IAM Annual Report 10/11

IAM Annual Report

Academic Year 2010/2011

July, 2011

Contents

1 Institute of Computer Science and Applied Mathematics (IAM)

1.1 Address

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www: http://www.iam.unibe.ch

1.2 Personnel

Board of directors

Prof. Dr. Torsten Braun; Prof. Dr. Horst Bunke; Prof. Dr. Gerhard Jäger; Prof. Dr. Oscar Nierstrasz; Prof. Dr. Matthias Zwicker.

Teaching staff

Thomas Bohnert; Dr. Marc Brogle; Prof. Dr. Torsten Braun; Prof. Dr. Horst Bunke; Prof. Dr. Gerhard Jäger; Dr. C. Latze; Prof. Dr. Oscar Nierstrasz; Prof. Dr. Thomas Strahm; PD Dr. Thomas Studer; Prof. Dr. Matthias Zwicker.

Director

Prof. Dr. Torsten Braun.

Head of Exams

Prof. Dr. Gerhard Jäger.

Administration

Ruth Bestgen; Bettina Choffat; Dragana Esser; Iris Keller; Daniela Schroth; Susanne Thüler.

Technical staff

Peppo Brambilla; Markus Anwander.

Scientific staff

C. Anastasiades; M. Anwander; P. Brambilla; J. Brugger; PD Dr. K. Brünnler; S. Bucheli; Dr. D. Dimitrova; D. Donatsch; S. Eberhard; A. Fischer; D. Flumini; V. Frinken; R. Goetschi; Prof. Dr. R. Haenni; P. Hurni; E. Indermühle; C. Knaus; J. Krähenbühl; Dr. A. Kuhn; Dr. R. Kuznets; Dr. A. Lienhard; W. Lo; Dr. M. Lungu; Dr. R. McKinley; B. Nyffenegger; Dr. T. Nemoto; F. Perin; L. Renggli; J. Ressia; K. Riesen; D. Röthlisberger; F. Rousselle; Dr. K. Sato; Dr. Y. Savateev; S. Schär; N. Schwarz; Dr. T. Staub; Prof. Dr. Th. Strahm; PD Dr. Th. Studer; T. Verwaest; G. Wagenknecht; J. Werner; E. Wernli; Z. Zhao; R. Zumbrunnen

2   Teaching Activities

2.1   Courses for Major and Minor in Computer Science

Autumn Semester 2010

- Bachelor 1st Semester

    Einführung in die Informatik (Die Dozenten der Informatik, 5 ECTS)

    Grundlagen der technischen Informatik (Th. Studer, 5 ECTS)

    Programmierung 1 (Th. Strahm, 5 ECTS)

- Bachelor 3rd Semester

    Diskrete Mathematik und Logik I (G. Jäger, G. Metcalfe, 5 ECTS)

    Computernetze (M. Brogle, T. Bohnert, 5 ECTS)

    Einführung in Software Engineering (O. Nierstrasz, 5 ECTS)

- Bachelor 5th Semester

    Mensch-Maschine-Schnittstelle (Th. Strahm, 5 ECTS)

    Künstliche Intelligenz (H. Bunke, 5 ECTS)

    Computergrafik (M. Zwicker, 5 ECTS)

- Master Courses

    Grundlagen der Mustererkennung (H. Bunke, 5 ECTS)

    Dynamic Object-Oriented Programming with Smalltalk (O. Nierstrasz, 5 ECTS)

    Computational Photography (M. Zwicker, 5 ECTS)

    Proof Theory (G. Jäger, 5 ECTS)

Graduate Seminar Logik und Information (G. Jäger, G. Metcalfe, K. Stoffel, U. Ultes-Nitsche, 5 ECTS)

Seminar: Künstliche Intelligenz (H. Bunke, 5 ECTS)

Seminar: Software Composition (O. Nierstrasz, 5 ECTS)

Seminar: Rechnernetze und Verteilte Systeme (T. Braun, 5 ECTS)

Seminar: Computer Graphics (M. Zwicker , 5 ECTS)

Seminar: Algebra und Logik (G. Jäger, G. Metcalfe, 5 ECTS)

Seminar: Theoretische Informatik und Logik (G. Jäger, 5 ECTS)

- Service Course

  Anwendungssoftware (Th. Studer, 3 ECTS)

Spring Semester 2011

- Bachelor 2nd Semester

  Datenbanken (K. Stoffel, 5 ECTS)

  Datenstrukturen und Algorithmen (M. Zwicker, 5 ECTS)

  Rechnerarchitektur (Th. Studer, 5 ECTS)

  Programmierung 2 (O. Nierstrasz, 5 ECTS)

- Bachelor 4th Semester

  Betriebssysteme (T. Braun, 5 ECTS)

  Diskrete Mathematik und Logik II (G. Jäger, G. Metcalfe, 6 ECTS)

  Berechenbarkeit und Komplexität (Th. Strahm, 5 ECTS)

  Automaten und formale Sprachen (H. Bunke, 5 ECTS)

  Praktikum Software Engineering (Th. Studer, 5 ECTS)

- Bachelor 6th Semester

Proseminare (5 ECTS)

- Master Courses

Gödel's Incompleteness Theorems and Gentzen's Proof Theory (G. Jäger, 5 ECTS)

Complexity Theory (Th. Strahm, 5 ECTS)

Rendering Algorithms (M. Zwicker, 5 ECTS)

Mustererkennung 2 (H. Bunke, 5 ECTS)

Programming Languages (O. Nierstrasz, 5 ECTS)

Mobile Communications (T. Braun, 5 ECTS)

Network Security (C. Latze, 5 ECTS)

Graduate Seminar Logik und Information (G. Jäger, G. Metcalfe, K. Stoffel, U. Ultes-Nitsche, 5 ECTS)

Seminar: Computer Graphics (M. Zwicker, 5 ECTS)

Seminar: Künstliche Intelligenz (H. Bunke, 5 ECTS)

Seminar: Software Composition (O. Nierstrasz, 5 ECTS)

Seminar: Rechnernetze und Verteilte Systeme (T. Braun, 5 ECTS)

Seminar: Algebra und Logik (G. Jäger, G. Metcalfe, 5 ECTS)

Seminar: Theoretische Informatik und Logik (G. Jäger, 5 ECTS)

- Service Course

Anwendungssoftware (Th. Strahm, 3 ECTS)

2.2   Colloquium in Computer Science

21/02/11   Dr. Eiko Yoneki
University of Cambridge, UK
Using Social Structure for Forwarding in Delay Tolerant Networks

28/03/11   Prof. Dr. Per Gunningberg
University of Uppsala, Sweden
Repeatable Experiments with Mobile Nodes
in a Relocatable WSN Testbed

09/05/11   Prof. Dr. Xiaoyi Jiang
University of Münster, Germany
Brücken schlagen, Grenzen überwinden -
Eine Mustererkennungs-Perspektive

09/05/11   Dr. Markus Eichenberger-Liwicki
German Research Center for Artificial Intelligence
Kaiserslautern, Germany
Was kommt nach der automatischen Handschrifterkennung?

26/05/11   Prof. Dr. Andreas Kassler
University of Karlstad, Sweden
Urban-X: Cognitive Wireless Mesh Networks

2.3 Students

- Major Subject Students: HS 2010: 228, FS 2011: 209

- Minor Subject Students: HS 2010: 135, FS 2011: 119

- Ph.D. Candidates: HS 2010: 28, FS 2011: 30

2.4 Degrees and Examinations

- Ph.D.: 6

- Diploma: 1

- Master: 18

- Bachelor: 11

- Completion of Minor Studies: 20 (90 E: 0, 60E: 1, 30E: 14, 25E: 0, 15E: 5 (555 ECTS)

- Semester Examinations Autumn Semester 2010: 458 (2082 ECTS)

- Bachelor/Diploma/Master Theses Autumn Semester 2010: 13 (515 ECTS)

- Semester Examinations Spring Semester 2011: 301 (1395 ECTS)

- Bachelor/Diploma/Master Theses Spring Semester 2011: 20 (655 ECTS)

2.5 Activities

- Contributing to the "Fit in IT - Roadshow" at the Kantonsschule Sargans, Sargans, September 6, 2010

- Contributing to the "Fit in IT - Roadshow" at the Kantonsschule Kollegium Spiritus Sanctus Brig, Brig, Oktober 1, 2010

- Contributing to the "Fit in IT - Roadshow" at the Kantonsschule Solothurn, Solothurn, November 11, 2010

- Offering a full day program for the "Nationaler Zukunftstag", Bern, November 11, 2010

- Contributing to the "Fit in IT - Roadshow" at the Kantonsschule St. Gallen Burggraben, St. Gallen, March 18, 2011

- Offering a full day program for students of the Freie Gymnasium Bern, May 3, 2011

- Offering an open day program for students of the Gymnasium Thun-Schadau, Bern, July 4, 2011

2.6 Awards

- IAM Alumni Prize 2010 for the Ph.D. thesis "Error Resilient and Robust Overlay Networks" of Dragan Milic

- IAM Alumni Prize 2010 for the Master thesis "Verification of Workflow Control-Flow Patterns with the SPIN Model Checker" of Manuela Stolz

- IAM Alumni Prize 2010 for the Bachelor thesis "Trust this Code? Improving Code Search Results through Human Trustability Factors" of Florian Gysin

3 Research Group on Computer Vision and Artificial Intelligence

3.1 Personnel

Head:	Prof. Dr. H. Bunke	Tel: +41 31 631 44 51 email: bunke@iam.unibe.ch
Office Manager:	S. Thüler	Tel.: +41 31 631 33 23 email: thueler@iam.unibe.ch
Scientific staff:	A. Fischer*	Tel: +41 31 511 76 23 email: afischer@iam.unibe.ch
	V. Frinken	Tel: +41 31 511 76 20 email: frinken@iam.unibe.ch
	E. Indermühle	Tel: +41 31 511 76 22 email: eindermu@iam.unibe.ch
	K. Riesen	Tel: +41 31 511 76 21 email: riesen@iam.unibe.ch
Guests:	N. Dahm	Griffith University, Queensland, Australia September – November 2010
	A. Fornés	Universitat Autònoma de Barcelona, Spain February – July, 2011

* with financial support from a third party

3.2 Overview

Since 1984, the FKI group has been working on various topics in pattern recognition, machine vision, and computational intelligence. One of the current subject areas is document image analysis with a special focus on handwriting recognition. Furthermore, we are working in the field of structural pattern recognition, where we aim at developing methods to extend and improve current algorithms for clustering and classification using non-vectorial object representations.

3.3   Research Projects

Document Image Analysis and Understanding

A variety of problems occurring in the context of document image analysis are being investigated. These include the processing and analysis of both machine printed and handwritten documents. Current focus is on handwriting recognition, particularly on general text recognition and the use of natural language processing techniques for both on-line and off-line handwriting data. Currently, the problem of text/non-text distinction in online documents and the application of handwriting recognition on mediaeval documents are studied. Furthermore, semi-supervised learning for handwriting recognition is under investigation. Some of these activities are carried out as part of the Swiss National Science Foundation Project "HisDoc: Historical Document Analysis, Recognition, and Retrieval".

Research staff: A. Fischer, V. Frinken, E. Indermühle

Structural Pattern Recognition

Feature vectors are the predominant representation formalism in pattern recognition. Recently, however, non-vectorial representations, such as strings, trees and graphs, are becoming more and more popular for a number of reasons. But in contrast to vector spaces, the domain of symbolic data structures does not have a rich mathematical structure. Therefore, there is a severe lack of mathematical tools and algorithms for graph clustering and classification. In this project, we study a variety of issues, including efficient algorithms for graph matching, graph kernels, embedding of symbolic data structures in vector spaces, and the adaptation of concepts from vector representations to the domains of strings, trees, and graphs.

Research Staff: K. Riesen

3.4   Phd Theses

- Frinken, V.: Semi-supervised Learning and Keyword Spotting for Handwriting Recognition (June 2011)

3.5   Master Theses

- Altuner, Ö.: Compressed Graph Representation Based on Lossy Coding (August 2010)

- Eggel, J,: Semi-supervised Learning for Digit Classification (December 2010)

- Peter, T.: Lexikon Reduction for Handwritten Word Recognition (March 2011)

- Asti, C.: Einzelworterkennung mit Dynamic Time Warping, ISOMAP und ungelabelten Daten (May 2011)

- Gerber, E.: Automatische Aufbereitung der Tagebücher von Jules Jacot-Guillarmod (June 2011)

- Schürch, S.: Hausdorff Features for Handwriting Recognition in Historical Documents (June 2011)

- Schmassmann, A.: Wortsegmentierung in historischen Dokumenten mittels Handschrifterkennung (June 2011)

- Jackson, G.: Classification of Mitochondrial Morphology in Trypanosoma Brucei (June 2011)

- Müller, Ch.: Erkennung der Sprache in handgeschriebenen Dokumenten (July 2011)

3.6   Bachelor Theses

- Nietlispach, J.: Graph Based Word Spotting on Medieval Documents (June 2011)

- Baumgartner, M.: Self-Training-Verfahren zur Verbesserung des Keyword Spotting in Handgeschriebenen Texten (June 2011)

3.7   Further Activities

Editorial Boards

H. Bunke

- Editor-in-Chief of *Electronic Letters on Computer Vision and Image Analysis*

- Member of the editorial board of the *International Journal of Pattern Recognition and Artificial Intelligence*

- Member of the editorial board of *Acta Cybernetica*

- Member of the editorial board of *Frontiers of Computer Science in China*

- Member of the advisory board of *Pattern Recognition*

- Editor-in-Chief of the book series *Machine Perception and Artificial Intelligence* by World Scientific Publ., Singapore

Membership in Program Committees

H. Bunke

- GbR 2011 (8th IAPT-TC-15 Int. Workshop on Graph based Representations in Pattern Recognition), Münster, Germany, May 18 – 20, 2011

- IbPRIA 2011 (5th Iberian Conference on Pattern Recognition and Image Analysis), Gran Canaria, Spain, June 8 – 10, 2011

- MCS 2011 (10th Int. Workshop on Multiple Classifier Systems), Naples, Italy, June 15 – 17, 2011

