Yearbook 2013




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 2013

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.

Alumni: M.Sc.

Elham AFSARI YEGANEH

NATIONALITY: Iranian
DEPARTMENT: Computer Graphics

THESIS TITLE:

Human Motion Alignment Using a Depth Camera

ABSTRACT OF MASTER'S THESIS:

The focus of this thesis is on alignment of human motion semantically meaningful and the thesis presents work within four major steps, namely motion capture, dimension reduction, finding optimal aligned path, and pose correction in RGB images. The input of our method is several mocap data in which a person is performing an action like walking but in his or her own style. The mocap data is provided by the Kinect camera as a depth camera to capture both depth and RGB information.

Component analysis is often important step in the analysis of human motion. By extracting informative components the subsequent analysis can be efficient. This thesis uses two components analysis methods, principal component analysis and independent component analysis which are capable of extracting important features of given motions. The user is able to specify number of components and change corresponding components from each motion for further steps.

Within finding optimal alined path the thesis utilizes dynamic time warping (DTW) algorithm for computing corresponding poses between given motion sequences. To determine the similarity between the frames of the two sequences to be aligned, we introduce local cost measures which computes all pairwise Euclidean distances between the sequences. In this step, a user is able to interactively control constraints of dynamic time warping process, which results in a better performance and more desirable for the user.

Pose correction in RGB images as final step of our work is achievable by changing a pose of the source motion to a specified pose of the target motion. As alignment results can be seen in RGB video, the user can interactively specify poses to be corrected.

Razvan BELET

NATIONALITY: Romanian
DEPARTMENT: Databases and Information Systems

THESIS TITLE:

Leveraging Independence and Locality for Random Forests in a Distributed Environment

ABSTRACT OF MASTER'S THESIS:

With the emergence of big data, inducting regression trees on very large data sets became a common data mining task. Even though centralized algorithms for computing ensembles of Classification/Regression trees are a well-studied machine learning/data mining problem, their distributed versions still raise scalability, efficiency and accuracy issues.

Most state of the art tree learning algorithms require data to reside in memory on a single machine. Adopting this approach for trees on big data is not feasible as the limited resources provided by only one machine lead to scalability problems. While more scalable implementations of tree learning algorithms have been proposed, they typically require specialized parallel computing architectures rendering those algorithms complex and error-prone.

In this thesis we will introduce two approaches to computing ensembles of regression trees on very large training data sets using the MapReduce framework as an underlying tool. The first approach employs the entire MapReduce cluster to parallely and fully distributedly learn tree ensembles. The second approach exploits locality and independence in the tree learning process.

Artem BOLDYREV

NATIONALITY: Russian
DEPARTMENT: Databases and Information Systems

THESIS TITLE:

Dictionary-Based Named Entity Recognition

ABSTRACT OF MASTER'S THESIS:

An important task in information extraction is the recognition of named entities in natural language texts, NER for short. A named entity is a phrase presenting an item of a class. This work represents a dictionary-based NER framework. It uses multiple dictionaries, which are freely available on the Web. A dictionary is a collection of phrases that describe named entities. The framework is composed of two stages: (1) *detection of named entity candidates* using dictionaries for lookups and (2) *filtering of false positives* based on a part-of-speech tagger. Dictionary lookups are performed using an efficient prefix-tree data structure. Optionally, additional filters using word-form-based evidence can be applied to increase precision and recall of the recognition. Most of the existing approaches for NER use machine learning techniques. The main drawback of these systems is the manual effort needed for the creation of labeled training data. Our dictionary-based recognizer does not need labeled text as training data. Furthermore, the dictionary-based framework can be applied to any language that is supported by a part-of-speech tagger. Our dictionary-based recognizer performs on German with up to 89.01 % precision at 77.64 % recall and 81.60 % F1 score, improving Stanford's NER by five percentage points for precision, recall, and F1 score.

Lavinia DINU

NATIONALITY: Romanian
DEPARTMENT: Theoretical Computer Science

THESIS TITLE:

Randomized Median-of-Three Trees

ABSTRACT OF MASTER'S THESIS:

This thesis introduces a new type of randomized search trees based on the median-of three improvement for quicksort (M3 quicksort). We consider the set of trees obtained by running M3 quicksort. This thesis show how to obtain them by a slightly changed insertion procedure for binary search trees. Furthermore, if the input is random, it generates the same probability distribution as M3 quicksort and consequently accesses in the tree are faster than for randomized search trees. In order to maintain randomness for any type of input sequence, we introduce the concept of support nodes, which define a path covering of the tree. With their help, and by storing the subtree size at each node, random updates take $O(\log n)$. If instead of subtree sizes, each node stores a random priority, updates take $O(\log^2 n)$ Experiments show that while accesses are indeed faster, update times take however too long for the method to be competitive.

