Statement

Motivation, Applicability, and Indications for Use

The programming type *Statement* is used to represent the ***abstract syntax tree*** (AST) of a (nested) statement in the *BL* language. Abstract syntax trees are common representations of programs used in language processing tools. They provide the necessary information about the source code needed to compile it or interpret it, while dispensing with the "concrete syntax" details.

Here is an example of a BL statement:

```
WHILE next-is-not-empty DO
    IF next-is-enemy THEN
        infect
    ELSE
        turnleft
    END IF
END WHILE
```

In Figure 1 you can see picture of a possible corresponding abstract syntax tree.

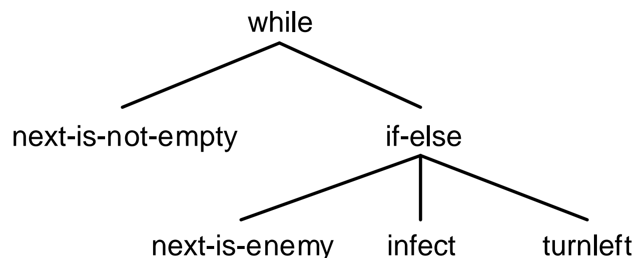


Figure 1 — An abstract syntax tree

As you can see, the AST is simply a different representation of the BL statement. The root item tells us that we are looking at a WHILE statement. The first child of the root shows the test condition for the while (`next-is-not-empty`), and the second child of the root is the AST for the nested statement. This happens to be an IF-ELSE statement, as indicated by the root of the second child of WHILE. The three children of the IF-THEN item are, from left to right, the IF-ELSE test condition (`next-is-enemy`), the AST for the THEN part of the IF-ELSE (`infect`), and the AST for the ELSE part of the IF-THEN (`turnleft`).

The structure of abstract syntax trees is not unique. In Figure 2 we show an alternative AST for the same statement.

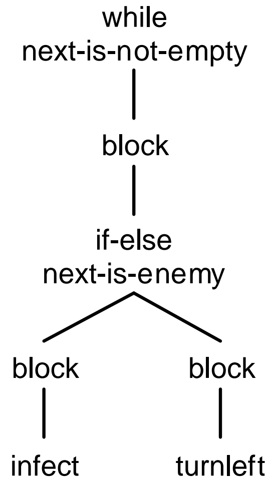


Figure 2 — An alternative abstract syntax tree

First, compare the AST in Figure 2 with the BL statement above, and convince yourself that the AST still is an exact representation of the statement (i.e., it contains enough information to unequivocally allow us to reconstruct the statement from the AST). Then, comparing the ASTs in Figures 1 and 2, we can see that there are two main differences:

1. In Figure 2, the test conditions for the WHILE and IF-ELSE statements have been attached to their corresponding statement items in the tree (i.e., `next-is-not-empty` to WHILE and `next-is-enemy` to IF-ELSE);

2. In Figure 2, a new item, labeled *block*, has been introduced in three places in the AST. The block item allows us to group together a string of statements nested inside one of BL's control structures (WHILE, IF, and IF-ELSE).

Here is another example that shows why blocks are useful. Consider the BL statement:

```
IF next-is-enemy THEN
    infect
    turnleft
ELSE
    IF next-is-wall THEN
        turnright
        turnright
    END IF
    infect
END IF
```

And in Figure 3 the corresponding AST.

