

BPLC Library

Christiano Braga
cbraga@ic.uff.br

Instituto de Computação
Universidade Federal Fluminense



BPLC

Simple and meaningful

Abstract. Basic Programming Languages Constructs (pronounced "beeplick") is a library of common programming language constructs whose semantics are formally specified. Therefore, to give semantics to a programming language means to relate constructions of the given language with the constructs of BPLC. It is implemented in the [Maude](#) language.

```
<gsmc>≡
-----
-- Generalized SMC machines.

fmod GSMC-SORTS is
  sorts SemComp .
endfm

view SemComp from TRIV to GSMC-SORTS is
  sort Elt to SemComp .
endv

fmod GSMC is
  ex SET{SemComp} * (op empty to noSemComp) .
  sorts Attrib Conf .
  op <_> : Set{SemComp} -> Conf [format(c! c! c! o)] .
endfm
```

```

<bplc-sem-comp>≡
  fmod VALUE-SORT is
    sort Value .
  endfm

  fmod CONTROL-SORT is
    sort Control .
  endfm

  view Control from TRIV to CONTROL-SORT is
    sort Elt to Control .
  endv

  view Value from TRIV to VALUE-SORT is
    sort Elt to Value .
  endv

  -- Note: AI theories are not currently supported by Maude unification,
  -- as of Alpha 115.
  fmod GNELIST{X :: TRIV} is
    pr NAT .
    sorts GNeList{X} .
    subsort X$Elt < GNeList{X} .

    op __ : GNeList{X} GNeList{X} -> GNeList{X} [ctor assoc prec 25] .
  endfm

  -----
  -- GSMC semantics for basic programming language constructs .

  fmod VALUE-STACK is
    pr GNELIST{Value} * (sort GNeList{Value} to NeValueStack) .
    sort ValueStack .
    subsort NeValueStack < ValueStack .
    op evs : -> ValueStack .
    op __ : ValueStack ValueStack -> ValueStack [ditto] .
  endfm

  fmod CONTROL-STACK is
    pr GNELIST{Control} * (sort GNeList{Control} to NeControlStack) .
    sort ControlStack .
    subsort NeControlStack < ControlStack .
    op ecs : -> ControlStack .
    op __ : ControlStack ControlStack -> ControlStack [ditto] .
  endfm

```

```

fmod STORE-SORTS is
  sorts Loc Storable .
endfm

view Loc from TRIV to STORE-SORTS is
  sort Elt to Loc .
endv

view Storable from TRIV to STORE-SORTS is
  sort Elt to Storable .
endv

fmod STORE is
  pr NAT .
  ex MAP{Loc,Storable} * (sort Entry{Loc,Storable} to Cell,
    sort Map{Loc,Storable} to Store,
    op undefined to undefloc, op empty to noStore).
  ex SET{Loc} * (op empty to noLocs) .

  op loc : Nat -> Loc [ctor] .
  op newLoc : Store -> Loc .
  op $newLoc : Store Nat -> Loc .
  eq newLoc(noStore) = loc(0) .
  eq newLoc(S:Store) = $newLoc(S:Store, 0) if S:Store /= noStore .
  eq $newLoc(noStore, N:Nat) = loc(N:Nat + 1) .
  eq $newLoc((S:Store, loc(N:Nat) |-> 0:Storable), N':Nat) =
    $newLoc(S:Store, N:Nat) if N:Nat >= N':Nat .
  eq $newLoc((S:Store, loc(N:Nat) |-> 0:Storable), N':Nat) =
    $newLoc(S:Store, N':Nat) if N:Nat < N':Nat .

  op $free : Loc Store -> Store .
  eq $free(L:Loc, ((L:Loc |-> 0:Storable), S:Store)) = S:Store .
  eq $free(L:Loc, S:Store) = S:Store [owise] .

  op free : Set{Loc} Store -> Store .
  eq free(noLocs, S:Store) = S:Store .
  eq free((L:Loc , SL:Set{Loc}), S:Store) =
    free(SL:Set{Loc}, $free(L:Loc, S:Store)) [owise] .
endfm

fmod ENV-SORTS is
  sorts Id Bindable .
endfm

