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Abhishek Anand

Research Interests

- design and meta-theory of Proof Assistants (PAs) and programming languages
- correct-by-construction programming for distributed and cyber-physical systems
- developing decision procedures to automate the above uses of PAs
- using PAs to make our education system more fun, fair, and effective
- machine-checked mathematics, especially constructive real analysis

Education

2010– **PhD**, *Computer Science*, Cornell University, Ithaca, NY USA
Thesis : Trustworthy Proof Assistants for Trustworthy Cyber-physical Systems
Committee : Robert L. Constable (chair), Ross Tate, Anil Nerode, Ross Knepper
Minor : Pure Mathematics .

2006–2010 **B.Tech**, *Computer Science*, Indian Institute of Technology (IIT) Guwahati, India
Thesis : Machine learning for garbage collection in flash filesystems
Advisor : Hemangee Kapoor .

Research Projects at Cornell University

2014- *Correct-by-construction Programming for Cyber-physical Systems*
[ITP15] We developed ROSCoq, a framework for writing and reasoning about robotic programs in the Coq proof assistant. Using the Robot Operating System (ROS), these programs can actually be run on robots, and guaranteed to behave as proved. Ideally, robotic programs need to compute with real numbers, and we showed that constructive reals are often a better alternative to floating points, especially for rigorous verification.

2013-2014 *Making Proof Assistants more Trustworthy*
[ITP14] [LFMTP14] While extending Proof Assistants (PAs), it is hard to ensure the their logic remains consistent. Mistakes have often been found in paper proofs of consistency. We argue that formalizing the consistency proof of a PA in a PA can greatly increase its trustworthiness. We used a semantic approach to prove the consistency of the Nuprl proof assistant in Coq.
Later, we generalized our tedious Coq proofs about Nuprl's substitution and alpha equality to work for an arbitrary language specified as a context free grammar with some variable-binding annotations.

2012-2013 *Untyped optimization of Nuprl programs*

[ITP13] The Nuprl group had developed provably correct programs for critical parts of replicated databases. Unfortunately, these programs were slower than the unverified versions by several orders of magnitude. Nuprl has a curry style type system where terms are not decorated with types. Rewriting with typed equalities generate additional proof obligations for typehood, and are hence hard to automate. Based on ideas from domain theory, we designed a method for untyped equational reasoning.

2011–2012 *Active 3D perception for robots*

[NIPS11] [IJRR12] We developed machine-learning algorithms for finding objects in 3D colored-pointclouds generated by 3D cameras. We also designed and implemented algorithms for robots to actively move to statistically maximize their chances of finding an object, based on contextual information from the already found objects

Research Internships

Summer 2015 Microsoft Research *A new F* compiler, with support for manual memory management*

To run F* programs, they need to be compiled to OCaml. Like Coq, F* has a type system which is richer than OCaml's. Previously, F* programs using such richer types (e.g. dependent types) could not be compiled to OCaml. Inspired by Coq, we wrote a compiler that compiles *all* well-typed F* programs to OCaml. Our compiler's design is perhaps simpler than Coq's, and also takes into account the effectful semantics of F*. Also, we extended F* to safely allow more efficient access to mutable memory.
Mentors : Nikhil Swamy, Jonathan Protzenko

Summer 2009 EPFL [SRDS11] We built a tool to find almost-invariants in distributed systems, based on annotations from programmers. Almost-invariants often reveal corner-case bugs.
Mentors : Dejan Kostic, Maysam Yabandeh

Teaching

Spring 2015 TA for Advanced PL : grading, helping with designing problem sets, holding office hours and Piazza, and 1 guest lecture on Using Coq for course assignments

Fall 2012 Part-time TA for Applied Logic : grading, holding office hours, and 2 guest lectures

Spring 2012 Part-time TA for Robot Learning : grading, mentoring students on course projects

Talks

Nov. 23, 2015 ROSCoq: Correct-by-construction programming for cyber-physical systems
IBM Programming Languages Day, T. J. Watson Research Center

2015 ROSCoq : Robots Powered by Constructive Reals
- Mar. 26, Logical Systems Lab, Carnegie Mellon University (invited)
- July 15, PL(X) Group, Microsoft Research, Redmond (invited)
- June 26, Coq workshop, Inria Sopia-Antipolis, France
- Aug. 27, Interactive Theorem Proving (conference), China
- Sep. 16, Programming Languages Discussion Group, Cornell University