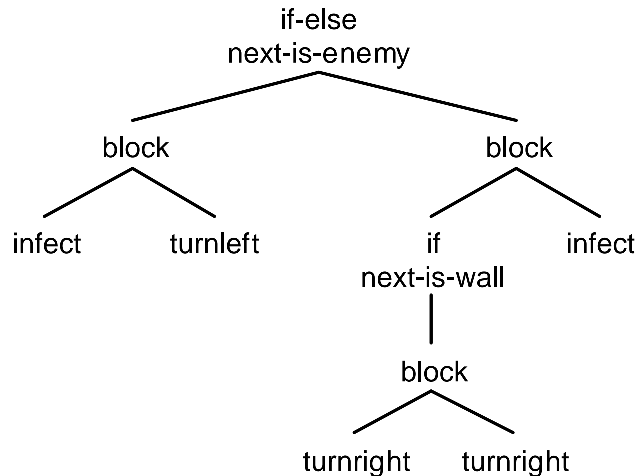


Figure 3 — Another abstract syntax tree

Without the block items in the tree, the root IF-ELSE would have 4 children (`infect`, `turnleft`, `if`, `infect`), and there would be no indication of which of these statements are in the THEN part and which are in the ELSE part.

Related Components

- *Program* — a type representing an abstract description of a BL program, and that uses *Statement* to represent both the body of the program and the bodies of the declared instructions.

Component Family Members

Abstract Components

- *Statement_Type* — the programming type of interest with the operations below
    - *Add_To_Block*
    - *Remove_From_Block*
    - *Length_Of_Block*
    - *Compose_If*
    - *Decompose_If*
    - *Compose_If_Else*

- *Decompose_If_Else*
- *Compose_While*
- *Decompose_While*
- *Compose_Call*
- *Decompose_Call*
- *Kind*

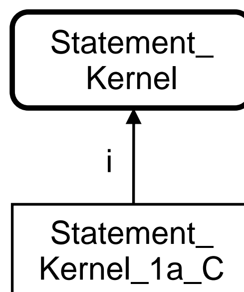
Concrete Components

- *Statement_Kernel_1a_C* — This is a checking implementation of *Statement_Kernel* in which the execution time for each of the operations constructor, *Length_Of_Block*, *Compose_If*, *Decompose_If*, *Compose_If_Else*, *Decompose_If_Else*, *Compose_While*, *Decompose_While*, *Compose_Call*, *Decompose_Call*, and the *Kind* is constant, while the execution time for *Add_To_Block* and *Remove_From_Block* is proportional to the number of statements in the block, and the execution time for the destructor is proportional to the overall size of the statement. All objects of this type have the interface of *Statement_Kernel*, with the concrete template name *Statement_Kernel_1a_C* substituted for the abstract template name *Statement_Kernel*.

  To bring this component into the context you write:

  ```
  #include "CI/Statement/Kernel_1a_C.h"
  ```

