The MetaOCaml files

Status report and research proposal

Oleg Kiselyov

Chung-chieh Shan

ICFP Eve, 2010   Somewhere in Maryland

Q&A

How to reconcile generality with performance?

- **Write custom code generators!** Common practice.

How to assure generated code well-formed? (Why?)

- **Use MetaOCaml!** Extends full OCaml. Widely used.

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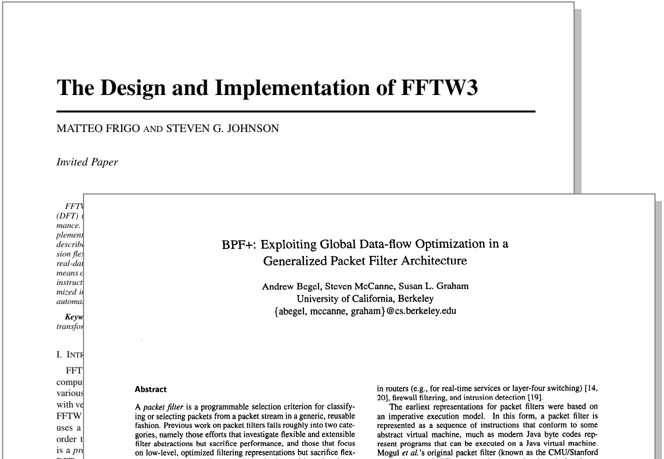

The Design and Implementation of FFTW3

MATTEO FRIGO AND STEVEN G. JOHNSON

Invited Paper

FFTW (DFT) mance. plement describ sion fle real-da means instruct mized i automa

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BPF+: Exploiting Global Data-flow Optimization in a Generalized Packet Filter Architecture

Andrew Begel, Steven McCanne, Susan L. Graham
University of California, Berkeley
{abegel, mccanne, graham}@cs.berkeley.edu

Abstract

A *packet filter* is a programmable selection criterion for classifying or selecting packets from a packet stream in a generic, reusable fashion. Previous work on packet filters falls roughly into two categories, namely those efforts that investigate flexible and extensible filter abstractions but sacrifice performance, and those that focus on low-level, optimized filtering representations but sacrifice flex-

in routers (e.g., for real-time services or layer-four switching) [14, 20], firewall filtering, and intrusion detection [19].

The earliest representations for packet filters were based on an imperative execution model. In this form, a packet filter is represented as a sequence of instructions that conform to some abstract virtual machine, much as modern Java byte codes represent programs that can be executed on a Java virtual machine. Mogul *et al.*'s original packet filter (known as the CMU/Stanford

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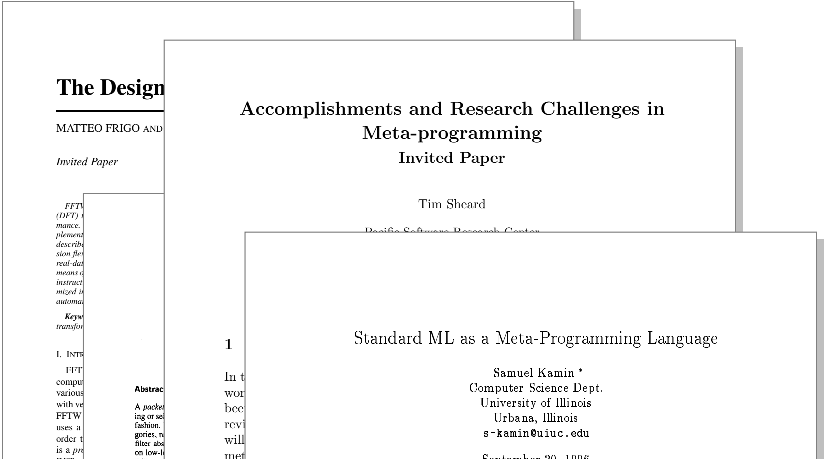
The Design

MATTEO FRIGO AND

Invited Paper

Accomplishments and Research Challenges in Meta-programming

Invited Paper

Tim Sheard

Standard ML as a Meta-Programming Language

Samuel Kamin *

Computer Science Dept.

University of Illinois

Urbana, Illinois

s-kamin@uiuc.edu

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MetaOCaml	BER MetaOCaml
–January 2006	March 2010–?
OCaml 3.09.1	OCaml 3.11.2
bytecode + native	bytecode

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How to implement code generation as syntactic sugar?

- `camlp4`/5 quotations
- Represent `let`-polymorphism by higher polymorphism?

