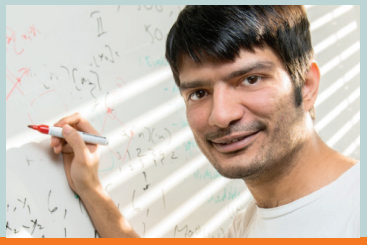
Yearbook 2016

International Max Planck Research School for Computer Science

Organized by the Max Planck Institutes for Informatics and Software Systems

In cooperation with the Computer Science Department at Saarland University

International Max Planck Research School
for Computer Science

Yearbook 2016

CONTENTS

ABOUT IMPRS-CS

The International Max Planck Research School for Computer Science (IMPRS-CS) is a graduate program jointly run by the Max Planck Institute for Informatics (MPI-INF), the Max Planck Institute for Software Systems (MPI-SWS), and the Computer Science Department at Saarland University.

MPI-INF and MPI-SWS are among the more than 80 institutes run by the Max Planck Society. The MPIs are Germany's prime basic research facilities with world-class, foundational research in the fields of medicine, biology, chemistry, physics, technology, and the humanities. Since 1948, MPI researchers have won 17 Nobel prizes, which testifies to the quality and innovation of MPI research programs.

Educating and training junior scientists is of primary importance for the future of science, research, and innovation. The Max Planck Society, in cooperation with German universities, has launched the International Max Planck Research Schools (IMPRS) initiative.

Admitted students receive a first rate, research-oriented education in their chosen area of concentration. They enjoy close supervision by world-renowned scientists in a competitive, yet collaborative, environment – rich in interaction with other students, post-docs, and scientists. The program is fully funded.

IMPRS-CS has around 120 PhD and approximately 25 Master's students. It graduates an average of fifteen M.Sc. and around twenty PhD students each year. Half of the M.Sc. graduates continue their studies in the PhD program.

Students come from diverse backgrounds, with the largest contingent of students coming from India, China, and Poland. More than 60 percent of the students come from abroad.

Graduates of the IMPRS-CS typically go on to academic or industrial research positions at leading universities and research laboratories world-wide.

Alumni: M.Sc.

Mohamed ALZAYAT

NATIONALITY: Egyptian
DEPARTMENT: Distributed Systems

THESIS TITLE:

PolSim: Automatic Policy Validation via Meta-Data Flow Simulation

ABSTRACT OF MASTER'S THESIS:

Every year millions of confidential data records are leaked accidentally due to bugs, misconfiguration, or operator error in large, complex, and fast evolving data processing systems. Ensuring compliance with data policies is a major challenge. Thoth is an information flow control system that uses coarse-grained taint tracking to control the flow of data, and to enforce relevant declarative policies at processes boundaries, regardless of bugs, misconfiguration, and compromises in application code, or actions by unprivileged operators. However, designing policies that make sure all and only compliant flows are allowed remains a complex and error prone process. In this thesis, we introduce PolSim, a simulation tool that aids system policy designers by validating the provided policies and systematically ensuring that the system allows all and only expected flows. Our proposed simulator approximates the dynamic run time environment, semi-automatically suggests internal flow policies based on data flow and provides debugging hints to help policy designers develop a working policy for the intended system before deployment.

Sinan BOZCA

NATIONALITY: **Turkish**
DEPARTMENT: **Mathematical Image Analysis**

THESIS TITLE:

Discrete Osmosis Methods for Image Processing

ABSTRACT OF MASTER'S THESIS:

Partial differential equations can model many physical phenomena and be used to simulate under computer. *Osmosis*, which is in the form of c*onvection-diffusion equation*, has found itself many application areas in image processing. However, slow convergence of this model, which depends on incompatibility of the drift vector field used in the model, under current methods does not allow us to have a fast, and possibly real-time application area.

Therefore, we get a deeper look into what incompatibility means and how it effects steady states of the osmosis process in this thesis. In addition, we evaluate several promising methods which offers substantial computational advantage over classical iterative methods.

Cuong XUAN CHU

NATIONALITY: **Vietnamese**
DEPARTMENT: **Databases and Information Systems**

THESIS TITLE:

Mining How-to Task Knowledge from Online Communities

ABSTRACT OF MASTER'S THESIS:

Nowadays, knowledge graphs have become a fundamental asset for search engines which need background commonsense knowledge for natural interactions. A fair amount of user queries seek information on problem-solving tasks such as painting a wall or repairing a bicycle. While projects like ConceptNet and Webchild have successfully compiled large amounts of knowledge on properties of objects in our daily life, there is still a big gap regarding knowledge on everyday activities, especially problem-solving tasks (how-to knowledge). Recent efforts to automatically compile commonsense have one or more the following weaknesses: (i) they ignore activity commonsense, (ii) they operate at a small scale, (iii) their outputs are not semantically organized, (iv) they are domain-specific (e.g. cooking scripts or movie scripts). All of them lack how-to knowledge.

The goal of this work is to overcome these limitations and compile a large-scale, semantically organized, domain-independent formal knowledge base on tasks and task-solving steps, by tapping the contents of online communities such as WikiHow.

We employ Open-IE techniques to extract noisy candidates for tasks, steps and the required tools and other items. For cleaning and properly organizing this data, we devise embedding-based clustering techniques. The resulting knowledge base, HowToKB, includes a hierarchical taxonomy of disambiguated tasks, temporal orders of sub-tasks, and attributes for involved items.

A comprehensive evaluation of HowToKB shows high accuracy. As an extrinsic use case, we evaluate automatically searching related YouTube videos for HowToKB tasks.

Omar DARWISH

NATIONALITY: Egyptian
DEPARTMENT: Algorithms and Complexity

THESIS TITLE:

Market Equilibrium Computation for the Linear Arrow-Debreu Model

ABSTRACT OF MASTER'S THESIS:

The problem of market equilibrium is defined as the problem of finding prices for the goods such that the supply in the market is equal to the demand. The problem is applicable to several market models, like the linear Arrow-Debreu model, which is one of the fundamental economic market models. Over the years, various algorithms have been developed to compute the market equilibrium of the linear Arrow-Debreu model. In 2013, Duan and Mehlhorn presented the first combinatorial polynomial time algorithm for computing the market equilibrium of this model.

In this thesis, we optimize, generalize, and implement the Duan-Mehlhorn algorithm. We present a novel algorithm for computing balanced ows in equality networks, which is an application of parametric ows. This algorithm outperforms the current best algorithm for computing balanced ows; hence, it improves Duan-Mehlhorn's algorithm by almost a factor of n, which is the size of the network. Moreover, we generalize Duan-Mehlhorn's algorithm by relaxing some of its assumptions. Finally, we describe our approach for implementing Duan-Mehlhorn's algorithm. The preliminary results of our implementation - based on random utility instances - show that the running time of the implementation scales significantly better than the theoretical time complexity.

Akram EL-KORASHY

NATIONALITY: Egyptian

DEPARTMENT: Foundations of Computer Security

THESIS TITLE:

A Formal Model for Capability Machines – An Illustrative Case Study towards Secure Compilation to CHERI

ABSTRACT OF MASTER'S THESIS:

Vulnerabilities in computer systems arise in part due to programmer's logical errors, and in part also due to programmer's false (i.e., over-optimistic) expectations about the guarantees that are given by the abstractions of a programming language.

For the latter kind of vulnerabilities, architectures with hardware or instruction-level support for protection mechanisms can be useful. One trend in computer systems protection is hardware-supported enforcement of security guarantees/policies. Capability-based machines are one instance of hardware-based protection mechanisms. CHERI is a recent implementation of a 64-bit MIPS-based capability architecture with byte-granularity memory protection.