Component Coupling Diagram



Bugs Catalog

AT/Statement/Kernel.h

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---

```
//  /*-------------------------------------------------------------------*\
//  |    Abstract Template : Statement_Kernel
//  \*-------------------------------------------------------------------*/

#ifndef AT_STATEMENT_KERNEL
#define AT_STATEMENT_KERNEL 1

///-------------------------------------------------------------------------
/// Interface -------------------------------------------------------------
///-------------------------------------------------------------------------

enumeration Kind
{
    BLOCK,
    IF,
    IF_ELSE,
    WHILE,
    CALL
};

///-------------------------------------------------------------------------

enumeration Condition
{
    NEXT_IS_EMPTY,
    NEXT_IS_NOT_EMPTY,
    NEXT_IS_WALL,
    NEXT_IS_NOT_WALL,
    NEXT_IS_FRIEND,
    NEXT_IS_NOT_FRIEND,
    NEXT_IS_ENEMY,
    NEXT_IS_NOT_ENEMY,
    RANDOM,
    TRUE
};

///-------------------------------------------------------------------------

abstract_template <
        concrete_instance class Nested_Statement_Type
        /*!
            implements
                abstract_instance Statement_Kernel <
                        Nested_Statement_Type
                    >
        !*/
```

```
    >
class Statement_Kernel
{
public:

    /*!
        math definition IS_IDENTIFIER (
                i: string of character
            ): boolean is
            i = empty_string or
            (there exists c: character, s: string of character
                 (i = <c> * s and
                  c is in {'a'..'z', 'A'..'Z'} and
                  for all x: character where (x is in elements (s))
                      (x is in {'a'..'z', 'A'..'Z', '0'..'9', '-'})) and
             i is not in {"PROGRAM", "IS", "INSTRUCTION", "WHILE", "DO",
                          "IF", "THEN", "ELSE", "BEGIN", "END",
                          "next-is-empty", "next-is-not-empty",
                          "next-is-wall", "next-is-not-wall",
                          "next-is-friend", "next-is-not-friend",
                          "next-is-enemy", "next-is-not-enemy",
                          "random", "true"})

        math subtype IDENTIFIER is string of character
            exemplar i
            constraint
                IS_IDENTIFIER (i)

        math definition IS_CONDITION (
                c: integer
            ): boolean is
            c is in Condition

        math definition IS_STATEMENT_LABEL (
                kind: integer
                test: integer
                instruction: string of character
            ): boolean is
            (kind = BLOCK and
             test = TRUE and
             instruction = empty_string) or
            ((kind = IF or kind = IF_ELSE or kind = WHILE) and
             instruction = empty_string) or
            (kind = CALL and
             test = TRUE and
             instruction /= empty_string)

        math subtype STATEMENT_LABEL is (
                kind: Kind
                test: Condition
                instruction: IDENTIFIER
            )
            exemplar n
            constraint
```

```
            IS_STATEMENT_LABEL (n.kind, n.test, n.instruction)

    math subtype STATEMENT is tree of STATEMENT_LABEL
        exemplar s
        constraint
            IS_LEGAL_STATEMENT (s)

    math definition IS_LEGAL_STATEMENT (
            t: tree of STATEMENT_LABEL
        ): boolean satisfies
        there exists label: STATEMENT_LABEL,
                     nested_stmts: string of tree of STATEMENT_LABEL
            (t = compose (label, nested_stmts) and
             for all x: tree of STATEMENT_LABEL
             where (x is in elements (nested_stmts))
                 (IS_LEGAL_STATEMENT (x)) and
             if label.kind = BLOCK
             then
                 for all x: tree of STATEMENT_LABEL
                 where (x is in elements (nested_stmts))
                     (root (x).kind /= BLOCK)
             else if label.kind = IF or label.kind = WHILE
             then
                 |nested_stmts| = 1 and
                 first (nested_stmts).kind = BLOCK
             else if label.kind = IF_ELSE
             then
                 |nested_stmts| = 2 and