Crash course

	MetaOCaml	is not quite like	Lisp
bracket	`.<x + y>.`	quasiquote	`` `(+ x y) ``
escape	`.~body`	unquote	`,body`
run	`.!code`	eval	`(eval code)`
persist	`r`		`',r`

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```
.<fun x -> .~(let body = .<x>.
              in .<fun x -> .~body>.)>.
```

```
`(lambda (x) ,(let ((body `x))
                `(lambda (x) ,body)))
```

```
`(lambda (x) (lambda (x) x))
```

Implicit binding context ...

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```
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```

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```
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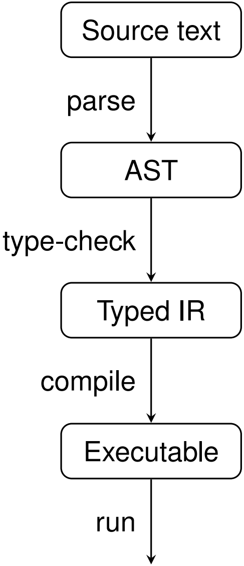
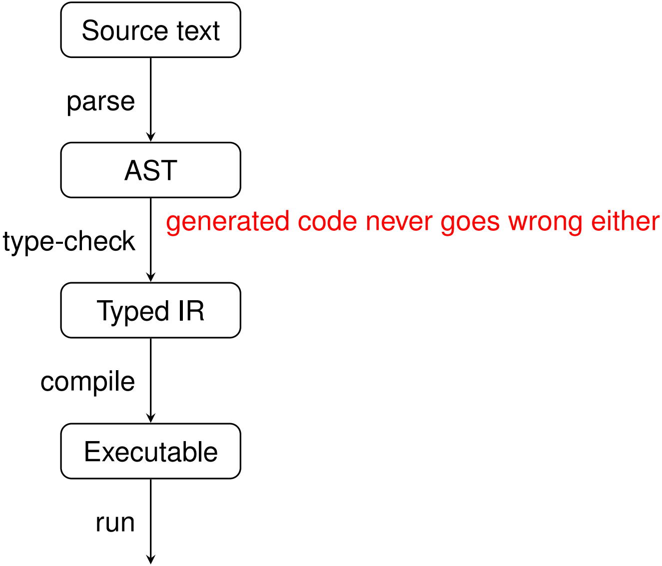
Passes


Source text
parse
AST
type-check
Typed IR
compile
Executable
run

Passes


Source text
parse
AST
type-check
generated code never goes wrong either
Typed IR
compile
Executable
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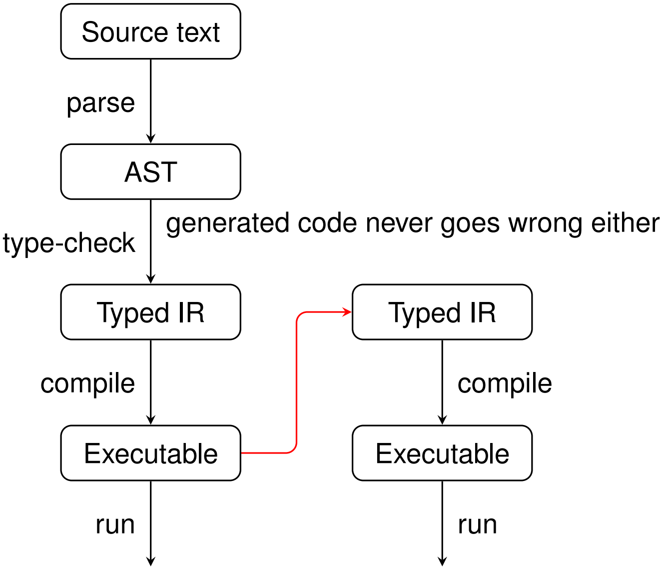
Passes


Source text
parse
AST
type-check
generated code never goes wrong either
Typed IR
compile
Executable
run
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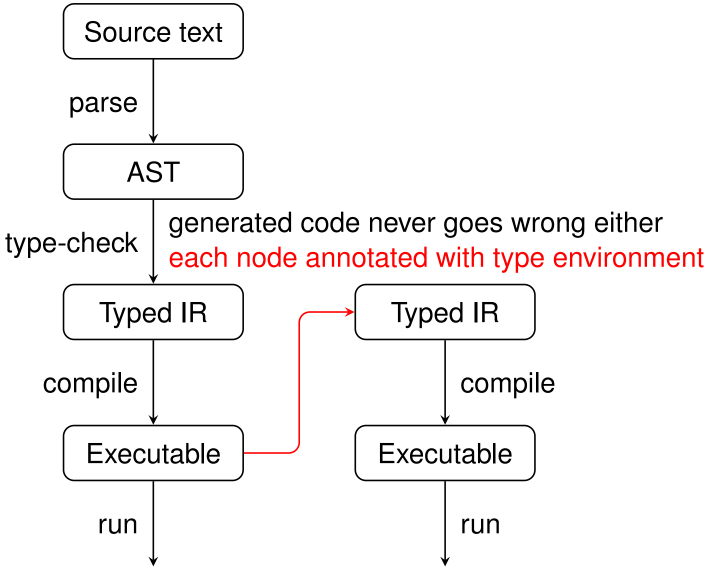
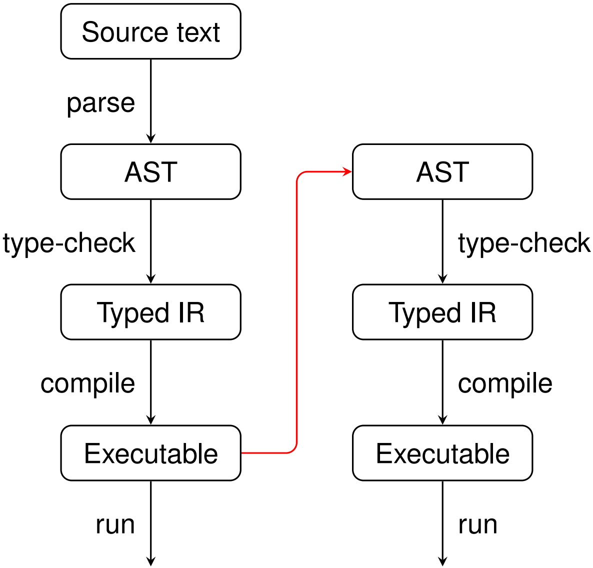
compile
Executable
run

Passes



Source text
parse
AST
type-check
generated code never goes wrong either
each node annotated with type environment
Typed IR
compile
Executable
run
Typed IR
compile
Executable
run

Passes


Source text
parse
AST
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Executable
run
AST
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Preserving type environments

