Activity Report 2014–2015
Institute of Communications Engineering
Prof. Dr.-Ing. Martin Bossert
Prof. Dr.-Ing. Robert Fischer
Prof. Dr. Dr.-Ing. Wolfgang Minker
Impressum

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Preface

The institute for Communications Engineering provides research and teaching for several courses of study in the area of communications within the faculty of Electrical Engineering, Computer Science, and Psychology of the Ulm University. Since 2014 the institute is largely responsible for the international Master Course Communications Technology. Research areas and offered lectures and labs range from physical-layer methods over reliable and secure information transmission in time and space, up to man-machine interfaces.

The present report covers all activities of members of our institute from January 2014 through December 2015.
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Sebastian Stern, M.Sc.  

Florian Wäckerle, M.Sc.  

George Yammme, M.Sc.
Visitors and Visits

Visiting Scholars

- **Siberian Federal University and Siberian State Aerospace University, Krasnoyarsk, Russia**
  Anastasiia Spirina
  03/2014

- **Princess Sumaya University for Technology Amman and Jordan University, Jordan**
  Prof. Wejdan Abu Alhija and Prof. Al-Wahadini
  03/2014

- **Siberian Federal University and Siberian State Aerospace University, Krasnoyarsk, Russia**
  Prof. Eugene Semenkin
  03/2014, 06/2015

- **University of Granada, Spain**
  Prof. Zoraida Callejas
  03/2014, 06/2015

- **University of Alicante, Spain**
  Prof. Joan-Josep Climent
  07/2014

- **German University Cairo (GUC), Cairo, Egypt**
  Injy Khairy, Nardine Raafat Basta
  07–08/2014

- **University of Helsinki, Finland**
  Prof. Kristiina Jokinen
  06/2015

- **University of the Witwatersrand Johannesburg, South Africa**
  Dr. Ing. Jaco Versfeld
  07/2015

- **Sun Yat-sen University, Guangdong, China**
  Prof. Li Chen
  07–09/2015

Research Stays at other Universities

- **University of Granada, Spain**
  Wolfgang Minker, Stefan Ultes
  05/2014, 10/2014, 04/2015

- **University of Helsinki, Finland**
  Wolfgang Minker, Florian Nothdurft
  05/2014, 08/2015
- **University of Tartu, Estonia**
  Wolfgang Minker, Florian Nothdurft  
  08/2014, 02/2015

- **Canadian Mathematical Society, Banff, Canada**
  Martin Bossert  
  10/2015

- **University of British Columbia, Vancouver, Canada**
  Martin Bossert  
  10/2015

- **University of Menoa, Hawaii, USA**
  Martin Bossert  
  10/2015

- **University of Granada, Spain**
  Wolfgang Minker, Stefan Ultes, Florian Nothdurft  
  10/2015

- **University of Melbourne, Australia**
  Martin Bossert  
  11–12/2015
3 Awards

- **Antonia Wachter-Zeh**  
  Award of the Ulmer Universitätsgesellschaft e.V. for the most outstanding Dissertation, July 2014  
  *Decoding of Block and Convolutional Codes in Rank Metric*

- **George Yammine**  
  ARGUS Research Award 2014  
  *A Comparison of Noncoherent Receivers Based on Different Modulation Schemes*

- **Alexander Zeh**  
  Ehrenpreis der Jury der Deutsch-Französischen Hochschule (DFH), Nov. 2014

- **Alexander Zeh**  
  Vodafone Foundation for Research, Sponsorship Prize for Natural and Engineering Sciences, June 2015
A detailed description of the modules is available online.

**Advanced Channel Coding** (English) Master 2L/1E
Symbol-by-Symbol APP Decoding; Iterative Decoding of Concatenated Codes; LDPC Codes; Algebraic List Decoding

**Angewandte Mathematik für Ingenieure** (German) Master 3L/1E
(Applied Mathematics for Engineers)
Stochastic Processes; Normal Forms of Matrices and their Application in System Theory; Special Functions (e.g., Bessel Functions) and their Application; Algebraic Structures (e.g., Finite Fields)