Jan. 27 and 28, 2015 — Intro to Martin Löf Type Theory
2 lectures at the Logic Seminar, *Math Dept.*, Cornell University (invited)

July 17, 2014 — A Generic Approach to Proofs about Substitution
Logical Frameworks and Meta-Languages: Theory and Practice (Workshop), Austria

Sep. 16, 2013 — Type Theories Behind Proof Assistants
Programming Languages Discussion Group, Cornell University

Oct. 12, 2012 — Bar Induction and the Fan Theorem in Constructive Type Theory
Proof Refinement Logic Seminar, Cornell University

Sep. 21, 2012 — The Type Base and Undecidability in Type Theory
Proof Refinement Logic Seminar, Cornell University

Jan. 5, 2009 — QDMAC: An Energy Efficient Low Latency MAC Protocol for Query Based Wireless Sensor Networks
International Conference on Distributed Computing and Networking, India

Upcoming Talks

July 2016 — Invited to present our work on verification of Proof Assistants
Session on Univalent Foundations and Proof Assistants, International Congress on Mathematical Software, ZIB Berlin, Germany

Demos

June 27, 2011 — Labeling 3D Scenes for Personal Assistant Robots
RGB-D Workshop at Robotics Science and Systems (RSS), Los Angeles

Awards and Media Coverage

July 21, 2011 — Robots use Kinect to understand our world, New Scientist

2010–2011 — Cornell Olin Fellowship

2009–2010 — Institute Merit Scholarship for highest yearly (2008-2009) GPA across all majors

Service

2013– — I actively answer questions on the mailing lists of Coq and Agda proof assistants.

\- — Reviewed submissions for ICRA. Sub-reviewed for NIPS, PLDI, and ITP

2008–2010 — Representative of the Computer Science class of 2010 at IIT Guwahati

Fall 2008 — Secretary of the Robotics Club at IIT Guwahati

Publications

[ITP15] Abhishek Anand and Ross Knepper. "ROSCoq: Robots Powered by Constructive Reals". In: Interactive Theorem Proving. LNCS. Aug. 19, 2015, pp. 34–50.

[LFMTP14] Abhishek Anand and Vincent Rahli. "A Generic Approach to Proofs about Substitution". In: International Workshop on Logical Frameworks and Meta-languages:

Theory and Practice. Vienna, Austria: ACM, July 2014, 5:1–5:8.

[ITP14] Abhishek Anand and Vincent Rahli. "Towards a Formally Verified Proof Assistant". In: Interactive Theorem Proving. LNCS. Tech. Report available. Springer, July 13, 2014, pp. 27–44.

[ITP13] Vincent Rahli, Mark Bickford, and Abhishek Anand. "Formal Program Optimization in Nuprl Using Computational Equivalence and Partial Types". In: *Interactive Theorem Proving*. LNCS. July 22, 2013, pp. 261–278.

[IJRR12] Abhishek Anand, Hema Swetha Koppula, Thorsten Joachims, and Ashutosh Saxena. "Contextually Guided Semantic Labeling and Search for Three-Dimensional Point Clouds". In: *International Journal of Robotics Research* 32.1 (2012), pp. 19–34.

[NIPS11] Hema S. Koppula, Abhishek Anand, Thorsten Joachims, and Ashutosh Saxena. "Semantic Labeling of 3D Point Clouds for Indoor Scenes". In: *Neural Information Processing Systems*. 2011, pp. 244–252.

[SRDS11] Maysam Yabandeh, Abhishek Anand, Marco Canini, and Dejan Kostic. "Finding Almost-Invariants in Distributed Systems". In: *Symposium on Reliable Distributed Systems*. Oct. 2011, pp. 177–182.

[ICDCN09] Abhishek Anand, Shikhar Sachan, Kalpesh Kapoor, and Sukumar Nandi. "QDMAC: An Energy Efficient Low Latency MAC Protocol for Query Based Wireless Sensor Networks". In: *International Conference on Distributed Computing and Networking*. LNCS. Jan. 3, 2009, pp. 306–317.