- ICDAR 2011 (11th Int. Conference on Document Analysis and Recognition), Beijing, China, September 18 – 21, 2011

- SIMBAD 2011 (1st Int. Workshop on Similarity Based Pattern Analysis), Venice, Italy, October 2011

Invited Talks at International Conferences

H. Bunke

- CCPR 2010 (Chinese Conference on Pattern Recognition), Chongqing, China, October 21 – 23, 2010

- ICIAP 2011 (International Conference on Image Analysis and Processing), Ravenna, Italy, September 14 – 16, 2011

Additional Activities

H. Bunke

- Member Scientific Advisory Board of the German Research Center for Artificial Intelligence

3.8 Publications

Journal Publications

- Ferrer, M., Karatzas, D., Valveny, E., Bardaji, I., Bunke, H.: A recursive embedding approach to median graph computation, Computer Vision and Image Understanding 115(7), 919 − 928, 2011

- Riesen, K., Bunke, H.: Recent advances in graph-based pattern recognition with applications in document analysis, Pattern Recognition 44(5), 2011, 1057 - 1067

- Bunke, H, Riesen, K.: Improving vector space embedding of graphs through feature selection algorithms, Pattern Recognition 44(9), 2011, 1928 - 1940

- Frinken, V., Fischer, A., Manmatha, R., Bunke, H.: A novel word spotting method based on recurrent neural networks, IEEE Trans. Pattern Analysis and Machine Intelligence, in press

- Bunke, H., Riesen, K.: Towards the unification of structural and statistical pattern recognition, Pattern Recognition Letters, in press

- Fankhauser, S., Riesen, K., Bunke, H., Dickinson. P.: Suboptimal graph isomorphism using bipartite matching, submitted

- Fischer, A., Keller, A., Frinken, V., Bunke, H.: Lexicon-free handwritten word spotting using character HMMs, submitted

- Gibert, J., Valveny, E., Bunke, H.: Embedding of graphs with discrete attributes via frequencies of node labels, submitted

- Frinken, V., Bunke, H.: Self-training for continuous handwritten text recognition, submitted

Papers in Refereed Conference Proceedings and Chapters in Edited Books

- Frinken, V., Fischer, A., Bunke, H.: Improving handwritten keyword spotting with self-learning, Proc. 26th Annual ACM Symposium on Applied Computing, Vol. 2, 840 – 845, 2011

- Fankhauser, S., Riesen, K., Bunke, H.: Speeding up graph edit distance computation through fast bipartite matching, in X. Jiang, M. Ferrer, A. Torsello (eds.): Graph-based Representations in Pattern Recognition, LNCS 6658, Springer, 102 – 111, 2011

- Gibert, J., Valveny, E., Bunke, H.: Dimensionality reduction for graph of words embedding, in X. Jiang, M. Ferrer, A. Torsello (eds.): Graph-based Representations in Pattern Recognition, LNCS 6658, Springer, 22 – 31, 2011

- Jiang, X., Lambers, M., Bunke, H.: Structure-based evaluation methodology for curvilinear structure detection algorithms, in X. Jiang, M. Ferrer, A. Torsello (eds.): Graph-based Representations in Pattern Recognition, LNCS 6658, Springer, 305 – 314, 2011

- Csirik, J., Bertholet, P., Bunke, H.: Pattern recognition in wireless sensor networks in presence of sensor failures, in N.B. Lupulescu, S. Yordanova, V. Mladenov (eds.): Recent Researches in Neural Networks, Fuzzy Systems, Evolutionary Computing & Automation, 104 – 109, 2011

- Gibert, J., Valveny, E., Bunke, H.: Vocabulary selection for graph of words embedding, in J. Vitria, J.M. Sanchez, M. Hernandez (eds.): IbPRIA 2011, LNCS 6669, 216 – 223, 2011

- Gibert, J., Valveny, E., Ramos Terrades, O., Bunke, H.: Multiple classifiers for graph of words embedding, in C. Sansone, J. Kittler, F. Roli (eds.): MCS 2011, LNCS 6713, 36 – 45, 2011

- Csirik, J., Bertholet, P., Bunke, H.: Sequential classifier combination for pattern recognition in wireless sensor networks, in C. Sansone, J. Kittler, F. Roli (eds.): MCS 2011, LNCS 6713, 187 – 196, 2011

- Fornes, A., Llados, J., Bunke, H.: Writer identification in old handwritten music scores, in C. Papaodysseus (ed.): Pattern Recognition and Signal Processing in Archaeometrics: Mathematical and Computational Solutions for Archaeology, in press

- Liwicki, M., Graves, A., Bunke, H.: Neural networks for handwriting recognition, in L. Jain (ed.): Computational Intelligence Paradigms in Advanced Pattern Classification, Springer, in press

- Ferrer, M., Bunke, H.: Graph edit distance – Theory, algorithms, and applications, in O. Lezoray, L. Grady (eds.): Image Processing and Analysis with Graphs: Theory and Practice, CRC Press, in press

- Csirik, J., Bunke, H.: Feature Selection and Ranking for Pattern Classification in Wireless Sensor Networks, in P. Wang (ed.): Pattern Recognition, Machine Intelligence and Biometrics, in press

- Riesen, K., Bunke, H.: Classification and clustering of vector space embedded graphs, in C. H. Chen (ed.): Emerging Topics in Computer Vision and its Applications, World Scientific, in press

- Riesen, K., Bunke, H.: Graph embedding using dissimilarities – applications in classification and clustering, in X. Bai, J. Ceng, E. Hancock (eds.): Graph-based Methods in Computer Vision: Developments and Applications, IGI Global, in press

- Fischer, A., Bunke, H.: Character prototype selection for handwriting recognition in historical documents with graph similarity features, EUSIPCO 2011, accepted for publication

- Fischer, A., Indermühle, E., Frinken, V., Bunke, H.: HMM-based alignment of inaccurate transcriptions for historical documents, ICDAR 2011, accepted for publication

- Indermühle, E., Frinken, V., Bunke, H.: Keyword spotting with BLSTM neural networks in online handwritten documents containing text and non-text, ICDAR 2011, accepted for publication

- Frinken, V., Bunke, H., Fornes, A.: Co-training for handwritten word recognition, ICDAR 2011, accepted for publication

- Bunke, H., Csirik, J., Gingl, Z., Griechisch, E.: Online signature verification method based on the acceleration signals of handwriting samples, CIARP 2011, accepted for publication

- Fischer, A., Frinken, V., Fornes, A., Bunke, H.: Transcription alignment of Latin manuscripts using hidden Markov modes, HIP 2011, accepted for publication

- Fornes, A., Finken, V., Fischer, A., Almazan, J., Jackson, G., Bunke, H.: A keyword spotting approach using blurred shape model-based descriptors, HIP 2011, accepted for publication

- Fischer, A., Frinken, V.: Hidden Markov models for off-line cursive handwriting recognition, submitted

- Indermühle, E., Bunke, H.: Mode detection in online handwritten documents using BLSTM neural networks, submitted

- Frinken, V., Bunke, H.: Continuous handwritten script recognition, submitted

4 Research Group on Computer Networks and Distributed Systems

4.1 Personnel

Head:	Prof. Dr. T. Braun	Tel.: +41 31 511 2631 email: braun@iam.unibe.ch
Office Manager:	R. Bestgen	Tel.: +41 31 511 2630 email: bestgen@iam.unibe.ch
Scientific Staff:	C. Anastasiades*	Tel.: +41 31 511 2635 email: anastasi@iam.unibe.ch
	M. Anwander*	Tel.: +41 31 511 2634 email: anwander@iam.unibe.ch
	Dr. D. Dimitrova*	Tel.: +41 31 511 2633 email: dimdes@iam.unibe.ch (since 15.03.2011)
	P. Hurni*	Tel.: +41 31 511 2640 email: hurni@iam.unibe.ch
	B. Nyffenegger*	Tel.: +41 31 511 2632 email: nyffeneg@iam.unibe.ch (since 01.01.2011)
	Dr. T. Staub*	Tel.: +41 31 511 2637 email: staub@iam.unibe.ch
	G. Wagenknecht*	Tel.: +41 31 511 2636 email: wagen@iam.unibe.ch
	Z. Zhao*	Tel.: +41 31 511 2638 email: zhao@iam.unibe.ch
External Ph.D. Students:	A. Antonescu	email: antonescu@iam.unibe.ch (since 01.02.2011)
	M. Thoma	email: thoma@iam.unibe.ch (since 01.02.2011)
Guests BNF - Swiss qualification program:	P. Goode*	email: goode@iam.unibe.ch (until 10.08.2010)
	M. Darriulat*	email: darriula@iam.unibe.ch (until 30.11.2010)
	M. Oberle*	email: oberle@iam.unibe.ch (01.11.2010 - 18.12.2010)

Guests:	Prof. G. Coulson	Lancaster University,
		UK
		August 2010
	Dr. S. Duquennoy	Swedish Institute of Computer Science,
		(SICS), Sweden
		May 2011

* with financial support from a third party

4.2 Overview

The research group for Computer Networks and Distributed Systems (Rechnernetze und Verteilte Systeme, RVS) has been active since 1998 in several areas of computer communications and distributed systems, mainly focused on Internet protocols. The Internet is increasingly being used for multimedia data transfer (audio, video, sensor data, etc.). We are investigating how services with high demands on the quality, reliability, and energy efficiency of communication systems and networks can be supported. The current focus of the research group are wireless networks with special emphasis on wireless mesh and sensor networks. Management architectures as well as protocols on link, routing, and transport layer are being investigated.

4.3 Research Projects

Wireless Sensor Network Testbeds (WISEBED)

The *WISEBED* project (http://www.wisebed.eu) started in June 2008. It aims to provide a multi-level infrastructure of interconnected testbeds of large-scale wireless sensor networks for research purposes, pursuing an interdisciplinary approach that integrates the aspects of hardware, software, algorithms, and data. In the *WISEBED* project, researchers are investigating new theoretical approaches on algorithms, mechanisms and protocols. The project's main aim is to make the distributed laboratories available to the European scientific community, so that other research groups can take advantage of a federated testbed infrastructure. Our research group is involved as task leaders in several work packages.

Within WP1 (*Hardware Installation*) we installed a persistent testbed of 42 TelosB and 7 MSB430 sensor nodes, using a wired backbone of mesh

nodes for code distribution and retrieval of debug/trace data. The sensor/mesh network spans over 5 floors of the building Neubrückstrasse 10 and over 2 floors at Schützenmattstrasse 14 in Bern. The TelosB and MSB430 sensor nodes are attached via USB cables to the mesh nodes, which also form the power supply. Using this reliable backbone infrastructure, all nodes can be reset, rebooted and reprogrammed remotely within a short time.

Within WP2 (*Testbed operation, access, and management*) we have designed and implemented the *Testbed Management Architecture for Wireless Sensor Networks (TARWIS)*, a generic experiment and testbed management system for wireless sensor network testbeds. TARWIS has been integrated into the testbed federation and is to-date already the management system of various testbeds of the all WISEBED project partners, as e.g., University of Lancaster and Technical University of Delft. Two major releases of the software have been published between July 2010 and July 2011. Major extensions are the support support for running concurrent experiments with subsets of nodes (of the same or different type), support for repeatability and batch processing of experiments, automated command entering, and the use of templates to to ease configuration of experiments. Further, many interoperability problems and problems related to inconsistencies and different WSDL-versions used have been solved. TARWIS is now fully interoperable with different backends, such as our perl-backend, gSOAP-backend from University of Lancaster, and the Jax-based backend from University of Lübeck. The current version is TARWIS 5.0.

Real-world environmental data is of major importance when it comes to real-world evaluation of protocol mechanisms. With yet no existing standard for real-world experimental data, the WISEBED project has developed the WiseML language, a XML-based XSD Schema that offers a uniform description of experiment trace data. Within WP4, we delivered to data sets: NULLMAC/XMAC and ECC-evaluation. For NULLMAC/XMAC the basic setup consists of a TCP server (receiving segments), a TCP client (sending segments), and a node chain of variable length, ranging from 2 to 6 hops. The experiments examined the behavior of TCP on top of Contiki's NULLMAC / CSMA-variant and 3 different radio duty-cycling protocols: X-MAC, Low-Power-Probing and ContikiMAC. For each setting, the amount of successfully delivered segments (of roughly 30 bytes each) was measured in 15 experimental runs of 15 minutes each. The ECC-evaluation data set was collected using the 7 MSB-430 sensor nodes operating with the ScatterWeb operating system. The performance of a selection of eight different Error Correction Codes (ECCs), ranging from simple bit-repetition schemes over hamming-based codes to complex and

powerful Bose-Chaudhuri-Hocquenghem (BCH) codes were evaluated.

All web interfaces of the WISEBED testbed infrastructure are protected by Shibboleth. Therefore, all WISEBED partners operate a Shibboleth identity provider (IDP) to administrate the users of the WISEBED federation. The IDP is responsible to authenticate users, which try to access a protected web resource (e.g., TARWIS, IDP administration, authorization management). We also implemented a sensor network authorization tool (SNA) to maintain the authorization of the different users at the existing TARWIS testbeds.

Within WP3, we finished the implementation of DYMO routing protocol and Eschenauer-Gligor key management algorithms for Shawn simulator. Beside this, we implemented the OLSR, DYMO routing protocols and Eschenauer-Gligor key management algorithms on real sensor nodes, such as TelosB and MSB430.

Research staff: Philipp Hurni, Markus Anwander, Gerald Wagenknecht, Zhongliang Zhao, Thomas Staub, Torsten Braun

Traffic Adaptivity in Wireless Sensor Networks (TRAWSN)

Energy efficiency is a major concern in the design of Wireless Sensor Networks (WSNs) and their communication protocols. Today's energy-efficient (E^2) MAC protocols are able to deliver little amounts of data with a low energy footprint, but introduce severe restrictions with respect to throughput and latency. Regrettably, they yet fail to adapt to varying traffic loads and changing requirements of the imposed traffic load.