```

```

view Id from TRIV to ENV-SORTS is sort Elt to Id . endv

view Bindable from TRIV to ENV-SORTS is sort Elt to Bindable . endv

fmod ENV is
  ex MAP{Id,Bindable} * (sort Entry{Id,Bindable} to Bind,
    sort Map{Id,Bindable} to Env,
    op undefined to undefid, op empty to noEnv).
endfm

```

```

<bplc-exp>≡
fmod EXP is
  pr RAT .
  ex GSMC . ex ENV .
  ex STORE . ex CONTROL-STACK .
  ex VALUE-STACK .

  sorts Exp NzExp Pred EnvAttrib StoreAttrib ControlAttrib ValueAttrib .
  subsort EnvAttrib StoreAttrib ControlAttrib ValueAttrib < Attrib .
  subsort Id < Exp < Control .

  -- Arithmetic

  op rat : Rat -> Exp [ctor format(!g o)] .
  op boo : Bool -> Exp [ctor format(!g o)] .
  op add : Exp Exp -> Exp [format(! o)] .
  op sub : Exp Exp -> Exp [format(! o)] .
  op mul : Exp Exp -> Exp [format(! o)] .
  op div : Exp Exp -> Exp [format(! o)] .

  ops ADD SUB MUL DIV : -> Control [ctor] .

  -- Boolean expressions

  op gt : Exp Exp -> Exp [format(! o)] .
  op ge : Exp Exp -> Exp [format(! o)] .
  op lt : Exp Exp -> Exp [format(! o)] .
  op le : Exp Exp -> Exp [format(! o)] .
  op eq : Exp Exp -> Exp [format(! o)] .
  op neg : Exp -> Exp [format(! o)] .
  op and : Exp Exp -> Exp [format(! o)] .
  op or : Exp Exp -> Exp [format(! o)] .

  ops LT LE EQ NEG AND OR : -> Control [ctor] .

  -- Semantic components

  op env : -> EnvAttrib .
  op sto : -> StoreAttrib .
  op cnt : -> ControlAttrib .
  op val : -> ValueAttrib .
  op _:_ : EnvAttrib Env -> SemComp [ctor format(c! b! o o)] .
  op _:_ : StoreAttrib Store -> SemComp [ctor format(r! b! o o)] .
  op _:_ : ControlAttrib ControlStack -> SemComp [ctor format(c! b! o o)] .
  op _:_ : ValueAttrib ValueStack -> SemComp [ctor format(c! b! o o)] .

```

```

op store : Rat -> Storable [ctor format(ru! o)] .
op store : Bool -> Storable [ctor format(ru! o)] .
op bind : Loc -> Bindable [ctor] .
op bind : Rat -> Bindable [ctor] .
op bind : Bool -> Bindable [ctor] .

op val : Storable -> Value [ctor] .
op val : Rat -> Value [ctor] .
op val : Bool -> Value [ctor] .
op val : Loc -> Value [ctor] .
op val : Id -> Value [ctor] .

var ... : Set{SemComp} .

eq gt(E1:Exp, E2:Exp) = neg(le(E1:Exp, E2:Exp)) .
eq ge(E1:Exp, E2:Exp) = neg(lt(E1:Exp, E2:Exp)) .

eq [rat-exp] :
  < cnt : (rat(R:Rat) C:ControlStack), val : SK:ValueStack, ... >
  =
  < cnt : C:ControlStack,
    val : (val(R:Rat) SK:ValueStack), ... > [variant] .

eq [bool-exp] :
  < cnt : (boo(B:Bool) C:ControlStack), val : SK:ValueStack, ... >
  =
  < cnt : C:ControlStack,
    val : (val(B:Bool) SK:ValueStack), ... > [variant] .

eq [add-exp] :
  < cnt : (add(E1:Exp, E2:Exp) C:ControlStack), ... >
  =
  < cnt : (E1:Exp E2:Exp ADD C:ControlStack), ... > [variant] .

eq [add-exp] :
  < cnt : (ADD C:ControlStack),
    val : (val(R1:Rat) val(R2:Rat) SK:ValueStack), ... >
  =
  < cnt : C:ControlStack,
    val : (val(R1:Rat + R2:Rat) SK:ValueStack), ... > [variant] .

eq [sub-exp] :
  < cnt : (sub(E1:Exp, E2:Exp) C:ControlStack), ... >
  =

