c	numeric value
a	array
x	term variable
f	function declaration?
κ	program counter
n	index variable
k	index variable

v	::=		values
	|	c	numeric value
	|	a	bytearray
e	::=		expressions
	|	c	numeric value
	|	a	bytearray
	|	x	variable
	|	$a[e]$	array access
	|	$\sim e$	unary operation
	|	$e_1 \oplus e_2$	binary operation
	|	$f(e_1, .., e_n)$	function application
	|	s `@`e	function body
s	::=		statements
	|	**skip**	skip
	|	$s_1; s_2$	sequence
	|	(s)	parens
	|	$\{x_1/v_1, .., x_k/v_k\}s$	variable substitution
	|	**def** $x := e$	variable declaration
	|	**def** $x := a$	array declaration
	|	$x := e$	variable assignment
	|	$a[e_1] := e_2$	array assignment
	|	**for** x **from** v_1 **to** $v_2 : s$	for loop
fval	::=		function spec
	|	$(x_1, .., x_n) : s$ `@`e	
fdef	::=		function definition
	|	*fdef f fval*	
program	::=		program
	|	$fdef_1; ..; fdef_n;$ **expose** *fdef*	list of fdefs
Λ	::=		function store
	|	$\emptyset_\Lambda$	empty function store
	|	$\Lambda[f \mapsto fval]$	define function
Γ	::=		global memory
	|	$\emptyset_\Gamma$	
	|	$\Gamma[a \mapsto$ `[]` $]$	new array
	|	$\Gamma(a)[v_1 \mapsto v_2]$	array update
μ	::=		local memory
	|	$\emptyset_\mu$	empty memory
	|	$\mu[x \mapsto v]$	add/update variable
	|	$\mu_1 \vert \mu_2$	push stack frame

$\boxed{\{\Lambda, \Gamma, \mu, \kappa\}\ e \longrightarrow \{\Lambda', \Gamma', \mu', \kappa'\}\ e'}$ e reduces to e'

$$\frac{\begin{array}{c}\mu = \mu'[x \mapsto v] \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ x \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ v}\ \textsc{Exr\_var}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e'}{\{\Lambda, \Gamma, \mu, \kappa\}\ a[e] \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ a[e']}\ \textsc{Exr\_arr\_get\_expr}$$

$$\frac{\begin{array}{c}v' = \Gamma(a)[v] \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ a[v] \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ v'}\ \textsc{Exr\_arr\_get\_val}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e'}{\{\Lambda, \Gamma, \mu, \kappa\}\ \sim e \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ \sim e'}\ \textsc{Exr\_unop\_expr}$$

$$\frac{\begin{array}{c}v' \equiv [\![\sim v]\!] \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ \sim v \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ v'}\ \textsc{Exr\_unop\_val}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e_1 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e_1'}{\{\Lambda, \Gamma, \mu, \kappa\}\ e_1 \oplus e_2 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e_1' \oplus e_2}\ \textsc{Exr\_binop\_l}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e_2 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e_2'}{\{\Lambda, \Gamma, \mu, \kappa\}\ v \oplus e_2 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ v \oplus e_2'}\ \textsc{Exr\_binop\_r}$$

$$\frac{\begin{array}{c}v_3 \equiv [\![v_1 \oplus v_2]\!] \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ v_1 \oplus v_2 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ v_3}\ \textsc{Exr\_binop\_val}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e_1 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e_1'}{\{\Lambda, \Gamma, \mu, \kappa\}\ f(v_1, \ldots, v_k, e_1, e_2, \ldots, e_n) \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ f(v_1, \ldots, v_k, e_1', e_2, \ldots, e_n)}\ \textsc{Exr\_fn\_expr}$$

$$\frac{\begin{array}{c}\Lambda = \Lambda'[f \mapsto (x_1, \ldots, x_k) : s\ \texttt{@}e] \\ \mu' = \mu|\emptyset_\mu \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ f(v_1, \ldots, v_k) \longrightarrow \{\Lambda, \Gamma, \mu', \kappa'\}\ \{x_1/v_1, \ldots, x_k/v_k\} s\ \texttt{@}e}\ \textsc{Exr\_fn\_call}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e'}{\{\Lambda, \Gamma, \mu, \kappa\}\ \textbf{skip}\ \texttt{@}e \longrightarrow \{\Lambda, \Gamma, \mu, \kappa\}\ e'}\ \textsc{Exr\_skip\_expr}$$