We intend to bridge this gap with the TRAWSN project, which started in October 2009. Within TRAWSN, we have developed MaxMAC, an energy-efficient MAC protocol for WSN scenarios with varying traffic conditions. While MaxMAC operates similarly as existing E^2-MAC protocols in low traffic situations, it is able to maximally adapt to changes in the network traffic load at run-time. We have published simulation-based results of the MaxMAC protocol at the European Conference on Wireless Sensor Networks (EWSN), Europe's most selective conference on WSNs in 2010, and have since then been working on a) software-based energy estimation mechanisms in order to evaluate our contribution b) the real-world prototype implementation of MaxMAC and its evaluation on our indoor WSN testbed. This evaluation was again conducted on the distributed testbed

facilities set up within two buildings on the Engehalde Campus during the WISEBED project, and which are operated by our management infrastructure TARWIS.

Another activity pursued within TRAWSN with the subordinate topic of dynamic resource allocation schemes in WSNs is our study on the potential of Forward Error Correction (FEC) mechanisms and dynamic/runtime adaptive FEC variants in WSNs. Throughout the last year, we implemented eight different Error Correction Codes (ECCs) and have made them available in a publicly available ECC library. The implemented codes range across four different classes, from simple bit-repetition schemes via Hamming codes to complex and powerful Bose-Chaudhuri-Hocquenghem codes, and further contain our three proposed run-time adaptive FEC schemes which adapt the correctional power of ECCs to the current link quality. We have thoroughly evaluated the computational costs and the resulting benefits with respect to packet delivery rate (PDR) of the static and adaptive FEC schemes under real-world conditions in a wide range of experiments on our distributed WSN testbed laboratory which is operated by our management infrastructure TARWIS.

Research staff: Philipp Hurni, Sebastian Barthlomé, Torsten Braun

Financial support: Swiss National Foundation Project No. 200021-126718/1

Authentication, Authorization, Accounting and Auditing in Wireless Mesh Networks (A^4-Mesh)

To successfully use Wireless Mesh Networks (WMNs) in the area of Swiss higher education, they have to support authentication, authorization, accounting, and auditing. They must also be seamlessly integrated into the organizations' authentication and authorization infrastructure. As there are usually multiple concurrent users of the network, a WMN has to support accounting to enable charging and network management. For a successful operation of a wireless mesh network, inconsistent and erroneous states in the network have to be detected and resolved. This requires constant auditing of network state and configuration. The auditing function may then trigger alarms or even perform self-healing of the network. The A4-Mesh project aims to develop a completely functional wireless mesh network infrastructure including support for authentication and authorization,

accounting, and auditing. In the first months of the project, we have developed concepts for user and machine authentication and authorization in a WMN using Shibboleth.

An indoor test bed, a pilot network for campus network extension, and a pilot network for environmental research are planned. We have set up the planned indoor test bed, which will be used for developing and testing the various A4-Mesh software components, at the University of Bern. The test bed includes 20 nodes consisting of an Alix 3D system board and featuring IEEE 802.11n connectivity. The goal of the pilot network for environmental research is to provide a broadband network service for measurement stations. Together with environmental researchers of the Institute of Geography (GIUB), the project MontanAqua was selected for the pilot network installation. The network consists of 11 mesh nodes, including four nodes installed at existing measurement stations sites (lysimeter, weather station, gauging station, IP camera), where they enable access to the measurement data through the network. We have completed a fully functiona nodel prototype, which is suitable for extreme weather conditions and may be powered by solar power only. This includes the completion of a tailored power supply box (solar panel, solar charger, and battery), a tailored mesh node box (up to 3 system boards), relay, custom mounts (antennas, supply box), as well as additions to ADAM Linux to meet the demands of the network. We have successfully tested the prototype on the roof of the IAM building. Currently, we are testing a mesh node, which is installed on the roof of the GIUB building and another one on the roof the ExWi building. In addition, we are preparing the installation of the pilot network in Crans Montana.

Research staff: Thomas Staub, Benjamin Nyffenegger, Markus Anwander, Torsten Braun

Wireless Mesh Networks

Besides the WMN for environmental monitoring and campus extenstion, there are further activities in the area of WMNs such as extensions of the framework for management and deployment of WMNs (ADAM), the extension of the WMN virtualization framework (VirtualMesh) to support WSNs and virtual mobility, the finalization of an '"easy-to-install" temporary network for video communication (OViS), and using wireless mesh technology

for unmanned aerial vehicles.

Administration and Deployment of Adhoc Mesh networks (ADAM) provides mechansims for fault-tolerant and safe deployment and configuration of WMNs as well as a build system for cross-compilation of tailored embedded Linux distribution with a very small footprint for the mesh nodes. ADAM has been extended to support the Gumstix Overo board, an ARM-8 based computer module. We updated the software with newer Linux kernels. In order to increase the self-healing capabilities, we added support for hardware watchdog and a specialised backup node using UMTS. ADAM is used in several ongoing projects such as LBA and A^4-Mesh.

VirtualMesh is an emulation framework for WMNs and provides new testing facilities during the development of architectures and protocols for WMNs. It virtualizes a complete wireless mesh network by using host virtualization (XEN) for the mesh nodes and redirecting their wireless network traffic to a network simulator. In order to use our wireless device driver enabled network emulation in WSNs, we designed a concept for supporting virtual mobility in WSN test beds (e.g., WISEBED). Our virtual mobility support for WSN test beds is currently being implemented.

On-site Video System (OViS) reduces the number of costly visits of engineers on construction sites by providing an easily deployable temporary video communication infrastructure. At the time of electrical installations, electricians may face unknown problems or plan deviations, which require consultations with a remote engineer. In-building communication networks, as well as electrical installations, are set up very lately in the building construction process. In addition, communication over cellular mobile networks is often not possible inside buildings, especially in basements. To support telepresence of the engineer, a temporary communication network has to be deployed. Our approach is to use a battery powered WMN supporting automatic configuration and an electronic wizard that guides the user through the deployment process of the network. We extended our prototype with electronic wizards for iPhones/iPads and Android smartphones. In addition, we enhanced OViS to support multi-channel communication.

Finally, we developed an *airborne communication network (UAVNet)*. A WMN is automatically deployed using small quadrocopters as *unmanned aerial vehicles (UAVs)*. They provide communication facilities in case of natural disasters such as floodings or earthquakes. The UAVs with the wireless mesh nodes position themselves automatically to enable communication between two distant communication peer (airborne relay) or to cover a defined area (airborne mesh). In our first UAVNet prototype, we connected small wireless mesh nodes to quadrocopters by a se-

rial interface and implemented an API to steer and coordinate the UAVs over the IEEE 802.11g-based WMN. Our research focus is on automatic deployment, replacement and routing. In order to simplify the deployment of UAVNet, we developed a control and monitoring application for iPhone/iPad. The prototype is further used in the ORMAN project.

Research staff: Thomas Staub, Paul Kim Goode, Stefan Ott, Simon Morgenthaler, Adrian Hänni, Marcel Stolz, Markus Anwander, Dhara Shah Manojkumar, Ulrich Bürgi, Gabriel Martins Dias, Geoff Coulson, Torsten Braun

Location Based Analyser (LBA)

The main goal of the LBA project is to develop a practical solution - from the design to deployment phase - which is able to locate and track Bluetooth and WiFi modules, embedded in personal devices, e.g., mobile phones. The solution is based on low cost wireless sensor networks (WSNs) and collects statistical information for personal devices on the (indoor) premises. These statistics can be used, for example, by network operators to adapt capacity provisioning or by businesses to improve their services. Privacy is protected since the system is passive and does NOT retrieve any data with which the phone's owner may be identified.

LBA is a technology transfer project in cooperation with DFRC AG and Wellness Telecom as industry partners. DFRC provides feedback on implementation and deployment issues and tries to bring the product to the market. In order to ensure the product quality and improve the development, DFRC provided us realistic measurements from already deployed networks in Singapore, Sevilla (Spain), Tel Aviv (Israel) and Zug (Switzerland).

During the project, contact was established with researchers from the Technical University of Catalonia (Spain) and the Aerospace Research and Technology Centre (Spain) who work on the development of indoor positioning systems based on WiFi.

The technological problem that LBA is trying to solve is a "non-cooperative" system able to track devices in indoor environments with sufficient accuracy. The system should scale well, i.e., no upper limit on the number of devices tracked, and should not interfere with the customer's privacy. The project targets the evolving market of business intelligence based on location data, which aims to provide businesses information on their customers' behavior (in time and space).

An initial WSN, using embedded Linux running on the Gumstix sensor nodes, was deployed in an indoor test location. Series of measurements were performed in order to gain insights on the indoor propagation of Bluetooth signals (for a 15-node WSN in a single room) and on the signal's sensitivity to various factors such as distance, obstacles, manufacturer and smart phone specifics and device orientation. Subsequently, we used our own embedded Linux platform (ADAM) on the Gumstix nodes.

Analysis of the collected measurements with Bluetooth showed that high precision positioning based on a single technology and a single parameter is not possible - room level precision is achieved. Then, we looked at the Received Signal Strength Indicator (RSSI) and the Response Rate (of a scan). Combining the information from both parameters offers improved results, e.g., proximity to a node, but is still insufficient for a precision of a few meters. Therefore, we move towards positioning algorithm based on combined analysis of Bluetooth and WiFi signals.

The number of deployed sensor nodes also has major impact on the location estimate. A grid of sensor nodes is better in providing a reliable estimate but also more costly than a few nodes on key positions. A middle-way solution that showed positive results is to work with the maxima of the measured RSSIs and to aggregate data from near sensor groups in order to explore signal diversity.

From the measurements we observed that the signal degrades quickly with the increase of distance, which in combination with the unreliable indoor propagation conditions is the biggest challenge to high-precision positioning. Further, the factor with most significant impact on received powers showed to be device orientation; manufacturer and smart phone specifics have negligible effects.

Research staff: Desislava Dimitrova, Thomas Staub, Ulrich Bürgi, Gabriel Martins Dias, Torsten Braun

Financial support: Swiss Federal Office for Professional Education and Technology, European Community Eureka Eurostars project 5533

Enhanced Mobile Communication with Content-Centric Networks

With the increased proliferation of modern smart phones, mobile data communication and network density has increased drastically. Current delay-tolerant communication solutions are not suited to these dense, mostly ur-

ban, environments due to the limited capacity of the wireless medium and inefficient communication schemes, i.e., hosts exchange content in multiple unicast transmissions without having the possibility to cache content at chunk level.

In this project, which started in May 2011, we will investigate the feasibility of Content-Centric Networks (CCNs) in the context of mobile ad hoc networks. Although CCNs as proposed by Van Jacobson et. al. mainly target wired Internet communication, they feature also many advantages over traditional host-based wireless communication. A user interested in specific content broadcasts Interest messages to receive available broadcasted Data message in response. Current scalability and security problems may be addressed by exploiting the inherent broadcast property of the wireless medium and signing content individually. In case of lost connectivity due to mobility, nearby hosts that hold the requested content may resume the data transfer.

We will base our investigations on available CCN implementations and adapt it to the needs of resource constraint devices. The project targets three main research areas: 1. Memory management to control the limited router cache storage. 2. Energy-efficient operation to optimize the lifetime of battery operated devices. 3. Efficient content discovery and delivery mechanisms to reduce the number of unnecessarily transmitted redundant broadcast messages without significantly decreasing connectivity.

Within this project, we have implemented a CCN framework in OMNeT++, inspired by the available CCNx implementation by PARC. Specific modifications were required to adapt the design to wireless and mobile networks. Similar to CCNx, a CCN layer processes all communication between an upper CCN application layer and the lower UDP transport layer. Received Data and Interest messages are stored and forwarded to the appropriate network interfaces or the application layer. Currently, the framework supports three node types: Wifi, Ethernet, and hybrid nodes. This simulation framework will allow us in a later stage to quickly assess our ideas in different simulation scenarios. We have also set up a VirtualMesh testbed consisting of several hosts that have the current CCNx-0.4.0 implementation installed. We have conducted basic communication tests and plan to implement a basic CCNx application for more elaborated performance testing.

Wireless Networking for Moving Objects

The Internet of the Future will incorporate a large number of autonomous wireless objects moving with diverse patterns and speeds while communicating via several radio interfaces. Examples of such objects may include humans, cars or unmanned aerial vehicles, with every object acting as a networking device generating, relaying and/or absorbing data. Achieving the Internet of the Future will require global interoperability among objects/devices. To overcome current shortcomings, a number of research challenges have to be addressed in the area of networking, including protocol engineering, development of applications and services, as well as realistic use-cases. The COST Action IC0906 coordinates research efforts of national and international projects in the area of Wireless Networking for Moving Objects (WiNeMO). Two Short Term Scientific Missions (STSMs) have been funded by the COST Action. Other related activities are our work on Enhanced Mobile Communication with Content-Centric Networks and Opportunistic Routing for highly Mobile Ad-hoc Networks.

The *Resource allocation in a hybrid sensor - mobile network* STSM focused on the resource allocation dynamics at the border of a mobile and a sensor network. In particular, it was investigated how different types of sensor traffic, e.g., continuous, burst, affect the resource management in a mobile network, i.e., radio bandwidth allocation, and how these inter-network dynamics can be modeled at best. Terminal mobility, of both mobile devices and sensor nodes, had central importance for the research. It was determined that two types of sensor traffic have the strongest impact - multimedia streams and large, simultaneous notifications burst. Eventually, a modeling approach was proposed that captures specifics of both mobile and sensor traffic and, hence, can represent the behavior of the combined system. The approach is based on the concept of Markov chains adapted to represent the traffic changes of a mobile network.

The *Testbed Architecture for Mobile Wireless Sensor and Mesh Networks* STSM further developed the proposed architecture for a mobile wireless sensor and mesh network testbed. The design is based on the concept of virtual mobility, cf. Virtual Mesh in the Wireless Mesh Networks research activity. Virtually mobile nodes can be physical, simulated or emulated, and virtual mobility for all three types is treated uniformly by embedding the nodes in a virtual space. In operation, the traffic of virtually-mobile nodes is intercepted and redirected to a mobility model from where it is selectively forwarded to other nodes that are virtually in range. A distributed implementation architecture that potentially allows the simulation/emulation of large-scale wireless sensor networks with large numbers of virtually-

mobile nodes has been designed. The architecture has strong scalability and can reuse existing simulation software components.

