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A Message from the Chair

The Department of Computer Science (DCS) at the University of Toronto has been a world leading research department for more than forty years. Established in 1964, DCS is the oldest Computer Science department in Canada. Our faculty and graduate students engage in ground-breaking research that shapes the future of computing and beyond. The impact of our research has resulted in our being ranked as one of the world’s top ten Computer Science departments in 2010. With a multitude of interdisciplinary collaborations, the impact of DCS incubated research is widespread; extending from biotechnology to business and from education to entertainment.

Our Research in Action Showcase is an annual event and this is the 5th year we are having it. The event showcases a cross-section of the cutting-edge work of our faculty and our graduate students. Much of this work is in conjunction with undergraduate students and multi-disciplinary partners. Our 2011 roster of projects once again showcases high-impact research. The projects on display this year include: a text entry interface system to support people with physical or motor disabilities; computational tools to assemble DNA sequences from individuals with autism that will lead to new insights into the genetic basis of autism; a software package which automatically extracts network flow features from a client computer and labels these flows with their corresponding process name; a mobile app and server system that turns smartphones and computer tablets into a customized speaking aid for people who have communications disorders; and the Undergraduate Capstone Open Source Project, a DCS-founded program that connects students from coast-to-coast to work on joint projects. The projects described within this program cover a wide spectrum from applications-oriented research that brings new insights to practical problems, to ground-breaking theoretical research that influences many areas of the discipline.

Much of our innovative research is shaped by collaborations with research partners in industry and in other academic disciplines. We’re proud of our deep interdisciplinary connections and our strong ties with the industrial and business communities. However, we are always striving to do more. Our Research in Action event is designed to facilitate the expansion of our collaborative efforts and I invite prospective partners to explore the breadth and depth of the world-class research in DCS and to share with us their own ideas for new collaborations.

Fahiem Bacchus
Professor and Acting Chair
01. HOP-Depth-MAP: Visual Depth Perception
Richard Zemel, Faculty
Nikola Karamanov, Graduate Student
Daniel Tarlow, Graduate Student
Konstantine Tsotsos, Undergraduate Student

When a person is presented with a visual scene, he or she not only perceives the objects in the scene but also has a belief about the 3D layout of the scene. To be able to construct accurate beliefs about how far things are from you and their relative distance, your brain uses “visual cues” things like shape, size, blurriness, etc. We “train” our system to use these cues by showing it many examples where the depth of the objects is known. The system then learns to accurately perceive depth for scenes it has never seen before.

02. Learning to Label Image Pixels: What Criteria Should Be Optimized?
Richard Zemel, Faculty
Danny Tarlow, Graduate Student

We consider the problem of image labeling—that is, assigning a label to each pixel in an image based on e.g. the object class that it belongs to, its distance from the camera, or whether it is the foreground object. Nearly all modern image labeling systems are based on machine learning. They operate by taking many ground truth example labelings as input, then they seek to find a model that is able to best reconstruct the given labels. However, what does “best” mean in this context? There are many conceivable ways of assigning a score based on how well a predicted labeling matches a ground truth labeling. We show that optimizing for the most obvious measure leads to learning biased models, and we show how to correct the bias by optimizing for a more complex scoring function.

03. Reliable Human Attributes Inference from 3D Pose Tracking
David Fleet, Faculty
Micha Livne, Graduate Student
Leonid Sigal, Disney Research, Pittsburgh
Nikolaus Troje, Faculty, Department of Psychology and School of Computing, Queen’s University

It is well known that biological motion conveys a wealth of socially meaningful information. From even a brief exposure, biological motion cues enable the recognition of familiar people, and the inference of attributes such as gender, age, mental state, actions and intentions. This holds even for unfamiliar people. We have recently shown that, from the output of a video-based 3D human tracking algorithm we can reliably infer physical attributes (e.g., gender and weight) and aspects of mental state (e.g., happiness or sadness). This task is useful for man-machine communication, and it provides a natural benchmark for evaluating the performance of 3D pose tracking methods (vs. conventional Euclidean joint error metrics). We show results on a large corpus of motion capture data and on the output of a simple 3D people tracker applied to videos of people walking.

