

Structured Flowcharts

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grammar StructuredFlowDiagrams
  nonterminal D(2), Stmt(2), S(0);
  terminal begin(1), stop(1), action(2), pred(3);
  start S;

  S()      ::= begin(x) D(x,y) stop(y)    [ init  ]
  D(x,y)   ::= Stmt(x,y)                 [ single ]
             | Stmt(x,z) D(z,y)         [ seq   ]
  Stmt(x,y) ::= action(x,y)              [ action ]
             | pred(x,u,v) D(u,y) D(v,y) [ alt   ]
             | pred(x,z,y) D(z,x)       [ while ]

end

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Structured flowcharts are not PSR because the CFA has conflicts (see below). This CFA is somewhat special because parameters, different from all other examples considered so far, can not only refer to a single node of the host graph, but to an arbitrary number. This is the case for formal parameter \mathbf{a} in states $q_2(\mathbf{a}, \mathbf{b}^*, \mathbf{c}, \mathbf{d})$ and $q_{10}(\mathbf{a}, \mathbf{b}, \mathbf{c}^*)$. To indicate these *multi parameters*, they are marked with an asterisk. The multi value is obtained by two transitions leaving from $q_2(\mathbf{a}, \mathbf{b}^*, \mathbf{c}, \mathbf{d})$ where the value of the target parameter is determined by expressions $\mathbf{a} \cdot \mathbf{b}$ and $\mathbf{b} \cdot \mathbf{a}$, respectively. These expressions mean that the value of \mathbf{b} , i.e., a list of nodes, is concatenated with the value of \mathbf{a} , i.e., a single node. That way, a longer list of host nodes is obtained and assigned to the corresponding formal parameter. Whenever such a multi parameter is used, any of its assigned host nodes can be used, for instance in the second transition leaving $q_2(\mathbf{a}, \mathbf{b}^*, \mathbf{c}, \mathbf{d})$, indicated by the condition $\exists i: n_0 = \mathbf{c}, n_1 = \mathbf{b}_i$. \mathbf{b}_i stands for the node at position i of the list being the value of \mathbf{b} . But as this grammar is not PSR, this has no effect on a parser.

Characteristic finite automaton(CFA):

Note: State q_6 has conflicts

State $q_0(\mathbf{a}, \mathbf{b})$

$S() \rightarrow \cdot \text{begin}(\mathbf{a}) \text{D}(\mathbf{a}, \mathbf{b}) \text{stop}(\mathbf{b})$

$$\frac{\text{begin}(n_0)}{n_0 = \mathbf{a}} \rightarrow q_1(n_0, \mathbf{b})$$

State $q_1(\mathbf{a}, \mathbf{b})$

$S() \rightarrow \text{begin}(\mathbf{a}) \cdot \text{D}(\mathbf{a}, \mathbf{b}) \text{stop}(\mathbf{b})$
$\text{D}(\mathbf{a}, \mathbf{b}) \rightarrow \cdot \text{Stmt}(\mathbf{a}, \mathbf{b})$
$\text{D}(\mathbf{a}, \mathbf{b}) \rightarrow \cdot \text{Stmt}(\mathbf{a}, n_1) \text{D}(n_1, \mathbf{b})$
$\text{Stmt}(\mathbf{a}, \mathbf{b}) \rightarrow \cdot \text{action}(\mathbf{a}, \mathbf{b})$
$\text{Stmt}(\mathbf{a}, \mathbf{b}) \rightarrow \cdot \text{pred}(\mathbf{a}, n_2, n_3) \text{D}(n_2, \mathbf{b}) \text{D}(n_3, \mathbf{b})$
$\text{Stmt}(\mathbf{a}, \mathbf{b}) \rightarrow \cdot \text{pred}(\mathbf{a}, n_4, \mathbf{b}) \text{D}(n_4, \mathbf{a})$
$\text{Stmt}(\mathbf{a}, n_5) \rightarrow \cdot \text{action}(\mathbf{a}, n_5)$
$\text{Stmt}(\mathbf{a}, n_6) \rightarrow \cdot \text{pred}(\mathbf{a}, n_7, n_8) \text{D}(n_7, n_6) \text{D}(n_8, n_6)$
$\text{Stmt}(\mathbf{a}, n_9) \rightarrow \cdot \text{pred}(\mathbf{a}, n_{10}, n_9) \text{D}(n_{10}, \mathbf{a})$

