Signal and Information Processing Laboratory

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

ANNUAL REPORT

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Foreword

It is difficult to believe that twelve months have passed since the last yearly report was released. Since this report, like its predecessors, will be posted on-line, as opposed to addressed and sent out, it is not clear to me who, exactly, my audience is, but my aim is to offer everyone something of interest.

This past year, I am happy to report, both little and much have changed. What has remained a happy constant is the institute's commitment to teamwork, idea-sharing, and striving for excellence. Those crucial elements will, I hope, sound familiar to all of you who have spent time with us in the past, and enticing to those of you who might like to work with us in the future. But the projects and ideas that took root, or, in some cases, came to fruition, in this fertile ground are of course varied, and I hope that you will appreciate the dedication and intellectual rigor required to produce work of such breadth and depth as you read the report itself.

In addition, the institute, together with the Communication Technology Laboratory, hosted the International Zurich Seminar in February 2010, which was a resounding success, both academically and socially, and whose crowning moment may just have been the performance, at the dinner, of the world's fastest piano player. I take full responsibility for the decision to invite a musician whose claim to fame is that he can play the piano with his feet.

Lastly, I would like to note that my secretary, Ms. Sylvia Beringer, left at the end of July, 2010, and was replaced by Ms. Silvia Tempel, who has been a great help to me in many ways, including the preparation of the next International Zurich Seminar, which will be held February 2012. And of course the institute extends its very best wishes to its most recently minted PhD, Maja Ostojic, who graduated in March 2010.

Amos Lapidoth

Contents

1. Personnel

Professor for Information Theory:

Prof. Amos Lapidoth

Professor for Signal Processing:

Prof. Hans-Andrea Loeliger

Secretaries:	**Sylvia Beringer** (left on 31.7.2010)
	Rita Hildebrand
	Silvia Tempel

Senior Researcher:	**Dr. Nikolai Nefedov**

Research Assistants:	**Jonas Biveroni**	Dipl.El.Eng.
	Lukas Bolliger	MSc ETH
	Murti Devarakonda	Dipl.El.Eng
	Mehdi Molkaraie	Postdoc
	Maja Ostojic	Dipl.El.Eng. (left on 31.03.2010)
	Christoph Reller	MSc ETH
	Ligong Wang	MSc ETH
	Georg Wilckens	MSc ETH
	Jiun-Hung Yu	MSc.NCTU Taiwan

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

Guest:	**Prof. Bernard Fleury**	University of Aalborg, Denmark
		November 12 – 17, 2010.

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
7th	Prof. A. Lapidoth	Applied Digital Information Theory I	227-0417
6th	Prof. A. Lapidoth	Communication and Detection Theory	227-0104
8th	Prof. A. Lapidoth	Information Theory II	227-0420
7th	Dr. H.P. Schmid	Analog Signal Processing and Filtering	227-0468

2.2 Lab Courses (Practica)

Sem.	Instructors	Title	ETH-No.
5/6th	Practica	Laboratory for "Fundamentals in Electrical Engineering"	227-0095
1st/2nd	M. Devarakonda L. Wang J. Yu	Coding and Cellular Automata in Matlab	PPS
3rd/4th	L. Bolliger, G. Wilckens	Blackfin DSP	PPS
2nd/3rd	Th. Schaerer	EMG Biofeedback Device	PPS

2.3 Student Projects

Students	Title	Supervisor

Semester Projects FS 2010

Andreas Malär	Rate Distortion Function for Poisson Processes	Ligong Wang
Christoph Bunte	Rewritable Memories with Cost Constraints	Ligong Wang
Adrian Waeber	Reconstruction of Continuous-Time Filtered White Noise from Discrete-Time Observations with Application to Samplingrate Conversion	Lukas Bolliger
Filip Gospodinov	On Fading Estimation from Noisy Observations	Ligong Wang
Samuel Gähwiler	An Audio Engine for an Ambisonics Surround Sequencer	Dr. Kurt Heutschi
Petrit Bunjaku	Dynamical Modeling, Estimation and Calibration of Force Sensors in Machine Tool	Lukas Bolliger
Matthias Flückiger	Wind Noise Synthesizer	Dr. Kurt Heutschi

Semester Projects HS 2010

David Sutter	An Achievable Region for the Muliple-Access Channel with Feedback and a Common Message	Prof. A. Lapidoth Michèle Wigger
Thomas Laich	Rate Distortion Function for a Gaussian Source with Two Distortions	Ligong Wang Prof. A. Lapidoth

Diploma Theses FS 2010

Matthias Brückner	Diagnosis of Defects in Loudspeakers	Christoph Reller
Raphael Jecker	Automatic Digital Model Creation of Analog Audio Units	Christoph Reller Georg Wilckens
Juan Pablo Marin Diaz	Signal Modeling With Likelihood Computations and Popper Complexity	Christoph Reller
Shahab Asoodeh	Feedback Coding Strategies for Channel Capacity Per Unit Cost	Ligong Wang

