Clojure Compilation, Backwards

- Nicola Mometto (Bronsa)

brobronsa@gmail.com
https://github.com/Bronsa

clojure compilation overview

- reader (text -> data)
- macroexpander (code -> code)
- analyzer (code -> AST)
- emitter (AST -> bytecode)

JVM bytecode

Classfile Structure

- Constant Pool (class/method refs, constant values)
- Class Fields
- Method Bodies

JVM bytecode

Method Bodies

- Local Variable Table
  - start, end offset, slot, name, signature
- Exception Table
  - start, end, catch handler, exception type
- Line Number Table
- Bytecode

tools.decompiler

- bytecode loader/parser (bytecode -> symbolic bytecode)
- analyzer (bytecode -> AST)
- sweetener (AST -> sugared AST)
- compiler (sugared AST -> code)
- (macro)compactor (code -> compacted code)
- pprinter (compacted code -> formatted text)

bytecode loader/parser

- BCEL to load bytecode
- parse class fields
- parse class methods
- build exception table
- build local variable table
- build jump table
- build symbolic bytecode vector

bytecode loader/parser

```
#:class{:name "test$foo",
        :super "clojure.lang.AFunction",
        ...
        :methods [#:method{:name "invokeStatic",
                           :return-type "java.lang.Object",
                           :arg-types [],
                           :bytecode [#:insn{:name "ldc",
                                             :length 2,
                                             :pool-element #:insn{:target-value "hello"
                                                                  ..}
                                             :label 0}
                                      #:insn{:name "areturn", :length 1, :label 2}],
                           :jump-table {0 0, 2 1}
                           ..}
                  ..]}
```

analyzer

- dispatches on super class/interface/class name
  - AFunction/RestFn -> function
  - IType/IRecord -> deftype/defrecord
  - IObj and name contains "reify" -> reify
  - name ends with "__init" -> namespace initializer

analyzer

- ignore abstract/bridge methods
- initialize static fields
- collect methods to decompile (invoke, load, deftype methods)
- process each method
  - stack machine interpreter to build AST
  - process using ctx map (statements, stack, pc, lvt, etc)

analyzer

- instruction types
  - stack ops (dup, swap, ..)
  - branch ops (ifeq, instanceof, ..) -> conditionals
  - local variable ops (aload, astore, ..) -> lexical blocks
  - math ops (ladd, ldiv, ..) -> math intrinsics
  - other ops (invokevirtual, athrow, putstatic, ..) -> all else

analyzer

```
(defmethod process-insn :dup [{:keys [stack] :as ctx} _]
  (let [val (peek stack)]
    (-> ctx
        (update :stack conj val))))

;; simplified version
(defmethod process-insn :getstatic [ctx {:insn/keys [pool-element]}]
  (let [{:insn/keys [target-class target-name]} pool-element]
    (-> ctx
        (update :stack conj {:op :static-field
                             :target target-class
                             :field target-name}))))
```

analyzer

```
(defmethod process-insn :ifeq [{:keys [stack] :as ctx} insn]
  (let [else-label (goto-label insn)
        goto-end-insn (insn-at ctx {:label else-label :offset -2})

        end-label (goto-label goto-end-insn)

        {then-label :insn/label} (insn-at ctx {:offset 1})

        test (peek stack)]

    (-> ctx
        (update :stack pop)
        (process-if test [then-label (:insn/label goto-end-insn)]
                         [else-label end-label])))))
```

analyzer

```
{:op :fn,
 :name "foo",
 :fn-methods [{:op :fn-method,
               :fn-name "foo",
               :var-args? false,
               :args (),
               :body {:op :do,
                      :statements [],
                      :ret {:op :const,
                            :val "hello"}}}]}
```

sweetener

- pass over AST to add some syntax sugar
- some overlap with compactor
- e.g. clojure.lang.PersistentVector/EMPTY -> []

compiler

- compiles AST to clojure code
- same(ish) pass as tools.analyzer.jvm

(macro)compactor

- need to undo inlining/macroexpansion
- hardcoded patterns for clojure.core macros
- extension point with DSL for user-defined macros

(macro)compactor

attempt #1

- Kibit
- core.logic as a unification engine
- too slow
- no defined ordering is a problem

(macro)compactor

attempt #2

- core.match to pattern match over EDN
- fast!
- DSL over `match` to remove boilerplate
- no unification, use guards to enforce equality
- compact in postwalk over the source