The goal of this thesis is to provide a paper formal model of the CHERI architecture with the aim of formal reasoning about the security guarantees that can be offered by the features of CHERI. We first give simplified instruction operational semantics, then we prove that capabilities are unforgeable in our model. Second, we show that existing techniques for enforcing control-ow integrity can be adapted to the CHERI ISA. Third, we show that one notion of memory compartmentalization can be achieved with the help of CHERI's memory protection. We conclude by suggesting other security building blocks that would be helpful to reason about, and laying down a plan for potentially using this work for building a secure compiler, i.e., a compiler that preserves security properties.

The outlook and motivation for this work is to highlight the potential of using CHERI as a target architecture for secure compilation.

Adam HANKA

NATIONALITY: Czech
DEPARTMENT: Computer Graphics

THESIS TITLE:

Material Appearance Editing in Complex Volume and Surface Renderingss

ABSTRACT OF MASTER'S THESIS:

When considering global illumination, material editing is a non-linear task and even in scenes with moderate complexity, the global nature of material editing makes final prediction of appearance of other objects in the scene a difficult task.

In this thesis, a novel interactive method is proposed for object appearance design. To achieve this, a randomized per-pixel parametrization of scene materials is defined. At rendering time, parametrized materials have different properties for every pixel. This way, encoding of multiple rendered results into one image is obtained. We call this collection of data a *hyperimage*.

Material editing means projecting the hyperimage onto a given parameter vector, which is achieved using non-linear weighted regression. Pixel guides based on geometry (normals, depth and unique object ID), materials and lighting properties of the scene enter the regression problem as pixel weights. In order to ensure that only relevant features are considered, a rendering-based feature selection method is introduced, which uses a precomputed pixelfeature function, encoding per-pixel importance of each parametrized material.

The method of hyperimages is independent of the underlying rendering algorithm, while supporting a full global illumination and surface interactions.

Our method is not limited to parametrization of materials, and can be extended to other scene properties. As an example, we show parametrization of position of an area light source.

Ashkan MOKARIAN FOROOSHANI

NATIONALITY: **Iranian**
DEPARTMENT: **Computer Vision and Multimodal Computing**

THESIS TITLE:

Deep Learning for Filling Blanks in Image Captions

ABSTRACT OF MASTER'S THESIS:

Visual Question Answering is a fairly new, interdisciplinary task in both Computer Vision and Natural Language Processing communities, and is considered as a Turing test proxy to push the boundaries of AI. Generally, it takes an image and a free-form question as input and produces a human understandable answer. The task considered in this thesis is slightly different. First of all, instead of free form questions, there are prompts with blanks. Secondly, the correct answer has to be chosen from multiple choices which further facilitates evaluation.

Surprisingly, CCA which is a standard multimodal joint embedding method developed in 1936, outperforms recent models developed for the Visual Question Answering task on the Visual Madlibs dataset. Therefore, our focus is mostly about this method, trying to overcome its shortcomings, and making use of its ideas. One drawback of CCA is that it does not allow back-propagation, a standard technique for training deep networks. We try to solve this issue by reformulating the method by Lagrangian relaxation and propose our back propagable CCA (bCCA) model.

Moreover, we propose a novel image representation by pooling features from Edge Box proposals and show its effectiveness on different methods and datasets. Since this representation does not require joint training and fine tuning, it suits the shortcomings of CCA, obtaining state-of-the-art results on the Visual Madlibs dataset.

Finally, we show that for the filling blanks task with multiple choices, learning a joint space directly instead of generating an answer followed by choosing the best multiple choice, produces better results.

Riccha SETHI

NATIONALITY: Indian

DEPARTMENT: Algorithms for Computational Genomics

THESIS TITLE:

Evaluation of Population-Based Haplotype Phasing Algorithms

ABSTRACT OF MASTER'S THESIS:

The valuable information in correct order of alleles on the haplotypes has many applications in GWAS studies and population genetics. A considerable number of computational and statistical algorithms have been developed for haplotype phasing. Historically, these algorithms were compared using the simulated population data with less dense markers which was inspired by genotype data from the HapMap project. Currently due to the advancement and reduction in cost of NGS, thousands of individuals across the world have been sequenced in 1000 Genomes Project. This has generated the genotype information of individuals from different ethnicity along with much denser genetic variations in them. Here, we have developed a scalable approach to assess state-of-the-art population-based haplotype phasing algorithms with benchmark data designed by simulation of the population (unrelated and related individuals), NGS pipeline and genotype calling. The most accurate algorithm was MVNCall (v1) for phase inference in unrelated individuals while DuoHMM approach of Shapeit (v2) had lowest switch error rate of 0.298 % (with true genotype likelihoods) in the related individuals. Moreover, we also conducted a comprehensive assessment of algorithms for the imputation of missing genotypes in the population with a reference panel. For this metrics, Impute2 (v2.3.2) and Beagle (v4.1) both performed competitively under different imputation scenarios and had genotype concordance rate of >99 %. However, Impute2 was better in imputation of genotypes with minor allele frequency of <0.025 in the reference panel.

Birhan TADELE TEKLEHAIMANOT

NATIONALITY: **Ethiopian**
DEPARTMENT: **Telecommunications Lab**

THESIS TITLE:

Virtualization of Video Streaming Functions

ABSTRACT OF MASTER'S THESIS:

Edgeware is a leading provider of video streaming solutions to network and service operators. The Edgeware Video Consolidation Platform(VCP) is a complete video streaming solution consisting of the Convoy Management system and Orbit streaming servers. The Orbit streaming servers are purpose designed hardware platforms which are composed of a dedicated hardware streaming engine and a purpose designed flash as a storage system. The Orbit streaming server is an accelerated HTTP streaming cache server which have up to 80 Gbps bandwidth and can stream to 128000 clients from a single rack unit. In line with the new trend of moving more and more functionalities towards a virtualized or software environment, the main goal of this thesis is to make a performance comparison between Edgeware's Orbit streaming server and one of the best generic HTTP accelerators (reverse proxy severs) after implementing logging functionality of the Orbit on top of it. This is achieved by implementing test cases for the use cases that can help to evaluate those servers. Finally, after evaluating those proxy servers Varnish is selected and then compared the modified Varnish and Orbit to investigate the performance difference.

Menglin ZHENG

NATIONALITY: **Chinese**
DEPARTMENT: **Clinical Bioinformatics**

THESIS TITLE:

Comparison of Software Tools for microRNA Next Generation Sequencing Data Analysis

ABSTRACT OF MASTER'S THESIS:

Next-generation sequencing (NGS) appears to be very promising to study miRNAs comprehensively, which can not only profile known miRNAs, but also predict novel miRNAs. There are an increasing number of software tools developed for microRNA NGS data analysis. Nevertheless, an overall comparison of these tools is still rare and how divergent these software tools are is still unknown, which confuses the researchers to select an optimal tool. In our study, we performed a comprehensive comparison of seven representative software tools based on real data in various aspects, including detected known miRNAs, miRNAs abundance, differential expression and predicted novel miRNAs. We presented the divergences and similarities of these tools and gave some basic evaluation of the tools' performances. In addition, some extreme cases in miRNAkey were explored. The comparison of these tools suggests that the performances of these software tools are very diverse and the caution is necessary to take when choosing a software tool. The summarization of the tools' features and comparison of their performances in our study will provide useful information for the researchers to promote their selection of an appropriate software tool.