```

```

    < cnt : (E1:Exp E2:Exp SUB C:ControlStack), ... > [variant] .

eq [sub-exp] :
  < cnt : (SUB C:ControlStack),
    val : (val(R1:Rat) val(R2:Rat) SK:ValueStack), ... >
  =
  < cnt : C:ControlStack,
    val : (val(R2:Rat - R1:Rat) SK:ValueStack), ... > [variant] .

eq [mul-exp] :
  < cnt : (mul(E1:Exp, E2:Exp) C:ControlStack), ... >
  =
  < cnt : (E1:Exp E2:Exp MUL C:ControlStack), ... > [variant] .

eq [mul-exp] :
  < cnt : (MUL C:ControlStack),
    val : (val(R1:Rat) val(R2:Rat) SK:ValueStack), ... >
  =
  < cnt : C:ControlStack,
    val : (val(R1:Rat * R2:Rat) SK:ValueStack), ... > [variant] .

eq [div-exp] :
  < cnt : (div(E1:Exp, E2:Exp) C:ControlStack), ... >
  =
  < cnt : (E1:Exp E2:Exp DIV C:ControlStack), ... > [variant] .

eq [div-exp] :
  < cnt : (DIV C:ControlStack),
    val : (val(R1:Rat) val(R2:NzRat) SK:ValueStack), ... >
  =
  < cnt : C:ControlStack,
    val : (val(R1:Rat / R2:NzRat) SK:ValueStack), ... > [variant] .

eq [lt-exp] :
  < cnt : (lt(E1:Exp, E2:Exp) C:ControlStack), ... >
  =
  < cnt : (E2:Exp E1:Exp LT C:ControlStack), ... > [variant] .

eq [lt-exp] :
  < cnt : (LT C:ControlStack),
    val : (val(R1:Rat) val(R2:Rat) SK:ValueStack), ... >
  =
  < cnt : C:ControlStack,
    val : (val(R1:Rat < R2:Rat) SK:ValueStack), ... > [variant] .

```

```

eq [le-exp] :
  < cnt : (le(E1:Exp, E2:Exp) C:ControlStack), ... >
=
  < cnt : (E2:Exp E1:Exp LE C:ControlStack), ... > [variant] .

eq [le-exp] :
  < cnt : (LE C:ControlStack),
    val : (val(R1:Rat) val(R2:Rat) SK:ValueStack), ... >
=
  < cnt : C:ControlStack,
    val : (val(R1:Rat <= R2:Rat) SK:ValueStack), ... > [variant] .

eq [eq-exp] :
  < cnt : (eq(E1:Exp, E2:Exp) C:ControlStack), ... >
=
  < cnt : (E2:Exp E1:Exp EQ C:ControlStack), ... > [variant] .

eq [eq-exp] :
  < cnt : (EQ C:ControlStack),
    val : (val(R1:Rat) val(R2:Rat) SK:ValueStack), ... >
=
  < cnt : C:ControlStack,
    val : (val(R1:Rat == R2:Rat) SK:ValueStack), ... > [variant] .

eq [eq-exp] :
  < cnt : (EQ C:ControlStack),
    val : (val(B1:Bool) val(B2:Bool) SK:ValueStack), ... >
=
  < cnt : C:ControlStack,
    val : (val(B1:Bool == B2:Bool) SK:ValueStack), ... > [variant] .

eq [neg-exp] :
  < cnt : (neg(E:Exp) C:ControlStack), ... >
=
  < cnt : (E:Exp NEG C:ControlStack), ... > [variant] .

eq [neg-exp] :
  < cnt : (NEG C:ControlStack),
    val : (val(B:Bool) SK:ValueStack), ... >
=
  < cnt : C:ControlStack,
    val : (val(not(B:Bool)) SK:ValueStack), ... > [variant] .

eq [and-exp] :
  < cnt : (and(E1:Exp, E2:Exp) C:ControlStack), ... >

