Beyond Overdubbing

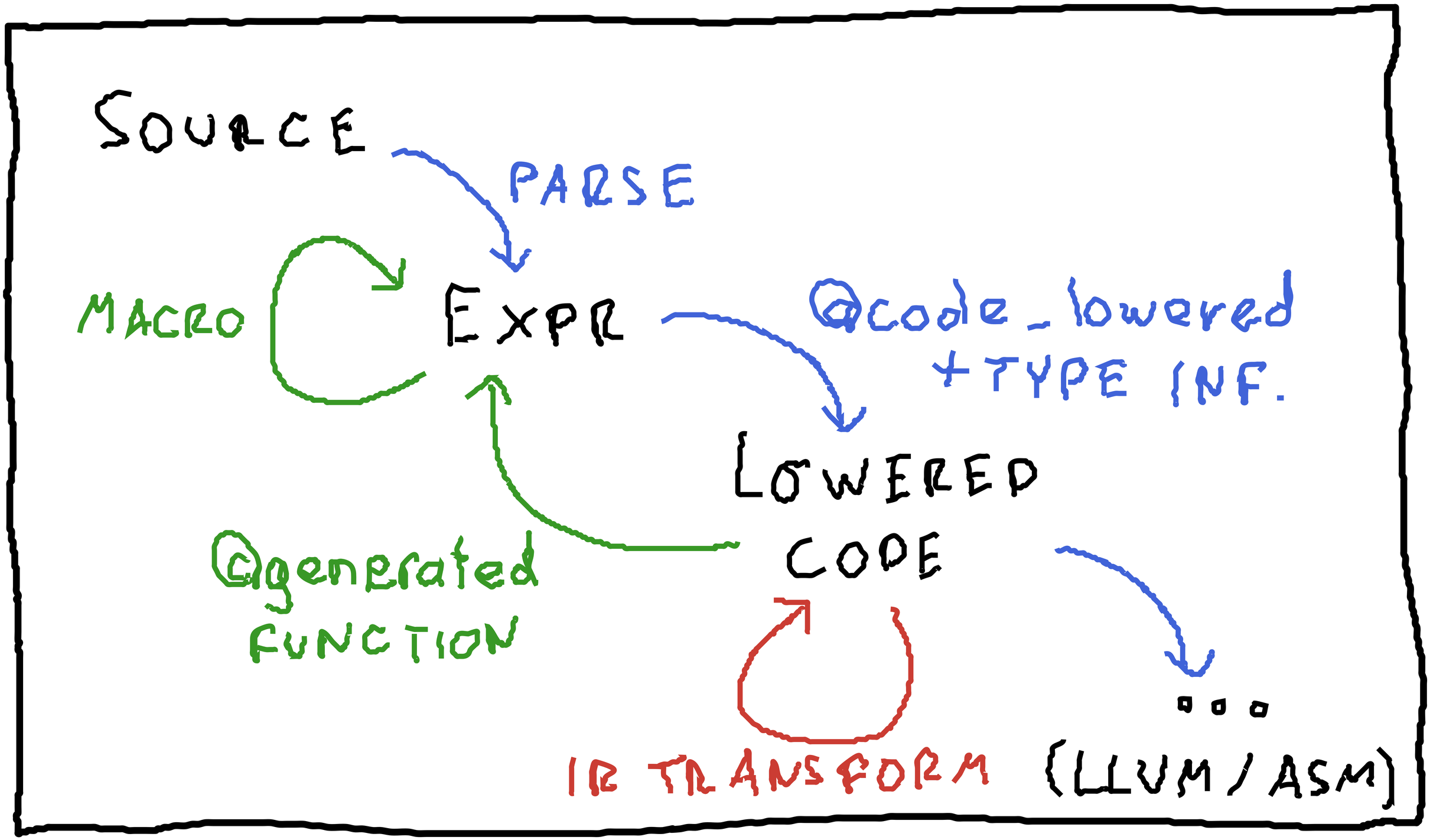
Building a generic IR Tracker

Philipp Gabler
(@phipsgabler)

