Signal and Information Processing Laboratory

Prof. A. Lapidoth and Prof. H.-A. Loeliger

ANNUAL REPORT

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Foreword

I am happy to report that 2014 was another pleasant and productive year in our institute for faculty, students, and staff alike. Our high standards in teaching and research were confirmed by the positive report issued by the visiting committee, who spent a week in the Department of Information Technology and Electrical Engineering in the second half of October. If they had just read the previous years' annual reports, they could have spared themselves the trip, since it is clear that by all accounts we are thriving!

In 2014 our institute co-hosted the twenty-third successful International Zurich Seminar on Communications, which gave us a chance to intellectually and socially reconnect with colleagues from the world over. Hosting, learning from, and collaborating with them was, as ever, a winter highlight, topped by a snowy adventure on the Parsenn in Davos. In addition, our annual events, such as the ISI Christmas Dinner, held at the Zunfthaus zur Saffran, and the Wander- and Skitag brought us fine dining and exploration opportunities and allowed us to recharge our batteries together.

2014 brought a few changes, as well. We had the privilege of congratulating Dr. Christoph Bunte on his successful dissertation defense last August, and then on his receipt of the ISIT Student Paper award. We wish him well in his new position in industry, but are glad to have the occasional pleasure of seeing him when he swings by the institute for old times' sake.

We were also glad to congratulate Dr. Jiun Hung Yu on his PhD, particularly as we did not have to bid him farewell, given that he accepted a post-doctoral fellowship with us.

In February we welcomed Federico Wadehn, who began his PhD with Andi Loeliger, and in October Prof. Christian Schlegel, who spent his sabbatical with us.

With a sense of profound gratitude for the many individuals whose time and energy create the wonderful atmosphere of the institute, I will sign off on 2014 with the sincere hope that the institute will continue to flourish in the future as we have in the past.

Amos Lapidoth

Contents

1. Personnel

Professor for Information Theory:

Prof. Amos Lapidoth

Professor for Signal Processing:

Prof. Hans-Andrea Loeliger

Secretaries: **Rita Hildebrand**
Silvia Tempel

Senior Researcher: **Dr. Stefan Moser**

Research Assistants:		
	Annina Bracher	Msc ETH
	Lukas Bruderer	MSc ETH
	Christoph Bunte	MSc ETH (left on 15.8.2014)
	Neff Sarah	MSc ETH
	Christian Schürch	MSc ETH
	Federico Wadehn	MSc ETH
	Georg Wilckens	MSc ETH
	Jiun-Hung Yu	MSc.NCTU Taiwan
	Zalmai Nour	MSc ETH

Technical Staff: **Thomas Schärer**
Patrik Strebel El.Eng.HTL

2. Teaching

2.1 Courses

Sem.	Instructors	Title	ETH-No.
5th	Prof. H.-A. Loeliger	Zeitdiskrete und statistische Signal-verarbeitung	227-0101
7th	Prof. H.-A. Loeliger	Signal and Information Processing	227-0427
8th	Prof. H.-A. Loeliger	Algebra and Error Correcting Codes	227-0418
6th	Prof. A. Lapidoth	Communication and Detection Theory	227-0104
7th	Prof. A. Lapidoth	Information Theory I	227-0417
8th	Prof. A. Lapidoth	Information Theory II	227-0420

Courses by external Lecturers

7th	Dr. K. Heutschi	Accoustics I	227-0477
8th	Dr. K. Heutschi	Accoustics II	227-0478
8th	Dr. H.P. Schmid	Analog Signal Processing and Filtering	227-0478

2.2 Lab Courses (Practica)

5/6th	Practica	Laboratory for "Fundamentals in Electrical Engineering"	227-0095/96
3rd/4th	Ch. Schürch	Blackfin DSP	227-0085
2nd/3rd	Th. Schaerer	EMG Biofeedback Device	227-0085

2.3 Student Projects

Students	Title	Supervisor

Semester Projects FS 2014

Students	Title	Supervisor
Patrick Murer	Localizing Model Switch by Means of Local Statstical State-Space Models	Nour Zalmai Sarah Neff
Samuel Welschen	Regularization in Kernel Methods for Regression	Nour Zalmai Federico Wadehn
Daniel Gilgen Fabio Marti	Variations of Phase-Locked Loops for Harmonic-related Signals	Nour Zalmai Lukas Bruderer
Alec Green	Signal Processing for XRF Spectroscopy	Sarah Neff
Josef Ziegler	Analysis of a Simple Model for Molecular Communication Between Nano Devices on a Fluid	Stefan M. Moser
George Negulescu	Spatially Couples LDPC Codes	Christian Schürch