04. Fast Image Search with Minimal Loss Hashing
David Fleet, Faculty
Mohammad Norouzi, Graduate Student

We present a new approach for extremely fast image search in large corpora. Given a query image, the goal is to find similar images. For huge corpora, simple exhaustive search is unacceptably slow. Instead, we learn a mapping from images to binary codes, which respects some measure of similarity between images. Given a set of training images, and a corresponding pairwise binary similarity matrix, we learn a mapping such that similar items are mapped to binary codes which differ by just a few bits, while dissimilar items are mapped onto distant codes. Treating these binary codes as hash keys, we can find items with binary codes close to a query code extremely quickly. Our new approach significantly outperforms recent state-of-the-art methods for learning compact binary codes on multiple datasets. While it was originally designed with images in mind, it can be used with other sources of data.
05. Learning a Hierarchical Compositional Shape Vocabulary for Multi-Class Object Representation

Ales Leonardis, Faculty, University of Ljubljana
Sanja Fidler, Postdoctoral Researcher
Marko Boben, Postdoctoral Researcher, University of Ljubljana

Visual categorization of objects has been an area of active research in the vision community for decades. Ultimately the goal is to recognize and detect an increasing number of object classes in images within an acceptable time frame. The problem entangles three highly interconnected issues: the internal object representation which should compactly capture the visual variability of objects and generalize well over each class, means of learning the representation from a set of images with as little supervision as possible, and an effective inference algorithm that robustly matches the object representation against the image and scales favorably with the number of objects.

In this work we represent objects in a hierarchical compositional manner: objects are composed of parts and parts are recursively composed of simpler constituents. The representation is automatically learned from images. To be fast at detecting multiple objects in an image, we use a coarse-to-fine matching scheme that exploits a taxonomy of objects to perform object detection in an efficient way.

http://vicos.fri.uni-lj.si/sanja/research/

06. The Genetics of Autism

Michael Brudno, Faculty
Marc Fiume, Graduate Student

Autism is the classic form of a group of conditions, the “autism spectrum disorders” (ASD), which are characterized by impaired socialization and communication, as well as repetitive interests and behaviours. ASD occurs in about 1 in every 150 children, making it among the most common developmental disorders. Our group is designing state-of-the-art computational tools to assemble DNA sequences from individuals with autism, identify their genetic abnormalities, and visualize this information in the context of previous knowledge about the human genome. Careful analysis of this information will lead to profound new insights into the genetic basis of autism, inspiring new diagnostic and treatment methods, and ultimately, help ease lifelong disability of people with ASD in Canada and worldwide.

07. Helping to Cure Cancer Using Topic Models

Quaid Morris, Faculty
Paul Boutros, Research Fellow, Ontario Institute for Cancer Research
Gerald Quon, Graduate Student
Syed Haider, Graduate Student, Ontario Institute for Cancer Research
Amit Deshwar, Graduate Student
Ang Cui, Undergraduate Student

New genomic technologies allow the activity levels of tens of thousands of different genes in a tumor sample to be measured simultaneously. These molecular fingerprints should allow clinicians to tailor treatments to individual patients and their tumors, thereby improving patient survival and reducing side effects. However, these samples also contain healthy, non-tumor cells that interfere with the measurement of the tumor gene activity levels. We have developed a series of algorithms to remove this contaminating signal by adapting a class of statistical models, called topic models, originally developed to analyze text.

08. Interactive Fluid Animation

Eugene Fiume, Faculty
Tyler de Witt, Graduate Student

Computer simulation of physical phenomena is important in computer graphics applications, for example to produce animations of smoke, water or fire. We present a novel method for fluid simulation with many useful properties, including interactive performance rates. We demonstrate an accurate, responsive physical fluid simulation allowing animators to interact with fluid phenomena in real time.

http://www.dgp.toronto.edu/~tyler/msc/
11. RolloText
Khai N. Truong, Faculty
Frank Chun Yat Li, Graduate Student
Koji Yatani, Graduate Student
Alyssa Rosenzweig, Alumni
Leila S. Rezai, Graduate Student

This work studies color compatibility theories using large datasets and develops new tools for choosing colors. There are three parts to this work. First, using on-line datasets, we test new and existing theories of human color preferences. Second, we learn quantitative models that score the quality of a five-color set of colors, called a color theme, which can be used to rate the quality of a new color theme. Third, we demonstrate simple prototypes that apply a learned model to tasks in color design, including improving existing themes and extracting themes from images.

http://www.youtube.com/watch?v=qd-MkdQOrJs

10. EscapeKeyboard: Sight-Free Text Entry on Touch Screen Mobile Devices
Khai N. Truong, Faculty
Nikola Banovic, Graduate Student

EscapeKeyboard is a novel gesture-based sight-free text entry interaction technique for mobile touchscreen devices. In this technique the user uses thumb gestures to type letters, thereby entering text. The research examines the use of this virtual keyboard in sighted and sight-free conditions.