```



```

=
  < cnt : (E1:Exp E2:Exp AND C:ControlStack), ... > [variant] .

eq [and-exp] :
  < cnt : (AND C:ControlStack),
    val : (val(B1:Bool) val(B2:Bool) SK:ValueStack), ... >
=
  < cnt : C:ControlStack,
    val : (val(B1:Bool and B2:Bool) SK:ValueStack), ... > [variant] .

eq [or-exp] :
  < cnt : (or(E1:Exp, E2:Exp) C:ControlStack), ... >
=
  < cnt : (E1:Exp E2:Exp OR C:ControlStack), ... > [variant] .

eq [and-exp] :
  < cnt : (OR C:ControlStack),
    val : (val(B1:Bool) val(B2:Bool) SK:ValueStack), ... >
=
  < cnt : C:ControlStack,
    val : (val(B1:Bool or B2:Bool) SK:ValueStack), ... > [variant] .

eq [variable-exp] :
  < env : (I:Id |-> bind(L:Loc), E:Env),
    sto : (L:Loc |-> store(R:Rat), S:Store),
    cnt : (I:Id C:ControlStack), val : SK:ValueStack, ... >
=
  < env : (I:Id |-> bind(L:Loc), E:Env),
    sto : (L:Loc |-> store(R:Rat), S:Store),
    cnt : C:ControlStack ,
    val : (val(R:Rat) SK:ValueStack) , ... > [variant] .

eq [variable-exp] :
  < env : (I:Id |-> bind(L:Loc), E:Env),
    sto : (L:Loc |-> store(B:Bool), S:Store),
    cnt : (I:Id C:ControlStack), val : SK:ValueStack, ... >
=
  < env : (I:Id |-> bind(L:Loc), E:Env),
    sto : (L:Loc |-> store(B:Bool), S:Store),
    cnt : C:ControlStack ,
    val : (val(B:Bool) SK:ValueStack) , ... > [variant] .

eq [constant-rat-exp] :
  < env : (I:Id |-> bind(R:Rat), E:Env), cnt : (I:Id C:ControlStack),
    val : SK:ValueStack , ... >

```

```

=
  < env : (I:Id |-> bind(R:Rat), E:Env), cnt : C:ControlStack,
    val : (val(R:Rat) SK:ValueStack), ... > [variant] .

eq [constant-bool-exp] :
  < env : (I:Id |-> bind(B:Bool), E:Env), cnt : (I:Id C:ControlStack),
    val : SK:ValueStack, ... >
=
  < env : (I:Id |-> bind(B:Bool), E:Env), cnt : C:ControlStack,
    val : (val(B:Bool) SK:ValueStack), ... > [variant] .
endfm

```

```

<bplc-cmd>≡
  mod CMD is
    ex EXP .

    sorts Cmd ExcAttrib Exc .
    subsort Cmd < Control .

    op nop : -> Cmd [ctor format(! o)] .
    op choice : Cmd Cmd -> Cmd [ctor assoc comm format(! o)] .
    op assign : Id Exp -> Cmd [ctor format(! o)] .
    op ASSIGN : -> Control [ctor] .
    op loop : Exp Cmd -> Cmd [ctor format(! o)] .
    op LOOP : -> Control [ctor] .
    op if : Exp Cmd Cmd -> Cmd [ctor format(! o)] .
    op IF : -> Control [ctor] .
    op val : Cmd -> Value [ctor] .

    var ... : Set{SemComp} . var E : Env . var S : Store .
    var C : ControlStack . var V : ValueStack .

    eq [nop-cmd] :
      < cnt : nop C, ... > = < cnt : C, ... > [variant] .

    rl [choice-cmd] :
      < cnt : choice(M1:Cmd, M2:Cmd) C, ... > =>
      < cnt : M1:Cmd C, ... > .

    ***(
      rl [choice-cmd] :
        < cnt : choice(M1:Cmd, M2:Cmd) C, ... > =>
        < cnt : M1:Cmd C, ... > [narrowing] .
    )

    eq [assign-cmd] :
      < env : (I:Id |-> bind(L:Loc), E),
        cnt : (assign(I:Id, E:Exp) C),
        val : V, ... >
      =
      < env : (I:Id |-> bind(L:Loc), E),
        cnt : (E:Exp ASSIGN C),
        val : (val(I:Id) V), ... > [variant] .

    eq [assign-cmd] :
      < env : (I:Id |-> bind(L:Loc), E),
        sto : (L:Loc |-> T:Storable, S),
        cnt : (ASSIGN C),
        val : (val(R:Rat) val(I:Id) V), ... >