Alumni: PhD

Dr. Noran AZMY

NATIONALITY: Egyptian
DEPARTMENT: Automation of Logic

THESIS TITLE:

A Machine–Checked Proof of Correctness of Pastry

ABSTRACT OF PHD THESIS:

A distributed hash table (DHT) is a peer-to-peer network that offers the function of a classic hash table, but where different key-value pairs are stored at different nodes on the network. Like a classic hash table, the main function provided by a DHT is key lookup, which retrieves the value stored at a given key. Examples of DHT protocols include Chord, Pastry, Kademlia and Tapestry. Such DHT protocols certain correctness and performance guarantees, but formal verification typically discovers border cases that violate those guarantees. In his PhD thesis, Tianxiang Lu reported correctness problems in published versions of Pastry and developed a model called LuPastry, for which he provided a partial proof of correct delivery of lookup messages assuming no node failure, mechanized in the TLA$^+$ Proof System. In analyzing Lu's proof, I discovered that it contained unproven assumptions, and found counterexamples to several of these assumptions. The contribution of this thesis is threefold. First, I present LuPastry$^+$, a revised TLA$^+$ specification of LuPastry. Aside from needed bug fixes, LuPastry$^+$ contains new definitions that make the specification more modular and significantly improve proof automation. Second, I present a complete TLA+ proof of correct delivery for LuPastry$^+$. Third, I prove that the final step of the node join process of LuPastry/LuPastry$^+$ is not necessary to achieve consistency. In particular, I develop a new specification with a simpler node join process, which I denote by Simplified LuPastry$^+$, and prove correct delivery of lookup messages for this new specification. The proof of correctness of Simplified LuPastry$^+$ is written by reusing the proof for LuPastry$^+$, which represents a success story in proof reuse, especially for proofs of this size.

Each of the two proofs amounts to over 32,000 proof steps; to my knowledge, they are currently the largest proofs written in the TLA$^+$ language, and – together with Lu's proof – the only examples of applying full theorem proving for the verification of DHT protocols.

Dr. Myroslav BACHYNSKYI

NATIONALITY: **Ukrainian**
DEPARTMENT: **Human Computer Interaction**

THESIS TITLE:

Biomechanical Models for Human-Computer Interaction

ABSTRACT OF PHD THESIS:

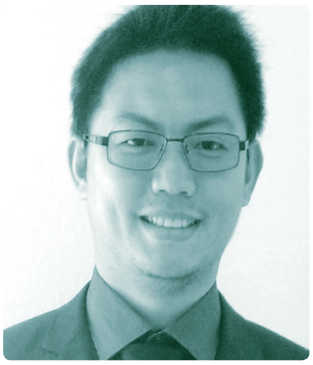
Post-desktop user interfaces, such as smartphones, tablets, interactive tabletops, public displays and mid-air interfaces, already are a ubiquitous part of everyday human life, or have the potential to be. One of the key features of these interfaces is the reduced number or even absence of input movement constraints imposed by a device form-factor. This freedom is advantageous for users, allowing them to interact with computers using more natural limb movements; however, it is a source of 4 issues for research and design of post-desktop interfaces which make traditional analysis methods inefficient: the new movement space is orders of magnitude larger than the one analyzed for traditional desktops; the existing knowledge on post-desktop input methods is sparse and sporadic; the movement space is non-uniform with respect to performance; and traditional methods are ineffective or inefficient in tackling physical ergonomics pitfalls in post-desktop interfaces. These issues lead to the research problem of efficient assessment, analysis and design methods for high-throughput ergonomic post-desktop interfaces.

To solve this research problem and support researchers and designers, this thesis proposes efficient experiment- and model-based assessment methods for post-desktop user interfaces. We achieve this through the following contributions:

- adopt optical motion capture and biomechanical simulation for HCI experiments as a versatile source of both performance and ergonomics data describing an input method;

- identify applicability limits of the method for a range of HCI tasks;
- validate the method outputs against ground truth recordings in typical HCI setting;
- demonstrate the added value of the method in analysis of performance and ergonomics of touchscreen devices; and
- summarize performance and ergonomics of a movement space through a clustering of physiological data.

The proposed method successfully deals with the 4 above-mentioned issues of post-desktop input. The efficiency of the methods makes it possible to effectively tackle the issue of large post-desktop movement spaces both at early design stages (through a generic model of a movement space) as well as at later design stages (through user studies). The method provides rich data on physical ergonomics (joint angles and moments, muscle forces and activations, energy expenditure and fatigue), making it possible to solve the issue of ergonomics pitfalls. Additionally, the method provides performance data (speed, accuracy and through-put) which can be related to the physiological data to solve the issue of non-uniformity of movement space. In our adaptation the method does not require experimenters to have specialized expertise, thus making it accessible to a wide range of researchers and designers and contributing towards the solution of the issue of post-desktop knowledge sparsity.



Dr. Walon Wei-Chen CHIU

NATIONALITY: Chinese
DEPARTMENT: Computer Vision and Multimodal Computing

THESIS TITLE:

Bayesian Non-Parametrics for Multi-Modal Segmentation

ABSTRACT OF PHD THESIS:

Segmentation is a fundamental and core problem in computer vision research which has applications in many tasks, such as object recognition, content-based image retrieval, and semantic labelling. To partition the data into groups coherent in one or more characteristics such as semantic classes, is often a first step towards understanding the content of data. As information in the real world is generally perceived in multiple modalities, segmentation performed on multi-modal data for extracting the latent structure usually encounters a challenge: how to combine features from multiple modalities and resolve accidental ambiguities. This thesis tackles three main axes of multi-modal segmentation problems: video segmentation and object discovery, activity segmentation and discovery, and segmentation in 3D data.

For the first two axes, we introduce non-parametric Bayesian approaches for segmenting multi-modal data collections, including groups of videos and context sensor streams. The proposed method shows benefits on: integrating multiple features and data dependencies in a probabilistic formulation, inferring the number of clusters from data and hierarchical semantic partitions, as well as resolving ambiguities by joint segmentation across videos or streams.

The third axis focuses on the robust use of 3D information for various applications, as 3D perception provides richer geometric structure and holistic observation of the visual scene. The studies covered in this thesis for utilizing various types of 3D data include: 3D object segmentation based on Kinect depth sensing improved by cross-modal stereo, matching 3D CAD models to objects on 2D image plane by exploiting the differentiability of the HOG descriptor, segmenting stereo videos based on adaptive ensemble models, and fusing 2D object detectors with3D context information for an augmented reality application scenario.

Dr. Luciano DEL CORRO

NATIONALITY: **Spanish**
DEPARTMENT: **Databases and Information Systems**

THESIS TITLE:

Methods for Open Information Extraction and Sense Disambiguation on Natural Language Text

ABSTRACT OF PHD THESIS:

Natural language text has been the main and most comprehensive way of expressing and storing knowledge. A long standing goal in computer science is to develop systems that automatically understand textual data, making this knowledge accessible to computers and humans alike. We conceive automatic text understanding as a bottom-up approach, in which a series of interleaved tasks build upon each other. Each task achieves more understanding over the text than the previous one. In this regard, we present three methods that aim to contribute to the primary stages of this setting.

Our first contribution, ClausIE, is an open information extraction method intended to recognize textual expressions of potential facts in text (e.g. “Dante wrote the Divine Comedy”) and represent them with an amenable structure for computers [(“Dante”, “wrote”, “the Divine Comedy”)]. Unlike previous approaches, ClausIE separates the recognition of the information from its representation, a process that understands the former as universal (i.e., domain-independent) and the later as application-dependent. ClausIE is a principled method that relies on properties of the English language and thereby avoids the use of manually or automatically generated training data.

Once the information in text has been correctly identified, probably the most important element in a structured fact is the relation which links its arguments, a relation whose main component is usually a verbal phrase. Our second contribution, Werdy, is a word entry recognition and disambiguation method. It aims to recognize words or multi-word expressions (e.g., “Divine Comedy” is

a multi-word expression) in a fact and disambiguate verbs (e.g., what does "write" mean?). Werdy is also an unsupervised approach, mainly relying on the syntactic and semantic relation established between a verb sense and its arguments.