12. Let the Market Drive Deployment: A Strategy for Transitioning to BGP Security
Phillipa Gill, Graduate Student
Michael Schapira, Postdoctoral Researcher, Princeton University
Sharon Goldberg, Assistant Professor, Boston University

With a cryptographic root-of-trust for Internet routing (RPKI) on the horizon, we can finally start planning the deployment of one of the secure interdomain routing protocols proposed over a decade ago (Secure BGP, secure origin BGP). However, if experience with IPv6 is any indicator, this will be no easy task. Security concerns alone seem unlikely to provide sufficient local incentive to drive the deployment process forward. Worse yet, the security benefits provided by the S*BGP protocols do not even kick in until a large number of ASes have deployed them.

Instead, we appeal to ISPs’ interest in increasing revenue-generating traffic. We propose a strategy that governments and industry groups can use to harness ISPs’ local business objectives and drive global S*BGP deployment. We evaluate our deployment strategy using theoretical analysis and large-scale simulations on empirical data. Our results give evidence that the market dynamics created by our proposal can transition the majority of the Internet to S*BGP.


Yashar Ganjali, Faculty
Mohammad Jalali, Graduate Student

FlowAware is a software package which automatically extracts network flow features from a client computer and labels them with their corresponding process name. These flow features are the patterns of the network traffic and do not contain any personally identifiable information. These labeled flows are then uploaded to a secured web server where they are used for software analysis and training statistical network traffic classifiers.

14. Repeat After Me “I am a Human”:
A Speech Based Method to Detect Spammers in VOIP

Yashar Ganjali, Faculty
Sajad Shirali-Shahreza, Graduate Student

Spam in Internet Telephony (SPIT) is a major threat for VOIP networks. To protect VOIP users, automated systems are required to identify and block spam generators (spitters). One of the modules for these systems is verifying whether a caller is human or a computer program. In this work, we present a method to distinguish between computer programs and human users. Simply stated, our method asks the user to repeat a sentence. The reply is analyzed to verify if it is the requested sentence said by a human. The main advantage of our system is that it is entirely speech-based, making it more usable and accessible compared to today’s audio-CAPTCHA systems.

15. Runtime Verification of File System Consistency

Angela Demke-Brown, Faculty
Daniel Fryer, Graduate Student
Ashvin Goel, Faculty, Electrical and Computer Engineering

Modern file systems are designed to handle a large number of failure conditions, while preserving consistency and data integrity. Ironically, the resulting complexity leads to bugs that can cause serious corruption. Current workarounds, based on backups or offline file system consistency checks, are painfully slow and may still lose or corrupt data because errors can propagate through the file system.

We are exploring ways to protect file system metadata (the critical data structures of the file system itself) from buggy file system operations. Our approach leverages modern journaling file systems that aim to ensure file system consistency after each journal transaction and can detect random file system corruption at runtime as effectively as an offline file system checker, with low performance overhead.

16. Comprehensive Kernel Instrumentation with Dynamic Binary Translation

Angela Demke-Brown, Faculty
Peter Feiner, Graduate Student
Ashvin Goel, Faculty, Electrical and Computer Engineering

Dynamic binary instrumentation (DBI) has been used extensively at the user level to develop bug-finding and security tools, such as Memcheck and Program Shepherding. These tools are supported by sophisticated frameworks, such as DynamoRIO and Intel’s Pin, which enable complete program coverage, simplify the task of writing instrumentation, and preserve the original application behavior. However, comprehensive DBI frameworks do not exist for operating system kernels, thwarting the development of dependability and security tools for kernels.