$$\frac{\text{D}(n_0, n_1)}{n_0 = \mathbf{a}, n_1 = \mathbf{b}} \rightarrow q_9(n_0, n_1)$$

$$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{a}, n_1 \uparrow} \rightarrow q_7(n_0, \mathbf{b}, n_1)$$

$$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{a}, n_1 = \mathbf{b}} \rightarrow q_5(n_0, n_1)$$

$$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{a}, n_1 \uparrow} \rightarrow q_2(n_0, n_1)$$

$$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{a}, n_1 = \mathbf{b}} \rightarrow q_2(n_0, n_1)$$

$$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{a}, n_1 \uparrow, n_2 \uparrow} \rightarrow q_3(n_0, \mathbf{b}, n_1, n_2)$$

$$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{a}, n_1 \uparrow, n_2 = \mathbf{b}} \rightarrow q_4(n_0, n_2, n_1)$$

State $q_2(\mathbf{a}, \mathbf{b})$

$\text{Stmt}(\mathbf{a}, \mathbf{b}) \rightarrow \text{action}(\mathbf{a}, \mathbf{b}) \cdot$ [action]
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State $q_3(a, b^*, c, d)$

$\text{Stmt}(a, b)$	$\rightarrow \text{pred}(a, c, d) \cdot D(c, b) D(d, b)$
$\text{Stmt}(a, d)$	$\rightarrow \text{pred}(a, c, d) \cdot D(c, a)$
$\text{Stmt}(a, n_1)$	$\rightarrow \text{pred}(a, c, d) \cdot D(c, n_1) D(d, n_1)$
$D(c, a)$	$\rightarrow \cdot \text{Stmt}(c, a)$
$D(c, a)$	$\rightarrow \cdot \text{Stmt}(c, n_2) D(n_2, a)$
$D(c, n_3)$	$\rightarrow \cdot \text{Stmt}(c, n_3)$
$D(c, n_4)$	$\rightarrow \cdot \text{Stmt}(c, n_5) D(n_5, n_4)$
$D(c, b)$	$\rightarrow \cdot \text{Stmt}(c, b)$
$D(c, b)$	$\rightarrow \cdot \text{Stmt}(c, n_6) D(n_6, b)$
$\text{Stmt}(c, a)$	$\rightarrow \cdot \text{action}(c, a)$
$\text{Stmt}(c, a)$	$\rightarrow \cdot \text{pred}(c, n_7, n_8) D(n_7, a) D(n_8, a)$
$\text{Stmt}(c, a)$	$\rightarrow \cdot \text{pred}(c, n_9, a) D(n_9, c)$
$\text{Stmt}(c, n_{10})$	$\rightarrow \cdot \text{action}(c, n_{10})$
$\text{Stmt}(c, n_{11})$	$\rightarrow \cdot \text{pred}(c, n_{12}, n_{13}) D(n_{12}, n_{11}) D(n_{13}, n_{11})$
$\text{Stmt}(c, n_{14})$	$\rightarrow \cdot \text{pred}(c, n_{15}, n_{14}) D(n_{15}, c)$
$\text{Stmt}(c, b)$	$\rightarrow \cdot \text{action}(c, b)$
$\text{Stmt}(c, b)$	$\rightarrow \cdot \text{pred}(c, n_{16}, n_{17}) D(n_{16}, b) D(n_{17}, b)$
$\text{Stmt}(c, b)$	$\rightarrow \cdot \text{pred}(c, n_{18}, b) D(n_{18}, c)$