                 first (nested_stmts).kind = BLOCK and
                 last (nested_stmts).kind = BLOCK
             else if label.kind = CALL
             then
                 |nested_stmts| = 0)

    math definition IS_INITIAL_STATEMENT (
            s: STATEMENT
        ): boolean is
        root (s).kind = BLOCK and
        children (s) = empty_string
!*/

standard_abstract_operations (Statement_Kernel);
/*!
    Statement_Kernel is modeled by STATEMENT
    initialization
        ensures IS_INITIAL_STATEMENT (self)
!*/

procedure Add_To_Block (
        preserves Integer pos,
        consumes Nested_Statement_Type& statement
    ) is_abstract;
/*!
    requires
```

```
        root (self).kind = BLOCK and
        root (statement).kind /= BLOCK and
        0 <= pos and pos <= |children (self)|
    ensures
        there exists x, y: string of STATEMENT
            (|x| = pos and
             children (#self) = x * y and
             self = compose (root (#self), x * <#statement> * y))
!*/

procedure Remove_From_Block (
        preserves Integer pos,
        produces Nested_Statement_Type& statement
    ) is_abstract;
/*!
    requires
        root (self).kind = BLOCK and
        0 <= pos and pos < |children (self)|
    ensures
        there exists x, y: string of STATEMENT
            (|x| = pos and
             children (#self) = x * <statement> * y and
             self = compose (root (#self), x * y))
!*/

function Integer Length_Of_Block () is_abstract;
/*!
    requires
        root (self).kind = BLOCK
    ensures
        Length_Of_Block = |children (self)|
!*/

procedure Compose_If (
        consumes Integer& cond,
        consumes Nested_Statement_Type& block
    ) is_abstract;
/*!
    produces self
    requires
        IS_CONDITION (cond) and
        root (block).kind = BLOCK
    ensures
        self = compose ((IF, #cond, empty_string), <#block>)
!*/

procedure Decompose_If (
        produces Integer& cond,
        produces Nested_Statement_Type& block
    ) is_abstract;
/*!
    consumes self
    requires
        root (self).kind = IF
```

```
    ensures
        #self = compose ((IF, cond, empty_string), <block>)
!*/

procedure Compose_If_Else (
        consumes Integer& cond,
        consumes Nested_Statement_Type& if_block,
        consumes Nested_Statement_Type& else_block
    ) is_abstract;
/*!
    produces self
    requires
        IS_CONDITION (cond) and
        root (if_block).kind = BLOCK and
        root (else_block).kind = BLOCK
    ensures
        self = compose ((IF_ELSE, #cond, empty_string),
                        <#if_block> * <#else_block>)
!*/

procedure Decompose_If_Else (
        produces Integer& cond,
        produces Nested_Statement_Type& if_block,
        produces Nested_Statement_Type& else_block
    ) is_abstract;
/*!
    consumes self
    requires
        root (self).kind = IF_ELSE
    ensures
        #self = compose ((IF_ELSE, cond, empty_string),
                         <if_block> * <else_block>)
!*/

procedure Compose_While (
        consumes Integer& cond,
        consumes Nested_Statement_Type& block
    ) is_abstract;
/*!
    produces self
    requires
        IS_CONDITION (cond) and
        root (block).kind = BLOCK
    ensures
        self = compose ((WHILE, #cond, empty_string), <#block>)
!*/

procedure Decompose_While (
        produces Integer& cond,
        produces Nested_Statement_Type& block
    ) is_abstract;
/*!
    consumes self
    requires
```

```
            root (self).kind = WHILE
        ensures
            #self = compose ((WHILE, cond, empty_string), <block>)
    !*/

    procedure Compose_Call (
            consumes Text& inst
        ) is_abstract;
    /*!
        produces self
        requires
            IS_IDENTIFIER (inst) and inst /= empty_string
        ensures
            root (self) = (CALL, TRUE, #inst) and
            children (self) = empty_string
    !*/

    procedure Decompose_Call (
            produces Text& inst
        ) is_abstract;
    /*!
        consumes self
        requires
            root (self).kind = CALL
        ensures
            #self = compose ((CALL, TRUE, inst), empty_string)
    !*/

    function Integer Kind () is_abstract;
    /*!
        ensures
            Kind = root (self).kind
    !*/

};

#endif // AT_STATEMENT_KERNEL
```

