

Featherweight Java

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Contents

1	Syntax	2
1.1	Variable names	2
1.2	Field names	2
1.3	Method names	2
1.4	Class names	2
1.5	Expressions	2
1.6	Method definitions	3
1.7	Class definitions	3
1.8	Class environments	3
1.9	Expression environments	3
2	Static semantics	4
2.1	Name inequalities	4
2.2	List concatenations	4
2.3	Class definition lookups	4
2.4	Field definition lookups	4
2.5	Method definition lookups	4
2.6	Indexed expression lookups	5
2.7	Indexed class lookups	5
2.8	Subtypings	5
2.9	Expression typings	5
2.10	Method typings	6
2.11	Class typings	6
3	Dynamic semantics	7
3.1	Substitutions	7
3.2	Values	7
3.3	Evaluations	7

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1 Syntax

1.1 Variable names

$x ::= \dots$	x
$x ::= \text{this}$	(this)
$\bar{x} ::= \dots$	$\bar{x}s$
$\bar{x} ::= \cdot$	(xs z)
$\bar{x} ::= \bar{x}, x$	(xs x)

1.2 Field names

$f ::= \dots$	f
$\bar{f} ::= \dots$	$\bar{f}s$
$\bar{f} ::= \cdot$	(fs z)
$\bar{f} ::= \bar{f}, f$	(fs f)

1.3 Method names

$m ::= \dots$	m
$\bar{m} ::= \dots$	$\bar{m}s$
$\bar{m} ::= \cdot$	(ms z)
$\bar{m} ::= \bar{m}, m$	(ms m)

1.4 Class names

$c ::= \dots$	c
$c ::= \text{Object}$	(obj)
$c ::= \text{void}$	(void)
$\bar{c} ::= \dots$	$\bar{c}s$
$\bar{c} ::= \cdot$	(cs z)
$\bar{c} ::= \bar{c}, c$	(cs c)

1.5 Expressions

$e ::= \dots$	e
$\bar{e} ::= \dots$	$\bar{e}s$
$e ::= x$	(var)
$e ::= e.f$	(dot)
$e ::= e.m(\bar{e})$	(call)
$e ::= \text{new } c(\bar{e})$	(new)

$e ::= (c)e$	(cast)
$e ::= \perp$	(bot)
$e ::= c \ x = e; e$	(let)
$e ::= e; e$	(seq)
$\bar{e} ::= \cdot$	(esz)
$\bar{e} ::= \bar{e}, e$	(ese)

1.6 Method definitions

$M ::= \dots$	md
$M ::= c \ m(\bar{c} \ \bar{x}) \ \{\text{return } e;\}$	(mdz)
$\bar{M} ::= \dots$	mds
$\bar{M} ::= \cdot$	(mdsz)
$\bar{M} ::= \bar{M}, M$	(mdsm)
$M^? ::= \dots$	mdo
$M^? ::= \cdot$	(mdoz)
$M^? ::= M$	(mdom)

1.7 Class definitions

$C ::= \dots$	cd
$C ::= \text{class } c \ \text{extends } c \ \{\bar{c} \ \bar{f} \ \bar{M}\}$	(cdz)
$\bar{C} ::= \dots$	cds
$\bar{C} ::= \cdot$	(cdsz)
$\bar{C} ::= \bar{C}, c$	(cdsc)

1.8 Class environments

$\Delta ::= \dots$	d
$\Delta ::= \cdot$	(dz)
$\Delta ::= \Delta, c \mapsto C$	(dc)
$\Delta ::= \Delta^\dagger$	(dd)

1.9 Expression environments

$\Gamma ::= \dots$	g
$\Gamma ::= \cdot$	(gz)
$\Gamma ::= \Gamma, x : c$	(gx)

2 Static semantics

2.1 Name inequalities

$x \neq x$	xneq
$f \neq f$	fneq
$m \neq m$	mneq
$c \neq c$	cneq

2.2 List concatenations

$\bar{c}, \bar{c} = \bar{c}$	cscat
$\bar{c}, \cdot = \bar{c}$	(cscat-z)
$\frac{\bar{c}_1, \bar{c}_2 = \bar{c}_3}{\bar{c}_1, (\bar{c}_2, c) = (\bar{c}_3, c)}$	(cscat-c)
$\bar{f}, \bar{f} = \bar{f}$	fscat
$\bar{f}, \cdot = \bar{f}$	(fscat-z)
$\frac{\bar{f}_1, \bar{f}_2 = \bar{f}_3}{\bar{f}_1, (\bar{f}_2, f) = (\bar{f}_3, f)}$	(fscat-f)
$\Gamma, \bar{x} : \bar{c} = \Gamma$	gcat
$\Gamma, \cdot : \cdot = \Gamma$	(gcat-z)
$\frac{\Gamma_1, \bar{x} : \bar{c} = \Gamma_2}{\Gamma_1, (\bar{x}, x) : (\bar{c}, c) = (\Gamma_2, x : c)}$	(gcat-x)

