

Trampolining Architectures

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Computations are Represented with Monads

Multithreaded Systems Shouldn't have to be “One Size Fits All”

- Multithreaded systems are not all equal
- But they may all have something in common
- Trampolining architectures bring out the commonality

What is Trampolined Style?

- A transformation of programs
- Inserts *bounce* forms to interrupt threads
- Threads are interchanged by a scheduler

Factorial Trampolined

- Given an initial procedure:

```
(define fact  
  (lambda (n)  
    (if (zero? n)  
        1  
        (* n (fact (sub1 n))))))
```

- the trampolined version is:

```
(define fact-tramp
  (lambda (n)
    (if (zero? n)
        (unit 1)
        (m-let (v ((bounce
                    (lambda ()
                      (fact-tramp (sub1 n))))))
                (unit (* n v))))))
```

- and it can be run as

```
(trampoline  
  (lambda ()  
    (fact-tramp m)))
```

What is a Trampolining Architecture?

- A framework for providing powerful and efficient non-cooperative multiprocessing
- Provides an implementation for programs that have been converted to trampolined style

Trampolining Architecture

Defines the operators:

- **unit**

- **extend**

`(m-let (?var ?rhs) ?body) ⇒`

`((extend (lambda (?var) ?body)) ?rhs)`

- **bounce**

- **trampoline**

The Simplest Architecture: Pogo

```
(define-record done (value))
```

```
(define-record doing (thunk))
```

```
(define unit make-done)
```

```
(define bounce
```

```
  (lambda (thunk)
```

```
    (lambda ()
```

```
      (make-doing thunk))))))
```

```
(define extend
  (lambda (recvr)
    (lambda (comp)
      (record-case comp
        (done (value) (recvr value))
        (doing (thunk)
          (make-doing
            (compose (extend recvr)
              thunk))))))))))
```

```
(define trampoline
  (lambda (thunk)
    (letrec ((tramp
              (lambda (thread)
                (record-case thread
                  (done (value)
                       (stream-cons value
                                     (make-empty-stream)))
                  (doing (thunk)
                       (tramp (thunk)))))))
      (tramp (make-doing thunk)))))
```

➤ (trampoline (lambda () (fact-tramp 5)))

[120]

Dynamic Threads

```
➤ (trampoline  
  (lambda ()  
    (spawn  
      (lambda () (fact-tramp -1))  
      (lambda () (fact-tramp 5))))))
```

```
[120 ***]
```

```
(define unit (compose unitList make-done))
```

```
(define bounce  
  (lambda (thunk)  
    (lambda ()  
      (unitList (make-doing thunk))))))
```

```
(define extend
  (lambda (recvr)
    (extendList
      (lambda (thread)
        (record-case thread
          (done (value) (recvr value))
          (doing (thunk)
            ((bounce
              (compose (extend recvr) thunk))))))))))
```

```
(define die (lambda () '()))
```

```
(define spawn  
  (lambda (thunk1 thunk2)  
    (list (make-doing thunk1)  
          (make-doing thunk2))))
```

```
(define fib-async
  (lambda (n)
    (if (< n 2)
        (begin
          (set! acc (add1 acc))
          (die))
        (spawn
         (lambda () (fib-async (- n 1)))
         (lambda () (fib-async (- n 2)))))))
```

➤ (define acc 0)

➤ (stream-car
 (trampoline
 (lambda ()
 (spawn
 (lambda () (fact-tramp 9))
 (lambda () (fib-asynch 10)))))))

362880

➤ acc

89

Fair Threads

```
(define-record multi (siblings))
```

```
(define unit make-done)
```

```
(define bounce  
  (lambda (thunk)  
    (lambda ()  
      (make-doing thunk))))
```

```
(define extend
  (lambda (recvr)
    (Y (lambda (p)
        (lambda (thread)
          (record-case thread
            (done (value) (recvr value))
            (doing (thunk)
              (make-doing
                (compose (extend recvr) thunk))))
          (multi (siblings)
            (make-multi ((List p) siblings))))))))))
```

➤ (define acc 0)

➤ (stream-car

(trampoline

(lambda ()

(spawn

(lambda () (fact-tramp 9))

(lambda () (fib-asynch 10))))))

362880

➤ acc

0

Recycling Threads

```
(define unit  
  (lambda (value)  
    (lambda (thread)  
      (to-done! thread)  
      (done-value-set! thread value)  
      thread)))
```

```
(define bounce  
  (lambda (thunk)  
    (lambda ()  
      (lambda (thread)  
        (to-doing! thread)  
        (doing-proc-set! thread thunk)  
        thread))))
```

```
(define extend
  (lambda (recvr)
    (B (Y (lambda (p)
          (lambda (thread)
            (cond
              ((done? thread)
               (let ((value (done-value thread)))
                 (to-doing! thread)
                 (doing-proc-set! thread
                  (lambda () (recvr value))))))
              ((doing? thread)
               (doing-proc-set! thread
                (compose (extend recvr) (doing-proc thread))))
              ((multi? thread)
               (multi-sibs-set! thread ((List p) (multi-sibs thread))))
              (thread)))))))))
```

```

(compose (extend recvr) unit)
= (lambda (value)
  (lambda (thread)
    ((Y (lambda (p)
      (lambda (thread)
        (cond
          ((done? thread) (let ((value (done-value thread)))
                           (to-doing! thread)
                           (doing-proc-set! thread (lambda () (recvr value))))))
          ((doing? thread) (doing-proc-set! thread
        (compose (extend recvr) (doing-proc thread))))
          ((multi? thread) (multi-sibs-set! thread ((List p) (multi-sibs thread))))
        thread))))
    (begin (to-done! thread)
      (done-value-set! thread value)
      thread))))
= (lambda (value) ((bounce (lambda () (recvr value))))))
!= (lambda (value) (recvr value))
= recvr