The other key components in a structured fact are the named entities (e.g., "Dante") that often appear in the arguments. FINET, our last contribution, is a named entity typing method. It aims to understand the types or classes of those names entities (e.g., "Dante" refers to a writer). FINET is focused on typing named entities in short inputs (like facts). Unlike previous systems, it is designed to find the types that match the entity mention context (e.g., the fact in which it appears). It uses the most comprehensive type system of any entity typing method to date with more than 16k classes for persons, organizations and locations.

These contributions are intended to constitute constructive building blocks for deeper understanding tasks in a bottom-up automatic text understanding setting.

Dr. Nadezhda Tsankova DONCHEVA

NATIONALITY: Bulgarian
DEPARTMENT: Computational Biology and Applied Algorithmics

THESIS TITLE:

Network Biology Methods for Functional Characterization and Integrative Prioritization of Disease Genes and Proteins

ABSTRACT OF PHD THESIS:

Nowadays, large amounts of experimental data have been produced by high-through- put techniques, in order to provide more insight into complex phenotypes and cellular processes. The development of a variety of computational and, in particular, network-based approaches to analyze these data have already shed light on previously unknown mechanisms. However, we are still far from a comprehensive understanding of human diseases and their causes as well as appropriate preventive measures and successful therapies.

This thesis describes the development of methods and user-friendly software tools for the integrative analysis and interactive visualization of biological networks as well as their application to biomedical data for understanding diseases. We design an integrative phenotype-specific framework for prioritizing candidate disease genes and functionally characterizing similar phenotypes. It is applied to the identification of several disease-relevant genes and processes for in inflammatory bowel diseases and primary sclerosing cholangitis as well as for Parkinson's disease.

Since finding the causative disease genes does often not suffice to understand diseases, we also concentrate on the molecular characterization of sequence mutations and their effect on protein structure and function. We develop a software suite to support the interactive, multi-layered visual analysis of molecular interaction mechanisms such as protein binding, allostery and drug resistance. To capture the dynamic nature of proteins, we also devise an approach to visualizing and analyzing ensembles of protein structures as, for example, generated by molecular dynamics simulations.

Dr. Oskar ELEK

NATIONALITY: Slovakian
DEPARTMENT: Computer Graphics

THESIS TITLE:

Efficient Methods for Physically-based Rendering of Participating Media

ABSTRACT OF PHD THESIS:

This thesis proposes several novel methods for realistic synthesis of images containing participating media. This is a challenging problem, due to the multitude and complexity of ways how light interacts with participating media, but also an important one, since such media are ubiquitous in our environment and therefore are one of the main constituents of its appearance. The main paradigm we follow is designing efficient methods that provide their user with an interactive feedback, but are still physically plausible.

The presented contributions have varying degrees of specialisation and, in a loose connection to that, their resulting efficiency. First, the *screen-space scattering* algorithm simulates scattering in homogeneous media, such as fog and water, as a fast image filtering process. Next, the *amortised photon mapping* method focuses on rendering clouds as arguably one of the most difficult media due to their high scattering anisotropy. Here, interactivity is achieved through adapting to certain conditions specific to clouds. A generalisation of this approach is *principal-ordinates propagation*, which tackles a much wider class of heterogeneous media. The resulting method can handle almost arbitrary optical properties in such media, thanks to a custom finite element propagation scheme. Finally, *spectral ray differentials* aim at an efficient reconstruction of chromatic dispersion phenomena, which occur in transparent media such as water, glass and gemstones. This method is based on analytical ray differentiation and as such can be incorporated to any ray-based rendering framework, increasing the efficiency of reproducing dispersion by about an order of magnitude.

All four proposed methods achieve efficiency primarily by utilising high-level mathematical abstractions, building on the understanding of the underlying physical principles that guide light transport. The methods have also been designed around simple data structures, allowing high execution parallelism and removing the need to rely on any sort of preprocessing. Thanks to these properties, the presented work is not only suitable for interactively computing light transport in participating media, but also allows dynamic changes to the simulated environment, all while maintaining high levels of visual realism.

Dr. Hassan HATEFI ARDAKANI

NATIONALITY: Iranian

DEPARTMENT: Dependable Systems and Software

THESIS TITLE:

Finite Horizon Analysis of Markov Automata

ABSTRACT OF PHD THESIS:

Markov automata constitute an expressive continuous-time compositional modelling formalism, featuring stochastic timing and nondeterministic as well as probabilistic branching, all supported in one model. They span as special cases, the models of discrete and continuous-time Markov chains, as well as interactive Markov chains and probabilistic automata. Moreover, they might be equipped with reward and resource structures in order to be used for analysing quantitative aspects of systems, like performance metrics, energy consumption, repair and maintenance costs. Due to their expressive nature, they serve as semantic backbones of engineering frameworks, control applications and safety critical systems. The Architecture Analysis and Design Language (AADL), Dynamic Fault Trees (DFT) and Generalised Stochastic Petri Nets (GSPN) are just some examples. Their expressiveness thus far prevents them from efficient analysis by stochastic solvers and probabilistic model checkers. A major problem context of this thesis lies in their analysis under some budget constraints, i.e. when only a finite budget of resources can be spent by the model. We study mathematical foundations of Markov automata since these are essential for the analysis addressed in this thesis. This includes, in particular, understanding their measurability and establishing their probability measure. Furthermore, we address the analysis of Markov automata in the presence of both reward acquisition and resource consumption within a finite budget of resources. More specifically, we put the problem of computing the optimal expected resource-bounded reward in our focus. In our general setting, we support transient, instantaneous and final reward collection as well as transient resource consumption. Our general formulation of the problem encompasses in particular the optimal time-bound reward and reachability as well as resource-bounded reachability. We develop a sound theory together with a stable approximation scheme with a strict error bound to solve the problem in an efficient way. We report on an implementation of our approach in a supporting tool and also demonstrate its effectiveness and usability over an extensive collection of industrial and academic case studies.

Dr. Anne-Christin HAUSCHILD

NATIONALITY: German

DEPARTMENT: Computational Systems Biology

THESIS TITLE:

Computational Methods for Breath Metabolomics in Clinical Diagnostics

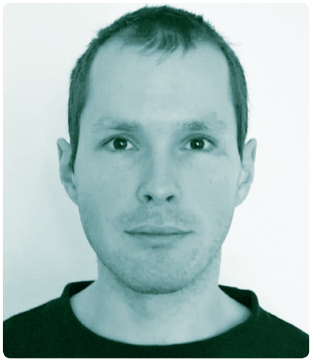
ABSTRACT OF PHD THESIS:

Odors and vapors of the body and breath have been known for their diagnostic power for millennia. More recent history confirmed this knowledge within clinical studies by successfully training dogs and mice to detect diseases, by sniffing specific volatile organic profiles. Like a vertebrate nose, there exist analytical technologies capable of capturing such metabolites. The science of analyzing the aggregation of all metabolites within the breath of an organism is called breathomics. The crucial task is to identify discriminating patterns that are predictive for certain diseases. Additionally, like other diagnostic technologies, breath is influenced by various sources of systematic or random noise. The field needs to move from separability to predictability by evolving from pilot studies to large scale screening studies. Therefore, there is a necessity for further standardization and automatization in managing, analyzing and evaluating this novel type of metabolomics data. In order to achieve this, several challenges remain to be addressed: data accumulation and heterogeneity; manual peak finding; unknown metabolites; robust statistics and biomarkers; background noise and confounding factors; heterogeneous diseases and disease stages; usability, maintainability, and re-usability.