$\frac{D(n_0, n_1)}{n_0 = c, n_1 \uparrow}$	$\rightarrow q_{10}(a, n_1, n_0, d)$
$\frac{D(n_0, n_1)}{n_0 = c, n_1 = a}$	$\rightarrow q_{11}(n_1, d, n_0)$
$\frac{D(n_0, n_1)}{\exists i: n_0 = c, n_1 = b_i}$	$\rightarrow q_{10}(a, n_1, n_0, d)$
$\frac{\text{Stmt}(n_0, n_1)}{n_0 = c, n_1 \uparrow}$	$\rightarrow q_6(n_0, n_1, a \cdot b)$
$\frac{\text{Stmt}(n_0, n_1)}{n_0 = c, n_1 = a}$	$\rightarrow q_5(n_0, n_1)$
$\frac{\text{Stmt}(n_0, n_1)}{\exists i: n_0 = c, n_1 = b_i}$	$\rightarrow q_5(n_0, n_1)$
$\frac{\text{action}(n_0, n_1)}{n_0 = c, n_1 \uparrow}$	$\rightarrow q_2(n_0, n_1)$
$\frac{\text{action}(n_0, n_1)}{n_0 = c, n_1 = a}$	$\rightarrow q_2(n_0, n_1)$
$\frac{\text{action}(n_0, n_1)}{\exists i: n_0 = c, n_1 = b_i}$	$\rightarrow q_2(n_0, n_1)$
$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = c, n_1 \uparrow, n_2 \uparrow}$	$\rightarrow q_3(n_0, a \cdot b, n_1, n_2)$
$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = c, n_1 \uparrow, n_2 = a}$	$\rightarrow q_4(n_0, n_2, n_1)$
$\frac{\text{pred}(n_0, n_1, n_2)}{\exists i: n_0 = c, n_1 \uparrow, n_2 = b_i}$	$\rightarrow q_4(n_0, n_2, n_1)$

State $q_4(a, b, c)$

$\text{Stmt}(a, b)$	$\rightarrow \text{pred}(a, c, b) \cdot D(c, a)$
$D(c, a)$	$\rightarrow \cdot \text{Stmt}(c, a)$
$D(c, a)$	$\rightarrow \cdot \text{Stmt}(c, n_1) D(n_1, a)$
$\text{Stmt}(c, a)$	$\rightarrow \cdot \text{action}(c, a)$
$\text{Stmt}(c, a)$	$\rightarrow \cdot \text{pred}(c, n_2, n_3) D(n_2, a) D(n_3, a)$
$\text{Stmt}(c, a)$	$\rightarrow \cdot \text{pred}(c, n_4, a) D(n_4, c)$
$\text{Stmt}(c, n_5)$	$\rightarrow \cdot \text{action}(c, n_5)$
$\text{Stmt}(c, n_6)$	$\rightarrow \cdot \text{pred}(c, n_7, n_8) D(n_7, n_6) D(n_8, n_6)$
$\text{Stmt}(c, n_9)$	$\rightarrow \cdot \text{pred}(c, n_{10}, n_9) D(n_{10}, c)$

$\frac{D(n_0, n_1)}{n_0 = \mathbf{c}, n_1 = \mathbf{a}}$	$\rightarrow q_{11}(n_1, \mathbf{b}, n_0)$
$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{c}, n_1 \uparrow}$	$\rightarrow q_7(n_0, \mathbf{a}, n_1)$
$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{c}, n_1 = \mathbf{a}}$	$\rightarrow q_5(n_0, n_1)$
$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{c}, n_1 \uparrow}$	$\rightarrow q_2(n_0, n_1)$
$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{c}, n_1 = \mathbf{a}}$	$\rightarrow q_2(n_0, n_1)$
$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{c}, n_1 \uparrow, n_2 \uparrow}$	$\rightarrow q_3(n_0, \mathbf{a}, n_1, n_2)$
$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{c}, n_1 \uparrow, n_2 = \mathbf{a}}$	$\rightarrow q_4(n_0, n_2, n_1)$