```

```

=
  < env : (I:Id |-> bind(L:Loc), E),
    sto : (L:Loc |-> store(R:Rat), S),
    cnt : C,
    val : V, ... > [variant] .

eq [assign-cmd] :
  < env : (I:Id |-> bind(L:Loc), E),
    sto : (L:Loc |-> T:Storable, S),
    cnt : (ASSIGN C),
    val : (val(B:Bool) val(I:Id) V), ... >
=
  < env : (I:Id |-> bind(L:Loc), E),
    sto : (L:Loc |-> store(B:Bool), S),
    cnt : C,
    val : V, ... > [variant] .

eq [loop] :
  < cnt : loop(E:Exp, K:Cmd) C, val : V, ... >
=
  < cnt : E:Exp LOOP C,
    val : val(loop(E:Exp, K:Cmd)) V, ... > [variant] .

rl [loop] :
  < cnt : LOOP C,
    val : val(true) val(loop(E:Exp, K:Cmd)) V, ... >
=>
  < cnt : K:Cmd loop(E:Exp, K:Cmd) C,
    val : V, ... > .

***(
  rl [loop] :
    < cnt : LOOP C,
      val : val(true) val(loop(E:Exp, K:Cmd)) V, ... > =>
    < cnt : K:Cmd loop(E:Exp, K:Cmd) C,
      val : V, ... > [narrowing] .
)

eq [loop] :
  < cnt : LOOP C,
    val : val(false) val(loop(E:Exp, K:Cmd)) V, ... >
=
  < cnt : C, val : V, ... > [variant] .

eq [if] :
  < cnt : if(E:Exp, K1:Cmd, K2:Cmd) C, val : V, ... >
=

```

```

    < cnt : E:Exp IF C,
      val : val(if(E:Exp, K1:Cmd, K2:Cmd)) V, ... > [variant] .

eq [if] :
  < cnt : IF C,
    val : val(true) val(if(E:Exp, K1:Cmd, K2:Cmd)) V, ... >
=
  < cnt : K1:Cmd C,
    val : V, ... > [variant] .

eq [if] :
  < cnt : IF C,
    val : val(false) val(if(E:Exp, K1:Cmd, K2:Cmd)) V, ... >
=
  < cnt : K2:Cmd C,
    val : V, ... > [variant] .
endm

```

```

<bplc-dec>=
  mod DEC is
    ex CMD .

    sorts Abs Blk Dec Formal Formals Actual Actuals LocsAttrib .
    subsort Actuals Dec < Control .
    subsort Formal < Formals .
    subsort Exp < Actual < Actuals .
    subsort Blk < Cmd .
    subsort Abs < Bindable .

    op cns : Id Exp -> Dec [ctor format(! o)] .
    op ref : Id Exp -> Dec [ctor format(! o)] .
    op prc : Id Blk -> Dec [ctor format(! o)] .
    op prc : Id Formals Blk -> Dec [ctor format(! o)] .
    op par : Id -> Formal [ctor format(! o)] .
    op vod : -> Formal [ctor format(! o)] .
    op for : Formals Formals -> Formals [ctor assoc format(! o)] .
    op dec : Dec Dec -> Dec [ctor format(! o)] .
    op blk : Cmd -> Blk [ctor format(! o)] .
    op blk : Dec Cmd -> Blk [ctor format(! o)] .
    op cal : Id -> Cmd [ctor format(! o)] .
    op cal : Id Actuals -> Cmd [ctor format(! o)] .
    op act : Actuals Actuals -> Actuals [ctor assoc format(! o)] .
    ops CNS REF CAL BLK FRE : -> Control [ctor] .

    op val : Env -> Value [ctor] .
    op val : Loc -> Value [ctor] .
    op val : Abs -> Value [ctor] .

    op abs : Blk -> Abs [ctor] .
    op abs : Formals Blk -> Abs [ctor] .
    op locs : -> LocsAttrib [ctor] .
    op _:_ : LocsAttrib Set{Loc} -> SemComp [ctor format(c! b! o o)] .

    var ... : Set{SemComp} . vars E E' : Env . var S : Store .
    var C : ControlStack . var V : ValueStack .

    eq [blk] :
      < cnt : blk(D:Dec, M:Cmd) C, env : E , val : V , ... >
      =
      < cnt : D:Dec M:Cmd BLK C, env : E , val : val(E) V , ... > [variant] .

    eq [blk] :
      < cnt : blk(M:Cmd) C, env : E , val : V , ... >