(macro)compactor

attempt #2

```
(compact expr

   [(`let [?t ?x]
       (if ?t ?y ?t))

    {?t #(and (symbol? %)
              (-> % name (.startsWith "and__")))}

   :-> `(and ~?x ~?y)]

...)
```

pprinter

- trim constant statements
- elide referred namespaces from symbols
- use aliases instead of long namespaces in symbols
- use fipp to pretty print the output in a readable format

down the rabbit hole

java.io.IOException: File name too long, compiling: (clojure/tools/decompiler/compact.clj:150:21)

clojure.tools.decompiler.compact$macrocompact_step$fn__6117$fn__6118$fn__6119$fn__6120$fn__6121$fn__6122$fn__6123$fn__6124$fn__6125$fn__6126$fn__6127$fn__6128$fn__6129$fn__6130$fn__6131$fn__6132$fn__6133$fn__6134$fn__6135$fn__6136$fn__6137$fn__6138$fn__6139$fn__6140$fn__6141$fn__6142$fn__6143$fn__6144$fn__6145$fn__6166$fn__6167$fn__6168$fn__6195$fn__6200$fn__6201$fn__6202$fn__6203$fn__6204$fn__6205$fn__6206$fn__6207$fn__6208$fn__6209$fn__6210$fn__6232$fn__6233$fn__6234$fn__6235$fn__6238$fn__6241$fn__6244$fn__6247$fn__6250$fn__6251$fn__6254$fn__6255$fn__6256$fn__6257$fn__6258$fn__6262$fn__6266$fn__6269$fn__6270$fn__6271$fn__6274$fn__6278$fn__6279$fn__6280$fn__6284$fn__6285$fn__6286$fn__6287$fn__6300$fn__6301$fn__6302$fn__6303.invoke()

down the rabbit hole

- workaround patch to Compiler.java
- it worked!
- but one thread kept 100% CPU

down the rabbit hole

- BCEL
- core.match
- fipp

down the rabbit hole

- ~~BCEL~~
- core.match
- fipp

down the rabbit hole

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down the rabbit hole

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- ~~core.match~~
- ~~fipp~~

down the rabbit hole

- ~~BCEL~~
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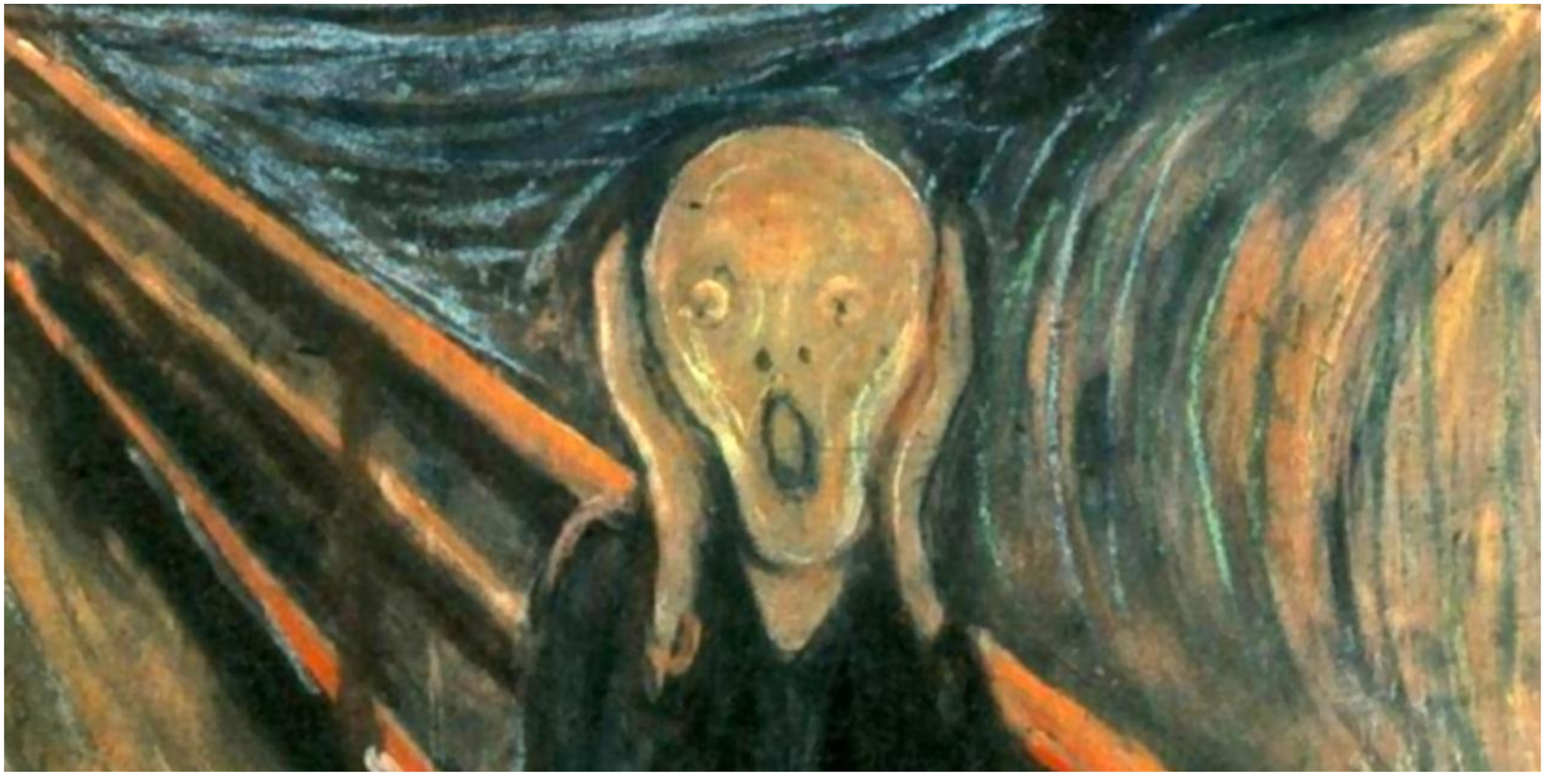
- clojure compiler?

