A Nanopass Framework for Commercial Compiler Development

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CISCO

Traditional Compilers

- Composed of a few large passes
- Each pass performs several tasks
- Difficult to maintain
- Difficult to add new optimizations

Nanopass Compilers

- Composed of many small passes
- Each pass performs a single task
- Easier to maintain
- Easier to add new optimizations

Potential Dangers

- Large languages can lead to large passes (lots of boilerplate)
- Tracking language changes can be difficult
- The nanopass framework helps address this

Nanopass Framework

- Embedded DSL for writing compilers
- Languages are formally defined
- Passes operate over languages
- Sarkar, Waddell, and Dybvig ICFP '04

Defining a language

```
(define-language Lsrc
  (terminals
    (datum      (d))
    (primitive (pr))
    (uvar       (x)))
  (Expr (e body)
        x
        (quote d)
        (if e0 e1 e2)
        (begin e* ... e)
        (lambda (x* ...) body)
        (let ([x* e*] ...) body)
        (letrec ([x* e*] ...) body)
        (set! x e)
        (pr e* ...)
        (call e e* ...)                    => (e e* ...)))
```

Extending a language

```
(define-language L1
  (extends Lsrc)
  (terminals
    (- (datum (d)))
    (+ (constant (c))))
  (Expr (e body)
    (- (quote d))
    (+ (quote c))))
```

Defining a pass

```
(define-pass convert-complex-datum : Lsrc (e) -> L1 ()
  (definitions
    (define const-x* '())
    (define const-e* '())
    (define datum->expr ---))
  (Expr : Expr (e) -> Expr ()
    [,x x]
    [(quote ,d)
     (if (constant? d)
         `(quote ,d)
         (let ([t (unique-name 't)])
           (set! const-x* (cons t const-x*))
           (set! const-e* (cons (datum->expr d) const-e*))
           t))]
    [(if ,e0 ,e1 ,e2) `(if ,(Expr e0) ,(Expr e1) ,(Expr e2))]
    [(begin ,e* ... ,e) `(begin ,(map Expr e*) ... ,(Expr e))]
    [(lambda (,x* ...) ,body) `(lambda (,x* ...) ,(Expr body))]
    [(let ([,x* ,e*] ...) ,body)
     `(let ([,x* ,(map Expr e*)] ...) ,(Expr body))]
    [(letrec ([,x* ,e*] ...) ,body)
     `(letrec ([,x* ,(map Expr e*)] ...) ,(Expr body))]
    [(set! ,x ,e) `(set! ,x ,(Expr e))]
    [(,pr ,e* ...) `(,pr ,(map Expr e*) ...)]
    [(call ,e ,e* ...) `(call ,(Expr e) ,(map Expr e*) ...)]
    [else (errorf who "invalid Expr form ~s" e)])
  (let ([e (Expr e)])
    (if (null? const-x*)
        e
        `(let ([,const-x* ,const-e*] ...) ,e))))
```

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    (define const-e* '())
    (define datum->expr ---))
  (Expr : Expr (e) -> Expr ()
    [(quote ,d)
     (guard (not (constant? d)))
     (let ([t (unique-name 't)])
       (set! const-x* (cons t const-x*))
       (set! const-e* (cons (datum->expr d) const-e*))
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Question

Is the nanopass methodology suitable for use in commercial compiler development?