```

```

=
  < cnt : M:Cmd BLK C, env : E , val : val(E) V , ... > [variant] .

eq [blk] :
  < cnt : BLK C ,
    env : E' ,
    val : val(E) V ,
    locs : SL:Set{Loc},
    sto : S:Store, ... >
=
  < cnt : C ,
    env : E ,
    val : V ,
    locs : noLocs,
    sto : free(SL:Set{Loc}, S:Store), ... > [variant] .

eq [ref] :
  < cnt : ref(I:Id, X:Exp) C , val : V , ... > =
  < cnt : X:Exp REF C , val : val(I:Id) V , ... > [variant] .

eq [ref] :
  < cnt : REF C, env : E ,
    sto : S ,
    val : val(R:Rat) val(I:Id) V ,
    locs : SL:Set{Loc} , ... >
=
  < cnt : C ,
    env : insert(I:Id, bind(newLoc(S)), E) ,
    sto : insert(newLoc(S), store(R:Rat), S) ,
    val : V ,
    locs : (newLoc(S) , SL:Set{Loc}) , ... > [variant] .

eq [cns] :
  < cnt : cns(I:Id, X:Exp) C , val : V , ... > =
  < cnt : X:Exp CNS C , val : val(I:Id) V , ... > [variant] .

eq [cns] :
  < cnt : CNS C, env : E , val : val(R:Rat) val(I:Id) V , ... > =
  < cnt : C ,
    env : (I:Id |-> bind(R:Rat) , E) ,
    val : V , ... > [variant] .

eq [prc] :
  < cnt : prc(I:Id, F:Formals, B:Blk) C, env : E, ... > =
  < cnt : C,

```

```

    env : insert(I:Id, abs(F:Formals, B:Blk), E), ... > [variant] .

eq [prc] :
  < cnt : prc(I:Id, B:Blk) C, env : E, ... > =
  < cnt : C,
    env : insert(I:Id, abs(B:Blk), E), ... > [variant] .

eq [dec] :
  < cnt : dec(D1:Dec, D2:Dec) C, ... > =
  < cnt : D1:Dec D2:Dec C , ... > [variant] .

eq [cal] :
  < cnt : cal(I:Id) C, ... > =
  < cnt : I:Id CAL C, ... > [variant] .

eq [cal] :
  < cnt : cal(I:Id, A:Actuals) C, ... > =
  < cnt : I:Id A:Actuals CAL C, ... > [variant] .

eq [cal] :
  < cnt : CAL C,
    val : V1:ValueStack
    val(abs(F:Formals, B:Blk)) V2:ValueStack, ... > =
  < cnt : addDec(match(F:Formals, V1:ValueStack), B:Blk) C,
    val : V2:ValueStack, ... > [variant] .

eq [cal] :
  < cnt : CAL C,
    val : val(abs(B:Blk)) V:ValueStack, ... > =
  < cnt : B:Blk C,
    val : V:ValueStack, ... > [variant] .

eq [prc-id] :
  < cnt : (I:Id C),
    env : (I:Id |-> A:Abs, E),
    val : V , ... > =
  < cnt : C,
    env : (I:Id |-> A:Abs, E),
    val : (val(A:Abs) V), ... > [variant] .

eq [act] :
  < cnt : act(E:Exp, A:Actuals) C, ... > =
  < cnt : A:Actuals E:Exp C, ... > [variant] .

op match : Formals ValueStack -> Dec .

