAM 2002, Second IEEE Sensor Array and Multichannel Signal Processing Workshop, Washington, USA, 4. – 6.8.2002.
Hofbauer Markus Korl Sascha	DGA, Jahrestagung der deutschen Gesellschaft fuer Audilogie, Zuerich, Switzerland, 27.2. – 2.3.2002.
Hofbauer Markus	Research Stay with Phonak Lab., Urbana-Champaign, USA, 7. – 15.8.2002.
Korl Sascha	NATO, Advanced Study Institute 2002, Dynamics of Speech Production and Perception, Il Ciocco, Italy, 24.6. – 6.7.2002.
Lapidoth Amos	MSRI Workshop, Information Theory, Berkeley, Calif., USA, 25.2. – 1.3.2002.
Lapidoth Amos	Institut EURECOM, Sophia Antipolis, France, 15. – 18.3.2002.
Lapidoth Amos	MIT, Boston, USA, 5.6. – 9.6.2002.
Lapidoth Amos	2nd Asian-European Workshop on Information Theory, Breisach, Germany, 26.6. – 29.6.2002.
Lapidoth Amos Hoesli Daniel Moser Stefan M.	2002 IEEE International Symposium on Information Theory, Lausanne, Switzerland, 30.6. – 5.7.2002.
Lapidoth Amos	EPFL, Lausanne, Switzerland, 8.11.2002.

Lapidoth Amos	2002 IEEE Information Theory Workshop, Bangalore, India, 20. – 25.10.2002.
Lapidoth Amos	2002 IEEE 22nd Convention of Electrical & Electronics Engineers in Israel, Tel-Aviv, Israel, 1.12.2002.
Loeliger Hans-Andrea	ISIT 2002, IEEE International Symposium on Information Theory, Lausanne, Switzerland, 30.6. - 5.7.2002.
Loeliger Hans-Andrea	15th International Symposium on Mathematical Theory of Networks and Systems, South Bend, Indiana, USA, 12. – 16.8.2003.
Loeliger Hans-Andrea Vontobel Pascal	40th Allerton Conference on Communication, Control, and Computing, Monticello, Indiana, USA, 2. – 4.10.2002.
Vontobel Pascal	AMS and MAA Joint Mathematics Meeting, San Diego, CA., USA, 6. – 9.1.2002.
Vontobel Pascal	IEEE International Conference on Communi-cations, New York, USA, 28.4. – 5.2.2002.
Vontobel Pascal	15th International Symposium on Mathematical Theory of Networks and Systems, University of Notre Dame, IN., USA, 12. – 16.8.2002.
Vontobel Pascal	Research Stay with University of Illinois at Urbana-Champaign, IL., USA, 31.7. – 11.8.2002.

4.3 Service Activities and Society Memberships

Prof. Lapidoth

Senior Member of the IEEE New York

Member of Search Committee for the Professorship in Wireless Communications, ETHZ

Prof. Loeliger

Member of the IEEE

Chairman of the IEEE Switzerland Chapter on Digital Communication Systems

Dr. Heutschi

Member, Acoustical Society of America

Member, Audio Engineering Society

Member, Swiss Acoustical Society (SGA)

4.4 Presentations by Institute Members

Arnold Dieter	"On the Information-Theoretic Capacity of Magnetic Recording Systems in the Presence of Media Noise", INTERMAG 2002, Amsterdam, The Netherlands, 5.2.2002.
Arnold Dieter	"On Finite-State Information Rates from Channel Simulations", ISIT 2002, Lausanne, Switzerland, 2.7.2002.
Arnold Dieter	"Computing Information Rates of Magnetic Recording Channels in the Presence of Medium Noise, GLOBECOM 2002, Taipei, Taiwan, 20.11.2002.
Frey Matthias Merkli Patrick	"Softgates – Building Blocks for Analog Decoders", Analog Decoding Workshop, Munich, Germany, 26.5.2002.
Gao Qun	"Binary Image Rotation using Cellular Neural Networks", ISCAS'2002, Phoenix, Arizona, USA, 28.5.2002.
Lapidoth Amos	"Are Multi-Antenna Capacity Gains mere Channel-Modeling Artifacts?"LIDS Seminar, MIT Boston, USA, 14.2.2002.
Lapidoth Amos	"Capacity-achieving Distributions that escape to Infinity and the Fading Number", MSRI IT Workshop, Berkeley, USA, 25.2. – 1.3.2002.
Lapidoth Amos	"An Invitation to Information Theory", University of Zurich, Switzerland, 8.5.2002.
Lapidoth Amos	"Capacity Bounds via Duality: A Phase-Noise Example", Signal and Information Processing Lab., ETH Zurich, Switzerland, 21.6.2002.
Lapidoth Amos	"Capacity Bounds via Duality – A Phase Noise Example", 2nd Asian-European Workshop on Information Theory, Breisach, Germany, 27.6.2002.
Lapidoth Amos	"On Phase Noise Channels at High SNR", ITW 2002, Bangalore, India, 20. – 25.10.2002.
Loeliger Hans-Andrea	"Factor Graphs: Least Squares and Kalman Filtering", 15th International Symposium on Mathematical Theory of Networks and Systems, South Bend, Indiana, USA,12. – 16.8.2002.