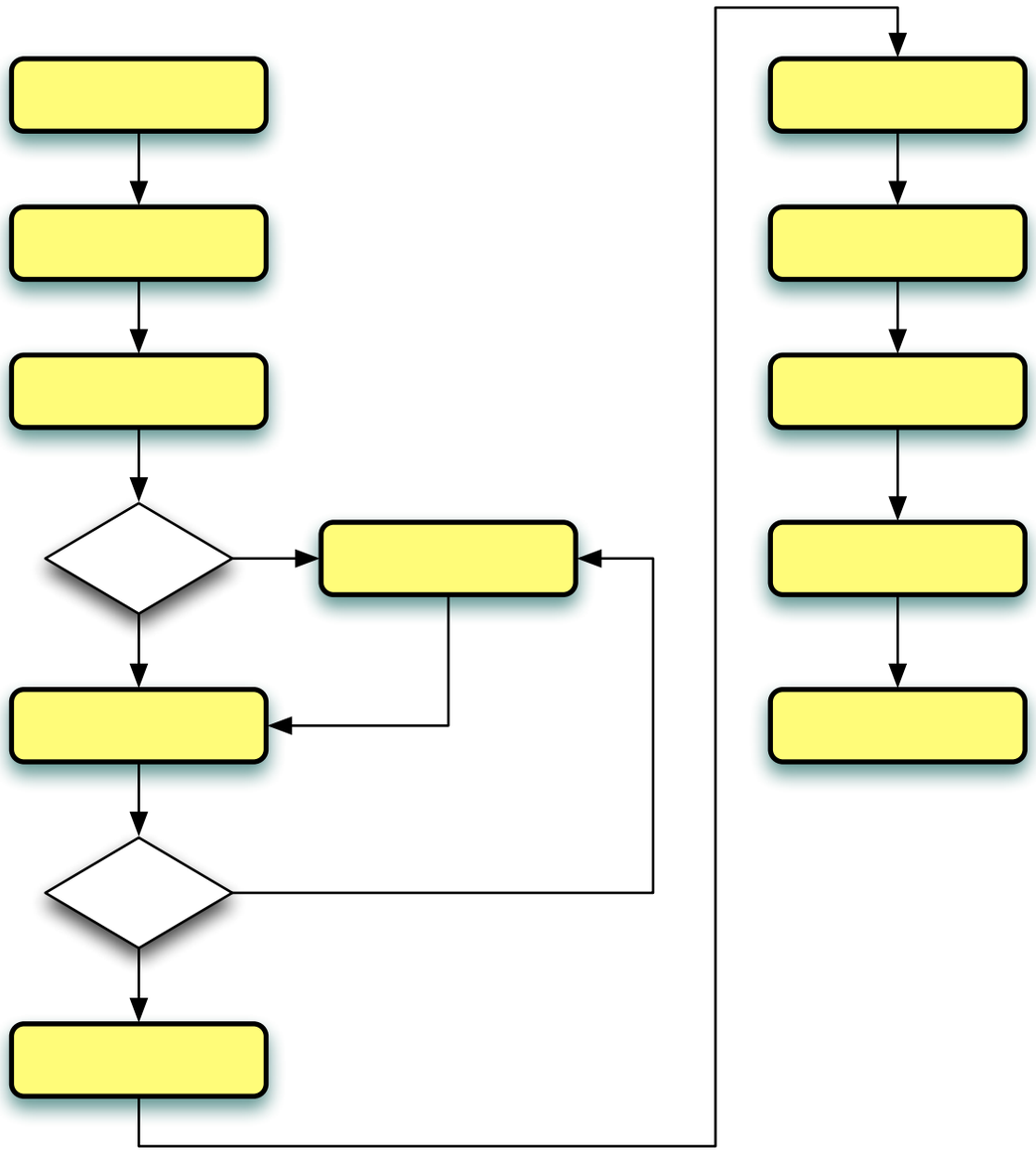
Approach

- Replace the compiler for Chez Scheme
- Support identical feature set
- Improve the nanopass framework (as needed)
- Graph coloring register allocator
- Improve and add optimizations

Comparing compilers

Front end:

Back end:



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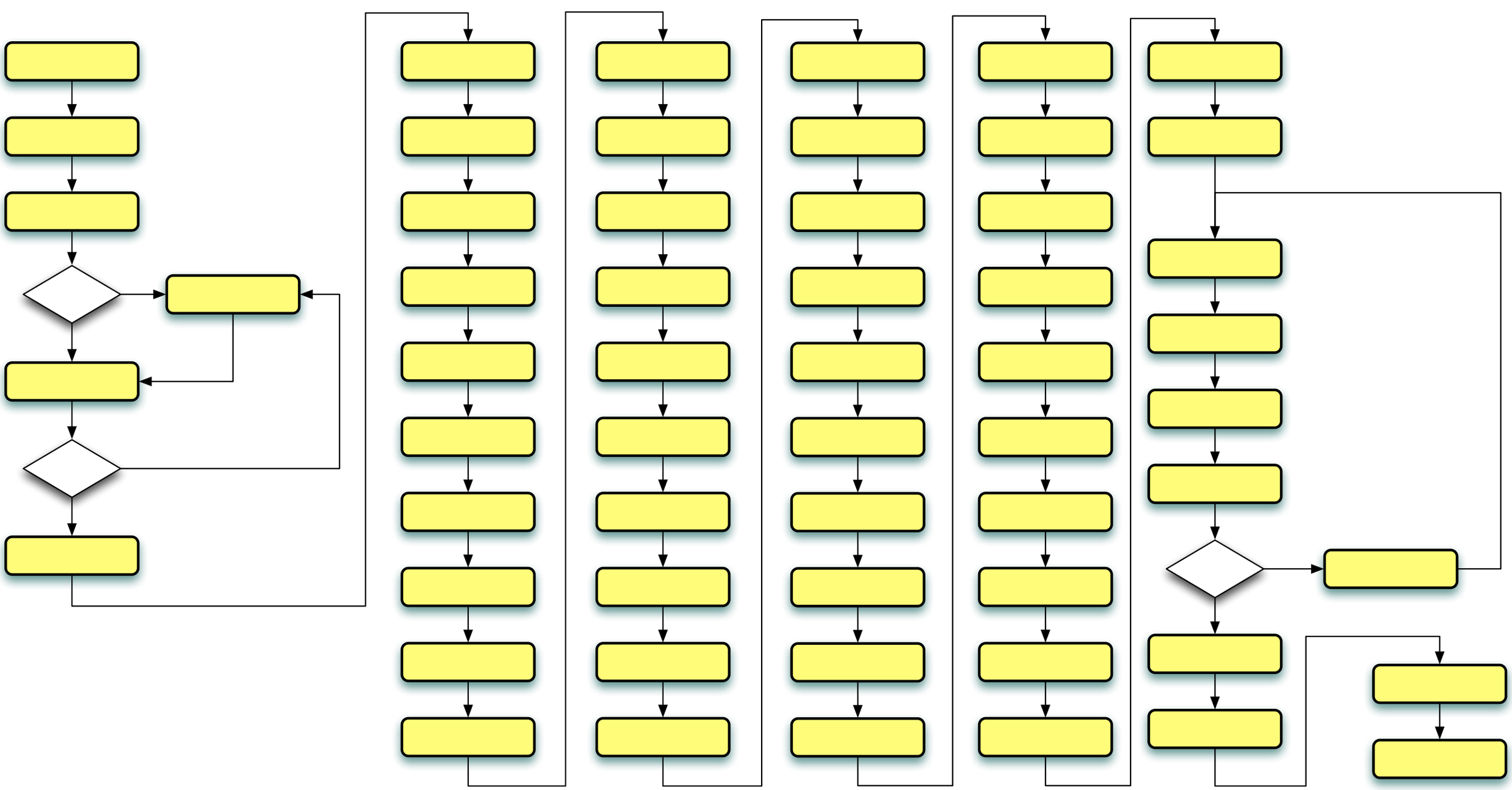

Evaluation

- Three sets of benchmarks
  - R6RS Benchmarks
  - Chez Scheme benchmarks
  - Source optimizer benchmarks

Compile-time factors

Optimize level	x86	x86_64
2	1.38	1.44
3	1.26	1.38

Average factor of compile-time slow down

Run-time Performance

Optimize level	x86	x86_64
2	0.72	0.76
3	0.76	0.83

Average improvement of benchmark run times

Improved Framework

- Error checking
- Robustness
- Functionality
- Performance

Conclusion

- Commercial nanopass compiler
  - Supports identical feature set
  - Modest compile-time penalty
  - 17%-28% average run-time speed-up
  - Has proved easier to extend

Nanopass Framework

- github.com/akeep/nanopass-framework
- Projects using the nanopass framework
  - Chez Scheme
  - Harlan - github.com/eholk/harlan