Research staff: Torsten Braun, Carlos Anastasiades, Desislava Dimitrova, Zhongliang Zhao

Financial support: European Science Foundation

Energy Efficiency in Large Scale Distributed Systems

The COST Action IC0804 proposes realistic energy-efficient solutions to share distributed information technology resources. As large scale distributed systems gather and share more and more computing nodes and storage resources, their energy consumption is exponentially increasing. While much effort is nowadays put into hardware specific solutions to lower energy consumptions, the need for a complementary approach is necessary at the distributed system level, i.e., middleware, network and applications. The Action characterizes the energy consumption and energy efficiencies of distributed applications. Our research group is contributing to the Action's focus group on green wireless, which aims to investigate energy efficient concepts for wireless communication. Related work performed in this area has been performed in the research activities on Wireless Mesh Networks and Traffic Adaptivity in Wireless Sensor Networks.

The *Energy Measurements of Wireless Network Devices* STSM aimed to explore the energy consumption of different network technologies, e.g., WLAN, WiMAX, GPRS/UMTS, etc. Detailed knowledge about energy consumption is urgently needed to design and evaluate new mechanisms to save the energy of mobile devices in mobile cloud computing scenarios. It is a prerequisite to select the appropriate combination of network technologies for given application requirements. We established a measurement and evaluation methodology using modified USB extension and power supply cables looping in a high performance digital multimeter. Using our methodology and the established test bed at the University of Coimbra, we are able to provide detailed measurements of the energy consumption of different network technologies, such as WiMAX, WLAN, or UMTS, in mobile cloud computing scenarios. We can identify potential energy saving gains of arbitrary combinations of these network technologies. With the test bed, we can evaluate novel energy saving mechanisms. Moreover, the gathered data set enables the development of a software based energy model, which could be used in future energy saving mechanisms and

their evaluation.

Research staff: Torsten Braun, Thomas Staub, Philipp Hurni

Financial support: European Science Foundation

Service-Centric Networking

Content-centric networking is a novel paradigm for the Future Internet. We argue that content-centric networking should be generalized towards a service-centric networking (SCN) scheme. We propose a service-centric networking design based on an object-oriented approach, in which content and services are considered objects. We identified implementation architectures for example services and how these can benefit from service-centric networking. Service-centric networking can be beneficial for saving network resources and reducing response time for service invocation as well as supporting location-based services. SCN has been presented at two international workshops and two invited talks.

Research staff: Torsten Braun

Financial support: Bell Labs, Holmdel, NJ

Opportunistic Routing for highly Mobile Ad-hoc Networks (ORMAN)

The ORMAN project started in April 2010 and aims to investigate, develop and evaluate novel routing and forwarding schemes based on opportunistic routing schemes. Existing mobile ad-hoc networks protocols are not appropriate for the highly mobile node application scenario such as unmanned aerial vehicle (UAV) ad hoc networks, because a packet source is unable to calculate a complete route to the destination. Opportunistic routing protocols do not calculate an end-to-end communication path, the forwarding choice is performed on a hop-by-hop basis. Therefore, an opportunistic routing scheme seems to be a possible solution for the highly mobile application scenario. We aim to develop a geographic opportunistic routing protocol exploiting the multi-channel capabilities to reduce interference and maximize throughput. In order to maintain basic connectivity required to apply the routing protocol, we aim to develop an appropriate

topology control protocol that not only achieves connectivity but also minimizes interference. Besides the simulation work, real implementations using unmanned aerial vehicles and interconnected test-beds has to be performed in order to prove feasibility of the developed concepts.

In the first year of the ORMAN project, our contribution targeted on the development of a common simulation framework that supports comprehensive and meaningful evaluation of different opportunistic routing schemes. In order to receive comparable results, we developed a framework for the OMNeT++ simulator that provides common building blocks for the implementation of opportunistic routing protocols. The framework decoupled the opportunistic routing schemes into four modules, and provided additional functions which are necessary for opportunistic routing protocol implementation.

We also validated, via simulation, the poor performance of traditional MANET routing protocols in the highly mobile ad-hoc networks environment. This result affirms the inapplicability of traditional MANET routing strategies in an intermittent environment, where speed and directions of node vary significantly. This observation confirms the importance of opportunistic routing in highly mobile networks.

The current research focus are novel opportunistic routing protocols design and mobility models in highly dynamic environments. We proposed to use bio-inspired technology.

Research staff: Zhongliang Zhao, Torsten Braun

Testbed for Mobile and Internet Communications

Our research group maintains its own comprehensive and heterogeneous testbed network for various purposes. The testbed is used to build networks of experimental routers and end systems in order to be able to evaluate the behavior of new networking protocols and architectures in realistic environments. The testbed also forms a productive network of Linux PCs and provides the storage capacity and CPU power for many of our research group's projects. An educational laboratory network for students' training is also connected and has been used for teaching in thr Bachelor program. Our research group also takes part in PlanetLab (http://planet-lab.org) and GpENI (https://wiki.ittc.ku.edu/gpeni/). PlanetLab is an open

platform for developing, deploying, and accessing planetary-scale services. For this purpose we are hosting three PlanetLab nodes in our testbed network.

GpENI is a distributed set of sites, interconnected at layer 2 (or layer 2 tunnels) to enable experimentation at layers 3 and higher. For this purpose we are hosting three GpENI nodes, two GpENI routers and one GpENI controller node in our testbed network. Moreover, we have installed three Cisco routers. Each of them is terminating a L2TP connections in order to provide a major European GpENI concentrator point (https://wiki.ittc.ku.edu/gpeni/Image:GpENI-Euro-topo.png). We are connected to the University of Kansas, the ETH Zürich and the University of Zürich.

Our research group owns a number of sensor nodes: Embedded Sensor Board (ESB), Modular Sensor Board (MSB), tmote SKY nodes, BTnodes, TelosB nodes, and micaZ nodes. Some of these nodes are operated as part of the Wisebed infrastrucuture. Another testbed consisting of multiple wireless mesh nodes (17 x PCEngines WRAP, 10 x Meraki Mini, 6 x PCEngines ALIX) has been deployed throughout the building and work environment of the research group. In this testbed, multi-channel communication, multi-path routing and the management framework ADAM have been evaluated. The testbed is currently used by several Ph.D. theses and student projects.

Research staff: All members of the RVS research group

4.4   Ph.D. Theses

- Thomas Staub: Development, Testing, Deployment and Operation of Wireless Mesh Networks, May 27, 2011

4.5   Master and Diploma Theses

- Milan Nikolic: GEZORA: A Self-Scalable Content Distribution Network, December 2010

- Benjamin Nyffenegger: Evaluation and Calibration of Software-based Energy Estimation Methodologies on MSB430 Sensor Nodes, December 2010

- Alican Gecyasar: Implementation and Evaluation of the Multicast File Transfer Protocol (MCFTP), December 2010

- Andreas Rüttimann: Quality of Service, End to End Delays and Overlay Multicast for Structured P2P Networks like Chord, March 2011

- Sebastian Barthlomé: Investigating Forward Error Correction Strategies on MSB430 Sensor Nodes, May 2011

- Gabriel Martins Dias: Implementing a Reliable Overlay Multicast Protocol on Wireless Sensor Nodes, July 2011

- Stefan Ott: Automated Deployment of a Wireless Mesh Communication Infrastructure for an On-Site Video-Conferencing System, July 2011

4.6 Bachelor Theses and Computer Science Projects

- Christoph Knecht: Secure Key Distribution in Wireless Sensor Networks (WSNs), December 2010

4.7 Awards

- Fritz Kutter Award 2010 for Reto Gantenbein's Master thesis "VirtualMesh: An Emulation Framework for Wireless Mesh Networks in OMNeT++"

4.8 Further Activities

Memberships

- Chair of ERCIM working group on eMobility (Torsten Braun)

- Erweitertes Leitungsgremium Fachgruppe "Kommunikation und Verteilte Systeme", Gesellschaft für Informatik (Torsten Braun)

- Integration Coordination Board and Steering Committee of EU IST project Wisebed (Torsten Braun)

- SWITCH Stiftungsrat (Torsten Braun)

- SWITCH Stiftungsratsausschuss (Torsten Braun)

- SWITCH AAI Advisory Committee (Thomas Staub)

- Kuratorium Fritz-Kutter-Fonds (Torsten Braun)

- Expert for Diploma Exams at Fachhochschule Bern (Torsten Braun)

- Expert for Matura Exams at Gymnasium Hofwil (Torsten Braun)

- Management committee member of the COST Action IC 0804 Energy-Efficiency In Large Scale Distributed Systems (Torsten Braun)

- Management committee member of the COST Action IC 0906 Wireless Networking for Moving Objects (WiNeMO) (Torsten Braun)

- External Advisory Board Member of Space Internetworking Center (SPICE) at Democritus University of Thrace, Greece (Torsten Braun)

Editorial Boards

Torsten Braun

- Editorial Board of Elsevier's Computer Communications Journal

- Editorial Board of Elsevier's Computer Networks Journal

- Editorial Board of Informatik Spektrum, Springer-Verlag

- Editorial Board of Journal of Internet Engineering (Editor in Chief)

Conference Chairs

- General Chair of 5th ERCIM Workshop on eMobility, June 14, 2011,Universitat Politecnica de Catalunya, Vilanova i la Geltru, Spain (Torsten Braun)

Conference Program Committees

Torsten Braun

- 10th International Conference on Next Generation Wired/Wireless Networking, St. Petersburg, Russia, August 23 - 25, 2010

- 3rd Workshop on Economic Traffic Management, Amsterdam, The Netherlands, September 6, 2010

- 35th IEEE Conference on Local Computer Networks, Denver CO, USA, October 11-14, 2010

- 2nd Second IEEE International Workshop on Mobile Computing and Networking Technologies, Moscow, October 18-19, 2010

- 2nd International Congress on Ultra Modern Telecommunications and Control Systems, Moscow, Russia, October 18-20, 2010

- 16th Asia-Pacific Conference on Communications, Auckland, New Zealand, October 31 - November 3, 2010

- 4th IEEE International Workshop on Enabling Technologies and Standards for Wireless Mesh Networking, San Francisco CA, USA, November 8, 2010

- 6th Fachgespräch Future Internet, GI/ITG-Fachgruppe "Kommunikation und Verteilte Systeme" (KuVS), Hannover, Germany, November 22, 2010

- 7th International Conference on Wireless Communication and Sensor Networks, Allahabd, India, December 5-9, 2010

- 1st IEEE Workshop on Pervasive Group Communication, Miami, FL, USA, December 6, 2010

- 5th IEEE International Workshop on Heterogenous, Multi-Hop, Wireless and Mobile Networks, Miami FL, USA, December 6, 2010

- 6th IEEE Broadband Wireless Access Workshop, Miami FL, USA, December 6, 2010

- IEEE Global Communications Conference 2010, Miami FL, USA, December 6-10, 2010

- 4th Workshop on Real-World Wireless Sensor Networks, Colombo, Sri Lanka, December 16-17, 2010

- 8th International Conference on Wireless On-demand Network Systems and Services, Bardonecchia, Italy, January 26-28, 2011

- 17th Conference on Communication in Distributed Systems 2011, Kiel, Germany, March 8-11, 2011

- 6th Workshop on Wireless and Mobile Ad-Hoc Networks, Kiel, March 10, 2011

- 4th International Workshop on OMNeT++, Barcelona, Spain, March 21, 2011

- IEEE Wireless Communications & Networking Conference, Cancun, Mecico, March 21-23, 2011

- 26th ACM Symposium On Applied Computing, Taichung, Taiwan, March 21-24, 2011

- 3rd International Workshop on Communication Technologies for Vehicles, German Aerospace Center (DLR), Oberpfaffenhofen, Germany, March 23-24,2011

- 2nd Baltic Congress on Future Internet Communications, Rigq, Latvia, April 25-27, 2011

- 3rd International ICST Conference on Mobile Lightweight Wireless Systems, Bilbao, Spain, May 9-11, 2011

- 10th IFIP Networking, Valencia, Spain, May 9-13, 2011

- Colloque Francophone sur l Ingenierie des Protocoles, Sainte-Maxime, May 10-13, 2011

- 1st Workshop on Sustainable Networking, Valencia, Spain, May 13, 2011

- 12th IFIP/IEEE International Symposium on Integrated Network Management, Dublin, Ireland, May 23-27, 2011

- 2nd International Conference on Energy-Efficient Computing and Networking, Columbia University, New York, USA, May 31-June 1, 2011

- IEEE International Communications Conference, Kyoto, Japan, June 5-9, 2011

- 19th International Workshop on Quality of Service, San Jose CA, USA, June 6-7, 2011

- 5th International Conference on Autonomous Infrastructure, Management and Security, Nancy, France, June 13-17, 2011

- 9th International Conference on Wired/Wireless Internet Communications, Vilanova i la Geltru,Spain, June 15-17, 2011.