Overview

- From zero to IRTracker
- IRTools & Cassette from a user perspective

Compiler Passes 101



Sloppy `if`s

```
julia> f(x) = x ? 1 : 0
f (generic function with 1 method)
```

ORIGINAL IR

```
julia> @code_ir f(0.0)
1: (%1, %2)
  br 2 unless %2
  return 1
2:
  return 0
```

TRANSFORMED IR

```
julia> @code_ir sloppyifs(f, 0.0)
1: (%1, %2)
  %3 = Base.getfield(%2, 1)
  %4 = Base.getfield(%2, 2)
  %5 = Base.convert(Bool, %4)
  br 2 unless %5
  return 1
2:
  return 0
```

NEW STUFF

Cassette Overdubbing

```
julia> @code_lowered 1/2
CodeInfo(
59 1 — %1 = (Base.float)(x)
   │    %2 = (Base.float)(y)
   │    %3 = %1 / %2
   └──       return %3
)
```

```
julia> @code_lowered overdub(Ctx(), /, 1, 2)
CodeInfo(
59 1 —       #self# = getfield(##args, 1)
   │         x = getfield(##args, 2)
   │         y = getfield(##args, 3)
   │         prehook(##ctx, float, x)
   │  %5  = overdub(##ctx, float, x)
   │         posthook(##ctx, %5, float, x)
   │  %7  = %5
   │         prehook(##ctx, float, y)
   │  %9  = overdub(##tx, float, y)
   │         posthook(##ctx, %9, float, y)
   │  %11 = %9
   │         prehook(##ctx, /, %7, %11)
   │  %13 = overdub(##ctx, /, %7, %11)
   │         posthook(##ctx, %13, /, %7, %11)
   │  %15 = %13
   └──       return %15
)
```

IRTools Dynamo

```
@dynamo function sloppyifs(f, args...)
    ir = IR(f, args...)
    ir === nothing && return

    for block in blocks(ir)
        bblock = BasicBlock(block)
        for b in eachindex(branches(bblock))
            branch = bblock.branches[b]
            if isconditional(branch)
                converted = push!(block, xcall(:convert, Bool, branch.condition))
                bblock.branches[b] = Branch(branch; condition=converted)
            end
        end
    end

    return ir
end
```

```
julia> @code_ir f(0.0)
1: (%1, %2)
  br 2 unless %2
  return 1
2:
  return 0
```

```
%3 = convert(Bool, %2)
```

IRTracker's Result

```
julia> @code_ir f(true)
1: (%1, %2)
  br 2 unless %2
  return 1
2:
  return 0
```

```
julia> @code_ir (x -> f(true) + x)(1)
1: (%1, %2)
  %3 = Main.f(true)
  %4 = %3 + %2
  return %4
```

```
julia> track(x -> f(true) + x, 1)
⟨var"#7#8"()⟩(⟨1⟩, ()...) → 2::Int64
  @1: [Arg:§1:%1] var"#7#8"()::var"#7#8"
  @2: [Arg:§1:%2] 1::Int64
  @3: [§1:%3] ⟨f⟩(⟨true⟩, ()...) → 1::Int64
    @1: [Arg:§1:%1] @3#1 → f::typeof(f)
    @2: [Arg:§1:%2] @3#2 → true::Bool
    @3: [§1:&2] return ⟨1⟩
  @4: [§1:%4] ⟨+⟩(@3, @2, ()...) → 2::Int64
    @1: [Arg:§1:%1] @4#1 → +::typeof(+)
    @2: [Arg:§1:%2] @4#2 → 1::Int64
    @3: [Arg:§1:%3] @4#3 → 1::Int64
    @4: [§1:%4] ⟨add_int⟩(@2, @3) → 2::Int64
    @5: [§1:&1] return @4 → 2::Int64
  @5: [§1:&1] return @4 → 2::Int64
```