We are porting the user-space DynamoRIO DBI framework to the Linux kernel, enabling comprehensive operating system kernel instrumentation, including the execution of native device drivers. In this presentation, we discuss the key challenges in designing an in-kernel DBI framework, and our design for addressing them. We also discuss uses of this framework to develop kernel-space tools for debugging and security.
17. MyVoice

Ron Baecker, Faculty
Alex Levy, Graduate Student and CEO, MyVoice
Aakash Sahney, Graduate Student and VP Engineering, MyVoice
Kevin Tonon, VP Research and Development, MyVoice
Andrew Rusk, VP Community, MyVoice

MyVoice is a mobile app and server system that turns smartphones and computer tablets into a customized speaking aid for people who have communications disorders caused by stroke, autism spectrum disorders and neurodegenerative disease. The app allows users to tap words and images that are spoken over the device’s speakers.

19. Tangra: The Mental Fitness Evaluation Portal

Ron Baecker, Faculty
Velian Pandeliev, Graduate Student
Liam Kaufman, Undergraduate Student
Chieh Schen Teng, Undergraduate Student
Kevin Tonon, Research Associate
Garry Ing, Designer

The number of “serious games” designed to improve abilities such as cognition, physical fitness, or language proficiency is growing faster than scientific validation of claims being made by the vendors of such games. This is partly because validation is a costly and difficult process typically relying upon in-person experimental protocols.

Tangra is a web portal that attempts to address these concerns by enabling researchers to deploy mental fitness interventions over the Internet, as well as to interview, assess and encourage participants to stay on track. Built using the Django web application framework, Tangra is OS-agnostic, robust and usable anywhere with a web browser.

The first validation study of the portal is underway, and approximately 15 seniors are currently participating in an intervention, logging accurate time-sensitive data on the site. This data, along with the subjective experiences of our first set of users, will inform designs of future iterations of the portal and help us address some of the pitfalls that still remain in online experimentation.

18. Multi-User Projector Cell Phone Games

Ravin Balakrishnan, Faculty
Rorik Henrikson, Graduate Student

With digital projection technology becoming more efficient and compact, we have started to witness cell phones and smart phones on the market with embedded projectors. These projector cell phones present a unique opportunity for social and user interaction. In particular, we have been exploring multi-user games on projector cell phones. To study this, we have developed several cell phone projector games, examining different aspects and properties of this unique configuration.

20. Take Me with You–A Mobile Fitness Game for Seniors and Their Grandchildren

Ron Baecker, Faculty
Deborah Ptak, Research Associate
Nermin Moufti, Graduate Student, OCAD University

Motivating an aging generation to stay fit and engaged in life will play a key part in enabling seniors to continue to live independently, while maintaining a high quality of life. Regular walking can be a protective factor against countless diseases including Alzheimer’s and depression. Shared activities with family can provide valuable inspiration for those who are not otherwise inclined to exercise and tend to self-isolate.

This project explores mobile fitness games designed specifically for seniors to play with their grandchildren (or others). The shared adventure game “Take Me with You” is intended to encourage physical activity, cognitive stimulation, and social engagement by using these elements to move the narrative of the game forward.
21. Active RFID-Based Smart Interruption Handling
Mark Chignell, Faculty
Hao Shi, Graduate Student, Interactive Media Lab, UofT
Robin Cohen, Faculty, University of Waterloo

- Hospital physicians are frequently interrupted in their work. Current interruption methods are unintelligent because they don’t take into account the status of the physician. Methods are needed for routing phone calls, lab test results, and other interruptions based on the availability of the physician and his/her priorities. We are using an active RFID reader on the physician’s smartphone, plus active tags in the environment to infer the physician’s current context and availability. This allows intelligent routing of interruptions and alerts. In this demonstration, our system will intelligently route phone calls to voicemail if the system decides that it is inappropriate for the doctor to take the phone call and notify doctors of lab results at the right moment and at the right place. We are planning to add AI-based reasoning to make intelligent inferences about interruptability based on the RFID data.