- 12th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks, Lucca, June 20-23, 2011

- 4th International Workshop on Sensor Networks, Minneapolis MN, USA. June 20-24, 2011

- 3rd International Workshop on Specialized Ad Hoc Networks and Systems, Minneapolis, MN, USA, June 23, 2011

Ph.D. and Licentiate Jury Memberships

Torsten Braun

- Desislava Dimitrova, Ph.D., University of Twente, The Netherlands, November 24, 2010

- Cristina Cano, Ph.D., Universitat Pompeu Fabra, Barcelona, Spain, March 4, 2011

- Niclas Finne, Licentiate, Uppsala Universitet, Sweden, May 30, 2011

Project and Person Reviewing Activities

Torsten Braun

- Academia of Finland

- The University of Kansas, Lawrence KS, USA

- Research Council of Norway

- Royal Melbourne Institute of Technology, Melbourne, Australia

- Forschungs- und Wissenschaftsstiftung Hamburg, Germany

- Universität Ulm, Germany

Article Reviewing Activities

Torsten Braun

- ACM Transactions on Embedded Computing Systems

- Elsevier Integration, the VLSI Journal

- EURASIP Journal on Wireless Communications and Networking

- IEEE Transactions on Aerospace and Electronic Systems

- IEEE Transactions on Computers

- IEEE Transactions on Mobile Computing

- IEEE Transactions on Network and Service Management

- IEEE Transactions on Vehicular Technology

- IEEE Transactions on Wireless Communications

- IEEE/ACM Transactions on Networking

- International Journal of Network Management

- Journal of Communications and Networks

Invited Talks and Tutorials

- Torsten Braun: Performance Evaluation of Adaptive and Energy-efficient MAC Protocols for Wireless Sensor Networks, COST Action IC0804 on Energy Efficiency in Large Scale Distributed Systems, FG Wireless Networks Meeting, Coimbra, November 9, 2011

- Torsten Braun: Design and Evaluation of an Adaptive and Energy-Efficient MAC Protocol for Wireless Sensor Networks, Seminar on Wireless Sensing, St. Andrews University, November 11, 2010

- Torsten Braun: Telematiknetze, Kaderkurs Telematik, Bundesamt für Bevölkerungsschutz, Schwarzenburg, Switzerland, November 16, 2010

- Thomas Staub: Telematiknetze, Kaderkurs Telematik, Bundesamt für Bevölkerungsschutz, Schwarzenburg, Switzerland, November 16, 2010

- Torsten Braun: Design and Evaluation of an Adaptive and Energy-Efficient MAC Protocol for Wireless Sensor Networks, WiSe/DACS colloquium, University of Twente, Enschede, November 24, 2010

- Torsten Braun: Design and Evaluation of Energy-Efficient Wireless Sensor Network Protocols, Colloquium, Universidade de Sao Paulo at Sao Carlos, Brazil, December 2, 2010

- Torsten Braun: Design and Evaluation of Energy-Efficient Wireless Sensor Network Protocols, Colloquium, Universidade Federal de Sao Carlos, Brazil, December 13, 2010

- Torsten Braun: Service-Centric Networking, Forschungsseminar, Karlsruhe Institute of Technology, Institut für Telematik, Germany, January 11, 2011

- Torsten Braun: User and Machine Authentication and Authorization Infrastructure for Distributed Testbeds, Security at CERIAS, Purdue University, West Lafayette, IL, January 26, 2011

- Torsten Braun: Design and Evaluation of an Adaptive and Energy-Efficient MAC Protocol for Wireless Sensor Networks, Colloquium, Computer Science Department, Purdue University, West Lafyette IL, USA, January 28, 2011

- Torsten Braun: Development, Test, Deployment and Operation of (Mobile) Wireless Mesh Networks, Keynote, 6th Workshop on Wireless and Mobile Ad-Hoc Networks, Kiel, Germany, March 10, 2011

- Torsten Braun: Telematiknetze, Kaderkurs Telematik, Bundesamt für Bevölkerungsschutz, Schwarzenburg, Switzerland, March 22, 2011

- Thomas Staub: Telematiknetze, Kaderkurs Telematik, Bundesamt für Bevölkerungsschutz, Schwarzenburg, Switzerland, March 22, 2011

- Torsten Braun: Content and Service-Centric Networking for Cloud Computing, Net!Works/NetWorld Workshop on European Research Strategy for Cloud Computing, Service, and Application Platforms, SAP, Walldorf, Germany, May 10, 2011

- Torsten Braun: Service-Centric Networking, Session I.1 Information-Centric Networking, Future Internet Assembly, Budapest, Hungary, May 18, 2011

- Torsten Braun: Solar-powered Wireless Mesh Networks for Environmental Monitoring, COST Action IC0804 on Energy Efficiency in Large Scale Distributed Systems, FG Wireless Networks Meeting, Budapest, May 20, 2011

- Torsten Braun: Langfristige Switch Strategie, Kommission Informatikdienste, Universität Bern, May 23, 2001

- Torsten Braun: Adaptive and Energy-Efficient Protocols for Wireless Sensor Networks, Keynote, Conference on Next Generation Internet 2011, Kaiserslautern, Germany, June 27, 2011

- Torsten Braun: Development of Adaptive and Energy-Efficient Protocols for Wireless Sensor Networks, Warsaw University of Techology, June 28, 2011

- Thomas Staub: Development, Testing, Deployment and Operation of Wireless Mesh Networks, invited lecture, University of Coimbra, Portugal, June 29, 2011

Institutional Research Cooperation

During his sabbatical, Prof. Torsten Braun performed several visits and established research collaborations at various research organizations. At Bell Labs, Holmdel NJ, USA (July 26 September 27, 2010), he worked in the group of Dr. Markus Hofmann on extending the paradigm of content-centric networking towards its applicability for more general services. This resulted in the novel concept of Service-Centric Networking (SCN). At Lancaster University, UK (September 19 November 12, 2010) he worked at the Infolab21 Department in the area of mobile sensor networks and content-centric networks. From November 28 to December 18, 2010, he visited Universidade de Sao Paulo in Sao Carlos, Brazil and collaborated on combining cloud computing and wireless sensor networks as well as scenarios and protocols for highly mobile ad-hoc networks etc. Finally, he visited the Department of Computer Science at Purdue University at West Lafayette IL, USA, from January 24 to February 2, 2011.

4.9 Publications

Publications submitted in the academic year 2010/2011 and appearing in 2011/2012 or later are not listed.

Books

- Torsten Braun, Markus Anwander, Philipp Hurni, Markus Waelchli: MAC Protocols for Wireless Sensor Networks, Next Generation Mobile Networks and Ubiquitous Computing, IGI Global, Hershey, New York, USA, October 01, 2010, pp. 165 - 174, ISBN 978-1-60566-250-3

- Marc Brogle, Xavier Masip Bruin, Torsten Braun, Geert Heijenk: Proceedings of the Fifth ERCIM Workshop on Emobility, Technical University of Catalonia, Barcelona, Spain, June 14, 2011, ISBN 978-84-920140-3-3

Reviewed Journal and Conference Papers

- Dragan Milic, Torsten Braun: NetICE9: A Stable Landmark-Less Network Positioning System, 35th Annual IEEE Conference on Local Computer Networks, Denver, Colorado, USA, October 11-14, 2010, pp. 96-103, ISBN 978-1-4244-8388-4

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- Philipp Hurni, Torsten Braun, Benjamin Nyffenegger, Anton Hergenroeder: On The Accuracy of Software-based Energy Estimation Techniques, European Conference on Wireless Sensor Networks (EWSN), Bonn, Germany, February 23-25, 2011, pp. 49-64, ISBN 978-3-642-19185-5

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- Thomas Staub, Simon Morgenthaler, Daniel Balsiger, Paul Kim Goode, Torsten Braun: ADAM: Administration and Deployment of Adhoc Mesh Networks, 3rd IEEE Workshop on Hot Topics in Mesh Networking (IEEE HotMESH 2011), Lucca, Italy, June 20-24, 2011, ISBN 978-1-4577-0351-5/11

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- Geoff Coulson, Torsten Braun, Thomas Staub: Adding Virtual Mobility to a Federated Testbed for Wireless Sensor Networks: a Proposal, Universität Bern, Institut für Informatik und angewandte Mathematik, Bern, Switzerland, August 30, 2010, TR IAM-10-004

- Philipp Hurni, Torsten Braun: Real-World Experiences with the Maximally Traffic Adaptive Medium Access Control Protocol, Universität Bern, Institut für Informatik und angewandte Mathematik , Bern, Switzerland, April 29, 2011, TR IAM-11-001

- Mesut Gunes, Torsten Braun, Philipp Hurni, et al.: Hardware Capabilities, Maintenance and Future Dimensions, WISEBED Deliverable D1.5, May 01, 2011

- Koen Langendoen, Torsten Braun, Philipp Hurni, et al.: Compendium of Experimental Scenarios, Traces and Benchmarks, WISEBED Deliverable D4.3, May 01, 2011

- Stefan Fischer, Dennis Pfisterer, Philipp Hurni, et al.: Final Report on Dissemination and Joint Research Activities, WISEBED Deliverable D5.5, May 01, 2011

- Sandor Fekete, Torsten Braun, Zhongliang Zhao, et. al.: Library of Algorithms for Wireless Sensor Networks , WISEBED Deliverable D3.4, May 01, 2011

5 Research Group on Theoretical Computer Science and Logic

5.1 Personnel

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5.2 Overview

The TIL research group (theoretical computer science and logic) focuses on theoretical computer science and mathematical logic, especially proof theory, computational logics and theory of computation. We have been dealing for many years with formal methods, analysis of deductions, general computations and, in particular, applications of mathematical logic to computer science. During the previous year the main subject areas have been the following:

Computational Logic: Logical formalisms are perfectly suited to the specification of complex systems, the representation of knowledge and information, the description of processes (e.g. in distributed multi-agent systems) and for providing formal proofs of important system properties such as, for example, correctness and fairness. The research group has long been interested in the deductive, procedural and dynamic aspects of the corresponding formalisms and in the design of modern deductive systems. New approaches are being developed for information update purposes. In addition, the way in which simple, logical formalisms can be extended to become genuine multi-user systems taking into account the dynamic aspects of ontologies in the data mining context and in connection with the semantic web is being investigated.

Proof Theory: This research topic focuses on the development and analysis of formal systems of first and second order arithmetic, set theory and of what are known as logical frameworks (type and set theoretical, explicit, constructive, extensional, intentional). Our interests range from feasible subsystems of arithmetic to highly impredicative set and type theories and

deals with the interplay between constructive, recursive and operational approaches. In addition, abstract computations and computable knowledge are being investigated.

5.3   Research Projects

A Proof Theory for Modal Fixed Point Logics

Temporal logics are widely used to specify and verify the correctness of information systems when system reliability is crucial. Epistemic logics with common knowledge are important for reasoning about knowledge. Both types of logics are examples of modal fixed point logics. While these logics are well-understood semantically, our syntactic understanding of them is lacking. The state of proof theory for modal logics in general is widely recognised as unsatisfactory. For modal fixed point logics in particular there are no satisfactory cut-free sequent systems. Such systems generally are suitable for automated proof search and, together with their cut elimination procedures, can serve as a basis for declarative programming languages. We intend to address the problem of designing cut-free sequent systems for modal fixed point logics on two levels:

1. Whenever possible we plan to develop such systems together with syntactic cut elimination procedures. If possible, we aim for traditional sequent systems in Gentzen style, but if needed we will also employ ideas from richer proof theoretic formalisms such as the display calculus or deep inference.

2. On the other hand, if no cut-free systems exist for modal fixed point logics, we hope to gain a better understanding of why they do not exist. In this case we are interested in good syntactic approximations.

The development of a proof theory for modal fixed point logics is an important theoretical contribution to the understanding of inference and deduction in these logics, and thus in particular a relevant underpinning of specification and verification of information systems. It is central ground work concerning the procedural aspects of frameworks dealing with information.

Algebraic and Logical Aspects of Knowledge Processing

In this project, we employ and set up conceptual frameworks, in particular, theories relating classical mathematics with constructive mathematics and feasible mathematics. Thereby we always emphasize the computational properties and complexities of our formalisms. We use proof theory as our main tool for analyzing the constructive and computational content of various formalisms and aim at further exploiting the proofs as computations paradigm. Besides the traditional subsystems of first- and second-order arithmetic and (admissible) set theory, we will focus on theories of explicit mathematics, operational set theories, and theories of partial truth.

Research staff: S. Eberhard, D. Flumini, G. Jäger, J. Krähenbühl, T. Nemoto, K. Sato, Th. Strahm, R. Zumbrunnen

Financial support: Swiss National Science Foundation

Structural Proof Theory and the Logic of Proofs

The original idea that prompted Artemov to develop the Logic of Proofs LP was to solve a long-standing problem posed by Gödel more than half a century before. This goal has been achieved by introducing into the formal logical language new objects called proof polynomials or, in epistemic setting, evidence terms. They enable us to reason about individual proofs or about evidence within the logical language. The goal of this project is to extend the benefits of this more expressive language to the logics used to describe common knowledge, a phenomenon important for distributed systems, temporal logics, which are used in specification and verification of correctness of computation, and a more general formalism of the so-called modal mu-calculus. A new promising area of application for evidence terms is belief revision, i.e., the change in opinions, for instance, as a result of announcements. The standard approaches to modeling such changes lead to paradoxical situations: an announcement of a true fact may make this announced fact false. The more expressive language with evidence terms, which represent reasons for beliefs, is also capable of modeling beliefs, including higher-order beliefs about beliefs of other agents. At the same time, it provides natural syntactic means of distinguishing between the beliefs held before the announcement and those resulting from the announcement, means lacking in the standard setting.

A public announcement is undeniably direct material evidence for the announced fact, albeit this evidence may not be conclusive. Thus, the use of a language capable of operating with such evidence is highly desirable.

We also study the relationship between the structure of proof polynomials and structural properties of formal proofs. Among other things, formal proofs allow for computer verification. This study includes automating the process of evidence extraction from a given formal proof of validity of a statement about provability or about agents' beliefs. Further, we plan to study a certain well-developed type of such formal proofs, called sequent proofs, and the process of the so-called cut-elimination, i.e., elimination of intermediate lemmas, which is central to this type of proofs. The goal of this study is to develop proof polynomials based on this particular type of formalism, whereas proof polynomials developed by Artemov are based on a different formalism, that of Hilbert proofs, and hence do not preserve the structure of sequent derivations.

Research staff: K. Brünnler, S. Bucheli, R. Goetschi, G. Jäger, R. Kuznets, Y. Savateev

Financial support: Swiss National Science Foundation

Computational Proof Theory

This is a joint research project of the TIL group and the Department of Mathematical Logic and Theory of Algorithms in Moscow. Both groups have a strong background in mathematical logic - in particular proof theory, provability logic and general modal logics - and expertise in applying concepts and techniques of mathematical logic in connection with recent developments in (theoretical) computer science. Among the interests of both groups are the attempts to analyze existing formal systems in order to classify their expressive as well as proof-theoretic powers and to design new and more flexible formal frameworks. In doing this, interesting results about computational and logical complexities (lower and upper bounds) of algorithms developed within these frameworks can be obtained frequently. Although working towards similar aims, the research traditions of Moscow and Bern are quite distinct.