Mandana EGHBALI

NATIONALITY: Iranian
DEPARTMENT: Computer Graphics

THESIS TITLE:

Facial Performance Capture Using a Single Kinect Camera

ABSTRACT OF MASTER'S THESIS:

Facial Performance Capture has a significant role in nowadays animation and video games products in order to provide photorealistic digital faces since the realistic characters are capable of transferring emotions and compelling storytelling. Although there many of significant methods are presented by the last recent years researches in this field, many of these methods have a limited applications because of the complex and professional camera setups they need to follow and use. Therefore in this thesis we aim to introduce a new approach to the facial performance capture which can be used by any unprofessional users in order to track the complex facial expressions in noisy depth and color images captured using a single Kinect camera. The presented method in this work can be used by any Kinect user in order to easily make their digital selves and track their performed facial expressions on the extracted digital character. Unlike many of the available approaches which are limited to the special studios and control lighting conditions, our method can perfectly perform in any indoor environments. Therefore using this method any Kinect user would be able to capture him/her facial expressions and map them on his/her facial animation. Producing a believable performance of a digital human face as a home application, once impossible, is now achievable through the presented approach in this thesis by means of Microsoft Kinect technology.

Evica ILIEVA

NATIONALITY: Macedonian

DEPARTMENT: Querying, Indexing, and Discovery in Dynamic Data

THESIS TITLE:

Analyzing and Creating Top-K Entity Rankings

ABSTRACT OF MASTER'S THESIS:

Rankings are everywhere since everything can and is being ranked. Restaurants are ranked by their service, cities by their cost of living, countries by their economic development, cars by their speed etc. Especially in recent years the popularity and importance of such rankings has been constantly increasing.

This thesis presents a study that describes characteristics, such as size and thematic focus, of entity rankings that originate from crowd sourced user votes on the Web. The frequency in which different types of rankings are generated gives insights on the importance of the various ingredients of a ranking and is further complemented by including the popularity of rankings in terms of attracted user views. Furthermore, the study also focuses on learning the dynamics of entity rankings.

In the second part of this thesis, we consider the task of automatically phrasing and computing top-k rankings over the information contained in common knowledge bases (KBs), such as YAGO or DBpedia. We assemble the thematic focus and ranking criteria of rankings by inspecting the present Subject, Predicate, Object (SPO) triples. Making use of numerical attributes contained in the KB we are also able to compute the actual ranking content, i.e., entities and their performances. We further discuss the integration of existing rankings into the ranking generation process for increased coverage and ranking quality. We report on first results obtained using the YAGO knowledge base.

Pavel KOLEV

NATIONALITY: **Bulgarian**
DEPARTMENT: **Algorithms and Complexity**

THESIS TITLE:

Community Analysis Using Local Random Walks

ABSTRACT OF MASTER'S THESIS:

The problem of graph clustering is a central optimization problem with various applications in numerous fields including computational biology, machine learning, computer vision, data mining, social network analysis, VLSI design and many more. Essentially, clustering refers to grouping objects with similar properties in the same cluster. Designing an appropriate similarity measure is currently a state of the art process and it is highly depended on the underlying application. Generally speaking, the problem of graph clustering asks to find subsets of vertices that are well-connected inside and sparsely connected outside.

Motivated by large-scale graph clustering, we investigate *local* algorithms, based on random walks, that find a set of vertices near a given starting vertex with good worst case approximation guarantees. The running time of these algorithms is nearly linear in the size of the output set and is independent of the size of the whole graph. This feature makes them perfect subroutines in the design of efficient parallel algorithms for graph clustering.

Evgeny LEVINKOV

NATIONALITY: Russian

DEPARTMENT: Computer Vision and Multimodal Computing

THESIS TITLE:

Scene Segmentation in Adverse Vision Conditions

ABSTRACT OF MASTER'S THESIS:

Semantic Image Segmentation is the task of segmenting images into homogeneous regions with semantic meaning. In Computer Vision it means assigning a class-label from a known set of classes to every pixel in the image. The standard approach is to take some sample data, divide it into training and testing sets, and to learn the class distribution on the training set, followed by checking the quality of the achieved generalization on the testing set. The generalization ability of the standard approaches is based on the assumption that the underlying class distribution does not change in both training and testing sets and does not evolve with time.

In this work we want to investigate in the problem of performing image segmentation in particularly difficult visual conditions. We want to look specifically into the conditions when the class distribution does change with time, which creates problems for the standard approaches.

As all the datasets, that are currently used in the image segmentation community, try not to break the constant class distribution assumption, we propose a new testing set, which exhibits significant variations in visual appearance of different classes and contains the class distribution different from the one in the training set.

We evaluate a number of standard approaches for image segmentation based on Conditional Random Fields, employing general and more specialized features. We look into the possible ways of performing adaptation to new conditions by means of online learning methods and propose our ideas on how to improve the generalization over previously unseen conditions without experiencing model drift.

Viktor MUKHA

NATIONALITY: **Russian**
DEPARTMENT: **Computer Graphics**

THESIS TITLE:

Real-time Display Reconfiguration within Multi-display Environments

ABSTRACT OF MASTER'S THESIS:

Multi-display environments (MDEs) of all kinds are used a lot nowadays. A wide variety of devices helps to build a common display space. TVs, monitors, projected surfaces, phones, tablets, everything that has the ability to display visual information can be incorporated in multi-display environments.

While the main research emphasis so far has been on interaction techniques and user experience within different MDEs, some research topics are dealing with static and dynamic display reconfiguration. In fact, several studies already work with MDEs that are capable of display reconfiguration on-the-fly. Different frameworks can perform splitting, streaming and rendering of visual data on large-scale displays with the ability of dynamic display reconfiguration to calibrate multiple-projectors or to combine different heterogeneous displays into one display wall dynamically. However, all of these frameworks require different approaches for display reconfiguration. Our goal is to create a model for display reconfiguration which will be abstract, transparent, will work in real-time, and will be easily deployable in any MDE.