**Applied Information Theory** (English) Master 3L/2E/1P
Uncertainty (Entropy); Mutual Information; Source Coding Theorem; Source Coding Schemes (Shannon–Fan, Huffman, Tunstall, Arithmetic Coding); Universal Source Coding (Lempel–Ziv, Elias–Willems); Channel Capacity and Channel Coding Theorem; Gaussian Channel; Random Coding; Multi-User Information Theory; Dirty Paper Coding; Tomlinson–Harashima Precoding; Information Theory and Cryptology

**Benutzerschnittstellen** (German) Bachelor/Master 2L/2S
(User Interfaces)
Introduction into the area of human-computer interaction (HCI); Focus: design and development principles of multimodal user interfaces; Usability engineering and evaluation of multimodal user interfaces

**Channel Coding** (English) Master 3L/2E/1P
Block Codes (BCH, Reed–Solomon, Reed–Muller, Hamming, Simplex, Golay); Decoding Algorithms (Majority Logic, Algebraic, Soft, Hard, GMD); Convolutional Codes and Decoding (Viterbi, Fano, Zigangirov–Jelinek); Generalized Code Concatenation; Coded Modulation
Institute of Communications Engineering

**Communications Engineering Seminar** (German/English) Master 2S

each semester a current, changing topic from the fields of Communications Engineering, Digital Transmission, Information Theory, Coding Theory, and Signal Processing and its related disciplines is addressed

**Communication Systems** (English) Master 2L/1E

Mobile Radio Channel; Basics of Mobile Communication Systems; GSM and UMTS

**Compressed Sensing** (English) Master 2L/1E

Geometry of $N$ Dimensions; Geometrical Interpretation of Systems of Linear Equations; Convex Polytopes; Arrangements of Hyperplanes; Approximation Theory; Distance Measures in Banach Spaces; Optimization and Linear Programming; Sampling by Compressed Sensing; Data Acquisition by Compressed Sensing

**Dialogue Systems** (German) Master 2L/2E

Introduction into the area of multimodal spoken natural language dialogue systems; Focus: Acoustic Processing; Speech Signal Analysis; Speech Recognition; Spoken Natural Language Understanding; Dialogue Processing and Speech Synthesis

**Dialogue Systems Project** (German/English) Master 4-6S

Multimodal spoken language dialogue systems; component development; practical studies; evaluation


Spoken dialogue systems development; human factor studies; human-centred design approach; practical studies; evaluation

**Digital Communications** (English) Master 4L/2E

Equivalent Complex Baseband; Pulse-Amplitude Modulation (PAM); Variants of PAM Transmission Schemes; Signal-Space Representation; Digital Frequency and Phase Modulation; Channel Models; Equalization of Dispersive Channels; Orthogonal Frequency-Division Multiplexing (OFDM)
Digital Communications LAB  (English) Master 4P


Einführung in die Nachrichtentechnik  (German) Bachelor 3L/2E/2P
(Introduction to Communication Engineering)

History and Milestones of Communications; Models in Communications; Shannons Uncertainty and Source Coding; Signals for Transmission of Information Channels; Decision Theory; Error Probability; Channel Coding Theorem; Error Correcting Codes; Reliable Data Transmission; Multiple Access; Routing; Security

Embedded Security  (German) Master 3L/1E

Implementation and Side-Channel Attacks in Cryptology; Countermeasures to Implementation Attacks; Arithmetic for Cryptographic Hardware; Random Number Generators; Physical Unclonable Functions; Digital Tachograph System; Secure Software Download for Electronic Control Units in Cars

Iterative Methods for Wireless Communications  (English) Master 2L/1E

Fix-Point Iteration; Convergence and Convergence Rate of Iterative Methods; Vector-Valued Transmission; (Iterative) Vector Equalization; Probability Theory for Iterative Decoding; Tanner Graph; Low-Density Parity Check Codes; BCJR Algorithm; Turbo Codes; Iterative Joint Demapping, Equalization, and Decoding (Turbo Equalization)

Multiuser Communications and MIMO Systems  (English) Master 3L/1E

MIMO Communications; Performance Criteria; Introduction to Lattices; Lattice Decoding and the “Sphere Decoder”; Equalization via Lattice Reduction; “Writing on Dirty Paper”; Multiuser Communications; Advanced Transmitter-Side Techniques; Interference Channel