Semester Projects HS 2014

Students	Title	Supervisor
Désirée Clausen	Detection and Classification of Heart Valve Sounds from Two-Channel Measurements	Nour Zalmai Reto Wildhaber
Florian Wassmer Timon Künzle	Phase Noise Estimation	Sarah Neff Lukas Bruderer
Christoph Pfister	Optimal Task Encoders	Amos Lapidoth
Vanessa Hunziker Vincenc Freiermuth	Inferring Mechanical Heart Condition from Sound Signals	Nour Zalmai Reto Wildhaber
Clément Luneau	Gesture Recognition from Magnetic Field Measurements: Extensions and Improvements	Nour Zalmai
David Carnal	A Heart Beat Detection Algorithm for Photoplethysmographic-Signals	Federico Wadehn
Michail Mylonakis	Rényi and Shannon Entropies	Amos Lapidoth Stefan Moser

Master Theses 2014

Christian Käslin	Gesture Recognition on Smartphone with Likelihood Filtering	Sarah Neff Lukas Bruderer Nour Zalmai
Erik Hampus Malmberg	Sparse Bayesian Learning for Blind Deconvolution	Lukas Bruderer
Salomon Diether	Blind Reverberation Time Estimation From Speech	Dr. Andreas Streich/Phonak Lukas Bruderer

3. Research

3.1 General 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:

- Combined source-channel coding for multi-access networks
- Multi-access channels with noisy feedback
- Network coding
- Capacity of fading channels
- Broadcasting correlated sources
- Multi-path channels
- Interference networks
- Optical channels
- Error correcting codes
- Monte Carlo algorithms and numerical information theory

Digital Signal Processing

Current topics:

- State-space methods in signal processing
- Fundamentals and applications of graphical models (factor graphs)
- Feature detection filters

Analog and Hybrid Signal Processing

Current topics:

- Digital-to-analog conversion and analog-to-digital conversion
- Joint synchronization and decoding

3.2 Current Research Topics

Prof. Amos Lapidoth (Information Theory)

The Free-Space Optical Intensity Channel at Low SNR

Free-space optical intensity channels are used to model infrared communication in an environment with strong ambient light. Hence of particular interest is the capacity at low SNR. We derive the asymptotic growth of the channel capacity at low SNR under average and/or peak power constraints.

On Multipath Fading Channels at High SNR

We study a discrete-time, non-coherent, multipath fading channel where the number of paths finite. The focus is on capacity at high signal-to-ratios (SNR). In particular, we investigate the capacity pre-loglog, defined as the limiting ratio of capacity to loglog SNR as SNR tends to infinity.

Multipath Channels of Unbounded Capacity

We investigate the capacity of discrete-time, non-coherent, multipath fading channels. We study conditions under which channel capacity is unbounded in the allowed transmit power.

The Poisson Channel at Low Input Powers

We study the asymptotic capacity at low input powers of an average-power limited or an average- and peak-power limited discrete-time Poisson channel. We consider channels whose dark currents are proportional to the input powers as well as channels whose dark currents are constant.

Wyner´s Interference Network with Side-Information at Transmitters and Receivers

We consider a linear interference network modeling the communication in wireless cellular systems. For this network we explore a duality regarding transmitter side-information (cognition of other transmitters´messages and receiver side-information (observation of other receivers´signals).

The Poisson Channel with Side Information

We study the capacity of the peak-limited Poisson channel with spurious counts whose positions are given a-causally as side-information to the transmitter but not to the receiver.

Coding for a Noisy Feedback Link

We study communication in the presence of a *noisy* feedback link. We assume that the feedback is active, so the noise on the feedback link can be combatted using coding. We study specific coding schemes as well as fundamental limits that hold for all coding schemes.

The Multiple Access Channel with Causal State Information

We study a state-dependent two-to-one multiple access channel (MAC), where the state sequence is available as side-information to the transmitters but not to the receiver. We consider two scenarios depending on whether the state sequence is known strictly causally or causally.

Prof. H.-A. Loeliger (Signal Processing)

State-Space Methods in Statistical Signal Processing

Most of our work in signal processing is based on linear state space models. Using IIR (infinite impulse response) models decouples the model order from the sampling rate and allows effortless transitions between discrete time and continuous time. We have extended such models to pulse-like (wavelet-like) signals that are localized anywhere in time. For given observations and unknown localization, the corresponding model likelihood is then itself a function of time, i.e., a signal. The computation of such a likelihood signal leads to the concept of a likelihood filter (or feature detection filter), a generalization of a matched filter.