Berns approach is rooted in traditional Gentzen- and Schütte-style (infinitary) proof theory and the proof-theoretic analysis of subsystems of second order arithmetic, set theory, explicit mathematics and type systems and still pursuing this line. Moscow school of logic has its roots in the

works of Kolmogorov, Novikov and Markov. It is traditionally strong in constructive logic and mathematics, algorithmic problems in algebra, various non-classical logics and their semantical and computational aspects, and in descriptive complexity and complexity of algorithms.

The following three research streams address topics of mutual interests:

1. Provability algebras, metapredicativity and impredicativity

2. Functionality and common knowledge in justification logic

3. Structurally enhanced proof-theory for modal and substructural logics

It is expected that the combination and integration of the conceptual approaches and methods of both groups will allow to clarify the general landscape and to solve some long-standing open problems.

Research staff: J. Brugger, K. Brünnler, G. Jäger, R. Kuznets, Th. Strahm, Th. Studer

Logics for Privacy

The problem of data privacy is to verify that confidential information stored in an information system is not provided to unauthorized users and, therefore, personal and other sensitive data remain private. The main challenge in such a context is to share some data while protecting other personally identifiable information. The aim of our project is to develop formal methods and the corresponding algorithms to enable automated reasoning about data privacy. Data stored in a relational database or knowledge base system usually is protected from unauthorized access. Users of such a system are then only allowed to access a limited portion of the stored information. In this situation the following important questions arise:

1. What can a user infer from the information to which he has access?

2. Can we guarantee that a user cannot obtain knowledge about certain sensitive information?

3. Is it possible to grant a user information access in such a way that she is able to fulfill her duties without letting her know secret information?

We will address these questions not in their full generality, but we intend to study the following concrete issue. Controlled query evaluation is an approach to privacy preserving query answering where the answer to a query is distorted if it would leak sensitive information to the user. We plan to develop a formal framework to enable controlled query evaluation for ontological knowledge base systems. To achieve this aim we will mainly use tools and techniques from modal logic in general and description logic in particular.

Research staff: Th. Studer, J. Werner

Financial support: Swiss National Science Foundation

Computational Structure of Classical Duality (Ambizione)

The Curry-Howard correspondence, also known as the proofs-as-programs correspondence, is the observation that logical proofs and computer programs are two ways of presenting the same mathematical objects. This project aims to extend the scope of the correspondence in two important directions: on the logical side, towards capturing classical logic, the logic used in natural and mathematical reasoning, and on the computational side to the idea of a "process"; a program which interacts with many other programs by passing messages.

Background: In the 1930s, Alonzo Church developed a calculus (the lambda calculus) a language for writing down what we now call computable functions. At the same time Gerhard Gentzen was developing natural deduction; a language for writing down formal proofs. Both these languages were conceived as tools for exploring the foundations of mathematics, with the advent of computer science, representations of computable functions became a more practicle concern. Lambda calculus was the inspiration for Lisp, the first functional programming language. Meanwhile, William Alvin Howard discovered a link between logic and functional programming: natural deduction proofs could be seen themselves as terms of the lambda calculus. In other words, a proof is a kind of computation, and a very well-behaved kind at that. This observation, known as the Curry-Howard correspondence, has led and continues to lead to an enormous body of theoretical and practical work in computer science and logic.

Goals of the project: Computer science has developed much since its inception, and we no longer think of computer problems as simply calculating a function, but more as interacting with a complex, varying en-

vironment comprised of users and other programs. The lambda calculus is unsuited for representing such programs, and other calculi (called process calculi) are used instead to reason about them. These calculi lack the elegant theoretic underpinning enjoyed by the lambda calculus. On the other hand, natural deduction fails to faithfully represent a fundamental reasoning mode: the ability to recognise that a statement is the same as its double negation. This property of logic is called "Duality". A much better calculus for reasoning under duality, called the sequent calculus, was also developed by Gentzen, but its computational meaning has been difficult to discern.

This project aims to extend the proofs as programs correspondence by representing proofs using duality within a new, theoretically inspired language of processes.

Research staff: R. McKinley

Financial support: Swiss National Science Foundation

Refining Reasoning via Justification Extraction: A Proof-Theoretic Approach (Ambizione)

This project aims to extend the scope of Justification Logic to areas where traditionally Modal Logic has been applied—such as artificial intelligence, multi-agent systems, belief revision, dynamic epistemic logic, knowledge representation, program specification and verification, etc. Despite the popularity of the modal language, it has well-known drawbacks such as the Logical Omniscience Problem and lacks expressivity to deal with the "Justified" part of the famous "Knowledge as Justified True Belief" paradigm. Justification Logic provides a solution by refining the language with syntactic objects that are interpreted as justifications (or proofs, or witnesses) and by introducing a formal machinery for handling them.

The success of Modal Logic is due in part to its versatility: the modal language can be used to describe different phenomena by varying the axioms within the same language. Thus, it is necessary to provide a translation not only for the modal language in general, but also for individual theories in the modal language that are used in various applications. This process of translating modal reasoning into reasoning with justifications is called realization. Unfortunately, the applicability scope of the currently known realization algorithms is greatly narrowed by the fact that they require that the modal logic being translated have a purely syntactic and cut-free proof

system. In particular, the most commonly used axiomatic, Hilbert-style representation of modal reasoning is not suitable for these realization algorithms.

Since developing cut-free proof systems has proven to be difficult, this project proposes to develop new cut-tolerant realization techniques. A natural way of achieving this goal is by using the tools of structural proof theory: manipulating symbolic representations of proofs and devising algorithms for obtaining representations with required structural properties. The success of this project will allow automating justification extraction for a wide range of modal logics, especially those that resist cut elimination, including temporal modal logics and public announcement logics.

Research staff: R. Kuznets

Financial support: Swiss National Science Foundation

Logic and Computation

This very general project deals with the close connections between mathematical logic and certain parts of computer science, and emphasis is put on a proof-theoretic approach to some of the central questions in this area of research. These include the development of perspicuous and feasible logical frameworks for studying typical questions in computer science like termination and correctness of functional programs, properties of distributed systems and the like.

We study applicative theories as well as strongly typed formalisms and are interested in the connections to constructive and explicit mathematics. Furthermore, we are interested in analyzing the close connections between the complexities of computations and proofs in suitable formalizations, ranging from propositional calculi up to abstract frameworks for computations (in higher types).

Research staff: All members of the research group

5.4 Ph.D. Thesis

- R. Wehbe: Annotated Systems for Common Knowledge

5.5 Master Theses

- C. Pulver: Self-Referentiality in Contraction-free Fragments of Modal Logic S4

- M. Stolz: Verification of Workflow Control-Flow Patterns with the SPIN Model Checker

5.6 Further Activities

Editorial Boards

- Member of the editorial board of Archive of Mathematical Logic (G. Jäger)

- Member of the editorial board of Logica Universalis (G. Jäger)

- Member of the consulting board of Dialectica (Th. Strahm)

Technical and Research Committees

- Research Council Member of the Swiss National Science Foundation (G. Jäger)

- Vice President of the Fachausschuss Personenförderung of the Swiss National Science Foundation (G. Jäger)

- Member of the Steering Committee of the Platform Mathematics, Astronomy and Physics (MAP) of the Swiss Academy of Sciences (G. Jäger)

- Member of the Scientific Council of the European Association for Computer Science Logic (G. Jäger)

- PC Member, Fixed Points in Computer Science, FICS 2010 (G. Jäger)

- PC Chair, Tableaux 2011 (K. Brünnler)

- Organizers, Tableaux 2011 (K. Brünnler, S. Bucheli, R. Kuznets, R. McKinley)

- Organizers, Gentzen Systems and Beyond, Satellite Workshop of Tableaux 2011 (R. McKinley and R. Kuznets)

- Member of the Kantonale Maturitätskommission (G. Jäger)

- Expert for Maturitätsprüfungen Mathematik und Informatik (G. Jäger, Th. Strahm, Th. Studer)

- President of the Swiss Society for Logic and Philosophy of Science (Th. Strahm)

- Secretary of the Swiss Society for Logic and Philosophy of Science (Th. Studer)

- Swiss representative in the International Union of History and Philosophy of Science (Th. Studer)

5.7 Publications

- S. Bucheli, R. Kuznets, B. Renne, J. Sack, and Th. Studer, Justified Belief Change, in *Proceedings of the Second ILCLI International Workshop on Logic and Philosphy of Knowledge, Communication and Action (LogKCA-10)*, ed. by X. Arrazola and M. Ponte, University of the Basque Country Press, 2010

- S. Bucheli, R. Kuznets, and Th. Studer, Partial Realization in Dynamic Justification Logic, in *Proceedings of Logic, Language, Information and Computation, 18th International Workshop, WoLLIC 2011*, ed. by L. Beklemishev and R. de Queiroz, Springer, 2011

- S. Bucheli, R. Kuznets, and Th. Studer, Justifications for Common Knowledge, in *Journal of Applied Non-classical Logics, vol. 21*, 2011

- K. Brünnler, How to Universally Close the Existential Rule, in *Proceedings of Logic for Programming, Artificial Intelligence and Reasoning LPAR 2010*, ed. by G. Fermüller and A. Voronkov, Springer, 2010

- K. Brünnler and Th. Studer, Syntactic cut-elimination for modal fixed point logics, submitted

- G. Jäger and D. Probst, The Suslin operator in applicative theories reconsidered, in *Annals of Pure and Applied Logic, vol. 162*, 2011

- G. Jäger and Th. Studer, A Buchholz Rule for Modal Fixed Point Logics, in *Logica Universalis, vol. 5*, 2011

- G. Jäger and R. Zumbrunnen, About the strength of operational regularity, submitted

- R. Kuznets and S. Buss, Lower Complexity Bounds in Justification Logic, submitted

- R. McKinley, Expansion nets: proof-nets for propositional classical logic, in *Logic for Programming, Artificial Intelligence, and Reasoning LPAR 17*, ed. by G. Fermüller and A. Voronkov, Springer, 2010

- R. McKinley, Canonical proof-nets for propositional classical logic, submitted

- R. McKinley, Proof nets for Herbrand's Theorem, submitted

- D. Probst and Th. Strahm, Admissible closures of polynomial time computable arithmetic, in *Archive for Mathematical Logic*, to appear

- K. Sato, The strength of extensionality II - Weak weak set theories without infinity, in *Annals of Pure and Applied Logic, vol. 162*, 2011

- Y. Savateev, Sequent Calculus for Justifications, submitted

- D. Spescha and Th. Strahm, Realisability in weak systems of explicit mathematics, in *Mathematical Logic Quarterly*, to appear

- Th. Strahm and S. Feferman, Unfolding finitist arithmetic, in *Review of Symbolic Logic, vol. 3*, 2010

- Th. Studer, Justified terminological reasoning, in *Proceedings of Perspectives of System Informatics*, ed. by E. Clarke, I. Virbitskaite, and A. Voronkov, Springer, to appear

6 Research Group on Software Composition

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6.2 Overview

Complex software systems must continuously change if they are to remain useful. The Software Composition Group carries out research in (1) programming language design, and (2) software reengineering with the goal of facilitating the development of flexible, open software systems. In both cases we are investigating mechanisms and techniques that enable the

graceful evolution of software systems by putting change at the center of the software process.

6.3   Research Projects

Synchronizing Models and Code

Successful software systems are under constant pressure to adapt to changing circumstances. Software adaptations take many forms, are of varying granularity, and may need to take effect over extreme variations in time scale. Running software systems are often subject to fine-grained, short-term adaptation to available resources and run-time context. Modest requirements changes typically provoke medium-grained, medium and long-term evolution of software source code, with consequent short-term adaptation of running software. Deeper requirements changes can provoke coarse-grained, long-term adaptation at the architectural level.

In each of these cases we are faced with the challenge of keeping the source code and the running software synchronized with changes in the higher-level domain and requirements models. This synchronization, however, is often difficult because current languages and runtime systems assume global consistency. They cannot cope with typical inconsistencies of systems with rapidly changing requirements, such as unpredictable variations in the execution environments, inconsistent versions of components, or dispersed code sources.

In this project we are studying novel techniques to keep software systems synchronized with models in the face of varying granularities of change over different time scales.

- *Dynamic meta-objects:* A running system should be able to dynamically respond to changes in its environment (fine-grained and short-term adaptations). Most common approaches to realize run-time adaptation are low-level, fragile, and unsuitable for composition. We are addressing these problems by means of dynamic meta-objects. These meta-objects manipulate high-level representations of an objects behavior, they can be introduced on a per-object basis, and they can be composed to address multiple adaptations at a time.

- *First-class, active contexts:* A software system needs to be able to locally and incrementally update code and program state (medium-grained and medium-term adaptations). Running applications

must increasingly cope with interface and data representation mismatches. Instead of placing strict barriers between software components of different versions, we associate versions to first-class, active contexts. A running object that enters such a context may need to be dynamically updated to reflect different versions of interfaces, behavior, or even state. Objects may even be in multiple contexts at once, yet still behave in a predictable way.

- *Linked, active source code:* Current software development tools fail to address synchronization of code shared between independent systems (medium-grained and medium-term as well as long-term adaptations). As software evolves, libraries, components and even fragments are frequently duplicated, adapted and specialized across software projects. Instead of treating software source code as passive text, we are pursuing a novel approach in which source code is linked to other source code, to other relevant semantic information, and to high-level models. We plan to draw inspiration not only from sites such as Wikipedia as possible models for linked software, but also from popular social networking sites.

- *Polyglot systems modeling and analyses:* Novel analyses are needed to help software architects assess the impact of changes (coarse-grained and long-term adaptations). These analyses need to account for sub-systems built with diverse technologies and programming languages. We are analyzing these "polyglot" systems by focusing on the technologies involved. To detect hidden architectural dependencies between diverse sub-systems we have developed a new meta-model that captures and connects the idiosyncrasies of each involved technology. based on this meta-model, we are developing novel metrics-based visualizations to support analyses such as the detection of architectural patterns.

Research staff: All members of the research group.

Duration: Oct. 2010 – Sept. 2012

Financial support: Swiss National Science Foundation,
Project #200020-131827

For further details, please consult:
`http://scg.unibe.ch/research/snf10`

6.4 Ph.D. Theses

- Adrian Kuhn. *Software Cartography and Code Navigation*. Phd thesis, University of Bern, April 2011. Available from: `http://scg.unibe.ch/archive/phd/kuhn-phd.pdf`.