Diploma Theses HS 2010

Boming Jin	Model-based Fire Detection with SGFET Gas Sensors	Christoph Reller (Dr. Ulrich Hoefer)
Daniel Baumann	Correction of Clock Jitter Using Factor Graphs	Lukas Bolliger
Andreas Malär	Source Coding with Reconstruction Constraints	Prof. A. Lapidoth Michèle Wigger
Adrian Waeber	Pulse Detection Using Factor Graphs with Application to Assessment of Micropollutant Loads in Wastewater	Lukas Bolliger
David Sele	Drilling Tools Defect Detection and Classification from Vibration Signals	Christoph Reller

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
- Topics in algebraic coding and probabilistic decoding

Digital Signal Processing

Current topics:

- Fundamentals and applications of graphical models (factor graphs)
- Model-based detection & estimation
- Digital calibration of analog circuits

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 is 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)

Fundamentals and Applications of Graphical Models

Most of our research is somehow related to graphical models (factor graphs) and to message passing algorithms on such graphs. Topics include adaptation and learning, applied signal processing, modeling physical systems, and more.

Digital Calibration of Analog Circuits

We study they use of digital calibration techniques to reduce the area and the power consumption of analog circuits such as, e.g., analog-to-digital converters and digital-to-analog converters.

Joint Demodulation, Synchronization, and Decoding

We study signals, algorithms, and circuits for joint demodulation, synchronization, and decoding.

Multitree Decoding

We study near-maximum-likelihood decoding of error correcting codes including LDPC codes and other codes by generalizations of sequential decoding.

Polynomial Remainder Codes

We study algebraic codes that are derived from the Chinese Remainder Theorem.

Computational Information Theory

We use Monte-Carlo methods to compute information rates of source/channel models with a nontrivial Markov structure.

Modeling and Denoising Almost-Periodic Signals

We use time-varying Fourier series for modeling and denoising almost-periodic signals.

Robust Analog Circuits

We investigate large-scale analog circuits that can be built with small (high-mismatch) transistors.

3.3 Publications

Bolliger L., Vogel Chr., Loeliger H.-A.	"Simulation, MMSE, estimation, and interpolation of sampled continuous-time signals using factor graphs", Information Theory and Applications Workshop, UCSD, La Jolla, CA., January 31-February 5, 2010.
Bross S.I., Lapidoth A. Tinguely S.	"Broadcasting correlated Gaussians", IEEE Transactions on Information Theory, IT-56, No. 7, pp. 3057-3068, 2010.
Koch T., Lapidoth A.	"Gaussian fading is the worst fading", IEEE Transactions on Information Theory, IT-56, No, 3, pp. 1158-1165, March, 2010.
Koch T., Lapidoth A.	"On multipath fading channel at high SNR", IEEE Transactions on Information Theory, IT-56, No. 12, pp. 5945-5957, 2010.
Lapidoth A., Tinguely S.	"Sending a bivariate Gaussian over a gaussian MAC", IEEE Transactions on Information Theory, IT-56, No.4, pp. 1852-1864, April, 2010.
Lapidoth A., Tinguely S.	"Sending a biveriate Gaussian over a gaussian MAC", IEEE Transactions on Information Theory, IT-56, No. 6, pp. 2714-2752, June, 2010.
Lapidoth A., Wigger M.	"On the AWGN MAX with imperfect feedback", IEEE Transactions on Information Theory, IT-56, No. 11, pp. 5432-5476, November, 2010.
Molkaraie M., Loeliger H.-A.	"Estimating the information rate of noisy two-dimensional constrained channels", IEEE International Symposium on Information Theory, Austin, Texas, USA, June 13-18, 2010.
Sabato G., Molkaraie M.	"Generalized belief propagation algorithm for the capacity of multi-dimensional run-length limited constraints", IEEE International Symposium on Information Theory, Austin, Texas, USA, June 13-18, 2010.
Ostojic M., Loeliger H.-A.	"Multitree decoding and multitree-aided LDPC decoding", IEEE International Symposium on Information Theory, Austin, Texas, USA, June 13-18, 2010.
Lapidoth Amos, Kim Y. H.	"Error exponents for the Gaussian channel with noisy active feedback", IEEE International Symposium on Information Theory Workshop,, Cairo, Egypt, January 6-8, 2010.
Lapidoth Amos, Steinberg Yossef	"The multiple access channel with causal and strictly causal side information at the encoders", International Zurich Seminar IZS, Zurich, Switzerland, March 3-5, 2010.

