

16-1/

# Control (non-local control / jumps)

✓ Fault

(% 1 0) — division by 0 is undef  
 (0 5), (@ 0 5) → can't call a fun as a fun

"stuck terms"

$M \rightarrow N$   
 $E = \mathbb{R} \mid EN \mid VE \quad E[M] \rightarrow E[N]$   
 $\mid 0^{\wedge} V \dots EN \dots$

$\beta : (\lambda x. m). v \rightarrow m[x \leftarrow v]$   
 $\Delta : 0^{\wedge} b_1 \dots b_n \rightarrow \delta(0^{\wedge}, b_1 \dots b_n)$   
 $\neg \exists M, (0 \ S) \rightarrow N$   
 $\delta(:, n, 0) = \perp$

eval is a partial function in ISWIM

- undefined on stuck terms
- undefined on infinite loops  $eval(\perp) = \perp$

$m ::= \dots \mid err_i$   
 $i = \text{some set}$

$\delta : 0 \ x \ b^{\wedge} \rightarrow v$   
 $\delta' : 0 \ x \ b^{\wedge} \rightarrow v \cup \{err_i\}$

ISWIM-Err

$(b \ v) \rightarrow err$   
 $(+ \ 1 \ (0 \ 5))$   
 $\rightarrow (+ \ 1 \ err)$

$(err \ N) \rightarrow err$   
 $(v \ err) \rightarrow err$

"If you see an err"  $\rightarrow err$

$E[err] \rightarrow err$   
 $E[(\lambda x. m) \ v] \rightarrow E[m[x \leftarrow v]]$   
 $E[0^{\wedge} b_1 \dots b_n] \rightarrow E[\delta(0^{\wedge}, b_1 \dots b_n)]$   
 $E[b \ v] \rightarrow E[err]$  on-constant

$E[0 \ b \dots (\lambda x. m) \ N \dots]$   
 $\rightarrow E[err_{\text{cant-send-fun-to-processor-or-it-will-fail}}]$

$\forall m \in \text{ISWIM}, \quad eval(m) = err_i \text{ iff } \exists! norm(m) = \perp$   
 $(M \xrightarrow{norm} N \rightarrow)$

16-2 / ISWIM-Err (based ISWIM)

$M ::= \dots \mid \text{throw } M \mid \text{catch } M \text{ with } \lambda X.N$

$(+ (\text{throw err}) 10) \Rightarrow^* \text{err div}$

$\text{catch } (+ \uparrow 10) \text{ with } \lambda X. 5 \Rightarrow^* 5$

$(+ 10 (\text{throw } 5)) \Rightarrow^* 5$        $\text{catch } 2 \text{ with } \lambda X. 3$

$\text{catch } (+ \uparrow 10) \text{ with } \lambda X. \text{add } X \Rightarrow^* 6$        $\Rightarrow^* 2$

catch

catch

throw 1

with  $\lambda X. 2$

with  $\lambda X. 3$

$\Rightarrow^* 2$

$\Rightarrow^* 3$

if x is odd

with  $\lambda X. \text{throw } X+1$

o.v.  
8

let  $f x = \text{if } x == 0 \text{ then throw bad}$   
else 17

in

catch

f 0

with  $\lambda X. 5$

$\Rightarrow^* 5$

$\lambda E [\text{throw } V] \rightarrow V$

$E = \text{catch } \square \text{ with } \lambda X. 5$

F

$E [\text{catch } \square [\text{throw } V] \text{ with } \lambda X. N]$

$E [\text{catch } V \text{ with } \lambda X. N] \Rightarrow E[V] \rightarrow E[(\lambda X. N) V]$

~~E [ ]~~

F = "catchless-context"

$\square \mid (F N) \mid (V F) \mid (0^n V \dots FN \dots)$

$F [\text{throw } V] \rightarrow V \mid \text{throw } F$

$K ::= \dots \mid \text{throw}(k) \mid \text{catch } (\lambda X. N, E, K)$

CEK

$\langle \text{throw } M, E, K \rangle \rightarrow \langle M, E, \text{throw}(k) \rangle$

CEK,  $\square$

$\langle \text{catch } M \text{ with } \lambda X. N, E, K \rangle \rightarrow \langle M, E, \text{catch } (\lambda X. N, E, K) \rangle$

$\perp$

$\langle V, E, \text{catch } (\lambda X. N, E', K) \rangle \rightarrow \langle V, E, K \rangle$

catch  $(\lambda X. N,$

$\langle V, E, \text{throw}(k) \rangle \rightarrow \text{find-handler}(k)(V)$

$E, k)$

b-3/

$$FH : K \rightarrow V \rightarrow \text{CEK-st } (\langle M, E, K \rangle)$$

$$FH(\text{ret}) = \lambda v. \langle V, \emptyset, \text{ret} \rangle$$

$$FH(\text{fn}(N, E, K)) = FH(K)$$

$$FH(\text{ar}(V, K)) = FH(K)$$

$$FH(\text{throw}(K)) = FH(K)$$

$$FH(\text{catch}(\lambda X.N, E, K)) = \lambda v. \langle (\lambda X.N) V, E, K \rangle$$

$$X \quad V = \emptyset \mid \lambda X.M \quad \langle CK$$

$$V = \emptyset \mid \text{clo}(\lambda X.M, E) \quad \langle EK$$

$$\text{throw}(V) \\ M = \dots$$

$$\langle V, E, \text{throw}(K) \rangle \rightarrow \langle \text{throw}(V), E, K \rangle$$

$$\langle \text{throw}(V), E, \text{ret} \rangle \rightarrow \langle V, E, \text{ret} \rangle$$

$$\langle \text{throw}(V), E, \text{fn}(N, E', K) \rangle \rightarrow \langle \text{throw}(V), E, K \rangle$$

$$\langle \text{throw}(V), E, \text{catch}(\lambda X.N, E', K) \rangle$$

$$\rightarrow \langle (\lambda X.N) V, E', K \rangle$$

$$\text{st} = \langle M, E, K \rangle$$

$$\text{st}' = \langle M, E, K, H \rangle$$

$$\text{eval}(M) =$$

$$H = \text{catch}(\lambda X.M, E, H, K)$$

$$\langle M, \emptyset, \text{ret}, \perp \rangle$$

$$\perp$$

$$\langle M N, E, K, H \rangle \rightarrow \langle M, E, \text{fn}(N, E, K), H \rangle$$

$$\langle \text{catch } M \text{ with } \lambda X.N, E, K, H \rangle$$

$$\rightarrow \langle M, E, \text{restore}(H, K), \text{catch}(\lambda X.N, E, H, K) \rangle$$

$$\langle V, E, \text{restore}(H, K), H' \rangle \rightarrow \langle V, E, K, H \rangle$$

$$\langle V, E, \text{throw}(K), \perp \rangle \rightarrow \langle V, \emptyset, \text{ret}, \perp \rangle$$

$$\langle V, E, \text{throw}(K), \text{catch}(\lambda X.N, E', H, K') \rangle$$

$$\rightarrow \langle (\lambda X.N) V, E', K', H \rangle$$

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