Pretty-big-step semantics

Arthur Charguéraud

INRIA

ESOP, 2013/03/19

Introduction

Operational semantics fall in two categories: small-step and big-step.

Big-step semantics suffer from a serious duplication problem.

Pretty-big-step semantics solve this duplication problem.

Why care about big-step semantics?

	Papers with big-step semantics	Papers with small-step semantics
ICFP'11	5	3
POPL'11	7	16
ICFP'12	5	4

Big-step semantics are useful.

Content of this talk

1. Duplication associated with big-step semantics
2. From big-step to pretty-big-step semantics
3. Scaling up to real languages

Duplication associated with big-step semantics

Big-step semantics for loops: regular behavior

Semantics of a C-style loop "for (; t_1 ; t_2) { t_3 }", written "for $t_1\ t_2\ t_3$", in terms of the evaluation judgment $t_{/m} \Rightarrow v_{/m'}$.

$$\frac{t_{1/m_1} \Rightarrow \mathsf{false}_{/m_2}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow tt_{/m_2}}$$

$$\frac{t_{1/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_{3/m_2} \Rightarrow tt_{/m_3} \quad t_{2/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_{3/m_4} \Rightarrow tt_{/m_5}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow tt_{/m_5}}$$

Big-step semantics for loops: exceptions

Exceptions in terms of the judgment $t_{/m} \Rightarrow^{\mathsf{exn}}{}_{/m'}$.

$$\frac{t_{1/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_2}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_2}}$$

$$\frac{t_{1/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_{3/m_2} \Rightarrow^{\mathsf{exn}}{}_{/m_3}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_3}}$$

$$\frac{t_{1/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_{3/m_2} \Rightarrow tt_{/m_3} \quad t_{2/m_3} \Rightarrow^{\mathsf{exn}}{}_{/m_4}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_4}}$$

$$\frac{t_{1/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_{3/m_2} \Rightarrow tt_{/m_3} \quad t_{2/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_{3/m_4} \Rightarrow^{\mathsf{exn}}{}_{/m_5}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_5}}$$

Big-step semantics for loops: divergence

Divergence in terms of the coinductive judgment $t_{/m} \Rightarrow^{\infty}$ (Leroy 2006).

$$\frac{t_{1/m_1} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_{1/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_{3/m_2} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_{1/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_{3/m_2} \Rightarrow tt_{/m_3} \quad t_{2/m_3} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_{1/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_{3/m_2} \Rightarrow tt_{/m_3} \quad t_{2/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_{3/m_4} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_{3/m_1} \Rightarrow^{\infty}}$$

Big-step semantics for loops: summary

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{false}_{/m_2}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow tt_{/m_2}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow tt_{/m_5}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow tt_{/m_5}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_2}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_2}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow^{\mathsf{exn}}{}_{/m_3}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_3}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow^{\mathsf{exn}}{}_{/m_4}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_4}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow^{\mathsf{exn}}{}_{/m_5}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_5}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

Big-step semantics for loops: summary

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{false}_{/m_2}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow tt_{/m_2}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow tt_{/m_5}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow tt_{/m_5}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_2}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_2}} \qquad \frac{t_1{}_{/m_1} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow^{\mathsf{exn}}{}_{/m_3}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_3}} \qquad \frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow^{\mathsf{exn}}{}_{/m_4}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_4}} \qquad \frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow^{\mathsf{exn}}{}_{/m_5}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_5}} \qquad \frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$\rightarrow$ Even with factorization: 9 rules, 21 premises.