![Active RFID tag](image1.png) ![Active RFID reader](image2.png)

22. Game-Based Cognitive Testing for Delirium Risk Assessment
Mark Chignell, Faculty
Phil Lam, Graduate Student, Interactive Media Lab, UofT
Dr. Jacques Lee, Emergency Medicine Research Program, Sunnybrook Hospital

- Delirium is an under-diagnosed condition where elderly people experience acute brain failure. Failure to detect risk of delirium is costly and dangerous. Recent research has shown that fluctuations in choice reaction time are indicators of risk of delirium onset. We have developed a simple game for collecting choice reaction time data using the Kinect Platform. Kinect allows us to collect input by simple and natural arm movements without the need for contact with keyboards or input devices that might harbour germs in a hospital environment. We are working with a researcher at Sunnybrook Hospital to develop a version of the game that can be evaluated against traditional delirium assessment tools at the Sunnybrook Hospital Emergency Department.

![You took 1.631 seconds to catch the ball!](image3.png)

23. Pricing Long-Dated Foreign Exchange Interest Rate Hybrids with an Efficient Implementation on Graphics Processing Units
Christina Christara, Faculty
Ken Jackson, Faculty
Duy Minh Dang, Graduate Student
Asif Lakhany, Algorithmics Inc., Toronto

- We’ve developed efficient Partial Differential Equation (PDE) based pricing methods for long-dated foreign exchange (FX) interest rate hybrid derivatives, with strong emphasis on Power Reverse Dual Currency (PRDC) swaps, one of the most widely traded and liquid FX interest rate hybrid derivatives.

- Our PDE pricing framework is based on partitioning the pricing problem into several independent pricing sub-problems over each period of the swap’s tenor structure, each of which requires a solution of the model-dependent PDE.

- Finite differences and the Alternating Direction Implicit (ADI) method are used for the spatial and time discretizations, respectively, of this PDE. To handle the increased computational requirements due to the inherent challenges in exotic features, we develop a Graphics Processing Unit (GPU) parallelization of the pricing procedure on a multi-GPU platform.

24. MarkUs: Online Marking Made Easy
Karen Reid, Faculty
Mike Conley, Graduate Student
Severin Gehwolf, Undergraduate Student
Danesh Dadachanji, Undergraduate Student
Bertan Guvan, Undergraduate Student
Karel Kahula, Undergraduate Student, University of Manitoba
Oloruntobi (Toby) Ogunbiyi, Undergraduate Student
Misa Sakamoto, Undergraduate Student
Ibrahim Shahi, Undergraduate Student, University of Manitoba
Vivien Suen, Undergraduate Student
Yansong Zang, Undergraduate Student, Simon Fraser University
Mike Conley, Alumni
Severin Gehwolf, Alumni
Nelle Varioquaux, Alumni
Benjamin Vialle, Alumni

- MarkUs is an open-source tool which recreates the ease and flexibility of grading assignments with pen on paper, within a web application. It also allows students and instructors to form groups, and collaborate on assignments. As students submit their work, MarkUs keeps track of the versions they submit. Graders annotate students’ code and assign grades directly in the web application. Instructors can monitor the progress of the graders and can easily release the results to the students.

http://markusproject.org/
25. UCOSP: Undergraduate Capstone Open Source Projects
Karen Reid, Faculty
Michelle Craig, Faculty
Eleni Stroulia, Faculty, Department of Computing Science, University of Alberta
Andrew Louis, Administrative Support

UCOSP brings together students from coast-to-coast to work together on joint capstone projects. Students learn first-hand what distributed development is like. Each team has students from two or three schools, and uses a mix of agile and open source processes under the supervision of a faculty or industry lead.

http://ucosp.ca/

26. Towards Representing and Reasoning with Sets of Repairs to Inconsistency
Marsha Chechik, Faculty
Michalis Famelis, Graduate Student
Richard Salay, Postdoctoral Researcher
Shoham Ben-David, Postdoctoral Researcher

Model-based software development involves the use of many interrelated models. In such a setting, inconsistencies are common and are induced by a variety of causes. Most existing approaches to resolving inconsistency aim at producing a single consistent model. This may lead to over-constrained decisions that need to be undone once additional information becomes available. Instead, we propose to leverage multiple possible repairs, deferring the choice of a particular one.

Such a set can be abstracted into a “repair model” which allows us to reason effectively about multiple repairs. Specifically, we can determine how they are related, understand which changes must be made immediately and which should be delayed, and maintain the repair set in subsequent development activities.

