Inside X10: Implementing a High-level Language on Distributed and Heterogeneous Platforms

Summary:

X10 is a type-safe, modern, parallel, distributed object-oriented language designed specifically to address the challenges of productively programming complex hardware systems consisting of clusters of multicore CPUs and accelerators. A single X10 source program can be compiled for efficient execution on a wide variety of target platforms including single machines running Linux, MacOS, or Windows; clusters of x86 and Power based SMP nodes; BlueGene/P supercomputers; and CUDA-enabled GPUs.

Implementing a high-level language like X10 on a variety of platforms and achieving high performance presents a number of challenges. In this tutorial we will briefly cover the core features of the X10 language and some current empirical results, but will mainly focus on presenting the implementation technology that underlies the system. Topics covered will include:

- an overview of the X10 compiler and runtime system
- a generalization of Cilk-style workstealing for non-strict task graphs
- compilation of X10 to CUDA-enabled GPUs
- optimization of specific X10 language features

The tutorial is intended both for people who are generally interested in the implementation technology used by X10 and other similar PGAS languages and at researchers who are interested in using the X10 implementation (available open source at x10-lang.org) as the basis for their own research projects.

Target Audience:

We envision this tutorial as being of interest to two, somewhat overlapping, groups of people. First, the general challenges being addressed by the X10 language design and implementation effort are not unique to the X10 project.

They are extremely relevant to the broader community of programming language researchers and language implementers who are facing the challenge of providing productive programming models for multi-core machines, scale out clusters, and heterogeneous systems. By learning more about the technology underlying the X10 implementation and how it relates to previous systems and research results, this group of people will be exposed to ideas and concepts that will be relevant to their own work on other languages and programming models.

Second, X10 is an open source project. IBM Research sponsored an “X10 Innovation Grant" program in 2010 to help grow the educational and research community around X10 (http://x10-lang.org/X10+Innovation+Awards). There

was an X10 BoF session at SPLASH/OOPSLA 2010 that had approximately 100 attendees. We think this growing X10 community can benefit from an tutorial covering the overall structure of the X10 implementation and some of the key advanced concepts embodied in it.

The goal is similar to the Jikes RVM tutorials given by Fink, Grove and Hind at OOSPLA 2002 and PLDI/CGO 2004. These early Jikes RVM tutorials were important in growing the research community around the Jikes RVM infrastructure and enabled many subsequent research results. We will not assume any familiarity with the X10 programming language.

We will assume general knowledge of compilers, optimization and analysis, and programming language implementation techniques that would be typical of a graduate student at CGO who has taken a graduate level compiler course.

Special requirements:

Participants are encouraged, but not required, to bring laptops with Eclipse and the prerequisites for building X10 (listed at http://x10.codehaus.org/Building+from+SVN+head) installed. We will run through some hands-on exercises in building and changing the X10 compiler.

Authors' bios:

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Bio: David Cunningham's PhD work involved novel lock inference techniques and correctness proofs for atomic sections in object-oriented languages (Imperial College London, 2010). He has been employed by IBM for 2 years as a software engineer working with the X10 team, responsible for X10RT (the communications runtime), CUDA backend / runtime implementation. He has also participated in general C++ backend and runtime implementation, X10 application development, and X10 language design discussions.

David Grove, IBM Research, groved@us.ibm.com
Bio: David Grove currently co-leads the X10 project at IBM Research. His primary research interests include the analysis and optimization of object-oriented languages, virtual machine design and implementation, JIT compilation, online feedback-directed optimization, and garbage collection. He played a leading role in IBM's Jalape\~{n}o project and has been a member of the Jikes RVM steering committee and core team since Jalapeno went open source in 2001. From 2004 to 2008 he was a member of the Metronome project and made significant contributions to the implementation of the Metronome GC in IBM's WebSphere Real Time Java product. He has been a Research Staff Member at IBM Research since 1998. He received his Ph.D. from the University of Washington in 1998 and a B.S from Yale in 1992.

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Bio: Igor Peshansky is a Senior Research Software Engineer with the Programming Technologies Department of the IBM T. J. Watson Research Center. He is currently one of the principal designers and implementers of the

X10 high-productivity high-performance programming language. His past research work includes combined analysis of programs and databases, integration of Java technology and XML programming, program analysis, annotation design, and program optimization. He has been at IBM Research in various capacities since February 1999. He received his Ph.D. in Computer Science in 2003 from the Courant Institute of Mathematical Sciences at the New York University, and a B.S. In 1995 from Brooklyn College of the City University of New York.

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Bio: Olivier Tardieu joined IBM Research in 2007. He graduated from Ecole Polytechnique, Paris, France in 1998 and Ecole des Mines, Paris, France in 2001. He received his Ph.D. in Computer Science from Institut National de Recherche en Informatique et en Automatique (INRIA), Sophia-Antipolis, France in 2004. His research interests include programming language design, compilers, runtimes, software safety, concurrency, and hardware synthesis. He is currently one of the core designers and implementers of the X10 programming language leading the runtime development. Prior to joining IBM, he conducted research at Bell Labs, Columbia University, and INRIA.

References:

http://x10-lang.org/