- Lukas Renggli. *Dynamic Language Embedding With Homogeneous Tool Support*. Phd thesis, University of Bern, October 2010. Available from: `http://scg.unibe.ch/archive/phd/renggli-phd.pdf`.

6.5 Master Theses

- Camillo Bruni. Optimizing Pinocchio. Master's thesis, University of Bern, January 2011. Available from: `http://scg.unibe.ch/archive/masters/Brun11a.pdf`.

- David Gurtner. Safe dynamic software updates in multi-threaded systems with ActiveContext. Master's thesis, University of Bern, April 2011. Available from: `http://scg.unibe.ch/archive/masters/Gurt11a.pdf`.

- Daniel Langone. Subjectopia — unifying subjectivity. Master's thesis, University of Bern, February 2011. Available from: `http://scg.unibe.ch/archive/masters/Lang11b.pdf`.

- Peter Loretan. Software cartography — a prototype for thematic software maps. Diploma thesis, University of Bern, April 2011. Available from: `http://scg.unibe.ch/archive/masters/Lore11a.pdf`.

6.6 Bachelor Theses and Computer Science Projects

- Manuel Friedli. ECCrawler — visualizations for Eclipse. Informatikprojekt, University of Bern, October 2010. Available from: `http://scg.unibe.ch/archive/projects/Frie10a.pdf`.

- Mascha Kurpicz. Tool support for scrum. Bachelor's thesis, University of Bern, March 2011. Available from: `http://scg.unibe.ch/archive/projects/Kurp11a.pdf`.

- Max Leske. The genesis of Pharo: The complete history of Pharo with Git. Bachelor's thesis, University of Bern, March 2011. Available from: `http://scg.unibe.ch/archive/projects/Lesk11a.pdf`.

- Max Leske. Introduction to Filesystem and GitFS. Bachelor's thesis, supplementary documentation, University of Bern, March 2011. Available from: `http://scg.unibe.ch/archive/projects/Lesk11b.pdf`.

6.7 Awards

- Faculty Prize for Lukas Renggli's PhD thesis, *Dynamic Language Embedding With Homogeneous Tool Support*

6.8 Further Activities

Invited Talks

Oscar Nierstrasz:

- Keynote speaker for TOOLS 2011 (49th International Conference on Objects, Models, Components and Patterns — Zurich, Switzerland, 27 June - 1 July 2011)

Mircea Lungu:

- Speaker at PL 2010 (3rd Summer School on Programming Languages, November 16, 2010 Antofagasta, Chile)

Editorial Boards and Steering Comittees

Oscar Nierstrasz:

- Journal of Object Technology (Editor-in-Chief)

- Springer LNCS – SL2 – Programming Techniques and Software Engineering (Series Editor)

- SARIT – Swiss Association for Research in Information Technology (Board Member)

- AITO – Association Internationale pour les Technologies Objets (Member)

- CHOOSE – Swiss Group for Object-Oriented Systems and Environments (Board Member)

- ESEC – European Software Engineering Conference (Steering Committee Member)

- MoDELS – International Conference on Model Driven Engineering Languages and Systems (Steering Committee Member)

- SC – Software Composition Symposium (Steering Committee Member)

- Moose Association (Board Member)

Program Committees

Oscar Nierstrasz:

- PC Member for ICMT 2011 (International Conference on Model Transformation Zurich - Switzerland, 27 - 28 June, 2011)

- PC Member of OOPS 2011 (Special track on Object-Oriented Programming Languages and Systems at SAC 2011 Tunghai University, TaiChung, Taiwan, Mar 21-25, 2011

- PC Member of CSMR 2011 (5th European Conference on Software Maintenance and Reengineering Oldenburg, Germany, March 14, 2011)

- PC Member of SE 2011 (Software Engineering 2011 Karlsruhe, Germany, Feb 2125 2011)

- PC Member of C5 (The Ninth International Conference on Creating, Connecting and Collaborating through Computing Kyoto University, Kyoto, Japan, 18-20 January 2011)

- Co-organizer of FOSD Dagstuhl Workshop (Feature-Oriented Software Development Schloss Dagstuhl, Germany, January 9-14, 2011)

- PC Member of PCODA 2010 (Program Comprehension through Dynamic Analysis (PCODA) workshop Colocated with WCRE 2010, Beverly, MA, USA, Oct 13-16, 2010)

- Co-organizer of FOSD 20010 (2nd Workshop on Feature-Oriented Software Development Colocated with GPCE'10/SLE 2010, Eindhoven, The Netherlands, Oct 10, 2010)

- PC Member of ICSM 2010 (26th IEEE International Conference on Software Maintenance Timisoara, Romania, Sept 12-18, 2010)

- Co-Chair of ICSM 2010 Doctoral Symposium (Special Track of ICSM 2010 Timisoara, Romania, Sept 13, 2010)

- PC Member of SEAA-EDISON 2010 (Euromicro Special track on Evolution of Distributed, Internet-based and Service-Oriented applicatioNs Lille, France, Sept. 1, 2010

Mircea Lungu

- Co-Organizer of FAMOOSR 2010 (4th Workshop on FAMIX and Moose in Reengineering, Timisoara, Romania. September 17, 2010)

- PC Member of ICSM 2010 Tool Demo Track (26th IEEE International Conference on Software Maintenance, Timisoara, Romania. Sept 12-18, 2010)

- PC Member of IWSECO 2011 (Third International Workshop on Software Ecosystems, Brussels, Belgium. 7th June 2011)

- PC Member of WSE 2011 (13th IEEE International Symposium on Web Systems Evolution. Williamsburg, Virginia. September 30, 2010)

Fabrizio Perin:

- Co-Chair of FAMOOSr 2010 (4th Workshop on FAMIX and Moose in Reengineering Colocated with ICSM 2010 Timisoara, Romania. September 12-18, 2010)

Reviewing Activities

Oscar Nierstrasz:

- IEEE Computer

- Swiss National Science Foundation

- Netherlands Organisation for Scientific Research

- Foundation for Scientific Research Belgium

Mircea Lungu:

- Journal of Systems and Software (JSS), Elsevier

- Science of Computer Progrmaming (SCP), Elsevier

- Journal of Software and Systems Modeling (JSoSyM), Springer

Fabrizio Perin:

- CSMR 2011 (European Conference on Software Maintenance and Reengineering)

- OOPSLA Onward 2011 (Object-Oriented Programming, Systems, Languages & Applications)

- ICSM 2011 (International Conference on Software Maintenance)

- ICMT 2011 (International Conference on Model Transformation)

- JOT (Journal of Object Technology)

Toon Verwaest:

- OOPSLA Onward 2011 (Object-Oriented Programming, Systems, Languages & Applications)

- CSMR 2011 (European Conference on Software Maintenance and Reengineering)

- ICSM 2011 (International Conference on Software Maintenance)

- C5 2011 (International Conference on Creating, Connecting and Collaborating through Computing)

- SE 2011 (Software Engineering)

- JOT (Journal of Object Technology)

Erwann Wernli:

- OOPSLA 2011 (Object-Oriented Programming, Systems, Languages & Applications)

- OOPSLA Onward 2011 (Object-Oriented Programming, Systems, Languages & Applications)

- IWPSE/EVOL 2011 (ERCIM Workshop on Software Evolution and International Workshop on Principles of Software Evolution)

- ICSM 2011 (International Conference on Software Maintenance)

- JOT (Journal of Object Technology)

- CSMR 2011 (European Conference on Software Maintenance and Reengineering)

6.9 Publications

Journal Papers

- Gabriela Arévalo, Stéphane Ducasse, Silvia Gordillo, and Oscar Nierstrasz. Generating a catalog of unanticipated schemas in class hierarchies using formal concept analysis. *Information and Software Technology*, In Press, Corrected Proof(52):1167–1187, December 2010. Available from: `http://scg.unibe.ch/archive/papers/Arev10aClassHierarchies.pdf`, `doi:10.1016/j.infsof.2010.05.010`.

- Adrian Lienhard, Tudor Gîrba, and Oscar Nierstrasz. Specifying dynamic analyses by extending language semantics. *Transactions on Software Engineering*, 2011. To appear (preprint online). Available from: `http://scg.unibe.ch/archive/papers/Lien11aDynamicAnalysis.pdf`, `doi:10.1109/TSE.2011.38`.

- Oscar Nierstrasz. Ten things i hate about object-oriented programming. *Journal of Object Technology*, 9(5), September 2010. (editorial — transcript of ECOOP 2010 banquet speech). Available from: `http://www.jot.fm/contents/issue_2010_09/editorial.html`, `doi:10.5381/jot.2010.9.5.e1`.

- David Röthlisberger, Marcel Härry, Alex Villazón, Danilo Ansaloni, Walter Binder, Oscar Nierstrasz, and Philippe Moret. Exploiting dynamic information in ides improves speed and correctness of software maintenance tasks. *Transactions on Software Engineering*, 2011. To appear (preprint online). Available from: `http://scg.unibe.ch/archive/papers/Roet11aSenseoTSE.pdf`, `doi:10.1109/TSE.2011.42`.

Conference Papers

- Alexandre Bergel, Oscar Nierstrasz, Lukas Renggli, and Jorge Ressia. Domain-specific profiling. In *Proceedings of the 49th International Conference on Objects, Models, Components and Patterns (TOOLS'11)*, volume 6705 of *LNCS*, pages 68–82. Springer-Verlag, June 2011. Available from: `http://scg.unibe.ch/archive/papers/Berg11b-Profiling.pdf, doi:10.1007/978-3-642-21952-8_7`.

- Marcus Denker, Jorge Ressia, Orla Greevy, and Oscar Nierstrasz. Modeling features at runtime. In *Proceedings of MODELS 2010 Part II*, volume 6395 of *LNCS*, pages 138–152. Springer-Verlag, October 2010. Available from: `http://scg.unibe.ch/archive/papers/Denk10a-Models10-FeatureModels.pdf, doi:10.1007/978-3-642-16129-2_11`.

- Adrian Kuhn, David Erni, and Oscar Nierstrasz. Embedding spatial software visualization in the ide: an exploratory study. In *SOFTVIS 2010*, pages 113–122, October 2010. Available from: `http://scg.unibe.ch/archive/papers/softvis2010-kuhn-codemap-userstudy.pdf, doi:10.1145/1879211.1879229`.

- Daniel Langone, Jorge Ressia, and Oscar Nierstrasz. Unifying subjectivity. In *Proceedings of the 49th International Conference on Objects, Models, Components and Patterns (TOOLS'11)*, volume 6705 of *LNCS*, pages 115–130. Springer-Verlag, June 2011. Available from: `http://scg.unibe.ch/archive/projects/Lang11aSubjectivity.pdf, doi:10.1007/978-3-642-21952-8_10`.

- Fabrizio Perin, Tudor Gîrba, and Oscar Nierstrasz. Recovery and analysis of transaction scope from scattered information in Java enterprise applications. In *Proceedings of International Conference on Software Maintenance 2010*, September 2010. Available from: `http://scg.unibe.ch/archive/papers/Peri10aTransactionRecovery.pdf, doi:10.1109/ICSM.2010.5609572`.

- Romain Robbes and Mircea Lungu. A study of ripple effects in software ecosystems (nier). In *Proceedings of the 33rd International Conference on Software Engineering (ICSE 2011)*, pages 904–907, May 2011. Available from: `http://scg.unibe.ch/archive/papers/Robb11aRipples.pdf, doi:10.1145/1985793.1985940`.

- Niko Schwarz. DoodleDebug, objects should sketch themselves for code understanding. In *Proceedings of the TOOLS 2011, 5th Workshop on Dynamic Languages and Applications (DYLA'11).*, 2011. Available from: `http://scg.unibe.ch/archive/papers/Schw11bDoodleDebug.pdf.`

- Niko Schwarz, Mircea Lungu, and Oscar Nierstrasz. Seuss: Cleaning up class responsibilities with language-based dependency injection. In *Objects, Components, Models and Patterns, Proceedings of TOOLS Europe 2011*, volume 33 of *LNCS*, pages 276–289. Springer-Verlag, 2011. Available from: `http://scg.unibe.ch/archive/papers/Schw11aSeuss.pdf,` `doi:10.1007/978-3-642-21952-8_20.`

- Toon Verwaest, Camillo Bruni, David Gurtner, Adrian Lienhard, and Oscar Nierstrasz. Pinocchio: Bringing reflection to life with first-class interpreters. In *OOPSLA Onward! '10*, 2010. Available from: `http://scg.unibe.ch/archive/papers/Verw10aPinocchio.pdf,` `doi:10.1145/1869459.1869522.`

- Toon Verwaest, Niko Schwarz, and Erwann Wernli. Runtime class updates using modification models. In *Proceedings of the TOOLS 2011 8th Workshop on Reflection, AOP and Meta-Data for Software Evolution (RAM-SE'11)*, page XXX, 2011. Available from: `http://scg.unibe.ch/archive/papers/Verw11aRuntimeUpdates.pdf.`

Workshop Papers

- Lile Hattori, Mircea Lungu, and Michele Lanza. Replaying past changes in multi-developer projects. In *Proceedings of the Joint ERCIM Workshop on Software Evolution (EVOL) and International Workshop on Principles of Software Evolution (IWPSE)*, pages 13–22, October 2010. Available from: `http://www.inf.usi.ch/faculty/lanza/Downloads/Hatt2010c.pdf,` `doi:10.1145/1862372.1862379.`

- Fabrizio Perin. MooseJEE: A Moose extension to enable the assessment of JEAs. In *Proceedings of the 26th International Conference on Software Maintenance (ICSM 2010) (Tool Demonstration)*, September 2010. Available from: `http://scg.unibe.ch/archive/papers/Peri10cMooseExtension.pdf,` `doi:10.1109/ICSM.2010.5609569.`

- Fabrizio Perin and Tudor Gîrba. Evaluating code duplication to identify rich business objects from data transfer objects. In *4th Workshop on FAMIX and Moose in Reengineering (FAMOOSr 2010)*, September 2010. Available from: `http://scg.unibe.ch/archive/papers/Peri10dDTOs.pdf`.