In this thesis I will describe six projects that propose possible solutions to these challenges. (1) The IMSDB is the first functional and flexible comprehensive breatomics database. It provides flexible yet quick storage of heterogeneous clinical and large amounts of metabolic breath data. (2) A pilot study lays the foundations for a more robust and adequate prediction, evaluation and feature selection of breathomics data, by introducing established machine learning techniques to the field of breath analysis. (3) Further, the thesis pres-

ents the first qualitative analysis of the performance of automated peak detection methods and thereby proves their ability to compete with the manual gold standard. (4) The MIMA software tool enables the automated identification of the captured organic components by mapping different analytical technologies. (5) The Carotta software system provides a user friendly unsupervised learning platform, that enables easy discovery of hidden structures in metabolomic breath data such as disease subtypes or confounding factors. (6) Finally, I will introduce the first longitudinal modeling of breath metabolite behavior during the course of an evolving disease.

In conclusion, the aggregation of these projects builds the foundation for a more robust and standardized analysis schema, leading to more comparability and generalization of future breathomics studies. Moreover, it sets the basis for automated frameworks integrating the described tools and approaches into steps of a continuous breath analysis pipeline.



Dr. Petr KELLNHOFER

NATIONALITY: Czech
DEPARTMENT: Computer Graphics

THESIS TITLE:

Perceptual Modeling for Stereoscopic 3D

ABSTRACT OF PHD THESIS:

Virtual and Augmented Reality applications typically rely on both stereoscopic presentation and involve intensive object and observer motion. A combination of high dynamic range and stereoscopic capabilities become popular for consumer displays, and is a desirable functionality of head mounted displays to come. The thesis is focused on complex interactions between all these visual cues on digital displays.

The first part investigates challenges of the stereoscopic 3D and motion combination. We consider an interaction between the continuous motion presented as discrete frames. Then, we discuss a disparity processing for accurate reproduction of objects moving in the depth direction. Finally, we investigate the depth perception as a function of motion parallax and eye fixation changes by means of saccadic motion.

The second part focuses on the role of high dynamic range imaging for stereoscopic displays. We go beyond the current display capabilities by considering the full perceivable luminance range and we simulate the real world experience in such adaptation conditions. In particular, we address the problems of disparity retargeting across such wide luminance ranges and reflective/refractive surface rendering.

The core of our research methodology is perceptual modeling supported by our own experimental studies to overcome limitations of current display technologies and improve the viewer experience by enhancing perceived depth, reducing visual artifacts or improving viewing comfort.

Dr. Oliver KLEHM

NATIONALITY: German
DEPARTMENT: Computer Graphics

THESIS TITLE:

User-Guided Scene Stylization using Efficient Rendering Techniques

ABSTRACT OF PHD THESIS:

In this dissertation, we propose new techniques to display and manipulate virtual worlds to support visual design.

The real-time constraint of applications such as games limits the accuracy at which rendering algorithms can simulate light transport. Our first method focuses on the efficient rendering of surfaces under natural illumination, extending previous work that ignores directionally-dependent effects in the lighting. In a second work, we present an approach for the efficient computation of scattering in homogeneous participating media. The main challenge is the accumulation of visibility along view rays, which we solve using an efficient filtering scheme.

In the second part of the dissertation, we investigate methods that provide artists with approaches to stylize and manipulate the appearance of volumetric scattering. First, we focus on the effect of light shafts that one can typically observe on hazy days due to openings in the clouds. While the effect is often used in games and movies, it is difficult to manipulate. We propose tools to directly manipulate parameters of the rendering, effectively providing control over the creation, shape, and color of these light shafts. In another work, we abstract from direct parameter changes and propose a goal-based design approach to manipulate the appearance of heterogeneous media such as clouds. We use inverse rendering to infer volume parameters from user paintings to achieve the desired look. The problem is expressed as an optimization procedure for which we show an efficient execution on the GPU. We show in several examples that these novel methods enable intuitive, expressive, and effective control over the stylization of volumetric scattering.

Dr. Marek KOSTA

NATIONALITY: Slovakian
DEPARTMENT: Automation of Logic

THESIS TITLE:

New Concepts for Real Quantifier Elimination by Virtual Substitution

ABSTRACT OF PHD THESIS:

Quantifier elimination methods for real closed fields are an intensively studied subject from both theoretical and practical points of view. This thesis studies quantifier elimination based on virtual substitution with a particular focus on practically applicable methods and techniques. We develop a novel, stand-alone, and modular quantifier elimination framework for virtual substitution that can in principle be extended to arbitrary but bounded degrees of quantified variables. The framework subsumes previous virtual substitution algorithms. Quantifier elimination algorithms are obtained via instantiation of our quantifier elimination algorithm scheme with three precisely specified subalgorithms. We give instantiations of our scheme up to degree three of a quantified variable, which yields a quantifier elimination algorithm by virtual substitution for the cubic case. Compared to previous virtual substitution-based approaches, we propose novel improvements like smaller elimination sets and clustering.

Furthermore, we exploit the Boolean structure and develop a structural quantifier elimination algorithm scheme. This allows us to take advantage of subformulas containing equations or negated equations, simplify virtual substitution results, and develop flexible bound selection strategies. We also revisit the established technique of degree shifts and show how to generalize this within our structural quantifier elimination algorithm scheme.

Restricting ourselves to existential problems, we address the established concept of extended quantified elimination, which in addition to quantifier-free equivalents yields answers for existentially quantified variables. We show how

to realize this concept within our quantifier elimination algorithm scheme. Moreover, we generalize our post-processing method for eliminating nonstandard symbols from answers to the general case.

Our implementation of most of the concepts developed in this thesis is the first implementation of a cubic virtual substitution method. Experimental results comparing our implementation with the established original implementation of the quadratic virtual substitution in the Redlog computer logic system demonstrate the relevance of our novel techniques: On more than two hundred quantifier elimination problems – considered in more than sixty scientific publications during the past twenty years – we never eliminate fewer quantifiers than the Redlog's original implementation. For a considerable number of problems we eliminate more quantifiers.

Dr. Marvin KÜNNEMANN

NATIONALITY: German
DEPARTMENT: Algorithms and Complexity

THESIS TITLE:

Tight(er) Bounds for Similarity Measures, Smoothed Approximation and Broadcasting

ABSTRACT OF PHD THESIS:

In this thesis, we prove upper and lower bounds on the complexity of sequence similarity measures, the approximability of geometric problems on realistic inputs, and the performance of randomized broadcasting protocols.

The first part approaches the question why a number of fundamental polynomial-time problems – specifically, Dynamic Time Warping, Longest Common Subsequence (LCS), and the Levenshtein distance – resists decades-long attempts to obtain polynomial improvements over their simple dynamic programming solutions. We prove that any (strongly) subquadratic algorithm for these and related sequence similarity measures would refute the Strong Exponential Time Hypothesis (SETH). Focusing particularly on LCS, we determine a tight running time bound (up to lower order factors and conditional on SETH) when the running time is expressed in terms of all input parameters that have been previously exploited in the extensive literature.

In the second part, we investigate the approximation performance of the popular 2-Opt heuristic for the Traveling Salesperson Problem using the smoothed analysis paradigm. For the Fréchet distance, we design an improved approximation algorithm for the natural input class of c-packed curves, matching a conditional lower bound.

Finally, in the third part we prove tighter performance bounds for processes that disseminate a piece of information, either as quickly as possible (rumor spreading) or as anonymously as possible (cryptogenography).

Dr. Sebastian OTT

NATIONALITY: German
DEPARTMENT: Algorithms and Complexity

THESIS TITLE:

Algorithms for Classical and Modern Scheduling Problems

ABSTRACT OF PHD THESIS:

Subject of this thesis is the design and the analysis of algorithms for scheduling problems. In the first part, we focus on energy-efficient scheduling, where one seeks to minimize the energy needed for processing certain jobs via dynamic adjustments of the processing speed (speed scaling). We consider variations and extensions of the standard model introduced by Yao, Demers, and Shenker in 1995, including the addition of a sleep state, the avoidance of preemption, and variable speed limits.