Big-step semantics for loops: summary

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{false}_{/m_2}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow tt_{/m_2}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow tt_{/m_5}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow tt_{/m_5}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_2}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_2}} \qquad \frac{t_1{}_{/m_1} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow^{\mathsf{exn}}{}_{/m_3}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_3}} \qquad \frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow^{\mathsf{exn}}{}_{/m_4}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_4}} \qquad \frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

$$\frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow^{\mathsf{exn}}{}_{/m_5}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\mathsf{exn}}{}_{/m_5}} \qquad \frac{t_1{}_{/m_1} \Rightarrow \mathsf{true}_{/m_2} \quad t_3{}_{/m_2} \Rightarrow tt_{/m_3} \quad t_2{}_{/m_3} \Rightarrow tt_{/m_4} \quad \mathsf{for}\ t_1\ t_2\ t_3{}_{/m_4} \Rightarrow^{\infty}}{\mathsf{for}\ t_1\ t_2\ t_3{}_{/m_1} \Rightarrow^{\infty}}$$

→ Even with factorization: 9 rules, 21 premises.

→ With pretty-big-step: 6 rules, 7 premises.

Pretty-big-step semantics

Source language

Grammar of λ-terms

$$\begin{array}{rcl} v & := & \mathsf{int}\,n \mid \mathsf{abs}\,x\,t \\ t & := & \mathsf{val}\,v \mid \mathsf{var}\,x \mid \mathsf{app}\,t\,t \end{array}$$

Call-by-value big-step semantics ($t \Rightarrow v$)

$$\frac{}{v \Rightarrow v} \qquad \frac{t_1 \Rightarrow \mathsf{abs}\,x\,t \qquad t_2 \Rightarrow v \qquad [x \to v]\,t \Rightarrow v'}{\mathsf{app}\,t_1\,t_2 \Rightarrow v'}$$

Towards pretty-big-step rules

A first attempt:

$$\frac{t_1 \;\Rightarrow\; v_1 \qquad \mathsf{app}\, v_1\, t_2 \;\Rightarrow\; v'}{\mathsf{app}\, t_1\, t_2 \;\Rightarrow\; v'} \qquad \frac{t_2 \;\Rightarrow\; v_2 \qquad \mathsf{app}\, v_1\, v_2 \;\Rightarrow\; v'}{\mathsf{app}\, v_1\, t_2 \;\Rightarrow\; v'}$$

$$\frac{[x \to v]\, t \;\Rightarrow\; v'}{\mathsf{app}\, (\mathsf{abs}\, x\, t)\, v \;\Rightarrow\; v'}$$

→ Similar idea in Cousot and Cousot's bi-inductive semantics (2007)

Intermediate terms

To prevent overlap between the rules, we use intermediate terms:

$$e \quad := \quad \mathsf{trm}\, t \mid \mathsf{app1}\, v\, t \mid \mathsf{app2}\, v\, v$$

Definition of the judgment $e \Downarrow v$, with trm implicit:

$$\frac{}{v \Downarrow v} \qquad \frac{t_1 \Downarrow v_1 \qquad \mathsf{app1}\, v_1\, t_2 \Downarrow v'}{\mathsf{app}\, t_1\, t_2 \Downarrow v'}$$

$$\frac{t_2 \Downarrow v_2 \qquad \mathsf{app2}\, v_1\, v_2 \Downarrow v'}{\mathsf{app1}\, v_1\, t_2 \Downarrow v'} \qquad \frac{[x \to v]\, t \Downarrow v'}{\mathsf{app2}\, (\mathsf{abs}\, x\, t)\, v \Downarrow v'}$$

Adding exceptions

Value-carrying exceptions and exception handlers

$$t \quad := \quad \ldots \mid \mathsf{raise}\, t \mid \mathsf{try}\, t\, t$$

Two behaviors: return a value or throw an exception carrying a value

$$e \Downarrow b \qquad\qquad b \quad := \quad \mathsf{ret}\, v \mid \mathsf{exn}\, v$$

Updated grammar for intermediate terms

$$e \quad := \quad \mathsf{trm}\, t \mid \mathsf{app1}\, b\, t \mid \mathsf{app2}\, v\, b \mid \mathsf{raise1}\, b \mid \mathsf{try1}\, b\, t$$