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Bugs Catalog

AT/Statement/Parse.h

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```
//  /*----------------------------------------------------------------------*\
//  |   Abstract Template : Statement_Parse
//  \*----------------------------------------------------------------------*/

#ifndef AT_STATEMENT_PARSE
#define AT_STATEMENT_PARSE 1

///------------------------------------------------------------------------
/// Global Context --------------------------------------------------------
///------------------------------------------------------------------------

#include "AT/Statement/Kernel.h"
/*!
    #include "AI/BL_Tokenizing_Machine/Kernel.h"
!*/

///------------------------------------------------------------------------
/// Interface -------------------------------------------------------------
///------------------------------------------------------------------------

abstract_template <
        concrete_instance class Statement_Base,
        /*!
            implements
                abstract_instance Statement_Kernel <
                        Statement_Base
                    >
        !*/
        concrete_instance class Tokenizing_Machine
        /*!
            implements
                abstract_instance BL_Tokenizing_Machine_Type
        !*/
    >
class Statement_Parse :
    extends
        abstract_instance Statement_Base
{
public:

    /*!
        math definition CONDITION_TO_TOKEN (
                i: integer
            ): string of character satisfies
            if i = NEXT_IS_EMPTY
```

```
    then CONDITION_TO_TOKEN (i) = "next-is-empty"
    else if i = NEXT_IS_NOT_EMPTY
    then CONDITION_TO_TOKEN (i) = "next-is-not-empty"
    else if i = NEXT_IS_WALL
    then CONDITION_TO_TOKEN (i) = "next-is-wall"
    else if i = NEXT_IS_NOT_WALL
    then CONDITION_TO_TOKEN (i) = "next-is-not-wall"
    else if i = NEXT_IS_FRIEND
    then CONDITION_TO_TOKEN (i) = "next-is-friend"
    else if i = NEXT_IS_NOT_FRIEND
    then CONDITION_TO_TOKEN (i) = "next-is-not-friend"
    else if i = NEXT_IS_ENEMY
    then CONDITION_TO_TOKEN (i) = "next-is-enemy"
    else if i = NEXT_IS_NOT_ENEMY
    then CONDITION_TO_TOKEN (i) = "next-is-not-enemy"
    else if i = RANDOM
    then CONDITION_TO_TOKEN (i) = "random"
    else if i = TRUE
    then CONDITION_TO_TOKEN (i) = "true"

math definition BLOCK_TO_STRING_OF_TOKENS (
        block: string of STATEMENT
    ): string of string of character satisfies
    if block = empty_string
    then
        BLOCK_TO_STRING_OF_TOKENS (block) = empty_string
    else
        there exists s: STATEMENT, rest: string of STATEMENT
            (block = <s> * rest and
             BLOCK_TO_STRING_OF_TOKENS (block) =
                 STATEMENT_TO_STRING_OF_TOKENS (s) *
                 BLOCK_TO_STRING_OF_TOKENS (rest))

math definition STATEMENT_TO_STRING_OF_TOKENS (
        s: STATEMENT
    ): string of string of character satisfies
    there exists label: STATEMENT_LABEL,
                 nested_stmts: string of STATEMENT
        (s = compose (label, nested_stmts) and
         if label.kind = BLOCK
         then
             STATEMENT_TO_STRING_OF_TOKENS (s) =
                 BLOCK_TO_STRING_OF_TOKENS (nested_stmts)
         else if label.kind = IF
         then
             STATEMENT_TO_STRING_OF_TOKENS (s) =
                 <"IF"> * <CONDITION_TO_TOKEN (label.test)> *
                 <"THEN"> *
                 STATEMENT_TO_STRING_OF_TOKENS (
                                            first (nested_stmts)) *
                 <"END"> * <"IF">
         else if label.kind = IF_ELSE
         then
             STATEMENT_TO_STRING_OF_TOKENS (s) =
```

```
                    <"IF"> * <CONDITION_TO_TOKEN (label.test)> *
                    <"THEN"> *
                    STATEMENT_TO_STRING_OF_TOKENS (
                                               first (nested_stmts)) *
                    <"ELSE"> *
                    STATEMENT_TO_STRING_OF_TOKENS (
                                               last (nested_stmts)) *
                    <"END"> * <"IF">
            else if label.kind = WHILE
            then
                STATEMENT_TO_STRING_OF_TOKENS (s) =
                    <"WHILE"> * <CONDITION_TO_TOKEN (label.test)> *
                    <"DO"> *
                    STATEMENT_TO_STRING_OF_TOKENS (
                                               first (nested_stmts)) *
                    <"END"> * <"WHILE">
            else if label.kind = CALL
            then
                STATEMENT_TO_STRING_OF_TOKENS (s) =
                                                 <label.instruction>)
!*/