In the second part, we look at classical makespan scheduling, where one aims to minimize the time in which certain jobs can be completed. We consider the restricted assignment model, where each job can only be processed by a specific subset of the given machines. For a special case of this problem, namely when heavy jobs can go to at most two machines, we present a combinatorial algorithm with approximation ratio strictly better than two.

Dr. Alejandro PIRONTI

NATIONALITY: Mexican

DEPARTMENT: Computational Biology and Applied Algorithmics

THESIS TITLE:

Improving and Validating Data-Driven Genotypic Interpretation Systems for the Selection of Antiretroviral Therapies

ABSTRACT OF PHD THESIS:

Infection with Human immunodeficiency virus type 1 (HIV-1) requires treatment with antiretroviral drugs. Without treatment, patients with HIV-1 infection develop symptoms referred to as acquired immunodeficiency syndrome (AIDS), ultimately leading to the death of the patient. The high productivity and variability of HIV-1 results in the continuous emergence of drug-resistant viral variants. In order to be able to suppress viral replication, several drug compounds must be used simultaneously in antiretroviral therapy. For this reason, a combination of drug compounds must be selected under consideration of the drug resistance of the virus and of the prospects that the drug combination has for attaining sustained therapeutic success.

Genotypic drug-resistance interpretation systems are frequently used for selecting combinations of antiretroviral drug compounds. These systems interpret HIV-1 genotypes in order to predict the susceptibility of the virus to each individual antiretroviral drug. However, the actual selection of an optimal drug combination needs to be carried out by the treating physician. In contrast, genotypic therapy-success interpretation systems provide their users with predictions for the success of antiretroviral drug combinations. However, a number of shortcomings of these systems have prevented them from reaching the bedside.

In this work, I present and validate novel methods for deriving genotype interpretation systems that are trained on HIV-1 data from routine clinical practice. All of these systems provide the user with an interpretation of their predictions. One system produces numbers called drug exposure scores (DES) for each available antiretroviral drug. DES are correlated with previous exposure of the virus to the drug and with drug resistance. I also present and validate methods for converting DES into clinically meaningful categories, such that they can readily be used by human experts for selecting optimal antiretroviral therapies. DES can be used as features for further analyses relating to antiretroviral therapy. I present a further, novel genotype interpretation system that is trained on DES to produce a prognostic score correlated with the time for which the antiretroviral therapy with a certain drug combination will remain effective.

The methods presented in this work represent an important advance in techniques for the interpretation of viral genotypes. Validation of the methods shows that their performance is comparable or, most frequently, superior to that of previously available methods. Their data-driven methodology allows for automatic retraining without the need for expert intervention. Their interpretability helps them gain the confidence of the users and delivers a rationale for predictions that could be considered surprising. Last but not least, the ability of the therapy-success interpretation system to consider cumulative, long-term therapeutic success allows it to produce predictions that are in line with the results of clinical studies.

Dr. Leonid PISHCHULIN

NATIONALITY: Russian

DEPARTMENT: Computer Vision and Multimodal Computing

THESIS TITLE:

Articulated People Detection and Pose Estimation in Challenging Real World Environments

ABSTRACT OF PHD THESIS:

In this thesis we are interested in the problem of articulated people detection and pose estimation being key ingredients towards understanding visual scenes containing people. Although extensive efforts are being made to address these problems, we identify three promising directions that, we believe, didn't get sufficient attention recently.

First, we investigate how statistical 3D human shape models from computer graphics can be leveraged to ease training data generation. We propose a range of automatic data generation techniques that allow to directly represent relevant variations in the training data. Sampling from both the underlying human shape distribution and a large dataset of human poses allows to generate novel samples with controllable shape and pose variations that are relevant for the task at hand. Furthermore, we improve the state-of-the-art 3D human shape model itself by re-building it from a large commercially available dataset of 3D bodies.

Second, we develop expressive spatial and strong appearance models for 2D single- and multi-person pose estimation. We propose an expressive single person model that incorporates higher order part dependencies while remaining efficient. We augment this model with various types of strong appearance representations aiming to substantially improve the body part hypotheses. Finally, we propose an expressive model for joint pose estimation of multiple people. To that end, we develop strong deep learning based body part detectors and an expressive fully connected spatial model. The proposed approach treats multi-person pose estimation as a joint partitioning and labeling prob-

lem of a set of body part hypotheses: it infers the number of persons in a scene, identifies occluded body parts and disambiguates body parts between people in close proximity of each other.

Third, we perform thorough evaluation and performance analysis of leading human pose estimation and activity recognition methods. To that end we introduce a novel benchmark that makes a significant advance in terms of diversity and difficulty, compared to the previous datasets, and includes over 40,000 annotated body poses and over 1.5 *M* frames. Furthermore, we provide a rich set of labels which are used to perform a detailed analysis of competing approaches gaining insights into successes and failures of these methods.

In summary, this thesis presents a novel approach to articulated people detection and pose estimation. Thorough experimental evaluation on standard benchmarks demonstrates significant improvements due to the proposed data augmentation techniques and novel body models, while detailed performance analysis of competing approaches on our newly introduced large-scale benchmark allows to identify the most promising directions of improvement.

Dr. Syama Sundar Yadav RANGAPURAM

NATIONALITY: **Indian**

DEPARTMENT: **Machine Learning**

THESIS TITLE:

Graph-based Methods for Unsupervised and Semi-supervised Data Analysis

ABSTRACT OF PHD THESIS:

Clustering and community detection are two important problems in data analysis with applications in various disciplines. Often in practice, there exists prior knowledge that helps the process of data analysis. In this thesis we develop generic graph-based methods for these data analysis problems both in unsupervised and semi-supervised settings. The main advantage of our methods is that they provide a common framework for integrating soft as well as hard prior knowledge. In the latter case, ours is the first method to have provable guarantees on the satisfaction of the given prior knowledge. The foundation of our methods is the exact continuous relaxation result that we derive for a class of combinatorial optimization problems. More specifically, we show that the (constrained) minimization of a ratio of set functions can be equivalently rewritten as a continuous optimization problem. We also present efficient algorithms for solving the continuous relaxations. While the global optimality is not guaranteed, in practice our methods consistently outperform the corresponding convex or spectral relaxations by a large margin. Moreover, our method has an additional guarantee that the solution respects the prior knowledge.

Bernhard REINERT

NATIONALITY: German
DEPARTMENT: Computer Graphics

THESIS TITLE:

Interactive, Example-driven Synthesis and Manipulation of Visual Media

ABSTRACT OF PHD THESIS:

This thesis proposes several novel techniques for interactive, example-driven synthesis and manipulation of visual media. The numerous display devices in our everyday lives make visual media, such as images, videos, or three-dimensional models, easily accessible to a large group of people. Consequently, there is a rising demand for efficient generation of synthetic visual content and its manipulation, especially by casual users operating on low-end, mobile devices. Off-the-shelf software supporting such tasks typically requires extensive training and in-depth understanding of the underlying concepts of content acquisition, on the one hand, and runs only on powerful desktop machines, on the other hand, limiting the possibility of artistic media generation to a small group of trained experts with appropriate hardware. Our proposed techniques aim to alleviate these requirements by allowing casual users to synthesize complex, high-quality content in real-time as well as to manipulate it by means of simple, example-driven interactions.