Adding exceptions

Evaluation rules for applications

$$\frac{t_1 \Downarrow b_1 \qquad \mathsf{app1}\, b_1\, t_2 \Downarrow b}{\mathsf{app}\, t_1\, t_2 \Downarrow b}$$

$$\frac{}{\mathsf{app1}\,(\mathsf{exn}\, v)\, t_2 \Downarrow \mathsf{exn}\, v} \qquad \frac{t_2 \Downarrow b_2 \qquad \mathsf{app2}\, v_1\, b_2 \Downarrow b}{\mathsf{app1}\,(\mathsf{ret}\, v_1)\, t_2 \Downarrow b}$$

Adding exceptions

Evaluation rules for applications

$$\frac{t_1 \Downarrow b_1 \qquad \mathsf{app1}\, b_1\, t_2 \Downarrow b}{\mathsf{app}\, t_1\, t_2 \Downarrow b}$$

$$\frac{}{\mathsf{app1}\,(\mathsf{exn}\, v)\, t_2 \Downarrow \mathsf{exn}\, v} \qquad \frac{t_2 \Downarrow b_2 \qquad \mathsf{app2}\, v_1\, b_2 \Downarrow b}{\mathsf{app1}\,(\mathsf{ret}\, v_1)\, t_2 \Downarrow b}$$

Evaluation rules for exception handlers

$$\frac{t_1 \Downarrow b_1 \qquad \mathsf{try1}\, b_1\, t_2 \Downarrow b}{\mathsf{try}\, t_1\, t_2 \Downarrow b} \qquad \frac{}{\mathsf{try1}\,(\mathsf{ret}\, v)\, t \Downarrow \mathsf{ret}\, v} \qquad \frac{\mathsf{app}\, t\, v \Downarrow b}{\mathsf{try1}\,(\mathsf{exn}\, v)\, t \Downarrow b}$$

Adding divergence

Grammars:

$$
\begin{array}{rcl}
b & := & \mathsf{ret}\,v \mid \mathsf{exn}\,v \\
o & := & \mathsf{ter}\,b \mid \mathsf{div} \\
e & := & \mathsf{trm}\,t \mid \mathsf{app1}\,o\,t \mid \mathsf{app2}\,v\,o \mid \mathsf{raise1}\,o \mid \mathsf{try1}\,o\,t
\end{array}
$$

Two judgments defined by a same set of rules:

$$e \Downarrow o \qquad\qquad e \Downarrow^{\mathsf{co}} o$$

Adding divergence

Grammars:

$$
\begin{array}{lll}
b & := & \mathsf{ret}\, v \mid \mathsf{exn}\, v \\
o & := & \mathsf{ter}\, b \mid \mathsf{div} \\
e & := & \mathsf{trm}\, t \mid \mathsf{app1}\, o\, t \mid \mathsf{app2}\, v\, o \mid \mathsf{raise1}\, o \mid \mathsf{try1}\, o\, t
\end{array}
$$

Two judgments defined by a same set of rules:

$$e \Downarrow o \qquad\qquad e \Downarrow^{\mathsf{co}} o$$

Theorem (equivalence with big-step)

$$t \Downarrow \mathit{ter}\, b \quad \Leftrightarrow \quad t \Rightarrow b$$

$$t \Downarrow^{co} \mathit{div} \quad \Leftrightarrow \quad t \Rightarrow^{\infty}$$

Example pretty-big-step rules

$$\frac{t_1 \Downarrow o_1 \qquad \mathsf{app1}\, o_1\, t_2 \Downarrow o}{\mathsf{app}\, t_1\, t_2 \Downarrow o} \qquad \frac{t_2 \Downarrow o_2 \qquad \mathsf{app2}\, v_1\, o_2 \Downarrow o}{\mathsf{app1}\,(\mathsf{ter}\,(\mathsf{ret}\, v_1))\, t_2 \Downarrow o}$$

$$\frac{}{\mathsf{app1}\,(\mathsf{ter}\,(\mathsf{exn}\, v))\, t \Downarrow \mathsf{ter}\,(\mathsf{exn}\, v)} \qquad \frac{}{\mathsf{app1}\,\mathsf{div}\, t \Downarrow \mathsf{div}}$$

