Signal and Information Processing Laboratory

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

ANNUAL REPORT

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Foreword

We look back with gratitude to another year with exciting research, rewarding teaching, and meeting friends old and new. Three people left us: Ligong Wang and Murthy Devarakonda both finished their PhD, an my postdoc, Mehdi Molkaraie, moved on as well. Two new PhD students, Christoph Bunte and Lukas Bruderer, had actually joined us already in fall 2010, but they were forgotten in last year's report.

We have long had a tradition of doing numerous small research projects for industry and others, usually in the form of student projects with substantial involvement of the supervising PhD student. As a novelty in this year's report, we include the corresponding list of companies and institutions (see Section 3.5).

And for once, I also wish to acknowledge the very substantial contributions to our teaching by our two regular external lecturers, Kurt Heutschi and Hanspeter Schmid.

Hans-Andrea Loeliger

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. Nikolai Nefedov**

Research Assistants:	**Jonas Biveroni**	Dipl.El.Eng.
	Lukas Bolliger	MSc ETH
	Lukas Bruderer	MSc ETH
	Christoph Bunte	MSc ETH
	Murti Devarakonda	Dipl.El.Eng (left on 30.08.2011)
	Andreas Malär	MSc ETH (23.05.–31.08.2011)
	Mehdi Molkaraie	Postdoc (left on 31.10.2011)
	Christoph Reller	MSc ETH
	Ligong Wang	MSc ETH (left on 30.04.2011)
	Georg Wilckens	MSc ETH
	Jiun-Hung Yu	MSc.NCTU Taiwan

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
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

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
1st/2nd	J. Yu M. Devarakonda	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 2011

Students	Title	Supervisor
Georg Hauzenberger	Rate-distortion bounds using hypothesis testing relative entropy	Ligong Wang Prof. A. Lapidoth
Annina Bracher	Average versus maximal probability of error criteria for multiple access channels: a polar coding approach	Dr. Emmanuel Abbé Prof. A. Lapidoth
Ekansh Anand	Identification of force sensors	Lukas Bolliger
Martin Polak Filipe de Conceiçao Barato	Detection of Doppler shifts in an acoustic environment with moving vehicles	Dr. Kurt Heutschi Lukas Bruderer
Santhiago A.Vieira	Learning finite Gaussian mixtures with Dirichlet processes	Lukas Bruderer

Master Theses 2011

Students	Title	Supervisor
Christoph Bunte	Computing the capacity of discrete rewritable memories	Prof. A. Lapidoth
Petrit Bunjaku	Splitting large state-space models	Lukas Bruderer Lukas Bolliger Christoph Reller
Matthias Flückiger	Interaction in loudspeaker arrays with shared enclosures	Christoph Reller Georg Wilckens
Samuel Gähwiler	Pattern recognition with hierarchical likelihood filters	Christoph Reller
Sarah Neff	Robust Feature extraction from vibration signals	Christoph Reller Lukas Bruderer
Simon Würgler	Learning and detection of sparse pulses with application to acoustic diagnosis	Christoph Reller 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
- 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.

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., Loeliger H.-A.	"Sampling jitter correction using factor graphs", *19ᵗʰ European Signal Processing Conference, EUSIPCO, Barcelona, Spain,* August 29 – September 2, 2011.
Bolliger L., Loeliger H.-A. Wilckens G., Biveroni J.	"Analog-to-digital conversion using unstable filters", *Information Theory and Applications Workshop, ITA, UCSD, La Jolla, CA,* February 6 – 11, 2011.
Bunte Ch., Lapidoth A.	"Computing the capacity of rewritable memories", *IEEE International Symposium on Information Theory, St. Petersburg, Russia,* pp. 2512 – 2516, July 31 – August 5, 2011.
Gastpar M., Lapidoth A. Steinberg Y., Wigger M.	"New achievable rates for the Gaussian broadcast channel with feedback", *8ᵗʰ International Symposium on Wireless Communication Systems (ISWSC), Aachen, Germany,* pp. 579- 583, November 6 – 9, 2011.
Kim Y.H., Lapidoth A., Weissmann T.	"Error exponents for the Gaussian channel with active noisy feedback", *IEEE Trans. Inform. Theory,* pp. 1223 – 1236, März, 2011.
Koch T., Lapidoth A.,	"Asymmetric quantizers are better at low SNR", *IEEE International Symposium on Information Theory, St. Petersburg, Russia,* pp. 2592 – 2596, July 31 – August 5, 2011.
Lapidoth A.	"Revisiting the penalty for making hard decision", *IEEE Wireless Advanced (formerly SPWC) London, UK.,* June 20 – 22, 2011.
Lapidoth A.	"How much energy is required to send one bit reliably over the poisson", *Information Theory Workshop, Technion, Haifa, Israel,* January 3, 2011.
Lapidoth A., Malär A. Wang L.	"Covering point patterns", *IEEE International Symposium on Information Theory, pp. 51 – 55, St. Petersburg, Russia,* July 31 – August 5, 2011.
Lapidoth A., Malär A. Wigger M.	"Constrained Wyner-Ziv coding", *IEEE International Symposium on Information Theory, St. Petersburg, Russia,* July 31 – August 5, 2011.
Lapidoth A., Wang L.	"Communicating remote Gaussian sources over Gaussian multiple access channels", *IEEE International Symposium on Information Theory, St. Petersburg, Russia,* July 31 - August 5, 2011.