```



```

eq match(par(I:Id), val(R:Rat)) = ref(I:Id, rat(R:Rat)) .
eq match(par(I:Id), val(B:Bool)) = ref(I:Id, boo(B:Bool)) .
eq match(for(F:Formal, L:Formals), (V:Value VS:ValueStack)) =
    dec(match(F:Formal, V:Value),
        match(L:Formals, VS:ValueStack)) .

op addDec : Dec Blk -> Blk .
eq addDec(D:Dec, B:Blk) = blk(D:Dec, B:Blk) .
endm

<bplc-out>≡
mod OUT is
ex DEC .

sort OutAttrib .

op out : -> OutAttrib [ctor] .
op _:_ : OutAttrib ValueStack -> SemComp [ctor format(c! b! o o)] .
op print : Exp -> Cmd [ctor format(! o)] .
op PRINT : -> Control [ctor] .

var ... : Set{SemComp} .

op out : Conf -> NeValueStack [ctor] .
eq out(< out : V:NeValueStack , ... >) = V:NeValueStack .

eq [print] :
    < cnt : (print(E:Exp) C:ControlStack), ... > =
    < cnt : (E:Exp PRINT C:ControlStack), ... > [variant] .

eq [print] :
    < cnt : (PRINT C:ControlStack),
      val : val(R:Rat) V:ValueStack,
      out : O:ValueStack, ... > =
    < cnt : C:ControlStack,
      val : V:ValueStack,
      out : val(R:Rat) O:ValueStack , ... > [variant] .
endm

```

```

<bplc-ext>≡
  mod EXIT is
    ex OUT .

    -- Sequences had to be moved "down" from CMD to this module because
    -- the evaluation of the next command only takes place if no
    -- exit was executed.
    op seq : Cmd Cmd -> Cmd [format(! o)] .

    op exit : Exp -> Cmd [format(! o)] .
    op EXT : -> Exc .
    op EXIT : -> Control .
    op CNT : -> Exc .
    op exc : -> ExcAttrib .
    op _:_ : ExcAttrib Exc -> SemComp [format(c! b! o o)] .

    var ... : Set{SemComp} . var E : Env . var S : Store .
    var C : ControlStack . var V : ValueStack .

    eq [exit-cmd] :
      < cnt : exit(X:Exp) C, ... > = < cnt : X:Exp EXIT C, ... > [variant] .

    -- Maybe define a flush operation that sets the semantic components
    -- to their identity values.
    eq [exit-cmd] :
      < cnt : EXIT C,
        env : E,
        sto : S,
        val : A:Value V,
        out : O:ValueStack,
        locs : SL:Set{Loc},
        exc : CNT, ... > =
      < cnt : ecs,
        env : noEnv,
        sto : noStore,
        val : evs,
        out : A:Value,
        locs : noLocs,
        exc : EXT, ... > [variant] .

    -- Sequences had to be moved "down" to this module because
    -- the evaluation of the next command only takes place if no
    -- exit was executed.
    eq [seq-cmd] :
      < cnt : seq(C1:Cmd, C2:Cmd) C, exc : CNT, ... > =

```

```

        < cnt : C1:Cmd C2:Cmd C, exc : CNT, ... > [variant] .

eq [seq-cmd] :
    < cnt : seq(C1:Cmd, C2:Cmd) C, exc : EXT, ... > =
    < cnt : ecs, exc : EXT, ... > [variant] .
endm

⟨bplc⟩≡
-- Basic programming languages constructs.
mod BPLC is
    ex EXIT .

    var ... : Set{SemComp} .

    op getValue : Id Conf -> Storable .
    eq getValue(I:Id,
        < env : (I:Id |-> bind(L:Loc), E:Env) ,
        sto : (L:Loc |-> S:Storable, S:Store) ,
        ... >) = S:Storable .
endm

⟨bplc-mc⟩≡
load lmc

mod BPLC-MODEL-CHECKER is
    ex BPLC .
    pr SYMBOLIC-CHECKER .

    subsort Conf < State .

    var ... : Set{SemComp} .

    op valueOf : Id Rat Conf -> Bool .
    op valueOf : Id Bool Conf -> Bool .
    eq valueOf(I:Id, R:Rat,
        < env : (I:Id |-> bind(L:Loc), E:Env) ,
        sto : (L:Loc |-> store(R:Rat), S:Store) ,
        ... >) = true .
    eq valueOf(I:Id, R:Rat, C:Conf) = false [owise] .

    eq valueOf(I:Id, B:Bool,
        < env : (I:Id |-> bind(L:Loc), E:Env) ,
        sto : (L:Loc |-> store(B:Bool), S:Store) ,
        ... >) = true .
    eq valueOf(I:Id, B:Bool, C:Conf) = false [owise] .
endm

```