2.3 Class definition lookups

$\Delta(c) = C$	ccd
$(\Delta, c \mapsto C)(c) = C$	(ccd-c1)
$\frac{\Delta(c_2) = c}{(\Delta, c_1 \mapsto C)(c_2) = C}$	(ccd-c2)

2.4 Field definition lookups

$\text{fields}(c) = \bar{c} \bar{f}$	ccsfs
$\text{fields}(\text{Object}) = \cdot \cdot$	(ccsfs-z)
$\frac{\Delta^!(c_1) = (\text{class } c_1 \text{ extends } c_2 \{ \bar{c}_1 \bar{f}_1 \bar{M} \}) \quad \text{fields}(c_2) = \bar{c}_2 \bar{f}_2 \quad \bar{c}_1, \bar{c}_2 = \bar{c}_3 \quad \bar{f}_1, \bar{f}_2 = \bar{f}_3}{\text{fields}(c_1) = \bar{c}_3 \bar{f}_3}$	(ccsfs-c)

2.5 Method definition lookups

$\bar{M}(m) = M^?$	mmdo
$\cdot(m) = \cdot$	(mmdo-z)

$$(\bar{M}, (c \ m(\bar{c} \ \bar{x}) \ \{\text{return } e; \})) (m) = ((c \ m(\bar{c} \ \bar{x}) \ \{\text{return } e; \})) \quad (\text{mmdo-m1})$$

$$\frac{m_1 \neq m_2 \quad \bar{M}(m_1) = M^?}{(\bar{M}, (c \ m_1(\bar{c} \ \bar{x}) \ \{\text{return } e; \})) (m_2) = M^?} \quad (\text{mmdo-m2})$$

$$\boxed{\text{method}(c, m) = M^?} \quad \boxed{\text{cmmdo}}$$

$$\text{method}(\text{Object}, m) = \cdot \quad (\text{cmmdo-o})$$

$$\frac{\Delta^\dagger(c_1) = (\text{class } c_1 \ \text{extends } c_2 \ \{\bar{c} \ \bar{f} \ \bar{M}\}) \quad \bar{M}(m) = (M)}{\text{method}(c_1, m) = (M)} \quad (\text{cmmdo-z})$$

$$\frac{\Delta^\dagger(c_1) = (\text{class } c_1 \ \text{extends } c_2 \ \{\bar{c} \ \bar{f} \ \bar{M}\}) \quad \bar{M}(m) = \cdot \quad \text{method}(c_2, m) = M^?}{\text{method}(c_1, m) = M^?} \quad (\text{cmmdo-m})$$

2.6 Indexed expression lookups

$$\boxed{\bar{f}.i = f \quad \bar{e}.i = \bar{e}} \quad \boxed{\text{fsfese}}$$

$$(\bar{f}, f).i = f \quad (\bar{e}, e).i = (\bar{e}, e) \quad (\text{fsfese-z})$$

$$\frac{f_1 \neq f_2 \quad \bar{f}.i = f_2 \quad \bar{e}.i = \bar{e}}{(\bar{f}, f_1).i = f_2 \quad (\bar{e}, e_1).i = (\bar{e}, e_1)} \quad (\text{fsfese-f})$$

2.7 Indexed class lookups

$$\boxed{\bar{f}.i = f \quad \bar{c}.i = \bar{c}} \quad \boxed{\text{fsfcsc}}$$

$$(\bar{f}, f).i = f \quad (\bar{c}, c).i = (\bar{c}, c) \quad (\text{fsfcsc-z})$$

$$\frac{f_1 \neq f_2 \quad \bar{f}.i = f_2 \quad \bar{c}.i = \bar{c}}{(\bar{f}, f_1).i = f_2 \quad (\bar{c}, c_1).i = (\bar{c}, c_1)} \quad (\text{fsfcsc-f})$$

2.8 Subtypings

$$\boxed{\text{guess } c} \quad \boxed{\text{guessc}}$$

$$\boxed{c \preceq c} \quad \boxed{\text{st}}$$

$$c \preceq c \quad (\text{st-z})$$

$$\frac{\text{guess } c_2 \quad c_1 \preceq c_2 \quad c_2 \preceq c_3}{c_1 \preceq c_3} \quad (\text{st-t})$$

$$\frac{\Delta^\dagger(c_1) = (\text{class } c_1 \ \text{extends } c_2 \ \{\bar{c} \ \bar{f} \ \bar{M}\})}{c_1 \preceq c_2} \quad (\text{st-c})$$

$$\boxed{\bar{c} \preceq \bar{c}} \quad \boxed{\text{sts}}$$

$$\cdot \preceq \cdot \quad (\text{sts-z})$$

$$\frac{\bar{c}_1 \preceq \bar{c}_2 \quad c_1 \preceq c_2}{(\bar{c}_1, c_1) \preceq (\bar{c}_2, c_2)} \quad (\text{sts-c})$$