Lapidoth A., Shapiro J., Venkatesan V., Wang L.	"The discrete-time poisson channel at low input powers", *IEEE Trans. Inform. Theory,* pp. 3260 – 3272, März, 2011.
Lapidoth A. Steinberg Y.	"A note on multiple-access channels with strictly-causal state information", *IEEE Wireless Advanced (formerly SPWC), London, London,* June 20 – 22, 2011.
Marano S., Reller Ch., Fäh D., Loeliger H.-A.	"Seismic waves estimation and wave field decomposition with factor graphs", *International Conference on Acoustics, Speech, and Signal Processing, ICASSP, Prague, Czech Republic,* pp. 2748 – 2751, May 22 – 27, 2011.
Marano S., Fäh D., Reller Ch., Loeliger H.-A.	"Maximum likelihood parameter estimation for surface waves: application to ambient vibrations", *4th International Symposium on the Effects of Surface Geology on Seismic Motion (ESG4), UCSB, Santa Barbara, CA, USA,* August 23 – 26, 2011.
Nefedov N., X. Dong, P. Frossard, P. Vandergheynst	"Regularization Framework for mobile social network analysis", *International Conference on Acoustics, Speech, and Signal Processing, ICASSP, Prague, Czech Republic,* May 22 – 27, 2011.
Nefedov N.	"Multiple membership communities detection in mobile networks", *International Conference on Web Intelligence, Mining and Semantics, WIMS, Songdal, Norway,* May 25 – 27, 2011.
Nefedov N., X. Dong, P. Frossard, P. Vandergheynst	"Methods for clustering of multi-layer graphs in mobile networks, *Workshop on Information and Decisions in Social Networks, WIDS/LIDS, MIT, Boston,* May 31 – June 1, 2011.
Nefedov N.	"Applications of system dynamics for communities detection in complex networks", *3rd International Workshop on Nonlinear Dynamics and Synchronization, INDS, Klagenfurt, Austria,* July 25 – 27, 2011.
Nefedov N., Biswas D., Niemi V.	"Distributed usage control", *The 8th International Conference on Mobile Web Information Systems, MobiWIS, Ontario, Canada,* September 19 – 21, 2011.
Nefedov N.	"Multiple-membership communities detection and its applications for mobile networks", pp.51 – 76, chapter in "Applications of Digital Signal Processing". ISBN 978-953-307-406-1, InTech, 2011.
Reller Ch., Loeliger H.-A.	"Multi-sensor estimation and detection of phase-locked sinusoids" , International Conference on Acousics, Speech and Signal Processing, ICASSP, pp. 3872 – 3875, Prague, Czech Republic, May 22 – 27, 2011.
Reller Ch., Loeliger H.-A. Diaz J.P. Marin	"A model for quasi-periodic signals with applications to rain estimation from microwave link gain", 19th European Signal Processing Conference, EUSIPCO, pp. 971 – 975, Barcelona, Spain, August 29 – September 2., 2011.

Yu Jiun Hung, Loeliger H.A.   "On irreducible polynomial remainder codes", IEEE International Symposium on Information Theory, pp. 1115 – 1119, St. Petersburg, Russia, July 31 – August 5, 2011.

3.4 Completed PhD Theses

DEGEN Thomas

Portables Devices for Mobile Health Monitory

ETH-Diss. Nr. 19640

Referee:	Prof. Hans-Andrea Loeliger
Co-examiner:	Dr. Hanspeter Schmid
	Dr. Rolf Vetter

DEVARAKONDA V.R.S. Murti

Joint Matched Filtering, Decoding, and Timing Synchronization

ETH Diss. Nr. 19882

Referee:	Prof. Dr. Göran Andersson
Examiner :	Prof. Dr. H.-A. Loeliger
Co-examiner:	Prof. Henk Wymeersch

3.5 Research for Industry and Other Institutions

Over the past two years, mostly master projects (or even semester projects) with substantial involvement of the supervising PhD student.

