

An Implementation of Type Inference for Featherweight Generic Java

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$$T := X \mid N$$
$$N := C \langle \bar{T} \rangle$$
$$L := \text{class } C \langle \bar{X} \triangleleft \bar{N} \rangle \triangleleft D \{ \bar{T} \bar{f} [K] \bar{M} \}$$
$$K := C(\bar{T} \bar{f}) \{ \text{super}(\bar{f}); \text{this}.\bar{f} = \bar{f}; \}$$
$$M := \langle \bar{X} \triangleleft \bar{N} \rangle T \text{ m}(\bar{T} \bar{x}) \{ \text{return } e \}$$
$$e := x \mid e.f \mid e.\langle \bar{T} \rangle \text{m}(\bar{e}) \mid \text{new } C(\bar{e}) \mid (C)e$$

AST

```
@dataclass
class ClassDef:
    name: str,
    superclass: Type,
    typed_fields: FieldEnv,
    methods: list[MethodDef]
```

Parser

```
# grammar rules
```

```
identifier: ...
```

```
variable: identifier
```

```
[...]
```

```
# function for shaping
```

```
def variable(tuple_of_elements_of_variable_rule):  
    (name, ) = tuple_of_elements_of_variable_rule  
    return Variable(name)
```

$$\text{genericSupertype}(C, \overline{T}, C) = \overline{T}$$

$$\frac{\text{class } C < \overline{Y} \triangleleft \overline{P} > \triangleleft C' < \overline{M} > \{ \dots \}}{\text{genericSupertype}(C, \overline{T}, D) = \text{genericSupertype}(C', [\overline{T}/\overline{Y}]\overline{M}, D)}$$

extended Syntax

$T := a \mid X \mid N$	type variable, type parameter, non type variable
$N := C < \bar{T} >$	class type (with type variables)
$sc := T < U \mid T = U$	simple constraint: subtype or equality
$oc := \{ \{ \bar{sc}_1 \}, \dots, \{ \bar{sc}_n \} \}$	or-constraint
$c := sc \mid oc$	constraint
$C := \{ \bar{c} \}$	constraint set
$\lambda := C < \bar{X} \triangleleft \bar{N} > . m : < \bar{Y} \triangleleft \bar{P} > \bar{T} \rightarrow T$	method type assumption
$\eta := x : T$	parameter assumption
$\Pi := \Pi \cup \bar{\lambda}$	method type environment
$\Theta := (\Pi; \bar{\eta})$	

Type Inference

$$\begin{aligned} \text{FJTypeInference}(\Pi, \text{class } C <\bar{X} \triangleleft \bar{N}> \triangleleft N\{\dots\}) = \\ \text{let } (\bar{\lambda}, C) &= \text{FJType}(\Pi, \text{class } C <\bar{X} \triangleleft \bar{N}> \triangleleft N\{\dots\}) \\ (\sigma, <\bar{Y} \triangleleft \bar{P}>) &= \text{Unify}(C, \{\bar{X} <: \bar{N}\} \cup \{<\bar{Z} \triangleleft \bar{Q}> \mid \\ &\quad (C <\bar{X} \triangleleft \bar{N}>.m : <\bar{Z} \triangleleft \bar{Q}> \bar{T} \rightarrow T) \in \bar{\lambda}\}) \\ \text{in } \Pi \cup \{ &((C <\bar{X} \triangleleft \bar{N}>.m : <\bar{Y} \triangleleft \bar{P}> \overline{\sigma(a)} \rightarrow \sigma(a)) \mid \\ &(C <\bar{X} \triangleleft \bar{N}>.m : \bar{a} \rightarrow a) \in \bar{\lambda}) \} \end{aligned}$$