Loeliger Hans-Andrea	"Computation of Information Rates from Finite-State Source/Channel Models", 40th Allerton Conference on Communication, Control, and Com puting, Monticello, Illinois, USA, 2. – 4.10.2002.
Loeliger Hans-Andrea	"Signal Processing with Factor Graphs", CGC Colloquium, Graduate Program on Combinatorics, Geometry, and Computation, ETH Zuerich, Switzerland, 25.11.2002.
Moser Stefan M.	"Kurzeinstieg in die Informationstheorie", Seminar über Wissensmanagement, ETH Zurich, Switzerland, 19.4.2002.
Moser Stefan M.	"On the Fading Number of Multi-Antenna Systems over Flat Fading Channels with Memory and Incomplete Side Information", Signal and Information Processing Lab., ETH Zurich, Switzerland, 21.6.2002.
Moser Stefan M.	"On the Fading Number of Multi-Antenna Systems over Flat Fading Channels with Memory and Incomplete Side Information", ISIT 2002, Lausanne, Switzerland, 5.7.2002.
Moser Stefan M.	"On Multi-Access Channels (MAC) at High SNR", Signal and Information Processing Lab., ETH Zurich, Switzerland, 19.12.2002.
Vontobel Pascal O.	"On the derivation of LDPC and Turbo Codes from Graphs with Large Girth". AMS Joint Mathematics Meeting, San Diego, CA., USA, 8.1.2002.
Vontobel Pascal O.	"On the Construction of Turbo Code Interleavers based on Graphs with Large Girth", International Conference on Communications, New York, USA, 28.4. – 2.-5.2001
Vontobel Pascal O.	"Factor Graphs, the Sum-Product Algorithm, LDPC Code Constructions, Density Evolution, and Kalman Filtering"- four lectures. San Diego State University, San Diego, CA., USA, 3. – 14.5.2002.
Vontobel Pascal O.	"Irregular Codes from Regular Graphs", International Symposium on Information Theory, Lausanne, Switzerland, 30.6. – 5.7.2002.
Vontobel Pascal O.	"Iterative Decoding and Design of Codes on Graphs", 15th International Symposium on Mathematical Theory of Networks and Systems", Notre Dame University, IN., USA, 13.8.2002.

Vontobel Pascal O.	"Kalman Filtering, Factor Graphs, and Electrical Networks", 15th International Symposium on Mathematical Theory of Networks and Systems, South Bend, IN.,USA,12. – 16.8.2002.
Vontobel Pascal O.	"Factor Graphs, Electrical Networks, and Entropy", 40th Annual Allerton Conference, Allerton Park, IL., USA, 2. – 4.10.2002.

4.5 Organization of Lectures, Seminars, and Colloquia

Colloquium Speakers for the Colloquium "Electronics and Communications" were:

Invited by Prof. Lapidoth:

21.03.02	**Dr. Jossy Sayir**, FTW Wien "Transmitting Stationary Sequences over Noisy Channels".
25.06.02	D**r. Zsolt Kukorelly**, UCSD, USA "Hexagonal (d, k) Constraints for Holographic Data Storage".
23.06.02	**Dr. I. Sason,** EPFL Lausanne, Switzerland "On the Density of Parity-Check Matrices of Capacity-Approaching Binary Linear Codes on Memoryless and Symmetric Channels".
25.06.02	**Prof. Dr. R.W. Yeung**, Chinese University, Hong Kong, China "On Factorization of Positive Functions".

Invited by Prof. Loeliger:

5.02.01	**Prof. Dr. N.B. Karayiannis,** University of Houston, Houston, USA "Reformulating Learning Vector Quantization and Radial Basis Neural Networks".
19.06.02	**Prof. Dr. P. Siegel,** University of California, San Diego, USA "Message Passing Decoding of Partial-Response Channel".
21.06.02	**Prof. Dr. P. Siegel,** University of California, San Diego, USA **"**Equalities among Capacities of (d,k)-Constraint Systems".
26.06.02	**Dr. M. Postol,** NSA, USA **"**Information Geometry, the Sum-Product Algorithmen, and Iterative Decoding".
26.06.02	**Prof. R. Blahut**, University of Illinois, Urbana, USA "Communications in Time and Space".
28.06.02	**Prof. Dr. M. Tanner,** University of Illinois, Chicago, USA "On Graph Construction for LDPC Codes by Quasi-Cyclic Extension".
16.09.02	**Prof. Dr. M. Fossorier,** University of Hawaii, Honolulu, USA "Probalistic Soft Decision List Decoding of Binary Linear Block Codes".
16.10.02	**Dr. L. Tolhuizen,** Philips Research Laboratories, Eindhoven, The Netherlands

"Coding for Informed Decoders, with an Application to Address Retrieval in Blu-Ray Disc".