- NTI AG, Schaan: acoustic fault detection
- Swiss Seismological Service (ETH): analysis of surface waves
- inspire AG (ETH) and Kistler AG: adaptive filtering for force sensors in machine tools
- Siemens Building Technologies: sensor signal processing
- Sonic Emotion AG, Oberglatt: acoustic signal processing
- EMPA: acoustic detection
- EAWAG, Dübendorf: rainfall estimation from microwave link attenuation
- Univ. Hospital Zurich: near-infrared spectroscopy
- Oerlikon Space AG

4. Trips and Talks

4.1 Participation in Conferences and Meetings

Lapidoth Amos	IEEE International Symposium on Information Theory, St. Petersburg, Russia, July 31 – August 5.
Lapidoth Amos	Ben Gurion University of the Negev, Israel, Seminar, January 3
Lapidoth Amos	Bar-Ilan University Ramat Gan, Israel Information Theory Workshop, March 14.
Lapidoth Amos	IEEE Wireless Advanced (formerly SPWC), London, UK, June 20 – 22.
Lapidoth Amos	IEEE International Symposium on Information Theory, St. Petersburg, Russia, July 31 – August 5.
Loeliger H.-A.	ITA Information Theory and Applications Workshop, La Jolla, San Diego, California, USA, February 6 – 11.
Loeliger H.-A.	IEEE International Symposium on Information Theory, St. Petersburg, Russia, July 31 – August 5.
Loeliger H.-A.	Workshop on "Counting, Inference and Optimization on Graphs", Princeton University, Princeton, November 2- 5.
Loeliger H.A.	Dagstuhl Workshop on Coding Theory, Schloss Dagstuhl, Wadern, Germany, November 14 – 18.
Bolliger Lukas	EUSIPCO 19th European Signal Processing Conference, Barcelona, Spain, August 29 – September 2.
Bunte Christoph	IEEE International Symposium on Information Theory, St. Petersburg, Russia, July 31 – August 5.
Malär Andreas	IEEE International Symposium on Information Theory, St. Petersburg, Russia, July 31 – August 5.
Reller Christoph	ICASSP International Conference on Acoustics, Speech and
Reller Christoph	EUSIPCO 19th European Signal Processing Conference, Barcelona, Spain, August 20 – September 2.
Wilckens Georg	ITA Information Theory and Applications Workshop Jolla, San Diego, California, USA, February 6 – 11.
Yu Jiun-Hung	IEEE International Symposium on Information Theory, St. Petersburg, Russia, July 31 – August 5.

4.2 Presentations by Institute Members Not Listed under 3.3

Loeliger H.-A.   "Soft Bits, Likelihoods Filters, Analog Computation",
Birthday Colloquium on the occasion of Prof. Joachim
Hagenauer's 70th birthday, TU Munich, July 21.

4.3 Invited Lectures and Seminars

01.03.2011   **Dr. Hanspeter Schmid,** IEEE CAS Distinguished Lecturer
"Lectures on human aspects of Engineering & Science, Part I."

25.03.2011   **Prof. Emmanuel A. Abbé,** EPFL, Lausanne
"Matrix polarization: a new way of handling randomness and
dependencies in information processing".

31.03.2011   **Dr. Pascal Vontobel,** Hewlett-Packard Laboratories, Palo Alto, USA
"Should we believe in numbers computed by Loopy Belief
Propagation?".

16.05.2011   **Prof. Erdal Arikan,** Bilkent University, Ankara, Turkey
"Polar codes: A Persepective".

24.06.2011   **Prof. Ashish Khisti ,** University of Toronto, Canada
"The price of channel uncertainty in secure communication with
multiple antennas".

27.06.2011   **Prof. Raymond Yeung,** Chinese University of Hong Kong, China
"Refinement of two fundamental tools in information theory".

13.07.2011   **Tobias Koch,** University of Cambridge, Cambridge, UK
"Hard decisions do not cause a 2dB power loss".

12.08.2011   **Prof. Henk Wymeersch,** Chalmers University of Technology,
Göteborg, Sweden
"Three vignettes in factor graphs: synchronization, navigation
and nonlinear communication".

30.08.2011   **Dr. Sascha Korl,** HILTI Corporation, Schaan, Liechtenstein

06.09.2011   **Christina Fragouli,** EPFL, Lausanne
"Bringing network coding closer to practice".

30.11.2011   **Prof. Frank R. Kschischang** University of Toronto, Canada
"Staircase codes: Error-correction for high-speed Fiber-Optic
Channels

5. Service Activities

5.1 Conference Organization

Prof. Lapidoth   Chair**,** 2012 International Zurich Seminar on Communications

5.2 Other Service Activities and Society Memberships

Prof. Lapidoth   Fellow of the IEEE

Member of the IMS Institute of Mathematical Statistics. 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   Studiendelegierter D-ITET, ETH Zurich

Associate Editor, IEEE Transactions on Information Theory

Chair, IEEE Switzerland Chapter on Digital Communication Systems

Member, Board of Governors, IEEE Information Theory Society

Member, TPC, ISIT 2011

Member, TPC, ISWCS 2011, Aachen