Abstract: This paper defines SuperPascal—a secure programming language for publication of parallel scientific algorithms. SuperPascal extends a subset of IEEE Standard Pascal with deterministic statements for parallel processes and synchronous message communication. A parallel statement denotes parallel execution of a fixed number of statements. A forall statement denotes parallel execution of the same statement by a dynamic number of processes. Recursive procedures may be combined with parallel and forall statements to define recursive parallel processes. Parallel processes communicate by sending typed messages through channels created dynamically. SuperPascal omits ambiguous and insecure features of Pascal. Restrictions on the use of variables enable a single-pass compiler to check that parallel processes are disjoint, even if the processes use procedures with global variables.

Key Words: Programming languages, Parallel programming, Recursive parallelism, Synchronous communication, SuperPascal.

1 Introduction

This paper defines SuperPascal—a secure programming language for publication of parallel scientific algorithms. SuperPascal extends a subset of IEEE Standard Pascal with deterministic statements for parallel processes and synchronous message communication. A parallel statement denotes parallel execution of a fixed number of statements. A forall statement denotes parallel execution of the same statement by a dynamic number of processes. Recursive procedures may be combined with parallel and forall statements to define recursive parallel processes. Parallel processes communicate by sending typed message through channels created dynamically. SuperPascal omits ambiguous and insecure features of Pascal. Restrictions on the use of variables enable a single-pass compiler to check that parallel processes are disjoint, even if the processes use procedures with global variables.

This paper defines the parallel features of SuperPascal using the terminology and syntax notation of the Standard Pascal report [IEEE 1983]. Brinch Hansen [1993a] illustrates SuperPascal by examples. The syntactic checking of parallel statements is discussed further in [Brinch Hansen 1993b].

A portable implementation of SuperPascal has been developed on a Sun workstation under Unix. It consists of a compiler and an interpreter written in Pascal.

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To obtain the SuperPascal software, use anonymous FTP from the directory pbh at top.cis.syr.edu.

2 Processes and Variables

command =
    variable-access | expression | statement | statement-sequence.

The evaluation or execution of a command is called a process. A structured process is a sequential or parallel composition of processes. The components of a parallel composition are called parallel processes. They proceed independently at unpredictable speeds until all of them have terminated.

In a program text an entire variable is a syntactic entity that has an identifier, a type, and a scope.

During program execution a block is activated when a process evaluates a function designator or executes a procedure statement or program. Every activation of a block B creates a new instance of every variable that is local to B. When an activation terminates, the corresponding variable instances cease to exist.

During recursive and parallel activations of a block, multiple instances of the local variables exist. Each variable instance is a dynamic entity that has a location, a current value, and a finite lifetime in memory.

The distinction between a variable as a syntactic entity in the program text and a class of dynamic entities in memory is usually clear from the context. Where it is necessary, this paper distinguishes between syntactic variables and variable instances.

Parallel processes are said to be disjoint if they satisfy the following condition: Any variable instance that is assigned a value by one of the processes is not accessed by any of the other processes. In other words, any variable instance that is accessed by more than one process is not assigned a value by any of the processes.

3 Type Definitions

Every type has an identifier. Two types are the same if they have the same identifier and the same scope.

Examples:

The following types are used in the examples of this paper:
type
  vector = record x, y: real end;
  body = record m: real; r, v, f: vector end;
  system = array [1..n] of body;
  channel = *(body);
  net = array [0..p] of channel;
  mixed = *(body, integer);
  two = array [0..1] of mixed;
  four = array [0..1] of two;

3.1 Channel Types

Processes communicate by means of values called messages transmitted through entities called channels. A communication takes place when one process is ready to output a message of some type through a channel and another process is ready to input a message of the same type through the same channel.

Processes create channels dynamically and access them by means of values known as channel references. The type of a channel reference is called a channel type.

channel-type =
  "*" "(" message-type-list ")" .
message-type-list =
  type-identifier { "" type-identifier } .

A channel type

*(T_1, T_2, \ldots, T_n)

denotes an unordered set of channel references created dynamically. Each channel reference denotes a distinct channel which can transmit messages of distinct types T_1, T_2, \ldots, T_n only (the message types).

A type definition cannot be of the recursive form:

T = *(\ldots, T, \ldots)

Examples:

*(body)
*(body, integer)
4 Variables

4.1 Entire Variables

An entire variable is a variable denoted by one of the following kinds of identifiers:

1. A variable identifier introduced by a variable declaration or a forall statement.
2. A function identifier that occurs as the left part of an assignment statement in the statement part of the corresponding function block.

Examples:
The following entire variables are used in the examples of this paper:

```plaintext
var
  inp, out: channel;
  c: net;
  a: system;
  ai, aj: body;
  left: mixed;
  top: four;
  i, j, k: integer;
```

A variable context is associated with each command $C$. This context consists of two sets of entire variables called the target and expression variables of $C$. If the process denoted by $C$ may assign a value to an entire variable $v$ (or one of its components), then $v$ is a target variable of $C$. If the process may use the value of $v$ (or one of its components) as an operand, then $v$ is an expression variable of $C$.