13.12.02 **Prof. Dr. J. Rosenthal,** University of Notre Dame, IN., USA
"A Numerical Approach for Designing Unitary Space Time Codes with Large Diversity".

Invited by Dr. Heutschi

06.02.02 **Prof. Dr. P. Lercher,** Institut für Hygiene und Sozialmedizin, Uni Insbruck, Austria
"Lärmwirkungsforschung im Kontext alpiner Topographie und alpinen Lebensstils: Das Beispiel Tirol".

29.05.02 **Dr. habil. D. Heimann, DLR -** Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany
"Simulation der Schallausbreitung im Freien unter konsistenter Berücksichtigung der Topographie und der Atmosphäre".

12.06.02 **P. Pellizzari,** Direktor der Schweizerischen Landesphonothek, Lugano, Switzerland
"Die Landesphonothek, das akustische Gedächtnis der Schweiz".

04.12.02 **Prof. Dr. R. Guski,** Fakultät für Psychologie, Ruhr-Uni Bochum, Germany
"Status und Desiderate der Lärmwirkungsforschung zu Beginn des 21. Jahrhunderts".

5. Publications

Arnold Dieter, Loeliger Hans-Andrea	"Computing Information Rates of the Microtrack Channel", Proc. of the IEEE INTERNAG Conference, Amsterdam, The Netherlands, pp. BR-11, April 28 - May 2, 2002.
Arnold Dieter, Loeliger Hans-Andrea	"On Finite-State Information Rates from Channel Simulations", Proceedings of the IEEE International Symposium on Information Theory, p. 164, June 30 - July 5, 2002.
Arnold Dieter, Eleftheriou E.	"On the Information-Theoretic Capacity of Magnetic Recording Systems in the Presence of Media Noise", Proceedings of the IEEE INTERMAG Conference, Amsterdam, The Netherlands, pp. EC-07, April 28-May 2, 2002.
Arnold Dieter, Eleftheriou E.	"On the Information-Theoretic Capacity of Magnetic Recording Systems in the Presence of Medium Noise", IEEE Transactions on Magnetics, vol. 38, no. 5, pp. 2319-2321, Sep, 2002.
Arnold Dieter, Eleftheriou E.	"Computing Information Rates of Magnetic Recording Channels in the Presence of Medium Noise", Proceedings of the IEEE GLOBECOM 2002, Taipei, Taiwan, Nov, 20, 2002.
Arnold Dieter, Loeliger Hans-Andreas, Vontobel Pascal O.	"Computation of Information Rates from Finite-State Source/Channel Models", Proceedings 40th Allerton Conference on Communications, Control, and Computing, Allerton House, Monticello, ILL., USA, Oct. 2 - 4, 2002.
Gao Qun, Moschytz George S.	"Binary Image Rotation Using Cellular Neural Networks", Proceedings of the 2002 IEEE International Symposium on Circuits and Systems, vol. 3, pp. 113-116, Phoenix, Arizona, USA, May, 2002.
Hu X.-Y., Eleftheriou E., Arnold Dieter	"Irregular Progressive-Edge Growth Tanner Graphs", Proceedings of the IEEE International Symposium on Information Theory, p. 480, June 30 - July 5, 2002.
Hu X.-Y., Eleftheriou E., Arnold Dieter	"Irregular Progressive-Edge Growth Tanner Graphs", Proceedings of the 4th International ITG Conference on Source and Channel Coding 2002, Berlin, Germany, pp. 61-68, January 28 - 30, 2002.
Lapidoth Amos	"Capacity Bounds Via Duality: A Phase Noise Example", Proceedings of the 2nd Asian-European Workshop on Information Theory, Breisach, Germany, June 26 -29, 2002.
Lapidoth Amos	"On Phase Noise Channels at High SNR", Proceedings 2002 IEEE Workshop on Information Theory, Bangalore, India, October 20 - 25, 2002.