First, this thesis discusses a manipulation technique that visualizes an additional level of information, such as importance, on images and three-dimensional surface models by local, non-uniform, and self-intersection-free size manipulations. Second, we propose a technique to automatically arrange and sort collections of images based on the images' shape and a sparse set of exemplar images that builds on a novel distribution algorithm. Along this line, an extension for higher dimensions such as three-dimensional models is presented and the implications of distributions for lower-dimensional projections are discussed. Further, the spectral properties of the distributions are analyzed and the results are applied for efficient, high-quality image synthesis. Finally, we

suggest an algorithm to extract deformable, three-dimensional content from a two-dimensional video leveraging a simple limb representation that the user sketches onto a sparse set of key frames.

All methods build on the availability of massively parallel execution hardware, such as *graphics processing units* (GPUs), nowadays built also into cheap mobile devices. By mathematical abstraction, parallelization, and task distribution our algorithms achieve a high efficiency that allows running our methods in real-time on low-end devices.

Dr. Helge RHODIN

NATIONALITY: German
DEPARTMENT: Computer Graphics

THESIS TITLE:

From Motion Capture to Interactive Virtual Worlds: Towards Unconstrained Motion-Capture Algorithms for Real-time Performance-Driven Character Animation

ABSTRACT OF PHD THESIS:

This dissertation takes performance-driven character animation as a representative application and advances motion capture algorithms and animation methods to meet its high demands. Existing approaches have either coarse resolution and restricted capture volume, require expensive and complex multi-camera systems, or use intrusive suits and controllers.

For motion capture, set-up time is reduced using fewer cameras, accuracy is in- creased despite occlusions and general environments, initialization is automated, and free roaming is enabled by egocentric cameras. For animation, increased robustness enables the use of low-cost sensors input, custom control gesture definition is guided to support novice users, and animation expressiveness is increased. The important contributions are: 1) an analytic and differentiable visibility model for pose optimization under strong occlusions, 2) a volumetric contour model for automatic actor initialization in general scenes, 3) a method to annotate and augment image-pose databases automatically, 4) the utilization of unlabeled examples for character control, and 5) the generalization and disambiguation of cyclical gestures for faithful character animation. In summary, the whole process of human motion capture, processing, and application to animation is advanced. These advances on the state of the art have the potential to improve many interactive applications, within and outside virtual reality.

Dr. Srinath SRIDHAR

NATIONALITY: Indian
DEPARTMENT: Computer Graphics

THESIS TITLE:

Tracking Hands in Action for Gesture-based Computer Input

ABSTRACT OF PHD THESIS:

The ubiquity of modern computers in the form of smartphones, smartwatches, and virtual and augmented reality glasses has lead to the need to create new ways of computer input. Conventional input devices like the keyboard and the mouse can no longer be used for such emerging devices. The human hands are highly dexterous and could provide an always-on input capability through the use of gestures. In this thesis, we introduce new methods for markerless tracking of the full articulated motion of hands and using tracked motion for gesture-based computer input.

First, we contribute to computer vision-based markerless tracking of hands for use in computer input. This is a hard problem due to occlusions, uniform skin color, fast motions, and scene clutter. We show that combining novel representations for model-based tracking with discriminative learning techniques can result in mutually exclusive failure modes that help overcome some of the challenges. We show the benefit of our contributions in a variety of scenarios including varying number of cameras, viewpoints, and run-time requirements. We also show that our contributions can scale with scene complexity – it can be used, to our knowledge for the first time, to jointly track hands interacting with objects.

Second, we contribute to gesture-based input driven by markerless hand tracking. The design of appropriate interaction techniques and gestures is a hard problem because of the large design space, and human factors such as ergonomics. We show that gestures elicited from users can be used to develop interaction techniques for 3D navigation tasks. We then identify limitations

with elicitation studies and propose a novel method for computational gesture design. This allows designers, for the first time, to automatically generate gestures satisfying criteria such as speed or accuracy. Finally, we show that even limiting hand tracking to only fingertips can enable new input methods for small form factor devices such as smartphones. We conclude the thesis with a critical discussion about limitations and directions for future work.

Dr. Niket TANDON

NATIONALITY: **Indian**

DEPARTMENT: **Databases and Information Systems**

THESIS TITLE:

Commonsense Knowledge Acquisition and Applications

ABSTRACT OF PHD THESIS:

Computers are increasingly expected to make smart decisions based on what humans consider commonsense. This would require computers to understand their environment, including properties of objects in the environment (e.g., a wheel is round), relations between objects (e.g., two wheels are part of a bike, or a bike is slower than a car) and interactions of objects (e.g., a driver drives a car on the road).

The goal of this dissertation is to investigate automated method for acquisition of large-scale, semantically organized commonsense knowledge. This goal poses challenges because commonsense knowledge is: (i) *implicit and sparse* as humans do not explicitly express the obvious, (ii) *multimodal* as it is spread across textual and visual contents, (iii) *affected by reporting bias* as uncommon facts are reported disproportionally, (iv) *context dependent* and thus holds merely with a certain confidence. Prior state-of-the-art methods to acquire commonsense are either not automated or based on shallow representations. Thus, they cannot produce large-scale, semantically organized commonsense knowledge. To achieve the goal, we divide the problem space into three research directions, making up the core contributions of this dissertation:

- Properties of objects: acquisition of properties like hasSize, hasShape, etc. We develop WebChild, a semi-supervised method to compile semantically organized properties.

- Relationships between objects: acquisition of relations like largerThan, partOf, memberOf, etc. We develop CMPKB, a linear-programming based

method to compile comparative relations, and, we develop PWKB, a method based on statistical and logical inference to compile part-whole relations.

- Interactions between objects: acquisition of activities like drive a car, park a car, etc., with attributes such as temporal or spatial attributes. We develop Knowlywood, a method based on semantic parsing and probabilistic graphical models to compile activity knowledge.

Together, these methods result in the construction of a large, clean and semantically organized Commonsense Knowledge Base that we call WebChild KB.

Dr. Christina TEFLIOUDI

NATIONALITY: **Greece**
DEPARTMENT: **Databases and Information Systems**

THESIS TITLE:

Algorithms for Shared-Memory Matrix Completion and Maximum Inner Product Search

ABSTRACT OF PHD THESIS:

In this thesis, we propose efficient and scalable algorithms for shared-memory matrix factorization and maximum inner product search. Matrix factorization is a popular tool in the data mining community due to its ability to quantify the interactions between different types of entities. It typically maps the (potentially noisy) original representations of the entities into a lower dimensional space, where the "true" structure of the dataset is revealed. Inner products of the new vector representations are then used to measure the interactions between different entities. The *strongest* of these interactions are usually of particular interest in applications and can be retrieved by solving a maximum inner product search problem.

For large real-life problem instances of matrix factorization and maximum inner product search, efficient and scalable methods are necessary. We first study large-scale matrix factorization in a shared-memory setting and we propose a cache-aware, parallel method that avoids fine-grained synchronization or locking. In more detail, our approach partitions the initial large problem into small, cache-fitting sub-problems that can be solved independently using stochastic gradient descent. Due to the low cache-miss rate and the absence of any locking or synchronization, our method achieves superior performance in terms of speed (up to 60 % faster) and scalability than previously proposed techniques.

We then proceed with investigating the problem of maximum inner product search and design a cache-friendly framework that allows for both exact and approximate search. Our approach reduces the original maximum inner product search problem into a set of smaller cosine similarity search problems that

can be solved using existing cosine similarity search techniques or our novel algorithms tailored for use within our framework. Experimental results show that our approach is multiple orders of magnitude faster than naive search, consistently faster than alternative methods for exact search, and achieves better quality-speedup tradeoff (up to 3.9 x faster for similar recall levels) than state-of-the-art approximate techniques.

