Trace-based Just-in-Time Type Specialization for Dynamic Languages

Andreas Gal*+, Brendan Eich*, Mike Shaver*, David Anderson*, David Mandelin*,
Mohammad R. Haghighat$, Blake Kaplan*, Graydon Hoare*, Boris Zbarsky*, Jason Orendorff*,
Jesse Ruderman*, Edwin Smith#, Rick Reitmaier#, Michael Bebenita+, Mason Chang+#, Michael Franz+

Mozilla Corporation*
{gal,brendan,shaver,danderson,dmandelin,mrbkap,graydon,bz,jorendorff,jruderman}@mozilla.com

Adobe Corporation#
{edwsmith,rreitmai}@adobe.com

Intel Corporation$
{mohammad.r.haghighat}@intel.com

University of California, Irvine+
{mbebenit,changm,franz}@uci.edu

Abstract

Dynamic languages such as JavaScript are more difficult to compile than statically typed ones. Since no concrete type information is available, traditional compilers need to emit generic code that can handle all possible type combinations at runtime. We present an alternative compilation technique for dynamically-typed languages that identifies frequently executed loop traces at run-time and then

and is used for the application logic of browser-based productivity applications such as Google Mail, Google Docs and Zimbra Collaboration Suite. In this domain, in order to provide a fluid user experience and enable a new generation of applications, virtual machines must provide a low startup time and high performance.

Compilers for statically typed languages rely on type information to generate efficient machine code. In a dynamically typed programming language such as JavaScript, the types of expressions

Show Knowledge Graph

Trace-based Just-in-Time Type Specialization for D
Languages

Andreas Gal*+, Brendan Eich*, Mike Shaver*, David Anderson*, David Mande
Mohammad R. Haghighat§, Blake Kaplan*, Graydon Hoare*, Boris Zbarsky*, Jason C
Jesse Ruderman*, Edwin Smith#, Rick Reitmaier#, Michael Bebenita+, Mason Chang+#,

Mozilla Corporation*
{gal,brendan,shaver,danderson,dmandelin,mrbkap,graydon,bz,jorendorff,jruderman}@

Adobe Corporation#
{edwsmith,rreitmai}@adobe.com

Intel Corporation§
{mohammad.r.haghighat}@intel.com

University of California, Irvine+
{mbebenit,changm,franz}@uci.edu

Abstract

Dynamic languages such as JavaScript are more difficult to compile than statically typed ones. Since no concrete type information is available, traditional compilers need to emit generic code that can handle all possible type combinations at runtime. We present an alternative compilation technique for dynamically-typed languages that identifies frequently executed loop traces at run-time and then generates machine code on the fly that is specialized for the actual dynamic types occurring on each path through the loop. Our method provides cheap inter-procedural type specialization, and an elegant and efficient way of incrementally compiling lazily discovered alternative paths through nested loops. We have implemented a dynamic compiler for JavaScript based on our technique and we have measured speedups of 10x and more for certain benchmark programs.

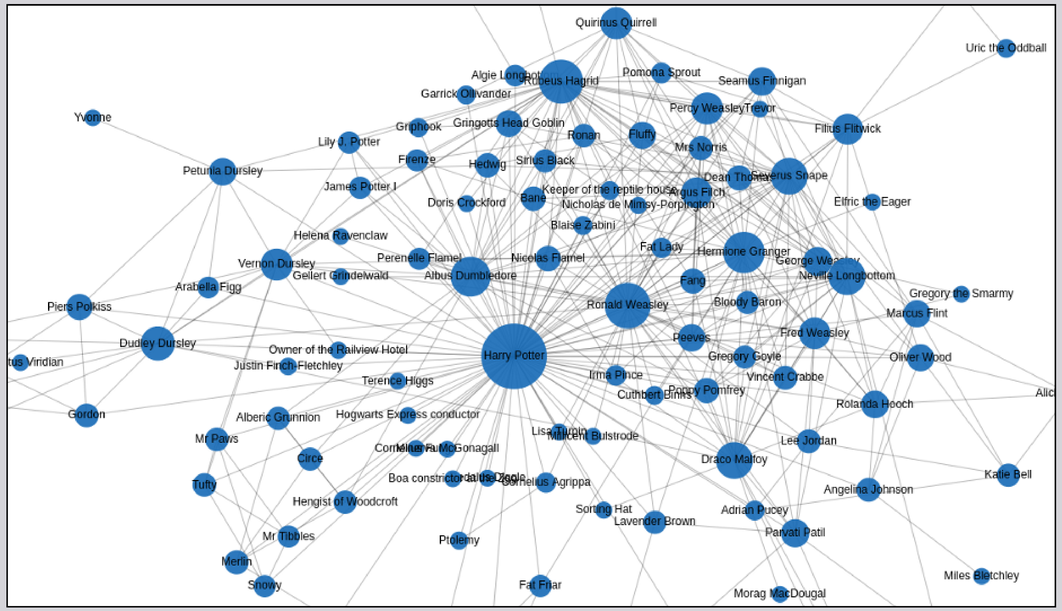
Categories and Subject Descriptors D.3.4 [*Programming Languages*]: Processors — *Incremental compilers, code generation.*