In this work we present an extension to a software framework called Display as a Service (DaaS). This extension is represented as a model for real-time display reconfiguration using DaaS. The DaaS framework allows for generic and transparent management of pixel transport assuming only a network connection, providing a simple high-level implementation for pixel-producing and pixel-displaying applications. The main limitation of this approach is a certain delay between pixel generation and display. However, the video encoding and network transport are subject of improvements which will solve the problem in the future.

As a proof of concept, we demonstrate three usage scenarios: manual dynamic display reconfiguration, automatic display calibration, and real-time display tracking. We also present a new algorithm for precise display calibration using markers and a handheld camera. The calibration results are evaluated using different tracking libraries. The additional precise calibration part for our proposed algorithm makes the calibration accuracy several times better compared to a naive approach.

Anastasia PODOSINNIKOVA

NATIONALITY: Russian
DEPARTMENT: Machine Learning

THESIS TITLE:

Robust Principal Component Analysis as a Nonlinear Eigenproblem

ABSTRACT OF MASTER'S THESIS:

Principal Component Analysis (PCA) is a widely used tool for, e.g., exploratory data analysis, dimensionality reduction and clustering. However, it is well known that PCA is strongly affected by the presence of outliers and, thus, is vulnerable to both gross measurement error and adversarial manipulation of the data. This phenomenon motivates the development of robust PCA as the problem of recovering the principal components of the uncontaminated data.

In this thesis, we propose two new algorithms, QRPCA and MDRPCA, for robust PCA components based on the projection-pursuit approach of Huber. While the resulting optimization problems are non-convex and non-smooth, we show that they can be efficiently minimized via the RatioDCA using bundle methods/accelerated proximal methods for the interior problem. The key ingredient for the most promising algorithm (QRPCA) is a robust, location invariant scale measure with breakdown point 0.5. Extensive experiments show that our QRPCA is competitive with current state-of-the-art methods and outperforms other methods in particular for a large number of outliers.

Maxim REZNITSKII

NATIONALITY: Canadian
DEPARTMENT: Mathematical Image Analysis

THESIS TITLE:

Stereo Vision under Adverse Conditions

ABSTRACT OF MASTER'S THESIS:

Autonomous Driving benefits strongly from a 3D reconstruction of the environment in real-time, often obtained via stereo vision. Semi-Global Matching (SGM) is a popular method of choice for solving this task and is already in use for production vehicles. Despite the enormous progress in the field and the high performance of modern methods, one key challenge remains: stereo vision in automotive scenarios during difficult weather or illumination conditions. Current methods generate strong temporal noise, many disparity outliers, and false positives on a segmentation level. This work addresses these issues by formulating a temporal prior and a scene prior and applying them to SGM. For image sequences captured on a highway during rain, during snowfall, or in low light, these priors significantly improve the object detection rate while reducing the false positive rate. The algorithm also outperforms the ECCV Robust Vision Challenge winner, iSGM.

Alumni: PhD

Dr. Avishek ANAND

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

DISSERTATION TITLE:

Indexing Methods for Web Archives

ABSTRACT OF PHD THESIS:

There have been numerous efforts recently to digitize previously published content and preserving born-digital content leading to the widespread growth of large text repositories. Web archives are such continuously growing text collections which contain versions of documents spanning over long time periods. Web archives present many opportunities for historical, cultural and political analyses. Consequently there is a growing need for tools which can efficiently access and search them.

In this work, we are interested in indexing methods for supporting text-search workloads over web archives like *time-travel queries and phrase queries*. To this end we make the following contributions:

- Time-travel queries are keyword queries with a temporal predicate, e.g., “mpii saarland” @ [06/2009], which return versions of documents in the past. We introduce a novel index organization strategy, called *index sharding*, for efficiently supporting time-travel queries without incurring additional index-size blowup. We also propose index-maintenance approaches which scale to such continuously growing collections.
- We develop query-optimization techniques for time-travel queries called *partition selection* which maximizes recall at any given query-execution stage.
- We propose indexing methods to support phrase queries, e.g., “to be or not to be that is the question”. We index multi-word sequences and devise novel queryoptimization methods over the indexed sequences to efficiently answer phrase queries.

We demonstrate the superior performance of our approaches over existing methods by extensive experimentation on real-world web archives.

Dr. Oana-Madalina CIOBOTARU

NATIONALITY: **Romanian**
DEPARTMENT: **Information Security and Cryptography**

DISSERTATION TITLE:

Rational Cryptography: Novel Constructions, Automated Verification and Unified Definitions

ABSTRACT OF PHD THESIS: :

Rational cryptography has recently emerged as a very promising field of research by combining notions and techniques from cryptography and game theory, because it offers an alternative to the rather inflexible traditional cryptographic model. In contrast to the classical view of cryptography where protocol participants are considered either honest or arbitrarily malicious, rational cryptography models participants as rational players that try to maximize their benefit and thus deviate from the protocol only if they gain an advantage by doing so.

The main research goals for rational cryptography are the design of more efficient protocols when players adhere to a rational model, the design and implementation of automated proofs for rational security notions and the study of the intrinsic connections between game theoretic and cryptographic notions. In this thesis, we address all these issues.