$$\frac{\mu = \mu_1|\mu_2}{\{\Lambda, \Gamma, \mu, \kappa\}\ \textbf{skip}\ \texttt{@}v \longrightarrow \{\Lambda, \Gamma, \mu_1, \kappa\}\ v}\ \textsc{Exr\_skip\_val}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ s_1\ \texttt{@}e_0 \longrightarrow \{\Lambda, \Gamma, \mu', \kappa'\}\ s_1'\ \texttt{@}e_0}{\{\Lambda, \Gamma, \mu, \kappa\}\ s_1; s_2\ \texttt{@}e_0 \longrightarrow \{\Lambda, \Gamma, \mu', \kappa'\}\ s_1'; s_2\ \texttt{@}e_0}\ \textsc{Exr\_seq}$$

$$\frac{}{\{\Lambda, \Gamma, \mu, \kappa\}\ \textbf{skip}; s\ \texttt{@}e_0 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa\}\ s\ \texttt{@}e_0}\ \textsc{Exr\_seq\_skip}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e'}{\{\Lambda, \Gamma, \mu, \kappa\}\ \textbf{def}\ x := e\ \texttt{@}e_0 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ \textbf{def}\ x := e'\ \texttt{@}e_0}\ \textsc{Exr\_def\_expr}$$

$$\frac{\begin{array}{c}\mu' = \mu[x \mapsto v] \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ \textbf{def}\ x := v\ \texttt{@}e_0 \longrightarrow \{\Lambda, \Gamma, \mu', \kappa'\}\ \textbf{skip}\ \texttt{@}e_0}\ \textsc{Exr\_def\_val}$$

$$\frac{\begin{array}{c}\Gamma' = \Gamma[a \mapsto []] \\ \mu' = \mu[x \mapsto a] \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ \mathbf{def}\ x := a\ @e_0 \longrightarrow \{\Lambda, \Gamma', \mu', \kappa'\}\ \mathbf{skip}\ @e_0}\ \textsc{Exr\_def\_arr}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e'}{\{\Lambda, \Gamma, \mu, \kappa\}\ x := e\ @e_0 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ x := e'\ @e_0}\ \textsc{Exr\_assign\_expr}$$

$$\frac{\begin{array}{c}\mu' = \mu[x \mapsto v] \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ x := v\ @e_0 \longrightarrow \{\Lambda, \Gamma, \mu', \kappa'\}\ \mathbf{skip}\ @e_0}\ \textsc{Exr\_assign\_val}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e_1 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e_1'}{\{\Lambda, \Gamma, \mu, \kappa\}\ a[e_1] := e_2\ @e_0 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ a[e_1'] := e_2\ @e_0}\ \textsc{Exr\_arr\_assign\_expr\_l}$$

$$\frac{\{\Lambda, \Gamma, \mu, \kappa\}\ e_2 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ e_2'}{\{\Lambda, \Gamma, \mu, \kappa\}\ a[v_1] := e_2\ @e_0 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ a[v_1] := e_2'\ @e_0}\ \textsc{Exr\_arr\_assign\_expr\_r}$$

$$\frac{\begin{array}{c}\Gamma' = \Gamma(a)[v_1 \mapsto v_2] \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ a[v_1] := v_2\ @e_0 \longrightarrow \{\Lambda, \Gamma', \mu, \kappa'\}\ \mathbf{skip}\ @e_0}\ \textsc{Exr\_arr\_assign\_val}$$

$$\frac{\begin{array}{c}x \notin \mu \\ v_1 < v_2 \\ v_1' = v_1 + 1 \\ \kappa' = \kappa + 1\end{array}}{\{\Lambda, \Gamma, \mu, \kappa\}\ \mathbf{for}\ x\ \mathbf{from}\ v_1\ \mathbf{to}\ v_2 : s\ @e_0 \longrightarrow \{\Lambda, \Gamma, \mu, \kappa'\}\ \{x/v_1\}s; \mathbf{for}\ x\ \mathbf{from}\ v_1'\ \mathbf{to}\ v_2 : s\ @e_0}\ \textsc{Exr\_for}$$

$$\frac{v_1 = v_2}{\{\Lambda, \Gamma, \mu, \kappa\}\ \mathbf{for}\ x\ \mathbf{from}\ v_2\ \mathbf{to}\ v_2 : s\ @e_0 \longrightarrow \{\Lambda, \Gamma, \mu', \kappa\}\ \mathbf{skip}\ @e_0}\ \textsc{Exr\_for\_base}$$

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Definition rules:         24 good    0 bad
Definition rule clauses:  61 good    0 bad
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