General Terms Design, Experimentation, Measurement, Perfor-

and is used for the application logic of bro
applications such as Google Mail, Google
laboration Suite. In this domain, in order
experience and enable a new generation of
chines must provide a low startup time and

Compilers for statically typed languag
tion to generate efficient machine code. In
gramming language such as JavaScript,
may vary at runtime. This means that the compiler can no longer easily transform operations into machine instructions that operate on one specific type. Without exact type information, the compiler must emit slower generalized machine code that can deal with all potential type combinations. While compile-time static type inference might be able to gather type information to generate optimized machine code, traditional static analysis is very expensive and hence not well suited for the highly interactive environment of a web browser.

We present a trace-based compilation technique for dynamic languages that reconciles speed of compilation with excellent performance of the generated machine code. Our system uses a mixed-



Summary

Semantic Scholar:
This work presents an alternative compilation technique for dynamically-typed languages that identifies frequently executed loop traces at run-time and then generates machine code on the fly that is specialized for the actual dynamic types occurring on each path through the loop.

Huggingface (bart-large-cnn):
Trace-based Just-in-Time Type Specialization for Dynamic languages. We present an alternative compilation technique for dynamically-typed languages that identifies frequently executed loop traces at run-time and then generates machine code on the fly. We have implemented a dynamic compiler for JavaScript based on our technique and we have measured speedups of 10x and more.

Trace-based Just-in-Time Type Specialization for D
Languages

Andreas Gal*+, Brendan Eich*, Mike Shaver*, David Anderson*, David Mande
Mohammad R. Haghighat§, Blake Kaplan*, Graydon Hoare*, Boris Zbarsky*, Jason C
Jesse Ruderman*, Edwin Smith#, Rick Reitmaier#, Michael Bebenita+, Mason Chang+#,

Mozilla Corporation*
{gal,brendan,shaver,danderson,dmandelin,mrbkap,graydon,bz,jorendorff,jruderman}@

Adobe Corporation#
{edwsmith,rreitmai}@adobe.com

Intel Corporation§
{mohammad.r.haghighat}@intel.com

University of California, Irvine+
{mbebenit,changm,franz}@uci.edu

Abstract

Dynamic languages such as JavaScript are more difficult to compile than statically typed ones. Since no concrete type information is available, traditional compilers need to emit generic code that can handle all possible type combinations at runtime. We present an alternative compilation technique for dynamically-typed languages that identifies frequently executed loop traces at run-time and then generates machine code on the fly that is specialized for the actual dynamic types occurring on each path through the loop. Our method provides cheap inter-procedural type specialization, and an elegant and efficient way of incrementally compiling lazily discovered alternative paths through nested loops. We have implemented a dynamic compiler for JavaScript based on our technique and we have measured speedups of 10x and more for certain benchmark programs.

Categories and Subject Descriptors D.3.4 [*Programming Languages*]: Processors — *Incremental compilers, code generation.*

General Terms Design, Experimentation, Measurement, Perfor-

and is used for the application logic of bro
applications such as Google Mail, Google
laboration Suite. In this domain, in order
experience and enable a new generation of
chines must provide a low startup time and

Compilers for statically typed languag
tion to generate efficient machine code. In
gramming language such as JavaScript,
may vary at runtime. This means that the compiler can no longer easily transform operations into machine instructions that operate on one specific type. Without exact type information, the compiler must emit slower generalized machine code that can deal with all potential type combinations. While compile-time static type inference might be able to gather type information to generate optimized machine code, traditional static analysis is very expensive and hence not well suited for the highly interactive environment of a web browser.