First we present the mathematical model and the design for a new rational file sharing protocol which we call RatFish. Next, we develop a general method for automated verification for rational cryptographic protocols and we show how to apply our technique in order to automatically derive the rational security property for RatFish. Finally, we study the intrinsic connections between game theory and cryptography by defining a new game theoretic notion, which we call game universal implementation, and by showing its equivalence with the notion of weak stand-alone security.

Dr. Miguel A. GRANADOS VELÁSQUEZ

NATIONALITY: **Colombian**
DEPARTMENT: **Computer Graphics**

DISSERTATION TITLE:

Advanced Editing Methods for Image and Video Sequences

ABSTRACT OF PHD THESIS:

In the context of image and video editing, this thesis proposes methods for modifying the semantic content of a recorded scene. Two different editing problems are approached: First, the removal of ghosting artifacts from high dynamic range (HDR) images recovered from exposure sequences, and second, the removal of objects from video sequences recorded with and without camera motion. These editings need to be performed in a way that the result looks plausible to humans, but without having to recover detailed models about the content of the scene, e.g. its geometry, reflectance, or illumination.

The proposed editing methods add new key ingredients, such as camera noise models and global optimization frameworks, that help achieving results that surpass the capabilities of state-of-the-art methods. Using these ingredients, each proposed method defines local visual properties that approximate well the specific editing requirements of each task. These properties are then encoded into a energy function that, when globally minimized, produces the required editing results. The optimization of such energy functions corresponds to Bayesian inference problems that are solved efficiently using graph cuts.

The proposed methods are demonstrated to outperform other state-of-the-art methods. Furthermore, they are demonstrated to work well on complex real-world scenarios that have not been previously addressed in the literature, i.e., highly cluttered scenes for HDR deghosting, and highly dynamic scenes and unconstraint camera motion for object removal from videos.

Dr. Thomas HELTEN

NATIONALITY: German
DEPARTMENT: Computer Graphics

DISSERTATION TITLE:

Processing and Tracking Human Motions Using Optical, Inertial, and Depth Sensors

ABSTRACT OF PHD THESIS:

The processing of human motion data constitutes an important strand of research with many applications in computer animation, sport science and medicine. Currently, there exist various systems for recording human motion data that employ sensors of different modalities such as optical, inertial and depth sensors. Each of these sensor modalities have intrinsic advantages and disadvantages that make them suitable for capturing specific aspects of human motions as, for example, the overall course of a motion, the shape of the human body, or the kinematic properties of motions. In this thesis, we contribute with algorithms that exploit the respective strengths of these different modalities for comparing, classifying, and tracking human motion in various scenarios. First, we show how our proposed techniques can be employed, e. g., for real-time motion reconstruction using efficient cross-modal retrieval techniques. Then, we discuss a practical application of inertial sensors-based features to the classification of trampoline motions. As a further contribution, we elaborate on estimating the human body shape from depth data with applications to personalized motion tracking. Finally, we introduce methods to stabilize a depth tracker in challenging situations such as in presence of occlusions. Here, we exploit the availability of complementary inertial-based sensor information.

Dr. Tomasz JURKIEWICZ

NATIONALITY: **Polish**
DEPARTMENT: **Algorithms and Complexity**

DISSERTATION TITLE:

Toward Better Computation Models for Modern Machines

ABSTRACT OF PHD THESIS:

Modern computers are not random access machines (RAMs). They have a memory hierarchy, multiple cores, and a virtual memory. We address the computational cost of the address translation in the virtual memory and difficulties in design of parallel algorithms on modern many-core machines.

Starting point for our work on virtual memory is the observation that the analysis of some simple algorithms (random scan of an array, binary search, heapsort) in either the RAM model or the EM model (external memory model) does not correctly predict growth rates of actual running times. We propose the VAT model (virtual address translation) to account for the cost of address translations and analyze the algorithms mentioned above and others in the model. The predictions agree with the measurements. We also analyze the VAT-cost of cache-oblivious algorithms.

In the second part of the paper we present a case study of the design of an efficient 2D convex hull algorithm for GPUs. The algorithm is based on *the ultimate planar convex hull algorithm* of Kirkpatrick and Seidel, and it has been referred to as *the first successful implementation of the QuickHull algorithm on the GPU* by Gao et al. in their 2012 paper on the 3D convex hull. Our motivation for work on modern many-core machines is the general belief of the engineering community that the theory does not produce applicable results, and that the theoretical researchers are not aware of the difficulties that arise while adapting algorithms for practical use. We concentrate on showing how the high degree of parallelism available on GPUs can be applied to problems that do not readily decompose into many independent tasks.

Dr. Jens KERBER

NATIONALITY: German
DEPARTMENT: Computer Graphics

DISSERTATION TITLE:

Of Assembling Small Sculptures and Disassembling Large Geometry

ABSTRACT OF PHD THESIS:

This thesis describes the research results and contributions that have been achieved during the author's doctoral work. It is divided into two independent parts, each of which is devoted to a particular research aspect.