```
# type foo = Foo
  let x = .<Foo>.
  type bar = Foo | Bar
  let y = .<Foo>.
  let z = .<(.~x, .~y)>. ;;
val z : ('a, foo * bar) code = .<((Foo), (Foo))>.
```

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```

Currently, `.<Foo>.` means to make an AST node `Foo`
and stash *the type environment here* in it.

Preserving type environments

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```

```
val z : ('a, foo * bar) code = .<((Foo), (Foo))>.
```

Perhaps simpler:

```
type foo = Foo1
type bar = Foo2 | Bar
```

.cmo

Need guidance from a calculus with explicit substitutions!

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Scope extrusion

Pure staging works great, especially with polymorphism.
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```
# let code =
    let r = ref .<1>. in
    let _ = .<fun x -> .~(r := .<x>.; .<()>.)>. in
    !r ;;
val code : ('a, int) code = .<x_1>.
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# .!code ;;
Unbound value x_1
Exception: Trx.TypeCheckingError.
```

To restore soundness: later binders delimit earlier effects
To express even more: regions of generated names?

Imperative polymorphism redux

```
# let f () = ref []
```

Imperative polymorphism redux

```
# let f () = ref []
  in f () := [1];
     "hello" :: !(f ()) ;;
- : string list = ["hello"]
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# let c = .<let f () = ref []
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val c : ('a, string list) code =
  .<let f_2 () = ref []
    in f_2 () := [1];
       "hello" :: !(f_2 ())>.

# .!c ;;

- : string list = ["hello"]
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# let c = .<let f () = .~(.<ref []>.)
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val c : ('a, string list) code =
  .<let f_2 () = (* cross-stage persistent value
                                          (as id: r) *)
    in f_2 () := [1];
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# .!c ;;

Segmentation fault
```

To restore soundness:
earlier effects prevent later generalization?

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Code generation as syntactic sugar

`camlp4/5` quotations? CUFP BoF, tutorial.

```
.<let id = fun x -> x in id 1>.
Let_ (Lam (fun x -> x)) (fun id -> App id (Lit 1))
```

Seems straightforward, but how to represent polymorphic `let`?

$$\frac{e : \tau}{e : \forall\alpha.\,\tau} \quad \mathsf{Gen} \;:\; \forall\tau{:}\star\to\star.\ (\forall\alpha.\ \alpha\,\tau\ \mathsf{code}) \to (\forall\alpha.\ \alpha\,\tau)\ \mathsf{code}$$

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Need higher-rank, higher-kind polymorphism?
Don't generate code that uses polymorphism? 'Metacircular `let`'

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let id = Lam (fun x -> x) in App id id
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