Example pretty-big-step rules

$$\frac{t_1 \Downarrow o_1 \qquad \mathsf{app1}\, o_1\, t_2 \Downarrow o}{\mathsf{app}\, t_1\, t_2 \Downarrow o} \qquad \frac{t_2 \Downarrow o_2 \qquad \mathsf{app2}\, v_1\, o_2 \Downarrow o}{\mathsf{app1}\, (\mathsf{ter}\, (\mathsf{ret}\, v_1))\, t_2 \Downarrow o}$$

$$\frac{}{\mathsf{app1}\, (\mathsf{ter}\, (\mathsf{exn}\, v))\, t \Downarrow \mathsf{ter}\, (\mathsf{exn}\, v)} \qquad \frac{}{\mathsf{app1}\, \mathsf{div}\, t \Downarrow \mathsf{div}}$$

Factorization of the rules propagating exceptions and divergence:

$$\frac{\mathsf{abort}\, o}{\mathsf{app1}\, o\, t \Downarrow o} \qquad \text{where} \qquad \frac{}{\mathsf{abort}\, (\mathsf{ter}\, (\mathsf{exn}\, v))} \qquad \frac{}{\mathsf{abort}\, \mathsf{div}}$$

All pretty-big-step rules

Evaluation rules, where val, ret and ter are implicit.

$$\frac{}{v \Downarrow v} \qquad \frac{t_1 \Downarrow o_1 \qquad \mathsf{app1}\, o_1\, t_2 \Downarrow o}{\mathsf{app}\, t_1\, t_2 \Downarrow o} \qquad \frac{\mathsf{abort}\, o}{\mathsf{app1}\, o\, t \Downarrow o}$$

$$\frac{t_2 \Downarrow o_2 \qquad \mathsf{app2}\, v_1\, o_2 \Downarrow o}{\mathsf{app1}\, v_1\, t_2 \Downarrow o} \qquad \frac{\mathsf{abort}\, o}{\mathsf{app2}\, v\, o \Downarrow o} \qquad \frac{[x \to v]\, t \Downarrow o}{\mathsf{app2}\, (\mathsf{abs}\, x\, t)\, v \Downarrow o}$$

$$\frac{t \Downarrow o_1 \qquad \mathsf{raise1}\, o_1 \Downarrow o}{\mathsf{raise}\, t \Downarrow o} \qquad \frac{\mathsf{abort}\, o}{\mathsf{raise1}\, o \Downarrow o} \qquad \frac{}{\mathsf{raise1}\, v \Downarrow \mathsf{exn}\, v}$$

$$\frac{t_1 \Downarrow o_1 \qquad \mathsf{try1}\, o_1\, t_2 \Downarrow o}{\mathsf{try}\, t_1\, t_2 \Downarrow o} \qquad \frac{}{\mathsf{try1}\, v\, t \Downarrow v} \qquad \frac{\mathsf{app}\, t\, v \Downarrow o}{\mathsf{try1}\, (\mathsf{exn}\, v)\, t \Downarrow o}$$

$$\frac{}{\mathsf{try1}\, \mathsf{div}\, t \Downarrow \mathsf{div}}$$

Pretty-big-step: scaling up to real languages

Side-effects

Generalization of terminating outcomes to carry a memory store:

$$o \quad := \quad \mathsf{ter}\, m\, b \mid \mathsf{div}$$

Evaluation judgment in the form $e_{/m} \Downarrow o$. Example rules:

$$\frac{t_{1\,/m_1} \Downarrow o_1 \qquad \mathsf{app1}\, o_1\, t_{2\,/m_1} \Downarrow o}{\mathsf{app}\, t_1\, t_{2\,/m_1} \Downarrow o} \qquad \frac{t_{2\,/m_2} \Downarrow o_2 \qquad \mathsf{app2}\, v_1\, o_{2\,/m_2} \Downarrow o}{\mathsf{app1}\, (\mathsf{ter}\, m_2\, v_1)\, t_{2\,/m_1} \Downarrow o}$$

$$\frac{}{\mathsf{app1}\, \mathsf{div}\, t_{2\,/m_1} \Downarrow \mathsf{div}}$$

Pretty-big-step semantics for loops

Intermediate terms: "$\text{for}_i\, o\, t_1\, t_2\, t_3$", where $i \in \{1,2,3\}$.