The first part covers the true-to-detail creation of digital pieces of art, so-called relief sculptures, from given 3D models. The main goal is to limit the depth of the contained objects with respect to a certain perspective without compromising the initial three-dimensional impression. Here, the preservation of significant features and especially their sharpness is crucial. Therefore, it is necessary to overemphasize fine surface details to ensure their perceptibility in the more complanate relief. Our developments are aimed at amending the flexibility and user-friendliness during the generation process. The main focus is on providing real-time solutions with intuitive usability that make it possible to create precise, lifelike and aesthetic results. These goals are reached by a GPU implementation, the use of efficient filtering techniques, and the replacement of user defined parameters by adaptive values. Our methods are capable of processing dynamic scenes and allow the generation of seamless artistic reliefs which can be composed of multiple elements.

The second part addresses the analysis of repetitive structures, so-called symmetries, within very large data sets. The automatic recognition of components and their patterns is a complex correspondence problem which has numerous applications ranging from information visualization over compression to automatic scene understanding. Recent algorithms reach their limits with a growing amount of data, since their runtimes rise quadratically. Our aim is to

make even massive data sets manageable. Therefore, it is necessary to abstract features and to develop a suitable, low-dimensional descriptor which ensures an efficient, robust, and purposive search. A simple inspection of the proximity within the descriptor space helps to significantly reduce the number of necessary pairwise comparisons. Our method scales quasi-linearly and allows a rapid analysis of data sets which could not be handled by prior approaches because of their size.

Dr. Evgeny KRUGLOV

NATIONALITY: **Russian**
DEPARTMENT: **Automation of Logic**

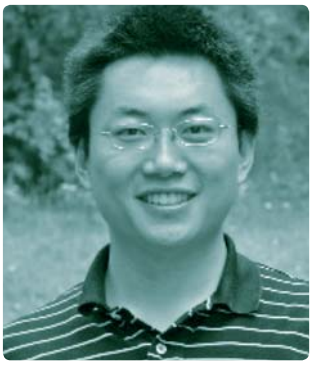
DISSERTATION TITLE:

Superposition Modulo Theory

ABSTRACT OF PHD THESIS:

This thesis is about the Hierarchic Superposition calculus SUP(T) and its application to reasoning in hierarchic combinations FOL(T) of the free first-order logic FOL with a background theory T where the hierarchic calculus is refutationally complete or serves as a decision procedure. Particular hierarchic combinations covered in the thesis are the combinations of FOL and linear and non-linear arithmetic, LA and NLA resp.

Recent progress in automated reasoning has greatly encouraged numerous applications in soft- and hardware verification and the analysis of complex systems. The applications typically require to determine the validity/unsatisfiability of quantified formulae over the combination of the free first-order logic with some background theories. The hierarchic superposition leverages both (i) the reasoning in FOL equational clauses with universally quantified variables, like the standard superposition does, and (ii) powerful reasoning techniques in such theories as, e.g., arithmetic, which are usually not (finitely) axiomatizable by FOL formulae, like modern SMT solvers do. The thesis significantly extends previous results on SUP(T), particularly: we introduce new substantially more effective sufficient completeness and hierarchic redundancy criteria turning SUP(T) to a complete ora decision procedure for various FOL(T) fragments; instantiate and refine SUP(T) to effectively support particular combinations of FOL with the LA and NLA theories enabling a fully automatic mechanism of reasoning about systems formalized in FOL(LA) or FOL(NLA).



Dr. Tianxiang LU

NATIONALITY: **Chinese**
DEPARTMENT: **Automation of Logic**

DISSERTATION TITLE:

Formal Verification of the Pastry Protocol

ABSTRACT OF PHD THESIS:

Pastry is a structured *P2P* algorithm realizing a Distributed Hash Table *(DHT)* over an underlying virtual ring of nodes. Hash keys are assigned to the numerically closest node, according to their Ids that both keys and nodes share from the same Id space. Nodes join and leave the ring dynamically and it is desired that a lookup request from arbitrary node for a key is routed to the responsible node for that key which then delivers the message as answer.

Several implementations of Pastry are available and have been applied in practice, but no attempt has so far been made to formally describe the algorithm or to verify its properties. Since Pastry combines rather complex data structures, asynchronous communication, concurrency, resilience to *churn*, i.e. spontaneous join and departure of nodes, it makes an interesting target for verification.

This thesis formally models and improves Pastry's core algorithms, such that they provide the correct lookup service in the presence of churn and maintain a local data structures to adapt the dynamic updates of neighborhood.

This thesis focuses on Join protocol of Pastry and formally defines different statuses (from "dead" to "ready") of a node according to its stage during join. Only "ready" nodes are suppose to have consistent key mapping among each other and are allowed to deliver the answer message. The correctness property is identified by this thesis to be *CorrectDelivery*, stating that there is always at most one node that can deliver an answer to a lookup request for a key and this node is the numerically closest "ready" node to that key. This property is non-trivial to preserve in the presence of *churn*.

The specification language TLA+ is used to model different versions of Pastry algorithm starting with CastroPastry, followed by HaeberlenPastry, IdealPastry and finally LuPastry. The TLA+ model checker TLC is employed to validate the models and to search for bugs. Validation ensures that the system has at least some useful executions; model analysis helps to discover unexpected corner cases to improve the model. Models are simplified for more efficient checking with TLC and consequently mitigating the state explosion problem.