State $q_5(\mathbf{a}, \mathbf{b})$

$D(\mathbf{a}, \mathbf{b}) \rightarrow \text{Stmt}(\mathbf{a}, \mathbf{b}) \cdot$ [single]
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State $q_6(\mathbf{a}, \mathbf{b}, \mathbf{c}^*)$

$D(\mathbf{a}, \mathbf{b}) \rightarrow \text{Stmt}(\mathbf{a}, \mathbf{b}) \cdot$	[single]
$D(\mathbf{a}, n_1) \rightarrow \text{Stmt}(\mathbf{a}, \mathbf{b}) \cdot D(\mathbf{b}, n_1)$	
$D(\mathbf{a}, \mathbf{c}) \rightarrow \text{Stmt}(\mathbf{a}, \mathbf{b}) \cdot D(\mathbf{b}, \mathbf{c})$	
$D(\mathbf{b}, n_2) \rightarrow \cdot \text{Stmt}(\mathbf{b}, n_2)$	
$D(\mathbf{b}, n_3) \rightarrow \cdot \text{Stmt}(\mathbf{b}, n_4) D(n_4, n_3)$	
$D(\mathbf{b}, \mathbf{c}) \rightarrow \cdot \text{Stmt}(\mathbf{b}, \mathbf{c})$	
$D(\mathbf{b}, \mathbf{c}) \rightarrow \cdot \text{Stmt}(\mathbf{b}, n_5) D(n_5, \mathbf{c})$	
$\text{Stmt}(\mathbf{b}, n_6) \rightarrow \cdot \text{action}(\mathbf{b}, n_6)$	
$\text{Stmt}(\mathbf{b}, n_7) \rightarrow \cdot \text{pred}(\mathbf{b}, n_8, n_9) D(n_8, n_7) D(n_9, n_7)$	
$\text{Stmt}(\mathbf{b}, n_{10}) \rightarrow \cdot \text{pred}(\mathbf{b}, n_{11}, n_{10}) D(n_{11}, \mathbf{b})$	
$\text{Stmt}(\mathbf{b}, \mathbf{c}) \rightarrow \cdot \text{action}(\mathbf{b}, \mathbf{c})$	
$\text{Stmt}(\mathbf{b}, \mathbf{c}) \rightarrow \cdot \text{pred}(\mathbf{b}, n_{12}, n_{13}) D(n_{12}, \mathbf{c}) D(n_{13}, \mathbf{c})$	
$\text{Stmt}(\mathbf{b}, \mathbf{c}) \rightarrow \cdot \text{pred}(\mathbf{b}, n_{14}, \mathbf{c}) D(n_{14}, \mathbf{b})$	

$\frac{D(n_0, n_1)}{n_0 = \mathbf{b}, n_1 \uparrow}$	$\rightarrow q_8(\mathbf{a}, n_1, n_0)$
$\frac{D(n_0, n_1)}{\exists i: n_0 = \mathbf{b}, n_1 = \mathbf{c}_i}$	$\rightarrow q_8(\mathbf{a}, n_1, n_0)$
$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{b}, n_1 \uparrow}$	$\rightarrow q_6(n_0, n_1, \mathbf{c})$
$\frac{\text{Stmt}(n_0, n_1)}{\exists i: n_0 = \mathbf{b}, n_1 = \mathbf{c}_i}$	$\rightarrow q_5(n_0, n_1)$
$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{b}, n_1 \uparrow}$	$\rightarrow q_2(n_0, n_1)$
$\frac{\text{action}(n_0, n_1)}{\exists i: n_0 = \mathbf{b}, n_1 = \mathbf{c}_i}$	$\rightarrow q_2(n_0, n_1)$
$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{b}, n_1 \uparrow, n_2 \uparrow}$	$\rightarrow q_3(n_0, \mathbf{c}, n_1, n_2)$
$\frac{\text{pred}(n_0, n_1, n_2)}{\exists i: n_0 = \mathbf{b}, n_1 \uparrow, n_2 = \mathbf{c}_i}$	$\rightarrow q_4(n_0, n_2, n_1)$