Satellite Communications and Navigation  (English) Master 2L/1E

History, Development, and Potential of Satellite Communications; Satellite Orbits; Launch and Installation in Orbit; Modulation and Multiple Access; Satellite Channel; Link Budget Calculations; Mobile Satellite Communication Systems; Satellite Navigation
Seminar zur Industriepraxis  (German/English)  Bachelor/Master  3S
Subject-related knowledge and experience from professional practice; experience the business of a typical workday; carry out typical engineering tasks in research and development, quality control, and technical distribution; gain insight into modern techniques and facilities for development and fabrication of electric, electronic, mechatronic and mechanical devices as well as software and hardware components and systems; learn typical operating procedures and organization in industry, as well as the social structure in companies

Signal Theory  (English)  Master  2L/2E
Part I: Stochastic Signals: Random Variables and their Characterization; Principles of Estimation; Stochastic Processes and their Characterization; Mean-Square Estimation and Ergodicity; Part II: Deterministic Signals: Sampling and Interpolation; Principles of Compressed Sensing

Signale und Systeme  (German)  Bachelor  3L/2E/2T/1P
(Signals and Systems)
Discrete Signals and Systems; z-Transformation; Generalized Functions and Distributions; Continuous Signals and Systems; Fourier-Transformation; Sampling Theorem; Fast Fourier Transform; Laplace-Transformation its Application to Continuous LTI Systems; Stochastic Processes

Statistical Signal Processing  (English, until 2013/14)  Master  3L/1E
Concept of Random Variables; Functions of Random Variables; Stochastic Processes; Spectral Representation and Spectrum Estimation; Mean Square Estimation

Theory of Digital Networks  (English)  Master  3L/2E/1P
Hierarchical Structure of Networks; OSI Model; Physical Layer; Framing; ARQ; Multiple Access (Aloha, CSMA, Token, ...); Queuing Theory; Routing (Bellman–Ford, Dijkstra)
5 Research

5.1 Research Topics

The research carried out at the institute is divided into the subsequent four groups.

**Algebraic Coding Theory**

Block and convolutional codes for error correction and detection over Hamming, rank, and combinatorial metrics are constructed and analyzed. The main focus is also on the soft- and hard-decision and list decoding of these code classes. Especially soft-decision decoding of Reed-Solomon codes is an important research area. The applications are random linear network coding, storage coding, compressed sensing, interleaved codes, concatenated codes, and hybrid ARQ protocols. Recently, the application of algebraic coding for cryptology was started.

**Bio Information Theory**

Information and communication theory is also applicable for living species, namely the DNA in cells is a storage which is read and transmitted. The particular projects are discrete models of genetic regulatory networks (random Boolean networks), overlapping genes, and next generation sequencing. In particular the erroneous measurements can be treated with methods from reliable data transmission and coding theory improves the labeling of the DNA fragments.

**Communication Theory**

The members of the Communication Theory group address the challenges of next-generation communications systems. The main focus is on the mathematical and theoretical foundations of communication and signal processing schemes. This includes equalization methods and the utilization of interference in multiantenna and multiuser systems, in particular, in form of precoding. The problems caused by nonlinearities in the transmission channel, both, the peak-power problem (e.g., in OFDM transmission), as well as nonlinear transmission media (e.g., fiber optics) are addressed. Moreover, the structure of signal is exploited, e.g., via compressed sensing methods, and transmission schemes without any channel knowledge are designed.
Dialogue Systems

The Dialogue Systems Group has placed its general research focus on the development and evaluation of user-friendly Spoken Language Dialogue Systems (SLDS). This objective is based on the following major aspects: adaptive dialogue management, assistiveness as well as evaluation and usability issues.

The Dialogue Systems Group is joint founder of the interdisciplinary Competence Center Perception and Interactive Technologies. Research groups from Ulm University aim at developing innovative technologies in different application domains and settings for the human-computer interaction. Major research areas include sensor-based models for perception, learning mechanisms and adaptivity, interactive systems in networked applications, ubiquitous computing, multimedia and visualization as well as spoken language dialogue systems interaction and multimodality. The center proposes a framework for fundamental and applied research and combines different interdisciplinary issues.
5.2 Research Projects

DFG Projects (German Research Council)

During 2014–2015 the following projects were supported by the German Research Council “Deutsche Forschungsgemeinschaft” (DFG).¹