Through this thesis, unexpected violations of *CorrectDelivery* in CastroPastry and HaeberlenPastry are discovered and analyzed. Based on the analysis, HaeberlenPastry is improved to a new design of the Pastry protocol IdealPastry, which is first verified using the interactive theorem prover TLAPS for TLA+. IdealPastry assumes that a "ready" node handles one joining node at a time and it assumes that (1) no departure of nodes (2) no concurrent join between two "ready" nodes closed to each other. The last assumption of IdealPastry is removed by its improved version LuPastry. In LuPastry, a "ready" node adds the joining node directly when it receives the join request and does not accepts any further join request until it gets the confirmation from the current joining node that it is "ready". LuPastry is proved to be correct w.r.t. *CorrectDelivery* under the assumption that no nodes leave the network, which cannot be further relaxed due to possible network separation when particular nodes simultaneously leave the network.

The most subtle part of the deductive system verification is the search for an appropriate inductive invariant which implies the required safety property and is inductively preserved by all possible actions. The search is guided by the construction of the proof, where TLC is used to discover unexpected violations of a hypothetical invariant postulated in an earlier stage. The final proof of LuPastry consists of more than 10,000 proof steps, which are interactively checked in time by using TLAPS launching different back-end automated theorem provers.

This thesis serves also as a case study giving the evidence of possibility and the methodology of how to formally model, to analyze and to manually conduct a formal proof of complex transition system for its safety property. Using LuPastry as template, a more general framework on verification of *DHT* can be constructed.

Dr. Kaustubh R. PATIL

NATIONALITY: Indian
DEPARTMENT: Computational Genomics and Epidemiology

DISSERTATION TITLE:

Genome Signature Based Sequence Comparison for Taxonomic Assignment and Tree Inference

ABSTRACT OF PHD THESIS:

In this work we consider the use of the genome signature for two important bioinformatics problems; the taxonomic assignment of metagenome sequences and tree inference from whole genomes. We look at those problems from a sequence comparison point of view and propose machine learning based methods as solutions. For the first problem, we propose a novel method based on structural support vector machines that can directly predict paths in a tree implied by evolutionary relationships between taxa. The method is based on an ensemble strategy to predict highly specific assignments for varying length sequences arising from metagenome projects. Through controlled experimental analyses on simulated and real data sets we show the benefits of our method under realistic conditions.

For the task of genome tree inference we propose a metric learning method. Based on the assumption that for different groups of prokaryotes, as defined by their phylogeny, genomic or ecological properties, different oligonucleotide weights can be more informative, our method learns group-specific distance metrics. We show that, indeed, it is possible to learn specific distance metrics that provide improved genome trees for the groups.

In the outlook, we expect that for the addressed problems the work of this thesis will complement and in some cases even outperform alignment-based sequence comparison at a considerably reduced computational cost, allowing it to keep up with advancements in sequencing technologies.

Dr. Lizhen QU

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

DISSERTATION TITLE:

Sentiment Analysis with Limited Training Data

ABSTRACT OF PHD THESIS:

Sentiments are positive and negative emotions, evaluations and stances. This dissertation focuses on learning based systems for automatic analysis of sentiments and comparisons in natural language text. The proposed approach consists of three contributions:

1. **Bag-of-opinions model:** For predicting document-level polarity and intensity, we proposed the bag-of-opinions model by modeling each document as a bag of sentiments, which can explore the syntactic structures of sentiment-bearing phrases for improved rating prediction of online reviews.

2. **Multi-experts model:** Due to the sparsity of manually-labeled training data, we designed the multi-experts model for sentence-level analysis of sentiment polarity and intensity by fully exploiting any available sentiment indicators, such as phrase-level predictors and sentence similarity measures.

3. **SENTI-LSSVM$_{RAE}$ model:** To understand the sentiments regarding entities, we proposed SENTI-LSSVMRAE model for extracting sentiments and comparisons of entities at both sentence and subsentential level.

Different granularity of analysis leads to different model complexity, the finer the more complex. All proposed models aim to minimize the use of hand-labeled data by maximizing the use of the freely available resources. These models explore also different feature representations to capture the compositional semantics inherent in sentiment-bearing expressions. Our experimental results on real-world data showed that all models significantly outperform the state-of-the-art methods on the respective tasks.

Dr. Kristina SCHERBAUM

NATIONALITY: German
DEPARTMENT: Computer Graphics

DISSERTATION TITLE:

Data Driven Analysis of Faces from Images

ABSTRACT OF PHD THESIS:

This thesis proposes three new data-driven approaches to detect, analyze, or modify faces in images. All presented contributions are inspired by the use of prior knowledge and they derive information about facial appearances from pre-collected databases of images or 3D face models.

First, we contribute an approach that extends a widely-used monocular face detector by an additional classifier that evaluates disparity maps of a passive stereo camera. The algorithm runs in real-time and significantly reduces the number of false positives compared to the monocular approach. Next, with a many-core implementation of the detector, we train view-dependent face detectors based on tailored views which guarantee that the statistical variability is fully covered. These detectors are superior to the state of the art on a challenging dataset and can be trained in an automated procedure. Finally, we contribute a model describing the relation of facial appearance and makeup. The approach extracts makeup from before/after images of faces and allows to modify faces in images. Applications such as machine-suggested makeup can improve perceived attractiveness as shown in a perceptual study.