Dr. Krzysztof TEMPLIN

NATIONALITY: Polish
DEPARTMENT: Computer Graphics

THESIS TITLE:

Depth, Shading, and Stylization in Stereoscopic Cinematography

ABSTRACT OF PHD THESIS:

Due to the constantly increasing focus of the entertainment industry on stereoscopic imaging, techniques and tools that enable precise control over the depth impression and help to overcome limitations of the current stereoscopic hardware are gaining in importance. In this dissertation, we address selected problems encountered during stereoscopic content production, with a particular focus on stereoscopic cinema. First, we consider abrupt changes of depth, such as those induced by cuts in films. We derive a model predicting the time the visual system needs to adapt to such changes and propose how to employ this model for film cut optimization. Second, we tackle the issue of discrepancies between the two views of a stereoscopic image due to view-dependent shading of glossy materials. The suggested solution eliminates discomfort caused by non-matching specular highlights while preserving the perception of gloss. Last, we deal with the problem of film grain management in stereoscopic productions and propose a new method for film grain application that reconciles visual comfort with the idea of medium-scene separation.

Dr. Beata TURONOVA

NATIONALITY: Czech
DEPARTMENT: Computer Graphics

THESIS TITLE:

Progressive Stochastic Reconstruction Technique for Cryo Electron Tomography

ABSTRACT OF PHD THESIS:

Cryo Electron Tomography (cryoET) plays an essential role in Structural Biology, as it is the only technique that allows us to study the structure of large macromolecular complexes in their close to native environment in situ. The reconstruction process is a challenging task as the single-tilt acquisition scheme imposes severe limitation on the input projections. High-resolution protocols such as Subtomogram Averaging (SA) can alleviate some of these limitations. Results of these protocols are highly dependent on the quality of the reconstruction. State-of-the-art methods deliver low-contrast and noisy reconstructions, which complicates their processing during the SA.

In this thesis we focus on improvement of the quality of tomograms in cryoET in order to facilitate their subsequent processing. We propose a Progressive Stochastic Reconstruction Technique (PSRT) – a novel iterative approach to tomographic reconstruction in cryoET that is based on Monte Carlo random walks. We design a progressive scheme to suit conditions present in cryoET and integrate PSRT into the SA pipeline, where it delivers high-contrast reconstructions that significantly improve template-based localization without any loss of high-resolution structural information. Furthermore, we perform a systematic study of the geometry-related acquisition artifacts and draw recommendations regarding the mutual influence of these artifacts and implications to the interpretation of both cryoET and SA experiments.

Dr. Mohamed YAHYA

NATIONALITY: **Palestinian**
DEPARTMENT: **Databases and Information Systems**

THESIS TITLE:

Question Answering and Query Processing for Extended Knowledge Graphs

ABSTRACT OF PHD THESIS:

Knowledge graphs have seen wide adoption, in large part owing to their schemaless nature that enables them to grow seamlessly, allowing for new relationships and entities as needed. With this rapid growth, several issues arise: (i) how to allow users to query knowledge graphs in an expressive and user-friendly manner, which shields them from all the underlying complexity, (ii) how, given a structured query, can we return satisfactory answers to the user despite possible mismatches between the query vocabulary and structure and the knowledge graph, and (iii) how to automatically acquire new knowledge, which can be fed into a knowledge graph. In this dissertation, we make the following contributions to address the above issues:

- We present DEANNA, a framework for question answering over knowledge graphs, allowing users to easily express complex information needs using natural language and obtain tuples of entities as answers thereby taking advantage of the structure in the knowledge graph.

- We introduce TriniT, a framework that compensates for unsatisfactory results of structured queries over knowledge graphs, either due to mismatches with the knowledge graph or the knowledge graph's inevitable incompleteness. TriniT tackles the two issues by extending the knowledge graph using information extraction over textual corpora, and supporting query relaxation where a user's query is rewritten in a manner transparent to the user to compensate for any mismatches with the data.

- We present ReNoun, an open information extraction framework for extracting binary relations mediated by noun phrases and their instances from text. Our scheme extends the state-of-the-art in open information extraction which has thus far focused on relations mediated by verbs.

Our experimental evaluations of each of the above contributions demonstrate the effectiveness of our methods in comparison to state-of-the-art approaches.

Current Students

Current Students: M.Sc.*

Name	Nationality
ABDELFATTAH ABOUHAMRA, Mostafa Ahmed	*Egyptian*
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AMANOVA, Dilafruz	*Uzbek*
ANTONYAN, Rafaella	*Uzbek*
CAO, Han	*Chinese*
CHEEMA, Noshaba	*German*
DIVO, Michaël	*French*
FIERARU, Mihai	*Romanian*
GANGULY, Soumen	*Indian*
GROVER, Priyanka	*Indian*
HAILU, Haftom Meles	*Ethiopian*
HEINEN, Tobias	*German*
HO, Vinh Thinh	*Vietnamese*
KLINGER, Christian	*German*
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NUKHAYEV, Maxat	*Kazakh*
PONPATHIRKOOTTAM, Shreeraman	*Indian*
RAKHMANBERDIEVA, Nurzat	*Kyrgyz*
RAMIREZ CHAVEZ, LUIS ENRIQUE	*Mexican*
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RIAHI, Siavash	*Iranian*
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SCHENCK, Michael	*German*
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* Master's students are assigned a scientific supervisor and become members of a research group when they start work on their thesis. Until then, therefore, they are supervised by the IMPRS-CS coordinator, Jennifer Gerling.

Name	Supervisor(s)	Department	Nationality
ABUJABAL, Abdalghani	Gerhard Weikum	Databases and Information Systems	*Palestinian*
ALAGI, Gábor	Christoph Weidenbach	Automation of Logic	*Hungarian*
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BASTYS, Tomas	Olga Kalinina	Computational Biology and Applied Algorithmics	*Lithuanian*
BECKER, Ruben	Andreas Karrenbauer	Algorithms and Complexity	*German*
BEHJATI ARDAKANI, Fatemeh	Marcel Schulz	High-throughput Genomics and Systems Biology	*Iranian*
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BIEGA, Joanna	Gerhard Weikum	Databases and Information Systems	*Polish*
BOLDYREVA, Natalia	Gerhard Weikum, Marc Spaniol	Databases and Information Systems	*Russian*
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BUDHATHOKI, Kailash	Jilles Vreeken	Exploratory Data Analysis	*Nepali*
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GRYCNER, Adam	Gerhard Weikum	Databases and Information Systems	*Polish*
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Name	Supervisor(s)	Department	Nationality
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IBRAHIM, Yusra	Gerhard Weikum	Databases and Information Systems	*Egyptian*
INSAFUTDINOV, Eldar	Bernt Schiele	Computer Vision and Multimodal Computing	*Russian*
ISSAC, Davis	Andreas Karrenbauer	Algorithms and Complexity	*Indian*
JINDAL, Gorav	Markus Bläser, Kurt Mehlhorn	Computational Complexity	*Indian*
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NALBACH, Oliver	Tobias Ritschel	Computer Graphics	*German*
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Awards

AWARDS

The following IMPRS-CS students received awards for their work in 2016:

Name of student	Award
Franziska Müller	Günter Hotz Medal
Franziska Müller	Stiftungspreis der "Erich-Ferdinand-Bläse-Stiftung für Forschung und Wissenschaft"
Kailash Budhathoki	Young Researcher at the Heidelberg Laureate Forum 2016, Heidelberg
Omar Darwish	Günter Hotz Medal
Sandy Heydrich	Google European Doctoral Fellowship
Sanjar Karaev	ECML PKDD '16 Best Student Paper Award
Siyu Tang	Winner of the Multi-Object Tracking Challenge at ECCV 2016
Vahid Hashemi	SIGAPP travel fellowship for ACM SAC 2016

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COMPUTER SCIENCE