We present a trace-based compilation technique for dynamic languages that reconciles speed of compilation with excellent performance of the generated machine code. Our system uses a mixed-

Figure 1. Sample program: sieve of Eratosthenes. primes is initialized to an array of 100 false values on entry to this code...

Figure 2. State machine describing the major activities of TraceMonkey and the conditions that cause transitions to a new activity. In the dark box...

Figure 3. LIR snippet for sample program. This is the LIR recorded for line 5 of the sample program in Figure 1. The LIR encodes...

Figure 4. x86 snippet for sample program. This is the x86 code compiled from the LIR snippet in Figure 3. Most LIR instructions compile...

Figure 5. A tree with two traces, a trunk trace and one branch trace. The trunk trace contains a guard to which a branch trace was...

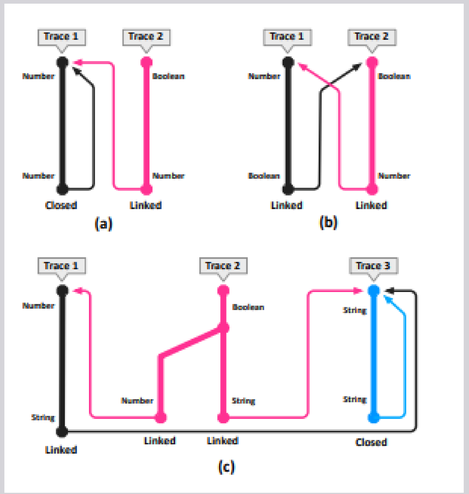


Figure 6. We handle type-unstable loops by allowing traces to compile that cannot loop back to themselves due to a type mismatch. As...

Figure 7. Control flow graph of a nested loop with an if statement inside the inner most loop (a). An inner tree...

Figure 8. Control flow graph of a loop with two nested loops (left) and its nested trace tree configuration (right). The outer tree calls...

Trace-based Just-in-Time Type Specialization for D Languages

Andreas Gal*+, Brendan Eich*, Mike Shaver*, David Anderson*, David Mande
Mohammad R. Haghighat§, Blake Kaplan*, Graydon Hoare*, Boris Zbarsky*, Jason C
Jesse Ruderman*, Edwin Smith#, Rick Reitmaier#, Michael Bebenita+, Mason Chang+#,

Mozilla Corporation*
{gal,brendan,shaver,danderson,dmandelin,mrbkap,graydon,bz,jorendorff,jruderman}@

Adobe Corporation#
{edwsmith,rreitmai}@adobe.com

Intel Corporation§
{mohammad.r.haghighat}@intel.com

University of California, Irvine+
{mbebenit,changm,franz}@uci.edu

Abstract

Dynamic languages such as JavaScript are more difficult to compile than statically typed ones. Since no concrete type information is available, traditional compilers need to emit generic code that can handle all possible type combinations at runtime. We present an alternative compilation technique for dynamically-typed languages that identifies frequently executed loop traces at run-time and then generates machine code on the fly that is specialized for the actual dynamic types occurring on each path through the loop. Our method provides cheap inter-procedural type specialization, and an elegant and efficient way of incrementally compiling lazily discovered alternative paths through nested loops. We have implemented a dynamic compiler for JavaScript based on our technique and we have measured speedups of 10x and more for certain benchmark programs.

Categories and Subject Descriptors D.3.4 [*Programming Languages*]: Processors — *Incremental compilers, code generation.*

General Terms Design, Experimentation, Measurement, Perfor-

and is used for the application logic of bro
applications such as Google Mail, Google
laboration Suite. In this domain, in order
experience and enable a new generation of
chines must provide a low startup time and

Compilers for statically typed languag
tion to generate efficient machine code. In
gramming language such as JavaScript,
may vary at runtime. This means that the compiler can no longer easily transform operations into machine instructions that operate on one specific type. Without exact type information, the compiler must emit slower generalized machine code that can deal with all potential type combinations. While compile-time static type inference might be able to gather type information to generate optimized machine code, traditional static analysis is very expensive and hence not well suited for the highly interactive environment of a web browser.

We present a trace-based compilation technique for dynamic languages that reconciles speed of compilation with excellent performance of the generated machine code. Our system uses a mixed-