2.9 Expression typings

$$\boxed{\Gamma \vdash e : c} \quad \boxed{\text{ety}}$$

$$\boxed{\Gamma \vdash \bar{e} : \bar{c}} \quad \boxed{\text{etys}}$$

$\Gamma, x : c \vdash x : c$	(ety-var1)
$\frac{x_1 \neq x_2 \quad \Gamma \vdash x_2 : c}{\Gamma, x_1 : c \vdash x_2 : c}$	(ety-var2)
$\frac{\Gamma \vdash e : c_1 \quad \text{fields}(c_1) = \bar{c} \bar{f} \quad \bar{f}.i = f \quad \bar{c}.i = \bar{c}}{\Gamma \vdash e.f : c_2}$	(ety-dot)
$\frac{\Gamma \vdash e_1 : c_1 \quad \text{method}(c_1, m) = ((c_2 \ m(\bar{c}_1 \ \bar{x}) \ \{\text{return } e_2; \})) \quad \Gamma \vdash \bar{e} : \bar{c}_2 \quad \bar{c}_2 \preceq \bar{c}_1}{\Gamma \vdash e_1.m(\bar{e}) : c_2}$	(ety-call)
$\frac{\Gamma \vdash \bar{e} : \bar{c}_2}{\Gamma \vdash \text{new } c(\bar{e}) : c}$	(ety-new)
$\frac{\Gamma \vdash e : c_2}{\Gamma \vdash (c_1)e : c_1}$	(ety-cast)
$\Gamma \vdash \perp : \text{void}$	(ety-bot)
$\frac{\Gamma \vdash e_1 : c_1 \quad \Gamma, x : c_1 \vdash e_2 : c_2}{\Gamma \vdash c_1 \ x = e_1; e_2 : c_2}$	(ety-let)
$\frac{\Gamma \vdash e_1 : \text{void} \quad \Gamma \vdash e_2 : c}{\Gamma \vdash e_1; e_2 : c}$	(ety-seq)
$\Gamma \vdash \cdot \cdot$	(etys-z)
$\frac{\Gamma \vdash \bar{e} : \bar{c} \quad \Gamma \vdash e : c}{\Gamma \vdash (\bar{e}, e) : (\bar{c}, c)}$	(etys-e)

2.10 Method typings

$\boxed{\text{override}(c, m, \bar{c} \rightarrow c)}$	$\boxed{\text{override}}$
$\frac{\text{method}(c_1, m) = \cdot}{\text{override}(c_1, m, \bar{c} \rightarrow c_2)}$	(override-z)
$\frac{\text{method}(c_1, m) = ((c_2 \ m(\bar{c} \ \bar{x}) \ \{\text{return } e; \}))}{\text{override}(c_1, m, \bar{c} \rightarrow c_2)}$	(override-m)
$\boxed{\vdash M}$	$\boxed{\text{mty}}$
$\frac{\Delta^\dagger(c_1) = (\text{class } c_1 \ \text{extends } c_2 \ \{\bar{c} \ \bar{f} \ \bar{M}\}) \quad (\cdot, \text{this} : c_1), \bar{x} : \bar{c} = \Gamma \quad \Gamma \vdash e : c_3 \quad \text{override}(c_2, m, \bar{c} \rightarrow c_1) \quad c_3 \preceq c_1}{\vdash (c_1 \ m(\bar{c} \ \bar{x}) \ \{\text{return } e; \})}$	(mty-z)
$\boxed{\vdash \bar{M}}$	$\boxed{\text{mtys}}$
$\vdash \cdot$	(mtys-z)
$\frac{\vdash \bar{M} \quad \vdash m}{\vdash (\bar{M}, m)}$	(mtys-m)

2.11 Class typings

$\boxed{\vdash C}$	$\boxed{\text{cty}}$
$\frac{\vdash \bar{M}}{\vdash (\text{class } c_1 \ \text{extends } c_2 \ \{\bar{c} \ \bar{f} \ \bar{M}\})}$	(cty-z)