In parallel with the development of this approach, we have applied it to applications including joint symbol synchronization and matched filtering, detection of seismic waves, analysis of biomedical signals, gesture detection using the magnetic sensor in smartphones, and many more.

Likelihood filters (feature detection filters) can also be cascaded into a new sort of neural network that works naturally with multichannel signals at multiple time scales. The exploration of this new approach has only just begun.

Fundamentals and Applications of Factor Graphs

Factor graphs are a graphical notation for system models and algorithms in a large variety of fields including error correcting codes, signal processing, statistical physics, linear algebra, and more. We find factor graphs to be very helpful in most of our research work, and we continue to develop the approach. Recent progress includes localized state space models (see above), and factor graphs for joint probability distributions in quantum systems with many variables.

Monte Carlo Algorithms and Numerical InformationTheory

Many hard computational problems in information theory and statistical estimation can be addressed with Monte Carlo techniques. We have been continuing to enlarge the scope of such algorithms, e.g., to computing the partition function of Markov random fields at low temperature using factor graph duality.

Error Correcting Codes

Our present interest is in a new perspective on decoding algorithms for Reed-Solomon codes (and similar codes), and on combining ideas from Reed-Solomon codes and polar codes.

Analog Computation and Analog-to-Digital Conversion

We have a long-standing interest in analog computation and analog circuits for information processing. Our recent research in this area has focused on ana-log-to-digital converters. However, many of our likelihood filters (see above) are eily implementable as analog crcuits.

3.3 Publications

H.-A. Loeliger, S.Neff, and Ch. Reller	"Self-synchronizing signal parsing with spiking feature-detection filters", *52nd Annual Allerton Conference on Communication, Control, and Computing,* Monticello, Illinois, USA, October 1 – 3, 2014.
H.-A. Loeliger and Jiun Hung Yu	"An algorithm for simultaneous partial inverses", *52nd Annual Conference on Communication, Control, and Computing,* Monticello, Illinois, USA, October 1 – 3, 2014.
H.-A. Loeliger, L. Bruderer, and N. Zalmai	"Local statistical models from deterministic state space models, likelihood filtering, and local typicality", *IEEE International Symposium on Information Theory,* Honolulu, Hawai, June 29 – July 4, 2014.
H.-A. Loeliger and L. Bruderer	"Estimation of sensor input signals that are neither bandlimited nor sparse", *Information Theory and Applications Workshops, (ITA),* San Diego, CA., February 9 – 14. 2014.
CH. Zechner, F. Wadehn, and H. Koeppl	"Sparse Learning of Markovian Population Models in Random Environments", *19th World Congress of the International Federation of Automatic Control, (IFAC),* Cape Town, South Africa, August 24 – 29, 2014.
X. Dong, P. Frossard, P. Vandergheynst , and Nefedov N.	"Clustering on Multi-Layer Graphs via Subspace Analysis on Grassmann Manifolds", *IEEE Transactions on Signal Processing,* vol. 60, no. 4, pp. 905 – 918, February 2014.
A. Bracher and A. Lapidoth	"Identification via the Broadcast Channel", *IEEE International Symposium on Information Theory,* Honolulu, Hawai, June 29 – July 4, 2014.
Ch. Bunte, A. Lapidoth, and Palzer L.	"Coding for the Gaussian Channel with Intermittend Feedback", *IEEE International Symposium on Information Theory,* Honolulu, Hawai, June 29 – July 4, 2014.
Ch. Bunte and A. Lapidoth	"Codes for Tasks and Rényi Entropy Rate", *IEEE International Symposium on Information Theory,* Honolulu, Hawai, *June 29 – July 4, 2014.*
Ch. Bunte and A. Lapidoth	"On Maximum Rényi Entropy Rate", *7th Joint Workshop on Coding and Communication,* Barcelona, Spain, November 13 – 15, 2014
Ch. Bunte and A. Lapidoth	"Maximizing Rényi Entropy Rate", *IEEE 28th Convention of Electrical and Electronics Engineers,* Eilat, Israel, December 3 -5 , 2014.
Ch. Bunte and A. Lapidoth	"A Proof of the Ahlswede-Cai-Zhang Conjecture", *IEEE Symposium on Information Theory,* Honolulu, Hawai, June 29 – July 4, 2014.

Ch. Bunte and A. Lapidoth — "Rényi Entropy and Quantization for Densities", *IEEE Information Theory Workshop (ITA),* Hobart, Australien, November 2 – 5, 2014.

A. Bracher, E. Hof, and A. Lapidoth — "Distributed Storage for Data Security", *IEEE Information Theory Workshop (ITA),* Hobart, Australien, November 2 – 5, 2014.