In summary, the presented methods help improve the outcome of face detection algorithms, ease and automate their training procedures and the modification of faces in images. Moreover, their data-driven nature enables new and powerful applications arising from the use of prior knowledge and statistical analyses.

Dr. Mohammed SHAHEEN

NATIONALITY: **Palestinian**
DEPARTMENT: **Computer Graphics**

DISSERTATION TITLE:

Cache based Optimization of Stencil Computations – An Algorithmic Approach

ABSTRACT OF PHD THESIS:

We are witnessing a fundamental paradigm shift in computer design. Memory has been and is becoming more hierarchical. Clock frequency is no longer crucial for performance. The on-chip core count is doubling rapidly. The quest for performance is growing. These facts have lead to complex computer systems which bestow high demands on scientific computing problems to achieve high performance.

Stencil computation is a frequent and important kernel that is affected by this complexity. Its importance stems from the wide variety of scientific and engineering applications that use it. The stencil kernel is a nearest-neighbor computation with low arithmetic intensity, thus it usually achieves only a tiny fraction of the peak performance when executed on modern computer systems. Fast on-chip memory modules were introduced as the hardware approach to alleviate the problem.

There are mainly three approaches to address the problem, cache aware, cache oblivious and automatic loop transformation approaches. In this thesis, comprehensive cache aware and cache oblivious algorithms to optimize stencil computations on structured rectangular 2D and 3D grids are presented. Our algorithms observe the challenges for high performance in the previous approaches, devise solutions for them, and carefully balance the solution building blocks against each other.

The many-core systems put the scalability of memory access at stake which has lead to hierarchical main memory systems. This adds another locality challenge for performance. We tailor our frameworks to meet the new performance challenge on these architectures. Experiments are performed to evaluate the performance of our frameworks on synthetic as well as real world problems.

Dr. Aleksandar STUPAR

NATIONALITY: **Serbian**

DEPARTMENT: **Querying, Indexing, and Discovery in Dynamic Data**

DISSERTATION TITLE:

Soundtrack Recommendation for Images

ABSTRACT OF PHD THESIS:

The drastic increase in production of multimedia content has emphasized the research concerning its organization and retrieval. In this thesis, we address the problem of music retrieval when a set of images is given as input query, i.e., the problem of soundtrack recommendation for images. The task at hand is to recommend appropriate music to be played during the presentation of a given set of query images. To tackle this problem, we formulate a hypothesis that the knowledge appropriate for the task is contained in publicly available contemporary movies. Our approach, Picasso, employs similarity search techniques inside the image and music domains, harvesting movies to form a link between the domains. To achieve a fair and unbiased comparison between different soundtrack recommendation approaches, we proposed an evaluation benchmark. The evaluation results are reported for Picasso and the baseline approach, using the proposed benchmark. We further address two efficiency aspects that arise from the Picasso approach. First, we investigate the problem of processing top-K queries with set-defined selections and propose an index structure that aims at minimizing the query answering latency. Second, we address the problem of similarity search in high-dimensional spaces and propose two enhancements to the Locality Sensitive Hashing (LSH) scheme. We also investigate the prospects of a distributed similarity search algorithm based on LSH using the MapReduce framework. Finally, we give an overview of the PicasSound – a smartphone application based on the Picasso approach.

Dr. Bilyana TANEVA

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

DISSERTATION TITLE:

Automatic Population of Knowledge Bases with Multimodal Data about Named Entities

ABSTRACT OF PHD THESIS:

Knowledge bases are of great importance for Web search, recommendations, and many Information Retrieval tasks. However, maintaining them for not so popular entities is often a bottleneck. Typically, such entities have limited textual coverage and only a few ontological facts. Moreover, these entities are not well populated with multimodal data, such as images, videos, or audio recordings.

The goals in this thesis are (1) to populate a given knowledge base with multimodal data about entities, such as images or audio recordings, and (2) to ease the task of maintaining and expanding the textual knowledge about a given entity, by recommending valuable text excerpts to the contributors of knowledge bases.

The thesis makes three main contributions. The first two contributions concentrate on finding images of named entities with high precision, high recall, and high visual diversity. Our main focus are less popular entities, for which the image search engines fail to retrieve good results. Our methods utilize background knowledge about the entity, such as ontological facts or a short description, and a visual-based image similarity to rank and diversify a set of candidate images.

Our third contribution is an approach for extracting text contents related to a given entity. It leverages a language-model-based similarity between a short description of the entity and the text sources, and solves a budget-constraint optimization program without any assumptions on the text structure. Moreover, our approach is also able to reliably extract entity related audio excerpts from news podcasts. We derive the time boundaries from the usually very noisy audio transcriptions.

Dr. Yafang WANG

NATIONALITY: **Chinese**

DEPARTMENT: **Databases and Information Systems**

DISSERTATION TITLE:

Methods and Tools for Temporal Knowledge Harvesting

ABSTRACT OF PHD THESIS:

To extend the traditional knowledge base with temporal dimension, this thesis offers methods and tools for harvesting temporal facts from both semi-structured and textual sources. Our contributions are briefly summarized as follows.

1. **Timely YAGO:** A temporal knowledge base called Timely YAGO (T-YAGO) which extends YAGO with temporal attributes is built. We define a simple RDF-style data model to support temporal knowledge.