27. From Under-Approximations to Over-Approximations and Back
Marsha Chechik, Faculty
Aws Albarghouthi, Graduate Student
Arie Gurfinkel, Software Engineering Institute, Carnegie Mellon University

We propose novel techniques for testing and verification of software that rely on combining testing techniques and static analysis techniques in an interactive manner, to enhance the effectiveness of both.

28. Strategic Analysis of Agile Practices
Eric Yu, Faculty
Hesam Chiniforooshan Esfahani, Graduate Student

Agile methods are widely believed to have the potential to improve software processes. Given the variety of agile practices, organizations face difficult decisions on which ones to adopt. Recognizing that agile adoption is often motivated by strategic concerns such as market competitiveness or responsiveness to customer needs, this work introduces a framework for the strategic analysis of agile practices. The framework aims to support the decision making process leading to agile adoption. An upfront analysis of how each candidate practice would contribute to which strategic objectives, and how they might complement or interfere with each other, can improve understanding within a team and ease the transition to agile. The framework builds upon a knowledge base of experiences collected from empirical studies. Goal modeling techniques from requirements engineering are incorporated in the form of a Strategies Graph. The graph resembles the Strategy Map from Balanced Scorecards familiar to many managers.
29. Inflo: Information Flow Visualization Tool

Steve Easterbrook, Faculty  
Jonathan Lung, Graduate Student

- Models used for decision-making, such as carbon calculators, contain many hidden assumptions or may even simply be black boxes. Inflo is a collaborative decision-support tool based on argumentation graphs that attempts to make such models transparent and to make assumptions explicit. Users can sketch out arguments or formulate and allow others users of the system to iteratively make improvements to them. Alternately, users can use models created by others in order to support their own decisions.

http://www.cs.toronto.edu/~lungj/inflo

30. Fast Local-Spin Abortable Mutual Exclusion with Bounded Space

Faith Ellen, Faculty  
Hyonho Lee, Graduate Student

- Abortable mutual exclusion is a variant mutual exclusion, where processes are allowed to abort their invocations while waiting to enter the critical section. We present the first abortable mutual exclusion algorithm with bounded space that is fast in the absence of aborts. It is based on a new memory management method for asynchronous shared memory.

31. Ranking Diversification

Allan Borodin, Faculty  
Yuli Ye, Graduate Student  
Chul Lee, Industrial Partner, Thoora Inc.

- Ranking is a central problem for many applications in information retrieval, database and data/web mining. The overall objective of a ranking problem is to compute an ordering of objects according to certain criteria.

In this project, we introduce the notion "diversity" to quality-based ranking and study the trade-off between the two. In particular, we formulate the ranking diversification problem as a combinatorial optimization problem. We show the problem is NP-hard even when the distance (a diversity measure) satisfies the triangle inequality. We propose and analyze conceptually simple polynomial time algorithms, proves their approximation bounds and experimentally validate our algorithms over different synthetic and real data-sets. We show that our approximation algorithms can be used to greatly enhance the diversity of ranked results without significantly sacrificing the original ranking quality.

This project is generously supported by MITACS Accelerate program, Thoora Inc. and the Department of Computer Science, University of Toronto.

32. A Universal Construction for Wait-Free Transaction Friendly Data Structure

Faith Ellen, Faculty  
Phong Chuong, Graduate Student  
Vijaya Ramachandran, Computer Science Department  
University of Texas at Austin

- In the field of distributed computing, writing code for asynchronous systems is inherently difficult because processes can halt or display arbitrary variations in speed and, a process cannot tell whether another process has halted or is simply running very slowly. A wait-free implementation of a shared object guarantees that a process will eventually completes its operation regardless of the actions of other processes. Given the sequential implementation of any data structure, we show how to obtain an efficient, wait-free implementation of that data structure shared by any fixed number of processes using only shared registers and CAS objects. In our implementation, we allow processes to gracefully exit from its operation if the operation is taking too much time or if the process deems that the operation is no longer useful. This is essential in moving toward a practical implementation because the time complexity of operations in any universal construction grows as the number of processes in the system increases.
For more information on the Department of Computer Science and its programs, activities, events and to obtain promotional materials, please contact the Communications Office at dcsevents@cs.toronto.edu or 416-978-3619

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