**Assistives und adaptives Dialogmanagement**

- Project Leader: Minker, Grant: SFB Transregio 62 TP B01
- Duration: 96 months, Begin: February 2009

**The Evolutive Adaptation of the Transriptional Information Transmission in E.Coli**

- Project Leader: Bossert, Grant: Bo 867/25-2 (SPP InKomBio)
- Duration: 48 months, Begin: January 2010, End: January 2014

**Finding New Overlapping Genes and their Theory (FOG-Theory)**

- Project Leader: Bossert, Grant: Bo 867/23-2 (SPP InKoMBio)
- Duration: 60 months, Begin: January 2010, End: March 2016

**Coordination Project InKoMBio**

- Project Leader: Bossert, Grant: Bo 867/31-3
- Duration: 60 months, Begin: January 2010, End: March 2016

**Methoden der Kanalcodierung für Compressed Sensing**

- Project Leader: Bossert, Grant: Bo 867/27-2
- Duration: 36 months, Begin: April 2011, End: April 2014

**Decoding in Weighted Combinatorial and Other Metrics**

- Project Leader: Bossert, Grant: Bo 867/28-2
- Duration: 24 months, Begin: April 2012, End: April 2014

**Interrelations between Channel Coding and Precoding in Transmission Strategies for Broadcast Channels and in Network Coding**

- Project Leader: Bossert, Grant: Bo 867/29-3 (SPP COIN), cooperation with Profs. Fischer and Huber
- Duration: 24 months, Begin: October 2013

¹SPP: “Schwerpunktprogramm” (priority project); SFB: “Sonderforschungsbereich” (SFB).
Interrelations between Channel Coding and Precoding in Transmission Strategies for Broadcast Channels and in Network Coding

Project Leader: Fischer, Grant: Fi 982/4-3 (SPP COIN), cooperation with Profs. Bossert and Huber
Duration: 24 months, Begin: October 2013

Analyse der Informationsverarbeitung in molekularen Netzwerken mithilfe der Kommunikationstheorie diskreter Prozesse

Project Leader: Schöber, Grant: SCHO 1576/1-1 (SPP InKoMBio)
Duration: 18 months, Begin: January 2014, End: July 2014

Verbesserte und zuverlässige RNA-Sequenzierung: Einzelzell-Transkriptomik zur Analyse bakterieller Individualität

Project Leader: Bossert, Grant: Bo 867/30-1 (SPP InKoMBio)
Duration: 24 months, Begin: January 2014

Rang-Metrik in der Codierungstheorie und im maschinellen Lernen

Project Leader: Bossert, Grant: Bo 867/32-1
Duration: 36 months, Begin: January 2014

Diskret-wertige, dünn besetzte Signale: Theorie, Algorithmen und Anwendungen

Project Leader: Fischer, Grant: Fi 982/8-1, cooperation with Profs. Kutyniok and Pfander
Duration: 24 months, Begin: October 2014

DFG Priority Program (SPP) InKoMBio (Homepage: www.inkombio.de)

Prof. Martin Bossert is the coordinator of the DFG priority program DFG SPP 1395 “Informations- und Kommunikationstheorie in der Molekularbiologie (InKoMBio)”
The program committee consists of Prof. Dr.-Ing. M. Bossert, Prof. Dr.-Ing. J. Hagenauer (Technische Universität München), Prof. Dr. H. P. Herzel (Humboldt-Universität Berlin), and Prof. Dr. M. Kühl (Universität Ulm).

Description: In the middle of the 20th century, information theory and molecular genetics have gone through a great history of success: namely the fundamental work of Shannon in 1948, which was giving rise to the modern information- and communication society we are living in, and also the discovery of the double helix structure of DNA by Watson and Crick in 1953, which was the beginning of
contemporary genetics and its use in medicine. The information read from the
DNA, is transmitted, duplicated, changed (mutated) and is used for controlling
many processes in and between cells. All these procedures can be described
and analyzed with models and methods of information theory. We are convinced
that information- and communication theorists, together with biologists and med-
ical scientists can contribute to a better understanding of processes in the cell
concerning communication, even though there have been significant results in re-
search over the last years. In information theory, transmission of information is
viewed in an abstract way, so it is expected that independently of concrete realiza-
tions, concepts, modules and results can be applied on molecular communication
processes. Therefore the program focuses exclusively on assisting interdisciplinary
projects in between information- and communication scientists on one side, and
biologists and medical scientists on the other side. Modern Biology, often referred
to as the key science of the 21st century, is currently undergoing a change. New
theoretical concepts, modern methods of data analysis and mathematical models
will play a strategical role in molecular biology and this can only be accomplished
by intensive interdisciplinary collaboration. This program intends to encourage
and assist this collaboration.