procedure Parse (
        alters Character_IStream& str,
        alters Tokenizing_Machine& m,
        alters Text& token_text,
        alters Integer& token_kind
    ) is_abstract;
/*!
    produces self
    requires
        str.is_open = true and
        token_kind = WHICH_KIND (token_text) and
        m.ready_to_dispense = false
    ensures
        if there exists s: STATEMENT, x, y: string of character
            (root (s).kind /= BLOCK and
             #token_text * #m.buffer * #str.content = x * y and
             STATEMENT_TO_STRING_OF_TOKENS (s) =
                 REMOVE_SEPARATORS (TOKENIZE_PROGRAM_TEXT (x)))
        then
            str.is_open = true and
            str.ext_name = #str.ext_name and
            there exists z: string of character
                (#token_text * #m.buffer * #str.content =
                     z * token_text * m.buffer * str.content and
                 STATEMENT_TO_STRING_OF_TOKENS (self) =
                     REMOVE_SEPARATORS (TOKENIZE_PROGRAM_TEXT (z)) and
                 root (self).kind /= BLOCK and
                 token_kind = WHICH_KIND (token_text) and
                 m.ready_to_dispense = false)
!*/

procedure Parse_Block (
```

```
            alters Character_IStream& str,
            alters Tokenizing_Machine& m,
            alters Text& token_text,
            alters Integer& token_kind
        ) is_abstract;
    /*!
        produces self
        requires
            str.is_open = true and
            token_kind = WHICH_KIND (token_text) and
            m.ready_to_dispense = false
        ensures
            if there exists x, y: string of character,
                            s: string of STATEMENT
                   (#token_text * #m.buffer * #str.content = x * y and
                    BLOCK_TO_STRING_OF_TOKENS (s) =
                        REMOVE_SEPARATORS (TOKENIZE_PROGRAM_TEXT (x)))
            then
                str.is_open = true and
                str.ext_name = #str.ext_name and
                there exists z: string of character
                    (#token_text * #m.buffer * #str.content =
                         z * token_text * m.buffer * str.content and
                     BLOCK_TO_STRING_OF_TOKENS (children (self)) =
                         REMOVE_SEPARATORS (TOKENIZE_PROGRAM_TEXT (z)) and
                     root (self).kind = BLOCK and
                     token_text is not in {"IF", "WHILE"} and
                     not IS_IDENTIFIER (token_text) and
                     not IS_WHITE_SPACE (token_text) and
                     not IS_COMMENT (token_text) and
                     token_kind = WHICH_KIND (token_text) and
                     m.ready_to_dispense = false)
    !*/
};