IRTracker's Implementation

```
1: (%1, %2)
  br 2 unless %2
  return 1
2:
  return 0
```

```
julia> @code_tracked f(true)
1: (%3, %4, %1, %2)
  %5 = saveir!(%4, ...)
  %6 = TapeConstant(%1)
  %7 = trackedargument(%4, %6, nothing, 1, $(§1:%1))
  %8 = record!(%4, %7)
  %9 = TapeConstant(%2)
  %10 = trackedargument(%4, %9, nothing, 1, $(§1:%2))
  %11 = record!(%4, %10)
  %12 = tuple()
  %13 = trackedvariable(%4, $(%2), %2)
  %14 = trackedjump(%4, 2, %12, %13, $(§1:&1))
  %15 = trackedreturn(%4, $(⟨1⟩), $(§1:&2))
  br 2 (%14) unless %2
  br 3 (1, %15)
2: (%16)
  %17 = record!(%4, %16)
  %18 = trackedreturn(%4, $(⟨0⟩), $(§2:&1))
  br 3 (0, %18)
3: (%19, %20)
  %21 = record!(%4, %20)
  return %19
```

Dependency Extraction

```
julia> @model function test0(x)
    λ ~ Gamma(2.0, inv(3.0))
    m ~ Normal(0, sqrt(1 / λ))
    x ~ Normal(m, sqrt(1 / λ))
end
```

Turing Model

↓ Track + Extract

```
julia> trackdependencies(test0(1.4))
⟨2⟩ = 1.4
⟨4:λ⟩ ~ Gamma(2.0, 0.3333333333333333) → 1.035160868902524 5
⟨5⟩ = /(1, ⟨4:λ⟩) → 0.9660334253749353
⟨6⟩ = sqrt(⟨5⟩) → 0.982869941370 35
⟨8:m⟩ ~ Normal(0, ⟨6⟩) → -2.015554380649120 5
⟨9⟩ = /(1, ⟨4:λ⟩) → 0.9660334253749353
⟨10⟩ = sqrt(⟨9⟩) → 0.982869941370 35
⟨12:x⟩ ≃ Normal(⟨8:m⟩, ⟨10⟩) ← ⟨2⟩
```

WISHFUL THINKING

```
geom(n, beta) =
    rand() < beta ? n : geom(n + 1, beta)
```

IR

```
1: (%1, %2, %3)
  %4 = Main.rand()
  %5 = %4 < %3
  br 2 (%5) unless %5
  return %2
2:
  %6 = %2 + 1
  %7 = Main.geom(%6, %3)
  return %7
```

REIFIED IR OVERDUBS

```
1: (%1, %4, %2, %3)
  %5 = quoted(%4, Arg, :(%1), %1)
  %6 = quoted(%4, Arg, :(%2),%2)
  %7 = quoted(%4, Arg, :(%3), %3)
  %8 = quoted(%4, Const, Main.rand)
  %9 = overdub(%4, Call, :(%4), %8)
  %10 = quoted(%4, Const, <)
  %11 = overdub(%4, Call, :(%5), %10, %9, %7)
  %12 = quoted(%4, CondBranch, 2, %11)
  %13 = quoted(%4, Return, %6)
  br 2 unless %11
  br 3 (%13)
2:
  %14 = quoted(%4, Const, +)
  %15 = quoted(%4, Const, 1)
  %16 = overdub(%4, Call, :(%6), %14, %6, %5)
  %17 = quoted(%4, Const, Main.geom)
  %18 = overdub(%4, Call, :(%7), %17, %16, %7)
  %19 = quoted(%4, Return, %18)
  br 3 (%19)
3 (%20):
  %21 = overdub(%4, Return, %20)
  return %20
```

Last Slide

- Special thanks to:
  Mike Innes, the Turing team

- Find slides & text at:
  github.com/phipsgabler/beyond_overdubbing