$$\begin{aligned}
 & \text{FJType}(\Pi, \text{class } C \langle \bar{X} \triangleleft \bar{N} \rangle \triangleleft N \{ \bar{T} \text{ f}; \bar{M} \}) = \\
 & \quad \text{let } \bar{a}_m \text{ be fresh type variables for each } m \in \bar{M} \\
 & \quad \bar{\lambda}_0 = \{ C \langle \bar{X} \triangleleft \bar{N} \rangle . m : \langle \bar{Y} \triangleleft \bar{P} \rangle \bar{T} \rightarrow a_m \\
 & \quad \quad \mid m \in \bar{M}, \text{ mtype}(m, N, \Pi) = \langle \bar{Y} \triangleleft \bar{P} \rangle \bar{T} \rightarrow T \} \\
 & \quad C_0 = \{ a_m < T \mid m \in \bar{M}, \text{ mtype}(m, N, \Pi) = \langle \bar{Y} \triangleleft \bar{P} \rangle \bar{T} \rightarrow T \} \\
 & \quad \bar{\lambda}' = \{ (C \langle \bar{X} \triangleleft \bar{N} \rangle . m : \bar{a} \rightarrow a_m) \\
 & \quad \quad \mid m \in \bar{M}, \text{ mtype}(m, N, \Pi) \text{ not defined, } \bar{a} \text{ fresh} \} \\
 & \quad C_m = \{ \{ a_m < \text{Object}, \bar{a} < \overline{\text{Object}} \} \mid (C \langle \bar{X} \triangleleft \bar{N} \rangle . m : \bar{a} \rightarrow a_m) \in \bar{\lambda}' \} \\
 & \quad \Pi = \Pi \cup \bar{\lambda}' \cup \bar{\lambda}_0 \\
 & \quad \text{in } (\Pi, C_0 \cup C_m \cup \bigcup_{m \in \bar{M}} \text{TYPEMethod}(\Pi, C \langle \bar{X} \rangle, m))
 \end{aligned}$$

$$\begin{aligned} \text{TYPEMethod}(\Pi, C\langle\bar{X}\rangle, m(\bar{x})\{\text{return } e; \}) = \\ \text{let } \langle\bar{Y} \triangleleft \bar{P}\rangle \bar{T} \rightarrow T = \Pi(C\langle\bar{X} \triangleleft \bar{N}\rangle.m) \\ (R, C) = \text{TYPEExpr}((\Pi; \{\text{this} : C\langle\bar{X}\rangle\} \cup \{\bar{x} : \bar{T}\}), e) \\ \text{in } C \cup \{R < T\} \end{aligned}$$

$$\text{TYPEExpr}((\Pi; \bar{\eta}), x) = (\bar{\eta}(x), \emptyset)$$

$$\begin{aligned}
 \text{TYPEExpr}((\Pi; \bar{\eta}), e.f) = & \\
 & \text{let } (R, C_R) = \text{TYPEExpr}((\Pi; \bar{\eta}), e) \\
 & \quad a \text{ fresh} \\
 & \quad c = \text{oc}\{ \{ R < C\langle \bar{a} \rangle, a = [\bar{a}/\bar{X}]T, \bar{a} < [\bar{a}/\bar{X}]\bar{N} \mid \bar{a} \text{ fresh} \} \\
 & \quad \quad \mid T f \in \text{class } C\langle \bar{X} \triangleleft \bar{N} \rangle \triangleleft N \{ \bar{X} \bar{N}; [K] \bar{M} \} \} \\
 & \text{in } (a, (C_R \cup \{c\}))
 \end{aligned}$$

Solved Form

1. $a < b$

2. $a = b$

3. $a < C<\bar{T}>$

4. $a = C<\bar{T}>$ with $a \notin \bar{T}$

No variable is allowed to occur twice on the left side of rules 3 and 4.

Step 1

$$\frac{C \cup \{a < C<\bar{T}>, a < D<\bar{V}>\}}{C \cup \{a < C<\bar{T}>, C<\bar{T}> < D<\bar{V}>\}} \quad \Delta \vdash C<\bar{X}> <: D<\bar{N}> \quad \text{match}$$

$$\frac{C \cup \{C<\bar{T}> < a, D<\bar{V}> < a\}}{C \cup \{C<\bar{T}> < D<\bar{V}>, D<\bar{V}> < a\}} \quad \Delta \vdash C<\bar{X}> <: D<\bar{N}> \quad \text{match reverse}$$

$$\frac{C \cup \{a < C<\bar{T}>, b <^* a, b < D<\bar{U}>\}}{C \cup \{a < C<\bar{T}>, b <^* a, b < D<\bar{U}>, b < C<\bar{T}>\}} \quad \text{adopt}$$

$$\frac{C \cup \{C<\bar{T}> < a, a <^* b, D<\bar{U}> < b\}}{C \cup \{C<\bar{T}> < a, a <^* b, D<\bar{U}> < b, C<\bar{T}> < b\}} \quad \text{reverse adopt}$$