#endif // AT_STATEMENT_PARSE
```

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Bugs Catalog

AT/Statement/Pretty_Print.h

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```
//  /*-------------------------------------------------------------------*\
//  |   Abstract Template : Statement_Pretty_Print
//  \*-------------------------------------------------------------------*/

#ifndef AT_STATEMENT_PRETTY_PRINT
#define AT_STATEMENT_PRETTY_PRINT 1

///-------------------------------------------------------------------------
/// Global Context ---------------------------------------------------------
///-------------------------------------------------------------------------

#include "AT/Statement/Kernel.h"

///-------------------------------------------------------------------------
/// Interface --------------------------------------------------------------
///-------------------------------------------------------------------------

abstract_template <
        concrete_instance class Statement_Base
        /*!
            implements
                abstract_instance Statement_Kernel <
                        Statement_Base
                    >
        !*/
    >
class Statement_Pretty_Print :
    extends
        abstract_instance Statement_Base
{
public:

    /*!
        math definition MAKE_A_STRING (
                i: integer
                ch: character
            ): string of character satisfies
           if i <= 0
           then
              MAKE_A_STRING (i, ch) = empty_string
           else
              MAKE_A_STRING (i, ch) = <ch> * MAKE_A_STRING (i-1, ch)

        math definition DISPLAY_CONDITION (
                i: integer
```

```
    ): string of character satisfies
    if i = NEXT_IS_EMPTY
    then DISPLAY_CONDITION (i) = "next-is-empty"
    else if i = NEXT_IS_NOT_EMPTY
    then DISPLAY_CONDITION (i) = "next-is-not-empty"
    else if i = NEXT_IS_WALL
    then DISPLAY_CONDITION (i) = "next-is-wall"
    else if i = NEXT_IS_NOT_WALL
    then DISPLAY_CONDITION (i) = "next-is-not-wall"
    else if i = NEXT_IS_FRIEND
    then DISPLAY_CONDITION (i) = "next-is-friend"
    else if i = NEXT_IS_NOT_FRIEND
    then DISPLAY_CONDITION (i) = "next-is-not-friend"
    else if i = NEXT_IS_ENEMY
    then DISPLAY_CONDITION (i) = "next-is-enemy"
    else if i = NEXT_IS_NOT_ENEMY
    then DISPLAY_CONDITION (i) = "next-is-not-enemy"
    else if i = RANDOM
    then DISPLAY_CONDITION (i) = "random"
    else if i = TRUE
    then DISPLAY_CONDITION (i) = "true"

math definition DISPLAY_BLOCK (
        s: string of STATEMENT
        i: integer
    ): string of character satisfies
    if s = empty_string
    then DISPLAY_BLOCK (s, i) = empty_string
    else
        there exists stmt: STATEMENT,
                     rest: string of STATEMENT
           (s = <stmt> * rest and
            DISPLAY_BLOCK (s, i) =
                PRETTY_DISPLAY (stmt, i) * DISPLAY_BLOCK (rest, i))

math definition PRETTY_DISPLAY (
        s: STATEMENT
        i: integer
    ): string of character satisfies
    there exists label: STATEMENT_LABEL,
                 nested_stmts: string of STATEMENT
         (s = compose (label, nested_stmts) and
          if label.kind = BLOCK
          then
              PRETTY_DISPLAY (s, i) = DISPLAY_BLOCK (nested_stmts, i)
          else if label.kind = IF
          then
              PRETTY_DISPLAY (s, i) =
               MAKE_A_STRING (i, ' ') * "IF " *
               DISPLAY_CONDITION (label.test) * " THEN\n" *
               PRETTY_DISPLAY (first (nested_stmts), i+4) *
               MAKE_A_STRING (i, ' ') * "END IF\n"
          else if label.kind = IF_ELSE
          then
```

```
                        PRETTY_DISPLAY (s, i) =
                         MAKE_A_STRING (i, ' ') * "IF " *
                         DISPLAY_CONDITION (label.test) * " THEN\n" *
                         PRETTY_DISPLAY (first (nested_stmts), i+4) *
                         MAKE_A_STRING (i, ' ') * "ELSE\n" *
                         PRETTY_DISPLAY (last (nested_stmts), i+4) *
                         MAKE_A_STRING (i, ' ') * "END IF\n"
                    else if label.kind = WHILE
                    then
                        PRETTY_DISPLAY (s, i) =
                         MAKE_A_STRING (i, ' ') * "WHILE " *
                         DISPLAY_CONDITION (label.test) * " DO\n" *
                         PRETTY_DISPLAY (first (nested_stmts), i+4) *
                         MAKE_A_STRING (i, ' ') * "END WHILE\n"
                    else if label.kind = CALL
                    then
                        PRETTY_DISPLAY (s, i) =
                         MAKE_A_STRING (i, ' ') * label.instruction * "\n")
    !*/

    procedure Pretty_Print (
            alters Character_OStream& out,
            preserves Integer indentation_factor
        ) is_abstract;
    /*!
        preserves self
        requires
            out.is_open = true
         ensures
            out.is_open = true and
            out.ext_name = #out.ext_name and
            out.content = #out.content *
                          PRETTY_DISPLAY (self, indentation_factor)
    !*/
};

#endif // AT_STATEMENT_PRETTY_PRINT
```

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