E. Abbe, A. S. Brandeira, A. Bracher, and A. Singer — "Linear inverse problems on Erdös-Rényi graphs: Information-, A. theoretic limits and efficient recovery", *IEEE International Symposium on Information Theory,* Honolulu, Hawai, June 29 – July 4. 2014.

Ch. Bunte and A. Lapidoth — "On the Listsize Capacity With Feedback", *IEEE Transactions on Information Theory,* vol. 60., no. 11., pp. 6733 – 6748, 2014.

A. Lapidoth, N. Levy, S. Shamai, and M. Wigger — "Cognitive Wyner Networks With Clustered Decoding", *IEEE Transactions on Information Theory,* vol. 60, no. 10, pp. 6342 – 6367, 2014.

Ch. Bunte and A. Lapidoth — "Encoding Tasks and Rényi Entropy", *IEEE Transactions on on Information Theory,* vol. 60., no. 9. Pp. 5065 – 5076, 2014.

Ch. Bunte, A. Lapidoth, and A. Samorodnitsky — "The Zero-Undetected-Error Capacity Approaches the Sperner Capacity", *IEEE Transactions on Informations Theory,* vol. 60, no. 7, pp. 3825 – 3833, 2014.

A. Lapidoth, A. Malär , and M. Wigger — "Constrained Source-Coding With Side Information", *IEEE Transactions on Information Theory,* vol. 60, no. 6., pp. 3218 – 3237, 2014.

M. Gastpar, A. Lapidoth, Y. Steinberg, and M. Wigger — "Coding Schemes and Asymptotic Capacity for the Gaussian Broadcast and Interference Channels with Feedback", *IEEE Transactions on Information Theory,* vol. 60., no. 1, pp. 54 – 71, January 2014.

A. Bracher and A. Lapidoth — "Feedback, Cribbing, and Causal State Information on the Multiple-Access Channel", *IEEE Transactions on Information Theory,* vol. 60, no. 12. pp. 7627 – 7654, December 2014.

Stefan M. Moser — "A Toy-Model for Molecular Communication Between Nano Devices in a Fluid", *3rd International Workshop on Advances in Communications,* Boppard, Germany, May 14 – 16, 2014.

Stefan M. Moser — "Capacity Bounds of the Memoryless AIGN Channel – a Toy-Model for Molecular Communication in a Fluid", *BIRS Workshop on Biological and Bio-Inspired Information Theory,* Banff, Canada, October 26 – 31, 2014.

Ch. Po-Ning, H. Lin, and Stefan M. Moser — "Optimal Ultra-Small Block-Codes on Two Special Binary Channels", *National Symposium on Telecommunication (NT`14),* Taichung, Taiwan, November 27 – 28. 2014.

Y. Guo, H. Lin, and Stefan M. Moser	"The Asymptotic-Capacity of Noncoherent Single-Input Multiple-Output Fading Channels with Memory and Feedback", *2014 Spring Workshop on Information Theory and Communications (ITC´14)*, Kaohsiung, Taiwan, January 23 – 24, 2014.
P. Chen, H. Lin, and Stefan M. Moser	"On the Suboptimality of Equidistant Codes Meeting the Plotkin Bound", *2014 Spring Workshop n Information Theory and Communications (ITC`14),* Kaohsiung, Taiwan, January 23 – 24, 2014.
H. Li, Stefan M. Moser, and Y. Guo	"Capacity of the Memoryless Additive Inverse Gaussian Noise Channel", *IEEE Journal on Selected Areas in Communications,* vol. 32, no. 12, pp. 2315 – 2329, December 2014.
Stefan M. Moser	"Impact of Feedback and Side Information on the Asymptotic Capacity of Single-Input Multiple-Output Fading Channels with Memory", *IEEE Transactions on Information Theory,* vol. 60, no. 6, pp. 3499 – 3528, June 2014.
Stefan M. Moser	"Information Theory (Lecture Notes), 4th edition", Signal and Information Processing Laboratory, ETH, Zurich, Switzerland, and Department of Electrical & Computer Engineering, National Chiao Tung University (NCTU*)*, Hsinchu, Taiwan, 2014.