Lapidoth Amos, Moser Stefan M.	"On the Fading Number of Multi-Antenna Systems over Flat Fading Channels with Memory and Incomplete Side Information", Proceedings 2002 IEEE International Symposium on Information Theory, p. 478, Lausanne, Switzerland, June 30 - July 5, 2002.
Lapidoth Amos, Moser Stefan M.	"Capacity Bounds via Duality with Applications to Multi-Antenna Systems on Flat Fading Channels", June 25, Preprint, 2002.
Lippuner Daniel	"Model-Based Step-Size Control for Adaptive Filters", Series in Signal and Information Processing, p. 160, January, Hartung-Gorre Verlag, Konstanz, Dissertation, ISBN 3-89649-755-3, 2002.
Loeliger Hans-Andrea	"Least Squares and Kalman Filtering on Forney Graphs", Codes, Graphs, and Systems, R.E. Blahut and R. Koetter, eds., Kluwer, 2002.
Mathis H.	"Blind Carrier Phase Synchronization for HDTV", Proceedings International Zurich Seminar IZS 2002, pp. 45-1--45-6, Zurich, Switzerland, Feb. 19 - 21, 2002.
Mathis H., Douglas S.C.	"On the Existence of Universal Nonlinearities for Blind Source Separation", IEEE Transactions on Signal Processing, vol. 50, no. 5, pp. 1007-1016, May, 2002.
Mathis Heinz, Joho Marcel	"Blind Signal Separation in Noisy Environments using a Three-Step Quantizer", Elsevier Neurocomputing, vol. 49, no. 1-4, pp. 61-78, Dec, 2002.
Schärer Thomas	"50-Hz-Notchfilterbank in SC-Technik: Das Übel an der Wurzel Packen (Teil I)", MegaLink, no. 4, pp. 60-62, April, 2002.
Schärer Thomas	"50-Hz-Notchfilterbank in SC-Technik: Das Übel an der Wurzel Packen (Teil II)", MegaLink, no. 5, pp. 50-52, Mai, 2002.
Schmid Hanspeter	"An 8.25-MHz 7th-Order Bessel Filter built with Single-Amplifier Biquadratic MOSFET C Filters", Analog Integrated Circuits and Signal Processing, vol. 30, no. 1, pp. 69-81, January, 2002.
Vontobel Pascal O.	"On the Construction of Turbo Code Interleavers Based on Graphs with Large Girth", Proc. IEEE Intern. Conf. Communications, vol. 3, pp. 1408-1412, New York, NY, USA, Apr. 28-May 2, 2002.
Vontobel Pascal O.	"Kalman Filters, Factor Graphs, and Electrical Networks", no. INT/200202, Post-diploma thesis, Laboratory for Signal and Information Processing, ETH Zurich, April, 2002.

Vontobel Pascal O.	"Factor Graphs, Electrical Networks, and Entropy", Proc. of the 40th Annual Allerton Conference, Allerton Park, IL, USA, Oct. 2-4, to appear, 2002.
Vontobel Pascal O.	"A Generalized Blahut-Arimoto Algorithm", ISI Internal Report, no. INT 200203, Laboratory for Signal and Information Processing, ETH Zurich, Switzerland, November, 2002.
Vontobel Pascal O., Lippuner Daniel, Loeliger Hans-Andrea	"Kalman Filtering, Factor Graphs, and Electrical Networks", CD Proceedings 15th International Symposium on Math. Theory of Networks and Systems, South Bend, Indiana, USA, August 12-16, 2002.
Vontobel Pascal O., Loeliger Hans-Andrea	"On Factor Graphs and Electrical Networks", Mathematical Systems Theory in Biology, Communication, Computation, and Finance, J. Rosenthal and D.S. Gilliam, eds, IMA Volumes in Math. and Appl., Springer Verlag.
Vontobel Pascal O., Loeliger Hans-Andrea	"Irregular Codes from Regular Graphs", Proc. IEEE International Symposium on Information Theory, p. 284, Lausanne. Switzerland, June 30-July 5, 2002.
Zennaro Daniel, Läubli Thomas, Wellig Peter, Krebs Denise, Schnoz Michael, Klipstein Andreas, Krueger Helmut	"A Method to test Reliability and Accuracy of the Decomposition of Multi-Channel Long-Term Intramuscular EMG Signal Recordings", vol. 30, no. 4-5, pp. 211-224, International Journal of Industrial Ergonomics, 2002.
Zennaro Daniel, Wellig Peter, Koch Volker M., Moschytz George S., Läubli Thomas, Krueger Helmut	"A Software Package for the Decomposition of Long-Term Multi-Channel EMG Signals using Wavelet Coefficients", IEEE Transaction in Biomedical Engineering, In press, 2002.

6. Honors and Awards

Arnold Dieter	Recipient of the 2001 Student Paper Award of the Signal Processing for Storage Technical Committee of the IEEE Communications Society in November 2002 for the paper "On the Information Rate of Binary-Input Channels with Memory", Proc. ICC, Helsinki, Finland, June 2001.
Schärer Thomas	The E-ONLINE-Newsletter (http://www.e-online.de) to which Thomas Schaerer has been very substantially contributing, obtained a Gold Award of Newsletters Online.