**BMBF Projects (Federal Ministry of Education and Research)**

**EUREKA-Projekt SASER (Safe and Secure European Routing): Adaptive Modulations- und Codierungsverfahren für flexible und sichere optische Metro- und Firmennetze (ADVantage-NET)**

Project Leader: Fischer, Grant: 16BP12406
Duration: 42 months, Begin: August 2012, End: December 2015

**EU — Horizon 2020**

**KRISTINA: A Knowledge-Based Information Agent with Social Competence and Human Interaction Capabilities**

Project Leader: Minker, Grant: HORIZON 2020-LEIT-ICT 22 - 2014
Duration: 36 months, Begin: March 2015

**Industry Project**

**Lower-Power-Mobile TV Tuner Architecture**

Project Leader: Fischer, Grant: Sony Deutschland GmbH Stuttgart
Duration: 12 months, Begin: June 2015
The publications are sorted according to the respective professor, which coincides with the research topics (Bossert: Groups A and B; Fischer and Lindner: Group C; Minker: Group D).

**Publications by Prof. Bossert’s Group**


Publications by Prof. Fischer’s Group


Publications by Prof. Minker’s Group


Publications by Other Members of the Institute


Seminars

- Prof. Joan-Josep Climent (University of Alicante, Spain). *Concatenated Convolutional Codes From Linear Systems Theory Point of View*, July 24, 2014.

Dr.-Ing. Alexander Zeh (Technion-Israel Institute of Technology, Haifa). An Improved Lower Bound on the Minimum Distance of Quasi-Cyclic Codes, July 24, 2014.


Prof. Jörg Kliewer (New Jersey Institute of Technology, USA). Coordination in Networks: An Information-Theoretic Approach, August 08, 2014.


Maria Platero Sánchez. Analysis of an Extended Data Set for Interaction Quality Recognition, September 15, 2014.


Tao Ding. Alamouti Coding and Decoding Scheme in Filter-Bank-Based Multicarrier System, March 18, 2015.

Institute of Communications Engineering

- Ahmed Moheeb Emara. Decoding Complex Reed-Solomon Codes Beyond Half the Minimum Distance, April 27, 2015.
- Prof. Li Chen (Sun Yat-sen University, China). Progressive Algebraic Soft-Decision Decoding of Reed–Solomon Codes July 29, 2015.

8 Ph.D. Theses

8.1 Supervised Ph.D. Theses

- Mohamad Mostafa. *Equalization and Decoding A Continuous-Time Dynamical Approach*, Institute of Communications Engineering, Ulm University, 2014. Reviewers: Prof. J. Lindner, Prof. L. Kocarev, Ss. Cyril and Methodius University in Skopje, Macedonia, and BioCircuits Institute, University of California, San Diego, USA.


- Thanawat Thiasiriphet. *Applications of Ultrawideband in Communications and Ranging*, Institute of Communications Engineering, Ulm University, 2014. Reviewers: Prof. J. Lindner, Prof. R. Thomä, Ilmenau University of Technology.

- Hansjörg Hofmann. *Intuitive Speech Interface Technology for Information Exchange Tasks*, Institute of Communications Engineering, Ulm University, 2014. Reviewers: Prof. W. Minker, Prof. K. Jokinen, University of Helsinki, Finland.

- Ulrich Epple. *OFDM Receiver Concept for the Aeronautical Communications System LDACS1 to Cope with Impulsive Interference*, Institute of Communications Engineering, Ulm University, 2014. Reviewers: Prof. J. Lindner, Prof. U.-C. Fiebig, DLR Oberpfaffenhofen, and Prof. W. Koch, University of Erlangen-Nürnberg.

- Eva Peiker-Feil. *Increasing the Bandwidth Efficiency of OFDM-MFSK*, Institute of Communications Engineering, Ulm University, 2014. Reviewers: Prof. J. Lindner, Prof. A. Czylik, University of Duisburg-Essen.