2. **PRAVDA:** To be able to harvest as many temporal facts from free-text as possible, we develop a system PRAVDA. It utilizes a graph-based semi-supervised learning algorithm to extract fact observations, which are further cleaned up by an Integer Linear Program based constraint solver. We also attempt to harvest spatio-temporal facts to track a person's trajectory.

3. **PRAVDA-live:** A user-centric interactive knowledge harvesting system, called PRAVDA-live, is developed for extracting facts from natural language free-text. It is built on the framework of PRAVDA. It supports fact extraction of user-defined relations from ad-hoc selected text documents and ready-to-use RDF exports.

4. **T-URDF:** We present a simple and efficient representation model for timedependent uncertainty in combination with first-order inference rules and recursive queries over RDF-like knowledge bases. We adopt the common possible-worlds semantics known from probabilistic databases and extend it towards histogram-like confidence distributions that capture the validity of facts across time.

All of these components are fully implemented systems, which together form an integrative architecture. PRAVDA and PRAVDA-live aim at gathering new facts (particularly temporal facts), and then T-URDF reconciles them. Finally these facts are stored in a (temporal) knowledge base, called T-YAGO. A SPARQL-like time-aware querying language, together with a visualization tool, are designed for T-YAGO. Temporal knowledge can also be applied for document summarization.

Current Students

Name	Nationality
AMANOVA, Dilafruz	*Uzbek*
ARVANITIDIS, Georgios	*Greek*
ASLAM, Shahzad	*Pakistani*
BOZCA, Sinan	*Turkish*
DEDIK, Darya	*Ukrainian*
ERENSOY, Özgün	*Turkish*
GAD-ELRAB, Mohamed	*Egyptian*
GOYAL, Mayank	*Indian*
GRISHCHENKO, Ilya	*Russian*
HANKA, Adam	*Czech*
HARIMAN, Charles Darwis	*Indonesian*
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SMITH, Adam	*Canadian*
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ZINCHENKO, Tania	*Russian*

* 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.

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ABDEL MAKSOUD, Mohamed	Reinhard Wilhelm, Gerhard Weikum	Compiler Construction	*Egyptian*
ABED, Fidaa	Kurt Mehlhorn	Algorithms and Complexity	*Palestinian*
ALAGI, Gábor	Christoph Weidenbach	Automation of Logic	*Hungarian*
ALVANAKI, Foteini	Sebastian Michel	Querying, Indexing, and Discovery in Dynamic Data	*Greek*
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BASTYS, Tomas	Olga Kalinina	Computational Biology and Applied Algorithmics	*Lithuanian*
BEEDKAR, Kaustubh	Rainer Gemulla	Databases and Information Systems	*Indian*
BEGGEL, Bastian	Thomas Lengauer	Computational Biology and Applied Algorithmics	*German*
BICHHAWAT, Abhishek	Christian Hammer	Algorithms and Complexity	*German*
BLANKENBURG, Hagen	Thomas Lengauer	Computational Biology and Applied Algorithmics	*German*
BRINGMANN, Karl	Tobias Friedrich	Algorithms and Complexity	*German*
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CHIU, Walon Wei-Chen	Mario Fritz	Computer Vision and Multimodal Computing	*Chinese*
CROITORU, Cosmina	Kurt Mehlhorn	Algorithms and Complexity	*Romanian*
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DIETZEN, Matthias	Thomas Lengauer	Computational Biology and Applied Algorithmics	*German*
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Name	Supervisor	Department	Nationality
DIRNBERGER, Michael	Kurt Mehlhorn	Algorithms and Complexity	*Austrian*
DONCHEVA, Nadezhda	Mario Albrecht, Thomas Lengauer	Computational Biology and Applied Algorithmics	*Bulgarian*
DUDZIAK, Tomasz	Reinhard Wilhelm, Sebastian Hack	Programming Languages and Compiler Construction	*Polish*
DUTTA, Sourav	Gerhard Weikum	Databases and Information Systems	*Indian*
DYLLA, Maximilian	Martin Theobald	Databases and Information Systems	*German*
EBERT, Peter	Thomas Lengauer	Computational Biology and Applied Algorithmics	*German*
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GERLING, Sebastian	Michael Backes	Information Security and Cryptography	*German*
GROCHULLA, Martin Peter	Thorsten Thormählen	Computer Graphics	*German*

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HASHEMI, Vahid	Holger Hermanns, Khaled Elbassioni	Dependable Systems and Software	*Iranian*
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EDUCATION: Computer Science
UNIVERSITY: University of Darmstadt

Awards

AWARDS

The following IMPRS students received awards for their work in 2013:

Name of student	Award
Matthias Dietzen	RCSB PDB Poster Prize of ISMB/ECCB 2013
Nadezhda Doncheva	2013 BioVis Data Contest Overall Favourite
Nadezhda Doncheva	Travel grant from the Boehringer Ingelheim Fonds, Foundation for Basic Research in Medicine, funding the research stay at UC San Francisco, CA, USA, March - May 2013
Vahid Hashemi	Sponsorship to attend SynCoP 2014 (1st International Workshop on Synthesis of Continuous Parameters)
Silke Jansen	Google Anita Borg Memorial Scholarship
Sven-Eric Schelhorn	Genome Biology DNA Day Bioinformatics Challenge
Carola Winzen	Otto Hahn Medal

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