down the rabbit hole

- ~~BCEL~~
- ~~core.match~~
- ~~fipp~~
- ~~clojure compiler?~~

down the rabbit hole



down the rabbit hole

- ~~BCEL~~
- ~~core.match~~
- ~~fipp~~
- ~~clojure compiler?~~
- JVM?

down the rabbit hole

```
2546 Thread_11839119: Java: C1 CompilerThread3
    + 2546 thread_start  (in libsystem_pthread.dylib) + 13  [0x7fffde257080]
    +   2546 _pthread_start  (in libsystem_pthread.dylib) + 286  [0x7fffde257887]
    +     2546 _pthread_body  (in libsystem_pthread.dylib) + 180  [0x7fffde25793b]
    +       2546 java_start(Thread*)  (in libjvm.dylib) + 246  [0x10908a5b2]
    +         2546 JavaThread::run()  (in libjvm.dylib) + 450  [0x10916c1fc]
    +           2546 JavaThread::thread_main_inner()  (in libjvm.dylib) + 155  [0x10916ab0f]
    +             2546 CompileBroker::compiler_thread_loop()  (in libjvm.dylib) + 657  [0x108db8d0f]
    +               2546 CompileBroker::invoke_compiler_on_method(CompileTask*)  (in libjvm.dylib) + 1458  [0x108db67c8]
    +                 2546 Compiler::compile_method(ciEnv*, ciMethod*, int)  (in libjvm.dylib) + 144  [0x108ce8e9a]
    +                   2546 Compilation::Compilation(AbstractCompiler*, ciEnv*, ciMethod*, int, BufferBlob*)  (in libjvm.dylib) + 418  [0x108ce8718]
    +                     2546 Compilation::compile_method()  (in libjvm.dylib) + 109  [0x108ce8503]
    +                   2546 Compilation::compile_java_method()  (in libjvm.dylib) + 88  [0x108ce82da]
    +                     2546 Compilation::build_hir()  (in libjvm.dylib) + 280  [0x108ce81bc]
    +                       2546 IR::compute_code()  (in libjvm.dylib) + 43  [0x108cfd243]
    +                         2546 ComputeLinearScanOrder::ComputeLinearScanOrder(Compilation*, BlockBegin*)  (in libjvm.dylib) + 482  [0x108cfd1fc]
    +                           2546 ComputeLinearScanOrder::compute_order(BlockBegin*)  (in libjvm.dylib) + 441  [0x108cfcd4d]
    +                             2546 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [0x108cfc36b]
    +                               2546 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [0x108cfc36b]
    +                                 2546 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [0x108cfc36b]
    +                                   2546 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [0x108cfc36b]
    +                                     2546 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [0x108cfc36b]
    +                                       2544 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [0x108cfc36b]
    +                                       ! 2540 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [0x108cfc36b]
    +                                       ! : 2525 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [..]
    +                                       ! : | 2487 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [..]
    +                                       ! : | + 2403 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [..]
    +                                       ! : | + ! 2259 ComputeLinearScanOrder::compute_dominator(BlockBegin*, BlockBegin*)  (in libjvm.dylib) + 121  [..]
```

down the rabbit hole

- core.match is implemented as a transpiler
- wrote new backend, continuations instead of exceptions for backtracking
- no more C1 issues
- after no-op continuation elision, 3x faster than default backend

light at the end of the tunnel

DEMO

limitations

- locals are munged, symbols could collide
- no type hints/mutable deftype fields printing support
- casts/widening missing or extra ones inserted
- genclass/definterface not properly supported
- not all macros are compacted
- some extra garbage is produced
- some known bugs when exceptions thrown in return context

future work

- detect and sugar syntax-quote expressions
- compact for/doseq/ns
- properly support type-hints/mutable deftype field decls
- use line table to guide pprinting

https://github.com/Bronsa/tools.decompiler

https://github.com/Bronsa/tools.decompiler-aot

fin.