3.4 Completed PhD Theses

BUNTE Christoph

Error-Free Source and Channel Coding with Lists

ETH-Diss. Nr. 21888

Referee:	Prof. Amos Lapidoth
Co-examiner:	Prof. Dr. Emre Telatar, Ecole Polytechnique Fédérale de Lausanne

YU Jiun-Hung

A Partial-Inverse Approach to Decoding Reed-Solomon Codes and Polynomial Remainder Codes

ETH-Diss. Nr. 22201

Referee:	Prof. Hans-Andrea Loeliger
Co-examiner:	Prof. Martin Bossert, Universität Ulm, Deutschland

4.Trips and Talks

4.1 Participation in Conferences and Meetings

Lapidoth Amos	IZS International Zurich Seminar on Communcations, Zurich, February 26 – 28.
Lapidoth Amos	IEEE International Symposium on Information Theory, Honolulu, Hawai, June 29 – July 4.
Lapidoth Amos	Workshop on Coding and Communications, Barcelona, Spain, November 14 – 15.
Lapidoth Amos	IEEE 28th Convention of Electrical and Electronics, Eilat, Israel, December 3 – 5.
Lapidoth Amos	The Fifth UPEMLV Workshop on Information Theory, Random Matrices and Applications, Ecole polytechnique fédéral, Lausanne, September 11 – 12.
Bunte Christoph	IZS International Zurich Seminar on Communications, Zurich, February 26 – 28.
Bunte Christoph	IEEE International Symposium on Information Theory, Honolulu, Hawai, June 29 – July 4.
Bracher Annina	IZS International Zurich Seminar on Communications, Zurich February 26 – 28.
Bracher Annina	IEEE International Symposium on Information Theory, Honolulu, Hawai, June 29 – July 4.
Bracher Annina	IEEE Information Theory Workshop, Hobart, Australia, November 2 – 5.
Moser Stefan	IZS International Zurich Seminar on Communications, Zurich February 26 – 28.
Moser Stefan	3rd International Workshop on Advances in Communications, Boppard, Germany, May 14 – 16.
Moser Stefan	Workshop on Biological and Bio-Inspired Information Theory, Banff, Canada, October 26 – 31.
Loeliger H.A.	Information Theory and Applications Workshop, San Diego, USA, February 9 – 16.
Loeliger H.A.	IZS International Zurich Seminar on Communications, Zurich February 26 – 28.
Loeliger H.A.	IEEE International Symposium on Information Theory, Honolulu, Hawai, June 29 – July 4.
Loeliger H.A.	52nd Annual Allerton Conference on Communication, Control and Computing, Monticello, Illinois, USA, October 1 – 3.
Loeliger H.A.	Joint Workshop on Coding and Communication, Barcelona, Spain, November 11 – 16.

Bruderer Lukas	Information Theory and Applications Workshop, San Diego, USA, February 9 – 16.
Bruderer Lukas	IEEE International Symposium on Information Theory, Honolulu, Hawai, June 29 – July 4.
Yu Jiun Hung	52nd Annual Allerton Conference on Communication, Control and Computing, Monticello, Illinois, USA, October 1 – 3.
Neff Sarah	52nd Annual Allerton Conference on Communication, Control and Computing, Monticelli, Illinois, USA, October 1 – 3.
Nour Zalmai	IEEE International Symposium on Information Theory, Honolulu, Hawai, June 29 – July 4.

4.2 Presentations by Institute Members Not Listed under 3.3

Loeliger H.A.	"Pattern detection filters with spiking signals: beginnings", Joint Workshop on Coding and Communications, Barcelona, Spain, November 11 – 16.
Loeliger H.A.	"Additionen", Promotionsfeier der ETH, April 11.

4.3 Invited Lectures and Seminars

04.04.2014	**Dr. Ligong Wang,** Massachusetts Institute of Technology, Cambridge, USA "Optical Communication and Key Distribution in the Wideband Regime"
09.04.2014	**Prof. Henk Wymeersch,** Chalmers University of Technology, Göteborg, Sweden "Accuracy and delay: a fundamental trade-off in indoor positioning"
18.06.2014	**Prof. Negar Kiyavash,** University of Illinois at Urbana Champaign Urbana, USA "Time is of the Essence: A Timing Approach to Network Inference"
09.09.2014	**Prof. Dr. Martin Bossert,** Ulm University, Ulm, BRD "Soft-decision decoding of Reed-Solomon codes"
22.12.2014	**Dr. Ligong Wang,** Massachussetts Insitute of Technology, Cambridge, USA "Communicating over a DMC without Being Detected"

5. Service Activities

5.1 Conference Organization

Prof. Lapidoth   Chair, 2014 International Zurich Seminar on Communications

5.2 Other Service Activities and Society Memberships

Prof. Lapidoth   Fellow of the IEEE

Research Affiliate in the Research Laboratory of Electronics RLE) at the Massachusetts Institute of Technology (MIT)

Member of the Center for Communication and Information Technologies (CCIT), Technion, Haifa, Israel

Prof. Loeliger   Chair, IEEE Switzerland Chapter on Digital Communication Systems

Member of the Executive Board of the IEEE Transactions on Information Theory