Evaluation rules, with the judgment $e_{\,/m} \Downarrow o$.

$$\frac{t_{1\,/m} \Downarrow o_1 \qquad \text{for}_1\, o_1\, t_1\, t_2\, t_{3\,/m} \Downarrow o}{\text{for}\, t_1\, t_2\, t_{3\,/m} \Downarrow o}$$

$$\frac{}{\text{for}_1\, (\text{ter}\, m\, \text{false})\, t_1\, t_2\, t_{3\,/m'} \Downarrow \text{ter}\, m\, tt}$$

$$\frac{t_{3\,/m} \Downarrow o_3 \qquad \text{for}_2\, o_3\, t_1\, t_2\, t_{3\,/m} \Downarrow o}{\text{for}_1\, (\text{ter}\, m\, \text{true})\, t_1\, t_2\, t_{3\,/m'} \Downarrow o}$$

$$\frac{t_{2\,/m} \Downarrow o_2 \qquad \text{for}_3\, o_2\, t_1\, t_2\, t_{3\,/m} \Downarrow o}{\text{for}_2\, (\text{ter}\, m\, tt)\, t_1\, t_2\, t_{3\,/m'} \Downarrow o}$$

$$\frac{\text{for}\, t_1\, t_2\, t_{3\,/m} \Downarrow o}{\text{for}_3\, (\text{ter}\, m\, tt)\, t_1\, t_2\, t_{3\,/m'} \Downarrow o}$$

$$\frac{\text{abort}\, o}{\text{for}_i\, o\, t_1\, t_2\, t_{3\,/m} \Downarrow o}$$

$\rightarrow$ From 9 rules and 21 premises to 6 rules with 7 evaluation premises.

Pretty-big-step semantics for core-Caml

Formalization in Coq of a large subset of Caml:
booleans, integers, tuples, algebraic data types, mutable records, boolean operators (lazy and, lazy or, negation), integer operators (negation, addition, subtraction, multiplication, division), comparison operator, functions, recursive functions, applications, sequences, let-bindings, conditionals (with optional *else* branch), *for* loops and *while* loops, pattern matching (with nested patterns, *as* patterns, *or* patterns, and *when* clauses), *raise* construct, *try-with* construct with pattern matching, and assertions.

	rules	premises	tokens
Big-step without divergence	71	83	1540
Big-step with divergence	113	143	2263
Pretty-big-step	70	60	1361

→ Pretty-big-step reduces the size of the definition by 40%.
→ Pretty-big-step reduces the number of premises by 60%.

Pretty-big-step semantics for JavaScript

Formalization in Coq of a large subset of JavaScript (ECMA5):
variable declarations, function declarations, function calls, objects, getters, setters, new, delete, access, assignment, unary and binary operators, sequence, conditional, while loop, with construct, this construct, throw, try-catch-finally, return, break, continue, type conversions, primitive functions on objects.
Not yet covered:
parsing, switch, arrays, for loops, library functions such as regexps.

	Language constructs	Meta operations	Total
Intermediate terms	97	165	262
Evaluation rules	147	258	432

Conclusion

In this talk:

1. Duplication associated with big-step semantics
2. From big-step to pretty-big-step semantics
3. Scaling up to real languages

Additional results described in the paper:

1. Type soundness proofs in pretty-big-step
2. Pretty-big-step semantics with traces

Conclusion

In this talk:

1. Duplication associated with big-step semantics
2. From big-step to pretty-big-step semantics
3. Scaling up to real languages

Additional results described in the paper:

1. Type soundness proofs in pretty-big-step
2. Pretty-big-step semantics with traces

Remaining challenges for pretty-big-step:

1. Unified proofs for terminating and diverging terms
2. Support for arbitrary goto instructions
3. Support for concurrency and weak memory models

Thanks!