Step 2

1. $C < \bar{T} > < D < \bar{U} >$ where C cannot be a subtype of D .
2. $a < C < \bar{T} >, a < D < \bar{U} >$ where C cannot be a subtype of D and vice versa.
3. $C < \bar{T} > < a$

$$\text{expandLB}(C < \bar{T} > < a, a < D < \bar{U} >) = \{ \{ a = [\bar{T}/\bar{X}]N \mid \Delta \vdash C < \bar{X} > < N, \Delta \vdash N < D < \bar{P} > \}$$

where \bar{P} is determined by $\Delta \vdash C < \bar{X} > < D < \bar{P} >$ and $[\bar{T}/\bar{X}]\bar{P} = \bar{U}$

Step 3

$$\frac{C \cup \{a = T\}}{[T/a]C \cup \{a = T\}} \quad \text{where } a \text{ occurs in } C \text{ but not in } T$$

Step 4

If C'' has changed, then start again from Step 1.

Step 5

$$\frac{C \cup \{C \cup a < b\}}{[a/b]C \cup \{b = a\}} \quad \text{sub elim}$$

$$\frac{C \cup \{a = a\}}{C} \quad \text{erase}$$

Step 6

$$\sigma = \{b \rightarrow [\bar{Y}/\bar{a}]T \mid (b = T) \in C_{=}\} \cup \{\bar{a} \rightarrow \bar{Y}\} \cup \{b \rightarrow X \mid (b < X) \in C_{<}\}$$

$$\gamma = \{Y \triangleleft [\bar{Y}/\bar{a}]N \mid (a < N) \in C_{<}\}$$

Type Inference

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Example

```
class Pair<X extends Object<>,
          Y extends Object<>> extends Object<>{
    X fst;
    Y snd;

    setfst(newfst) {
        return new Pair(newfst, this.snd);
    }
}
```

Example

$$\lambda = \{(\text{Pair}\langle X \triangleleft \text{Object} \rangle.\text{setfst}) : [a_1] \rightarrow a_0\}$$

$$C = \{a_0 < \text{Object}, a_1 < \text{Object}\}$$

$$C = \{a_0 < \text{Object}, a_1 < \text{Object}, \\ a_1 < a_5, a_5 < \text{Object}, a_2 < a_6, a_6 < \text{Object}, \\ \{\{\text{Pair}\langle X, Y \rangle < \text{Pair}\langle a_3, a_4 \rangle, a_2 = a_4, a_3 < \text{Object}, a_4 < \text{Object}\}\} \\ \}$$

Example

$\lambda = \{(\text{Pair}\langle X \triangleleft \text{Object} \rangle.\text{setfst}) : [a_1] \rightarrow a_0\}$

$C = \{a_0 < \text{Object}, a_1 < \text{Object},$
 $a_1 < a_5, a_5 < \text{Object}, a_2 < a_6, a_6 < \text{Object},$
 $\{\{\text{Pair}\langle X, Y \rangle < \text{Pair}\langle a_3, a_4 \rangle, a_2 = a_4, a_3 < \text{Object}, a_4 < \text{Object}\}\},$
 $\text{Pair}\langle a_5, a_6 \rangle < a_0$
 $\}$

Example

$$\frac{C \cup \{\text{Pair}\langle X \rangle, Y \rangle < \text{Pair}\langle a_3, a_4 \rangle\}}{C \cup \{\text{Pair}\langle X \rangle, Y \rangle = \text{Pair}\langle a_3, a_4 \rangle\}} \quad \text{adapt}$$

$$\frac{C \cup \{\text{Pair}\langle X \rangle, Y \rangle = \text{Pair}\langle a_3, a_4 \rangle\}}{C \cup \{X \rangle = a_3, Y \rangle = a_4\}} \quad \text{reduce}$$

$$\frac{C \cup \{X \rangle = a_3\}}{C \cup \{a_3 = X \rangle\}} \quad \text{and} \quad \frac{C \cup \{Y \rangle = a_4\}}{C \cup \{a_4 = Y \rangle\}} \quad \text{swap}$$

Example

$$C = \{Y<> < a_6, a_1 < a_5, a_6 < \text{Object}<>, a_1 < \text{Object}<>, \\ X<> < \text{Object}<>, a_4 = Y<>, Y<> < \text{Object}<>, \\ a_0 = \text{Pair}<a_5, a_6>, a_3 = X<>, a_2 = Y<>, a_5 < \text{Object}<> \\ \}$$

$$C_ = \{a_0 = \text{Pair}<a_1, Y>, a_6 = Y, a_5 = a_1, a_4 = Y, a_3 = X, a_2 = Y\}$$

$$C_ < = \{a_1 < \text{Object}<>\}$$

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