3 Dynamic semantics

3.1 Substitutions

$e\{e/x\} = e$	sub
$\bar{e}\{e/x\} = \bar{e}$	subs
$x\{e/x\} = e$	(sub-var1)
$\frac{x_1 \neq x_2}{x_1\{e/x_2\} = x_1}$	(sub-var2)
$\frac{e_1\{e/x\} = e_2}{(e_1.f)\{e/x\} = (e_2.f)}$	(sub-dot)
$\frac{e_1\{e/x\} = e_2 \quad \bar{e}_1\{e/x\} = \bar{e}_2}{(e_1.m(\bar{e}_1))\{e/x\} = (e_2.m(\bar{e}_2))}$	(sub-call)
$\frac{\bar{e}_1\{e/x\} = \bar{e}_2}{(\text{new } c(\bar{e}_1))\{e/x\} = (\text{new } c(\bar{e}_2))}$	(sub-new)
$\frac{e_1\{e/x\} = e_2}{((c)e_1)\{e/x\} = ((c)e_2)}$	(sub-cast)
$\cdot\{e/x\} = \cdot$	(subs-z)
$\frac{\bar{e}_1\{e/x\} = \bar{e}_2 \quad e_1\{e/x\} = e_2}{(\bar{e}_1, e_1)\{e/x\} = (\bar{e}_2, e_2)}$	(subs-e)
$e\{\bar{e}/\bar{x}\} = e$	subes
$e\{\cdot/\cdot\} = e$	(subes-z)
$\frac{e_1\{\bar{e}/\bar{x}\} = e_2 \quad e_2\{e/x\} = e_3}{e_1\{(\bar{e}, e)/(\bar{x}, x)\} = e_3}$	(subes-e)

3.2 Values

val e	val
vals \bar{e}	vals
$\frac{\text{vals } \bar{e}}{\text{val } (\text{new } c(\bar{e}))}$	(val-new)
val \perp	(val-bot)
vals \cdot	(vals-z)
$\frac{\text{vals } \bar{e} \quad \text{val } e}{\text{vals } (\bar{e}, e)}$	(vals-e)

3.3 Evaluations

$e \longrightarrow e$	ev
$\bar{e} \longrightarrow \bar{e}$	evs

$$\frac{e_1 \longrightarrow e_2}{e_1.f \longrightarrow e_2.f} \quad (\text{ev-dot1})$$

$$\frac{\text{vals } \bar{e} \text{ fields}(c) = \bar{c} \bar{f} \quad \bar{f}.i = f \quad \bar{e}.i = \bar{e}}{(\text{new } c(\bar{e})).f \longrightarrow e} \quad (\text{ev-dot2})$$

$$\frac{e_1 \longrightarrow e_2}{e_1.m(\bar{e}) \longrightarrow e_2.m(\bar{e})} \quad (\text{ev-call1})$$

$$\frac{\text{val } e \quad \bar{e}_1 \longrightarrow \bar{e}_2}{e.m(\bar{e}_1) \longrightarrow e.m(\bar{e}_2)} \quad (\text{ev-call2})$$

$$\frac{\text{vals } \bar{e}_1 \quad \text{vals } \bar{e}_2 \quad \text{method}(c,m) = ((c \ m(\bar{c} \ \bar{x}) \ \{\text{return } e_1;\}) \ e_1 \ \{\text{new } c(\bar{e}_1)\}/\text{this}) = e_2 \quad e_2 \ \{\bar{e}_2/\bar{x}\} = e_3}{(\text{new } c(\bar{e}_1)).m(\bar{e}_2) \longrightarrow e_3} \quad (\text{ev-call3})$$

$$\frac{e_1 \longrightarrow e_2}{(c)e_1 \longrightarrow (c)e_2} \quad (\text{ev-cast1})$$

$$\frac{c_2 \preceq c_1}{(c_1)(\text{new } c_2(\bar{e})) \longrightarrow \text{new } c_2(\bar{e})} \quad (\text{ev-cast2})$$

$$\frac{\bar{e}_1 \longrightarrow \bar{e}_2}{\text{new } c(\bar{e}_1) \longrightarrow \text{new } c(\bar{e}_2)} \quad (\text{ev-new})$$

$$\frac{e_1 \longrightarrow e_3}{c \ x = e_1; e_2 \longrightarrow c \ x = e_3; e_2} \quad (\text{ev-let1})$$

$$\frac{\text{val } e_1 \quad e_2 \ \{e_1/x\} = e_3}{c \ x = e_1; e_2 \longrightarrow e_3} \quad (\text{ev-let2})$$

$$\frac{e_1 \longrightarrow e_3}{e_1; e_2 \longrightarrow e_3; e_2} \quad (\text{ev-seq1})$$

$$\perp; e \longrightarrow e \quad (\text{ev-seq2})$$

$$\cdot \longrightarrow \cdot \quad (\text{evs-z})$$

$$\frac{\bar{e}_1 \longrightarrow \bar{e}_2 \quad e_1 \longrightarrow e_2}{(\bar{e}_1, e_1) \longrightarrow (\bar{e}_2, e_2)} \quad (\text{evs-e})$$