- Wenhui Li. *Decoding Evaluation Codes and their Interleaving*, Institute of Com-
Tatiana Olegovna Gasanova. *Novel Methods for Text Preprocessing and Classification*, Institute of Communications Engineering, Ulm University, 2015. Reviewers: Prof. W. Minker, Prof. E. Semenkin, Siberian State Aerospace University, Krasnoyarsk, and Prof. G. Palm, Ulm University.

Henning Alexander Zörlein. *Channel Coding Inspired Contributions to Compressed Sensing*, Institute of Communications Engineering, Ulm University, 2015. Reviewers: Prof. M. Bossert, Prof. N. Görtz, Vienna University of Technology.

Ksenia Zablotskaya. *Automatic Estimation of User’s Verbal Intelligence*, Inst. of Communications Engineering, Ulm University, 2015. Reviewers: Prof. W. Minker, Prof. M. McTear, University of Ulster, and apl. Prof. H. Traue, Ulm University.


Sergey Zablotskiy. *Lexical and Language Modeling for Russian Large Vocabulary Continuous Speech Recognition*, Inst. of Communications Engineering, Ulm University, 2015. Reviewers: Prof. W. Minker, Prof. A. Wendemuth, Otto-von-Guericke-University Magdeburg, and Prof. A. Karpov, ITMO University, Saint Petersburg, Russia.
8.2 Co-Supervised Ph.D. Theses


- Fernando Luis Piñero González. *An Algebraic Approach to Graph Codes*, Technical University of Denmark, 2014. Reviewers: Prof. T. Høholdt, Prof. M. Bossert.


9 Theses

9.1 Diploma Theses


9.2 Master Theses


### Bachelor Theses


The following conferences and meetings were organized and/or hosted by members of our institute:

- **ITG-Fachausschuss 5.1 Informations- und Systemtheorie**
  March 21, 2014, Ulm University

- **DFG Priority Program “InKoMBio” (SPP 1395)**
  October 9–10, 2014, Ulm University, Berichtskolloquium

- **DFG, Fachkollegium**
  March 30–31, 2015, Ulm University

- **Meeting BMBF-Verbundprojekt “ADVantage-Net”**
  June 2, 2015, Ulm University

- **KRISTINA Project Meeting**
  October 14–16, 2015, Ulm University
The members of the institute are active in various committees and at the university self-administration.

**Prof. Martin Bossert**
- Member of *Leopoldina, Deutsche Akademie der Wissenschaften*
- DFG-Fachkollegiat Nachrichtentechnik
- Vice Dean of the Faculty of Engineering, Computer Science, and Psychology (until Sep. 2015)
- Member of *Fakultätsrat*
- Head of *Promotionsausschuss Dr.-Ing.*
- Member of *Commission VDE Colloquium*
- Member of *ITG-Fachausschuss 5.1 Informations- und Systemtheorie*

**Prof. Robert Fischer**
- Dean of Studies *(Engineering)* of the Faculty of Engineering, Computer Science, and Psychology (since Oct. 2015)
- Program Director of the *International Master Course “Communications Technology”* (since June 2014)
- Head of the Admission Board for the *International Master Course “Communications Technology”* (since Sep. 2014)
- Associate Editor *IEEE Transactions on Information Theory* (until Dec. 2014)
- Member of *Studienkommission “Elektrotechnik”* (until Sep. 2015)
- Member of *Habilitationsausschuss*
- Member of *kiz-Ausschuss*
- Member of *Selection Committee for the Argus Award*
- Member of *ITG-Fachausschuss 5.1 Informations- und Systemtheorie*
Prof. Wolfgang Minker

- Head of Industrial Internship Office
- Member of Admission Board of the joint B.Sc./M.Sc. Programme “Informationsystemtechnik”

Dr. Werner Teich

- Member of Studienkommission “Informationssystemtechnik”
- Member of Prüfungskommission “Elektrotechnik”, “Informationssystemtechnik”, and “Communications Technology”
- Member of Admission Boards for the Master Courses “Elektrotechnik”, “Informationssystemtechnik”, and the International Master Course “Communications Technology”
- Student Advisor “Elektrotechnik”, “Informationssystemtechnik”, and “Communications Technology”