Conflicts:

- shift $\text{pred}(\mathbf{b}, \circ, \circ)$, reduce *single*, shift $\text{action}(\mathbf{b}, \circ)$

State $q_7(\mathbf{a}, \mathbf{b}, \mathbf{c})$

$D(\mathbf{a}, \mathbf{b}) \rightarrow \text{Stmt}(\mathbf{a}, \mathbf{c}) \cdot D(\mathbf{c}, \mathbf{b})$
$D(\mathbf{c}, \mathbf{b}) \rightarrow \cdot \text{Stmt}(\mathbf{c}, \mathbf{b})$
$D(\mathbf{c}, \mathbf{b}) \rightarrow \cdot \text{Stmt}(\mathbf{c}, n_1) D(n_1, \mathbf{b})$
$\text{Stmt}(\mathbf{c}, n_2) \rightarrow \cdot \text{action}(\mathbf{c}, n_2)$
$\text{Stmt}(\mathbf{c}, n_3) \rightarrow \cdot \text{pred}(\mathbf{c}, n_4, n_5) D(n_4, n_3) D(n_5, n_3)$
$\text{Stmt}(\mathbf{c}, n_6) \rightarrow \cdot \text{pred}(\mathbf{c}, n_7, n_6) D(n_7, \mathbf{c})$
$\text{Stmt}(\mathbf{c}, \mathbf{b}) \rightarrow \cdot \text{action}(\mathbf{c}, \mathbf{b})$
$\text{Stmt}(\mathbf{c}, \mathbf{b}) \rightarrow \cdot \text{pred}(\mathbf{c}, n_8, n_9) D(n_8, \mathbf{b}) D(n_9, \mathbf{b})$
$\text{Stmt}(\mathbf{c}, \mathbf{b}) \rightarrow \cdot \text{pred}(\mathbf{c}, n_{10}, \mathbf{b}) D(n_{10}, \mathbf{c})$

$$\frac{D(n_0, n_1)}{n_0 = \mathbf{c}, n_1 = \mathbf{b}} \rightarrow q_8(\mathbf{a}, n_1, n_0)$$

$$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{c}, n_1 \uparrow} \rightarrow q_7(n_0, \mathbf{b}, n_1)$$

$$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{c}, n_1 = \mathbf{b}} \rightarrow q_5(n_0, n_1)$$

$$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{c}, n_1 \uparrow} \rightarrow q_2(n_0, n_1)$$

$$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{c}, n_1 = \mathbf{b}} \rightarrow q_2(n_0, n_1)$$

$$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{c}, n_1 \uparrow, n_2 \uparrow} \rightarrow q_3(n_0, \mathbf{b}, n_1, n_2)$$

$$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{c}, n_1 \uparrow, n_2 = \mathbf{b}} \rightarrow q_4(n_0, n_2, n_1)$$

State $q_8(\mathbf{a}, \mathbf{b}, \mathbf{c})$

$$\boxed{D(\mathbf{a}, \mathbf{b}) \rightarrow \text{Stmt}(\mathbf{a}, \mathbf{c}) D(\mathbf{c}, \mathbf{b}) . \quad [\text{seq}]}$$

State $q_9(\mathbf{a}, \mathbf{b})$

$$\boxed{S() \rightarrow \text{begin}(\mathbf{a}) D(\mathbf{a}, \mathbf{b}) . \text{stop}(\mathbf{b})}$$

$$\frac{\text{stop}(n_0)}{n_0 = \mathbf{b}} \rightarrow q_{12}(\mathbf{a}, n_0)$$