```

So What is a Trampolining Architecture?

$$\approx \triangleq = \cup \{(\text{bounce}, \text{id}), (\text{id}, \text{bounce})\}$$

\Rightarrow

$$[\forall \text{recvr}. (\text{compose } (\text{extend } \text{recvr}) \text{unit}) \approx \text{recvr} \wedge$$

$$(\text{extend } \text{unit}) \approx \text{id}_{M\rho\alpha} \wedge$$

$$\forall f, g. (\text{extend } (\text{compose } (\text{extend } f) g)) \approx$$
$$(\text{compose } (\text{extend } f) (\text{extend } g)) \wedge$$

$$\forall \text{comp}, \text{recvr}.$$

$$(\text{compose } (\text{extend } \text{recvr}) (\text{bounce } (\text{lambda } () \text{comp}))) \approx$$
$$(\text{bounce } (\text{lambda } () ((\text{extend } \text{recvr}) \text{comp})))$$

\wedge

$$\exists i > 0. (\text{compose } \text{trampoline } \text{bounce}^i) = \text{trampoline}$$

Communicating Threads

See the paper

Logic Programming

```
(define unit (compose unitList make-done))
```

```
(define bounce  
  (lambda (goal)  
    (lambda (subst)  
      (unitList (make-doing goal subst))))))
```

```
(define interleave
  (lambda (recvr)
    (extendList
      (lambda (thread)
        (record-case thread
          (done (subst) (recvr subst))
          (doing (goal subst)
            ((bounce (compose (interleave goal) recvr))
              subst)))))))))
```

```
(define succeed unit)
```

```
(define fail (lambda (subst) '()))
```

```
(define any
```

```
  (lambda (goal1 goal2)
```

```
    (lambda (subst)
```

```
      (list (make-doing goal1 subst)
```

```
            (make-doing goal2 subst))))))
```

```
(define all
```

```
  (lambda (goal1 goal2)
```

```
    (compose (interleave goal2) goal1)))
```

```
(define trans
  (lambda (op)
    (lambda (goal)
      (op goal
        (bounce (lambda (subst)
                  (((trans op) goal) subst))))))))
```

```
(define any+ (trans any))
```

```
(define all+ (trans all))
```

```
(rewrites-as (gletrec ((x g1) ...) g2)
             (letrec ((x (bounce g1)) ...) g2))
```

➤ (trampoline (any⁺ succeed))

[() ...]

➤ (trampoline (all⁺ fail))

[]

➤ (trampoline (any (any⁺ fail) succeed))

[()]

➤ (trampoline (all (any⁺ fail) fail))

[]

➤ (trampoline (all (any⁺ succeed) fail))

[]

Trampolining and Reflection

- bounce provides Reification

```
(bounce  
  (lambda (subst)  
    (if (pred subst) comp1 comp2))  
  subst)
```

- For reflecting, translate as “simple”

```
(m-let (newSubst (modifySubst subst))  
  (let ((subst newSubst))  
    comp))
```

So What is a Trampolining Architecture?

$$\approx \triangleq = \cup \{(\text{bounce}, \text{id}), (\text{id}, \text{bounce})\}$$

\Rightarrow

$$[\forall \text{recvr}.(\text{compose } (\text{extend } \text{recvr}) \text{unit}) \approx \text{recvr} \wedge$$

$$(\text{extend } \text{unit}) \approx \text{id}_{M\rho\alpha} \wedge$$

$$\forall f, g.(\text{extend } (\text{compose } (\text{extend } f) g)) \approx$$
$$(\text{compose } (\text{extend } f) (\text{extend } g)) \wedge$$

$$\forall x^-, \text{comp}, \text{recvr}.$$

$$(\text{compose } (\text{extend } \text{recvr}) (\text{bounce } (\text{lambda } (x^-) \text{comp}))) \approx$$
$$(\text{bounce } (\text{lambda } (x^-) ((\text{extend } \text{recvr}) \text{comp})))]$$

\wedge

$$\exists i > 0. (\text{compose } \text{trampoline } \text{bounce}^i) = \text{trampoline}$$

Multithreaded Computations are
Represented
with “Relative” Monads

Most Relevant References

- Trampolining
(Filinski 1999; Claessen 1999;
Ganz, Friedman, Wand 1999; Harrison 2006)
- Small Bisimulations (used in proofs)
(Koutavas, Wand 2006)
- Fairness in Scheduling (Nagle 1987)
- Interleaving in Logic Programs
(Kiselyov, Shan, Friedman, Sabry 2005)
- Exposing Implementation Through Reflection
(Smith 1982; Friedman, Wand 1984)
- First-class Substitutions (Pientka 2008)

Conclusion

Trampolining Architectures:

- can provide useful and efficient implementations of multithreaded systems
- can provide a form of thread-level reflection
- need not be monads in the category of the programming language, but are closely related to monads