Lapidoth Amos, Steinberg Yossef	"The multiple access channel with two independent IEEE International Symposium on Information Theory (ISIT), Austin, Texas, USA, June 13-18, 2010.
Lapidoth Amos	"It takes half the energy of a photo to send one bit reliable on the poisson channel with feedback", Joint Workshop on Communications and Coding, JWCC, Santo Stefano Belbo, Italy, pp.34-35, Octobre 17-19, 2010.
Lapidoth Amos, Bunte Christoph	"On the storage capacity of rewritable memories", IEEE,, 26-th Convention of Electrical and Electronics Engineers in Israel, Eilat, November 17-19, 2010.
Lapidoth Amos, Shraga	"The state-dependent multiple-access channel with Bross states available at a cribbing encoder", IEEE, 26-th Convention of Electrical and Electronics Engineers in Israel, Eilat, November 17-19, 2010.
Lapidoth Amos, Koch Tobias	"Increased capacity per unit-cost by oversampling", IEEE, 26-th Convention of Electrical and Electronics Engineers in Israel, Eilat, November 17-19, 2010.

3.4 Completed PhD Theses

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Multitree Search Decoding of Linear Codes

ETH-Diss. Nr. 19108

Referee:	Prof. Hans-Andrea Loeliger
Co-examiner:	Prof. Daniel J. Costello Jr.

EL MECHAT M'Hamed-Ali

Statistical Range Estimation for Optical Time-of-Flight 3D Imaging

ETH Diss. Nr. 18989

Referee:	Prof. Hans-Andrea Loeliger
Co-referees:	Dr. Nicolas Blanc
	Prof. Helmut Bölcskei

4. Trips and Talks

4.1 Participation in Conferences and Meetings

Lapidoth Amos	IZS International Zurich Seminar on Communications, Zurich, March 3 – 5.
Lapidoth Amos	IEEE International Symposium on Information Theory, Austin, Texas, USA, June 13 – 18.
Lapidoth Amos	JWCC Joint Workshop on Coding and Communications, Santo Stefano Belbo, Italy, October 17 – 19.
Lapidoth Amos	IEEE 26-th Convention of Electrical and Electronics Engineers in Israel, Eilat, November 17 – 20.
Loeliger H.-A.	ITA Information Theory and Applications Workshop, San Diego, USA, January 31 – February 5.
Loeliger H.-A.	IZS International Zurich Seminar on Communications, Zurich, March 3 – 5.
Loeliger H.A.	IEEE International Symposium on Information Theory, Austin, Texas, USA, June 13 – 18.
Loeliger H.A.	Koetterfest, Monticello, Illinois, USA, September 26 – 28.
Loeliger H.A.	JWCC Joint Workshop on Coding and Communications, Santo Stefano Belbo, Italy, October 17 – 19.
Bolliger Lukas	ITA Information Theory and Applications Workshop, Diego, USA, January 31 – February 5.
Molkaraie Mehdi	IEEE International Symposium on Information Theory, Austin, Texas, USA, June 13 – 18.

4.2 Presentations by Institute Members Not Listed under 3.3

Loeliger H.-A.	"Model based signal processing using factor graphs" NEWCOM++ Winter School, Aalborg, February 24.
Loeliger H.-A.	"Model-based signal processing using factor graphs", TU Graz, April 15.
Loeliger H.-A.	"Discrete-time processing of continuous-time signals using factor graphs", Koetterfest, Monticello, Illinois, USA, September 26 – 28.
Loeliger H.-A.	"A factor-graph representation and a statistical-model interpretation of quantum mechanics", Joint Workshop on Coding and Communications, Santo Stefano Belbo, Italy, October 17 – 19.

4.3 Invited Lectures and Seminars

15.01.2010	**Emmanuel Abbe,** EPFL, Lausanne "Thresholds in Random Graphs and Concentration of k-SAT Solutions".
01.03.2010	**Prof. Yossef Steinberg,** Electrical Engineering Technion, Haifa, Israel "Variations on Coding with Side Information; Common Reconstructions and Reversible Information Embedding".
01.03.2010	**Prof. Yossef Steinberg,** Electrical Engineering Technion, Haifa, Israel "Lossy Source Coding with a Helper".
01.07.2010	**Prof. Dan Costello,** University of Notre Dame, South Bend, USA "LDPC Convolutional Codes – Approaching the Shannon Limit with Structured Irregularity".
08.10.2010	**Amir Ingber,** Tel-Aviv University, Israel "Parallel Bit-Interleaved Coded Modulation".

5. Service Activities

5.1 Conference Organization

Prof. Lapidoth   Co-Chair, 2010 International Zurich Seminar

5.2 Other Service Activities and Society Memberships

Prof. Lapidoth   Fellow of the IEEE

Member of the IMS Institute of Mathematical Statistiacs. Bethesda, USA

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   Fellow of the IEEE

Associate Editor, IEEE Transactions on Information Theory

Chair, IEEE Switzerland Chapter on Digital Communication Systems

Member, Board of Governors, IEEE Information Theory Society

Studiendelegierter D-ITET, ETH Zurich