- Fabrizio Perin, Lukas Renggli, and Jorge Ressia. Ranking software artifacts. In *4th Workshop on FAMIX and Moose in Reengineering (FAMOOSr 2010)*, 2010. Available from: `http://scg.unibe.ch/archive/papers/Peri10bRankingSoftware.pdf`.

- Jorge Ressia, Lukas Renggli, Tudor Gîrba, and Oscar Nierstrasz. Run-time evolution through explicit meta-objects. In *Proceedings of the 5th Workshop on Models@run.time at the ACM/IEEE 13th International Conference on Model Driven Engineering Languages and Systems (MODELS 2010)*, pages 37–48, October 2010. Available from: `http://scg.unibe.ch/archive/papers/Ress10a-RuntimeEvolution.pdfhttp://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-641/`.

7   Computer Graphics Group

7.1   Personnel

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* with financial support from a third party

7.2   Overview

The Computer Graphics Group (CGG) was established in September 2008, when Prof. Zwicker joined the University of Bern as the successor of Prof. Bieri. The research of the Computer Graphics Group focuses on fundamental methods to generate and manipulate images using computers. We develop algorithms and systems for realistic and real-time rendering, and animation and modeling of three-dimensional shapes. We are also interested in novel representations for 3D geometry, such as point-based representations. Finally, we investigate signal processing techniques, in particular for multi-view 3D displays. Our research has applications in digital entertainment, multimedia, and data visualization.

Rendering

Rendering, or image synthesis, is a core problem in computer graphics. We develop algorithms for efficient, physically-based rendering. We are

also interested in rendering for interactive applications, and we investigate techniques to simulate light transport in real-time.

Animation and Modeling

Computer graphics scenes are composed of three-dimensional shapes that are stored in computer memory using mathematical representations. Our research is concerned with modeling and animating these three-dimensional shapes. We focus on developing sophisticated mathematical methods that allow for realistic shapes and motions, and intuitive user interfaces that make modeling and animation simple and efficient.

Point-Based Graphics

We are interested in novel mathematical representations of three-dimensional shapes. In our research, we show that point-based techniques are viable alternatives to conventional approaches, such as triangle meshes or parametric surfaces, for a variety of applications from rendering to modeling.

Multi-View 3D Displays

Automultiscopic displays show stereoscopic images that can be viewed from any viewpoint without special glasses. They hold great promise for the future of television and digital entertainment. We develop signal processing techniques to optimize image quality by reducing sampling artifacts and adapting the signal to the display properties. We are also interested in multi-view content creation and manipulation techniques.

7.3   Research Projects

Multi-Dimensional Sampling for Image Synthesis

In this project we address research challenges that are still limiting the capabilities of image synthesis technology. In particular, we are developing more efficient algorithms for image synthesis by studying this problem from the perspective of multidimensional sampling.
Images represent distributions of light. While light in the physical world can be interpreted as a continuous quantity, it needs to be represented

discretely for computer processing. This leads to the problem of sampling, which is at the core of this project. Computer graphics deals with various forms of sampled light to achieve realistic and efficient image synthesis. This includes, for example, the notion of light paths that store the amount of light transmitted along paths including several reflections at surfaces; the concept of transport operators that describe how light is passed between pairs of surface points; or radiance distributions that represent the light that is reflected in each direction at each surface point. All three concepts represent multidimensional functions, which means that we need multiple parameters to identify each sample. Light paths are identified by their sequence of intersection points with surfaces. The dimensionality of a light path depends on the number of intersections, but is potentially unbounded. A sample of a transport operator can be identified by a pair of surface points. A surface point is given by two parameters, hence a pair of points is four-dimensional. Radiance distributions are functions of surface locations and directions, therefore they are also four-dimensional. This is to explain why multidimensional sampling plays a central role in image synthesis.

Our research in this project focuses on two areas, realistic image synthesis and light transport for interactive rendering, which at their core involve multidimensional sampling issues. We analyse both topics from the perspective of multidimensional sampling, identify specific research challenges, and develop more efficient and flexible algorithms. Improvements of these core algorithms for image synthesis will find broad applications in computer graphics. They will reduce the resources required for realistic image synthesis, and enable more natural and effective interactive applications.

Research staff: Claude Knaus, Fabrice Rousselle, Matthias Zwicker

Financial support: Swiss National Science Foundation

UNITED LIVING COLORS dot CH: Integrating Evolutionary Developmental Genetics, 3D Computer Graphics, and Natural Photonics for Deciphering Variation & Complexity in Reptilian Color Traits

This project integrates the expertise of three research groups in Switzerland (evolutionary and developmental geneticists, 3D computer graphics scientists, and condensed-matter physicists) to gain an improved understanding of the mechanisms generating variation, complexity, and convergence of color traits in animals, in particular reptiles.

A key issue in evolution is to understand how morphology and physiology are altered to produce new forms serving novel functions. Basically no study to date integrated genomics/transcriptomics, developmental genetics, quantitative genetics, and extensive phenotyping of corresponding traits in natural populations for a better understanding of the link between genotype and phenotype in an ecological and phylogenetic framework. The pigmentation system in vertebrates is promising for exploring that connection: closely-related species as well as natural populations exhibit astonishing variations in color and color patterns, and this variation is of great ecological importance as it plays critical roles in thermoregulation, photo-protection, camouflage, display, and reproductive isolation (hence, speciation). Other advantages of focusing on color traits are that they can be quantified and modeled objectively, some of the involved signalling pathways have been partly uncovered in model organisms, and they provide among the best examples of convergence within and among species.

In the context of this project, the Computer Graphics Group develops tools for the acquisition of both 3D geometry and color texture at very high resolution on living animals. Further, we perform the mathematical analysis of the acquired texture phenotypes, mathematical modeling of the mechanisms generating color patterns, as well as computer simulations of reaction-diffusion on 3D geometries acquired from real animals.

Research staff: Daljit Dhillon, Matthias Zwicker

Financial support: Swiss National Science Foundation, Sinergia program

Interactive Motion Synthesis for Character Animation

The goal of this project is to develop algorithms for interactive character animation. Synthesizing realistic motion of human characters is a core topic in computer animation and has broad applications in virtual reality for tele-collaboration and training, computer games, and movie production.

Many of the most successful character animation techniques are based on recombining fragments of motion capture data. Motion capture data records the motion of real people captured using special cameras. To re-use captured motion data to generate new animations, fragments of the captured data are organized in so-called motion graphs. In motion graphs each graph node corresponds to a pose, and potential transitions between

poses correspond to arcs in the graph. They produce natural motions because they directly reuse captured motion data, and they can generate complex motions by concatenating a large number of motion fragments. In most systems, a user needs to provide a number of constraints to specify a motion. Based on the user constraints, motion synthesis is cast as a search problem. A search algorithm finds a path through the motion graph that satisfies the user constraints while minimizing some additional cost function. There are many variations of this scheme available in the literature, describing various ways to construct motion graphs, specify constraints, concatenate and interpolate motion fragments, etc. Because the complexity of searching for an optimal path through a motion graph is exponential to the connectivity of the graph and in the length of the desired motion sequence, it is challenging to apply these techniques for interactive applications.

In this project we develop efficient algorithms to synthesize character animations for interactive applications. Our approach is based on a bidirectional search strategy for motion synthesis using motion graphs. Our goal is to improve the search efficiency while preserving the search quality. In addition, we develop intuitive user interfaces to allow animators to easily specify desired motions. Our approach builds on a sketching metaphor, where the user controls and edits the character animation by indicating desired motions using pen strokes.

Research staff: Wan-Yen Lo, Matthias Zwicker

Introducing Stereo Effects into Cel Animations

Animated cartoons are an imaginative movie genre, often, but not only, made for children. Stereo effects could improve the visual impact of such movies, especially since children are an audience amenable to different visual experiences. New, 3D computer generated imagery (CGI) animations can directly be rendered in stereo, but old, classical cartoons cannot be converted that easily. The goal of our work is to introduce stereo effects into such cartoon animations. The necessary conversion should be easy to perform by an unexperienced user and should not require much user interaction.

In this project, we analyze the characteristics of cel animations and the differences between them and live action movies. As 3D reconstruction from single images or videos is a broad field of research, we mainly study the prominent methods to estimate depth information for a monocular video

input (e.g. shape from shading, structure from motion, shape from texture, etc.) and their applicability to cel animations. We implement a conversion framework, define test cases and perform quality ratings of the visual 3D effect.

Research staff: Sonja Schär, Matthias Zwicker

Video Stabilization for Hand-Held Cameras

Video footage produced using hand-held cameras often suffers from shaky camera motion. This is most common in material captured casually with small devices such as cell phones or compact cameras. Often, watching such videos can be a rather uncomfortable experience because of excessive camera shake. While it is possible to avoid such problems during video capture using professional equipment such as steadicam stabilizing systems or sophisticated rigs, these are usually too expensive and too complex to use for casual videographers.
The goal of this project is to develop post-processing algorithms that automatically achieve a smooth camera motion after the fact. This is a challenging problem because it involves recovering the actual camera motion in three-dimensional space, obtaining a desired virtual camera motion that is smooth but still similar to the actual motion, and rendering an output video sequence from the perspective of the virtual camera.
Conventional approaches often try to extract information from static objects visible in the video data. The information gathered from static objects makes it possible to recover camera motion using standard techniques. In practice it is quite common, however, that input videos do not contain enough static objects for this to work. The goal of our approach, therefore, is to generalize such techniques to be able to process data that does not allow the extraction of information from static objects.

Research staff: Daniel Donatsch, Matthias Zwicker

Signal Processing for Multi-View 3D Displays

In this project we develop a multi-dimensional signal processing framework and signal processing algorithms for multi-view 3D displays. Multi-View 3D displays offer viewing of high-resolution stereoscopic images from arbitrary positions without glasses. These displays consist of view-dependent pixels that reveal a different color to the observer based on the viewing

angle. Although the basic optical principles of multi-view auto-stereoscopy have been known for over a century, it is only recently that displays with increased resolution, or systems based on multiple projectors, have made them practical.

Multi-view displays feature a number of advantages over competing autostereoscopic display technologies, such as stereo-projection systems using shuttered or polarized glasses. Most importantly, multi-view displays do not require users to wear any special glasses, which leads to a more natural and unrestricted viewing experience. They also do not require head tracking to provide motion parallax; instead, they provide accurate perspective views from any point inside a viewing frustum simultaneously. They are truly multi-user capable, since none of the display parameters needs to be adjusted to a specific individual user.

As a disadvantage, the amount of data that needs to be processed, rendered, and transmitted to such displays is an order of magnitude larger than for stereo-pair projection systems. In this project we develop techniques that aim at performing these operations as efficiently as possible based on a multi-dimensional signal processing framework for multi-view displays. This approach provides a concise tool to study various aspects of data acquisition, processing, rendering, and compression, and it promises to eliminate several drawbacks of multi-view displays that have been unresolved in the past.

Research staff: Matthias Zwicker

7.4 Phd Theses

- Thomas Buchberger: Ein generischer Ansatz zur 3D-Modellierung von Städten mit Anwendung auf die Berner Altstadt (Betreuer: Prof. Dr. Emeritus Hanspeter Bieri)

7.5 Master Theses

- Simon Willi: Cel Animation Compositing (December 2010)

- Thomas Killer: Real-Time Adaptive Global Illumination (December 2010)

7.6 Bachelor Theses

- Gian Calgeer: Multi View Video Streaming (March 2011)

- Daniel Frey: Video Stabilization (March 2011)

7.7 Further Activities

Editorial Boards

Matthias Zwicker

- Computer Graphics Forum: The International Journal of the Eurographics Association, Associate Editor

Conference Program Committees

Matthias Zwicker

- Pacific Graphics 2011, September 21 – 23, 2011, Kaohsiung, Taiwan

- IEEE Visualization 2011, October 23 – 28, 2011, Providence, RI, USA

- Eurographics Symposium on Rendering 2011, June 27 – 29, Prague, Czech Republic

Ph.D. Jury Memberships

Matthias Zwicker

- Derek Nowrouzezahari, Exploiting Coherence and Data-Driven Models for Real-Time Global Illumination, University of Toronto, September 24, 2010

Reviewing Activities

Matthias Zwicker

- Swiss National Science Foundation

- European Research Council

- Hasler Stiftung

- ACM Transactions on Graphics

- IEEE Transactions on Visualization and Computer Graphics

- IEEE Transactions on Circuits and Systems for Video Technology

- Computer Graphics Forum, The International Journal of the Eurographics Association

- Computers & Graphics, An International Journal of Systems & Applications in Computer Graphics, Elsevier

- ACM SIGGRAPH conference

- ACM SIGGRAPH Asia conference

- Eurographics conference

7.8 Publications

Journal Publications

- Wan-Yen Lo, Jeroen van Baar, Claude Knaus, Matthias Zwicker and Markus Gross: Stereoscopic 3D Copy & Paste, ACM Transactions on Graphics, 29(6):147:1-147:10, 2010.

- A. Lagae, S. Lefebvre, R. Cook, T. DeRose, G. Drettakis, D.S. Ebert, J.P. Lewis, K. Perlin, and M. Zwicker: A Survey of Procedural Noise Functions, Computer Graphics Forum, 29(8):2579-2600, 2010.

- Claude Knaus and Matthias Zwicker: Progressive Photon Mapping: A Probabilistic Approach, ACM Transactions on Graphics, 30(3):25:1-25:13, 2011.

- Will Chang and Matthias Zwicker: Global Registration of Dynamic Range Scans for Articulated Model Reconstruction, ACM Transactions on Graphics, 30(3):26:1-26:15, 2011.

8   Administration

University:

T. Braun: Member of the Committee for Computing Services (Kommission für Informatikdienste)

H. Bunke: Member of the Senat

Faculty:

G. Jäger: Member of the Planning Board

Th. Studer: Member of the Planning Board

Institute:

T. Braun: Director of IAM

H. Bunke: Member of Hauskommission Engehalde

G. Jäger: Director of Studies

O. Nierstrasz: Deputy Director of IAM

T. Strahm: Member of Library Committee Exakte Wissenschaften

                 Member of Hauskommission Exakte Wissenschaften