State $q_{10}(\mathbf{a}, \mathbf{b}, \mathbf{c}, \mathbf{d})$

$\text{Stmt}(\mathbf{a}, \mathbf{b}) \rightarrow \text{pred}(\mathbf{a}, \mathbf{c}, \mathbf{d}) D(\mathbf{c}, \mathbf{b}) . D(\mathbf{d}, \mathbf{b})$
$D(\mathbf{d}, \mathbf{b}) \rightarrow . \text{Stmt}(\mathbf{d}, \mathbf{b})$
$D(\mathbf{d}, \mathbf{b}) \rightarrow . \text{Stmt}(\mathbf{d}, n_1) D(n_1, \mathbf{b})$
$\text{Stmt}(\mathbf{d}, \mathbf{b}) \rightarrow . \text{action}(\mathbf{d}, \mathbf{b})$
$\text{Stmt}(\mathbf{d}, \mathbf{b}) \rightarrow . \text{pred}(\mathbf{d}, n_2, n_3) D(n_2, \mathbf{b}) D(n_3, \mathbf{b})$
$\text{Stmt}(\mathbf{d}, \mathbf{b}) \rightarrow . \text{pred}(\mathbf{d}, n_4, \mathbf{b}) D(n_4, \mathbf{d})$
$\text{Stmt}(\mathbf{d}, n_5) \rightarrow . \text{action}(\mathbf{d}, n_5)$
$\text{Stmt}(\mathbf{d}, n_6) \rightarrow . \text{pred}(\mathbf{d}, n_7, n_8) D(n_7, n_6) D(n_8, n_6)$
$\text{Stmt}(\mathbf{d}, n_9) \rightarrow . \text{pred}(\mathbf{d}, n_{10}, n_9) D(n_{10}, \mathbf{d})$

$$\frac{D(n_0, n_1)}{n_0 = \mathbf{d}, n_1 = \mathbf{b}} \rightarrow q_{13}(\mathbf{a}, n_1, \mathbf{c}, n_0)$$

$$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{d}, n_1 \uparrow} \rightarrow q_7(n_0, \mathbf{b}, n_1)$$

$$\frac{\text{Stmt}(n_0, n_1)}{n_0 = \mathbf{d}, n_1 = \mathbf{b}} \rightarrow q_5(n_0, n_1)$$

$$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{d}, n_1 \uparrow} \rightarrow q_2(n_0, n_1)$$

$$\frac{\text{action}(n_0, n_1)}{n_0 = \mathbf{d}, n_1 = \mathbf{b}} \rightarrow q_2(n_0, n_1)$$

$$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{d}, n_1 \uparrow, n_2 \uparrow} \rightarrow q_3(n_0, \mathbf{b}, n_1, n_2)$$

$$\frac{\text{pred}(n_0, n_1, n_2)}{n_0 = \mathbf{d}, n_1 \uparrow, n_2 = \mathbf{b}} \rightarrow q_4(n_0, n_2, n_1)$$

State $q_{11}(\mathbf{a}, \mathbf{b}, \mathbf{c})$

$$\boxed{\text{Stmt}(\mathbf{a}, \mathbf{b}) \rightarrow \text{pred}(\mathbf{a}, \mathbf{c}, \mathbf{b}) D(\mathbf{c}, \mathbf{a}) . \quad [\text{while}]}$$

State $q_{12}(\mathbf{a}, \mathbf{b})$

$$\boxed{S() \rightarrow \text{begin}(\mathbf{a}) D(\mathbf{a}, \mathbf{b}) \text{stop}(\mathbf{b}) . \quad [\text{init}]}$$

State $q_{13}(\mathbf{a}, \mathbf{b}, \mathbf{c}, \mathbf{d})$

$$\boxed{\text{Stmt}(\mathbf{a}, \mathbf{b}) \rightarrow \text{pred}(\mathbf{a}, \mathbf{c}, \mathbf{d}) D(\mathbf{c}, \mathbf{b}) D(\mathbf{d}, \mathbf{b}) . \quad [\text{alt}]}$$