4.2 Block Parameters

Consider a procedure or function block $B$ with a statement part $S$. An implicit parameter of $B$ is an entire variable $v$ that is global to $B$ and is part of the variable context of $S$. If $v$ is a target variable of $S$, then $v$ is an implicit variable parameter of $B$. If $v$ is an expression variable of $S$, then $v$ is an implicit value parameter of $B$.

A function block cannot use formal variable parameters or implicit variable parameters.

A recursive procedure or function block cannot use implicit parameters.

4.3 Target Variables

An entire variable $v$ is a target variable of a command $C$ in the following cases:

1. The variable identifier $v$ occurs in an assignment statement $C$ that denotes assignment to $v$ (or one of its components).
2. The variable identifier $v$ occurs in a for statement $C$ that uses $v$ as the control variable.

3. The variable identifier $v$ occurs in a procedure statement $C$ that uses $v$ (or one of its components) as an actual variable parameter.

4. The variable $v$ is an implicit variable parameter of a procedure block $B$, and $C$ is a procedure statement that denotes activation of $B$.

5. The variable $v$ is a target variable of a command $D$, and $C$ is a structured command that contains $D$.

### 4.4 Expression Variables

An entire variable $v$ is an expression variable of a command $C$ in the following cases:

1. The variable identifier $v$ occurs in an expression $C$ that uses $v$ (or one of its components) as an operand.

2. The variable identifier $v$ occurs in the element statement $C$ of a forall statement that introduces $v$ as the index variable.

3. The variable $v$ is an implicit value parameter of a function block $B$, and $C$ is a function designator that denotes activation of $B$.

4. The variable $v$ is an implicit value parameter of a procedure block $B$, and $C$ is a procedure statement that denotes activation of $B$.

5. The variable $v$ is an expression variable of a command $D$, and $C$ is a structured command that contains $D$.

### 4.5 Channel Variables

A channel variable is a variable of a channel type. The value of a channel variable is undefined unless a channel reference has been assigned to the variable.

\[
\text{channel-variable-access} = \text{variable-access} .
\]

**Examples:**

\[
\text{inp} \\
\text{c[0]} \\
\text{top[i,j]}
\]
5 Expressions

5.1 Channel Expressions

\[
\text{channel-expression} = \text{expression}.
\]

A channel expression is an expression of a channel type. The expression is said to be \textit{well-defined} if it denotes a channel; otherwise, it is \textit{undefined}.

\textit{Examples:}

\begin{align*}
\text{out} \\
\text{c[k−1]}
\end{align*}

5.2 Relational Operators

If \( x \) and \( y \) are well-defined channel expressions of the same type, the following expressions denote boolean values:

\[
x = y \quad x <> y
\]

The value of \( x = y \) is true if \( x \) and \( y \) denote the same channel, and is false otherwise. The value of \( x <> y \) is the same as the value of \( \text{not} (x = y) \).

\textit{Example:}

\[
\text{left} = \text{top[i,j]}
\]

6 Message Communication

The required procedures for message communication are

\[
\text{open} \quad \text{send} \quad \text{receive}
\]

6.1 The Procedure Open

\[
\text{open-statement} =
\]

\[
\text{"open" \{" open-parameters \}"}.
\]

\[
\text{open-parameters} =
\]

\[
\text{open-parameter \{"," open-parameter \}}.
\]

\[
\text{open-parameter} =
\]
channel-variable-access.

If \( v \) is a channel variable, the statement

\[
\text{open}(v)
\]

denotes creation of a new channel.

The \textit{open} statement is executed by creating a new channel and assigning the corresponding reference to the channel variable \( v \). The channel reference is of the same type as the channel variable. The channel exists until the program execution terminates.

The abbreviation

\[
\text{open}(v_1, v_2, \ldots, v_n)
\]

is equivalent to

\[
\text{begin } \text{open}(v_1); \text{open}(v_2, \ldots, v_n) \text{ end}
\]

Examples:

\[
\text{open}(c[k]) \\
\text{open}(\text{inp}, \text{out})
\]

### 6.2 The Procedures Send and Receive

send-statement =

"send" "(" send-parameters ")"

send-parameters =

channel-expression "," output-expression-list

output-expression-list =

output-expression { "," output-expression }

output-expression =

expression

receive-statement =

"receive" "(" receive-parameters ")"

receive-parameters =

channel-expression "," input-variable-list

input-variable-list =

input-variable-access { "," input-variable-access }

input-variable-access =

variable-access

The statement
denotes output of the value of an expression $e$ through the channel denoted by an expression $b$. The expression $b$ must be of a channel type $T$, and the type of the expression $e$ must be a message type of $T$.

The statement

\[ \text{receive}(c, v) \]

denotes input of the value of a variable $v$ through the channel denoted by an expression $c$. The expression $c$ must be of a channel type $T$, and the type of the variable $v$ must be a message type of $T$.

The \textit{send} and \textit{receive} operations defined by the above statements are said to \textit{match} if they satisfy the following conditions:

1. The channel expressions $b$ and $c$ are of the same type $T$ and denote the same channel.
2. The output expression $e$ and the input variable $v$ are of the same type, which is a message type of $T$.

The execution of a \textit{send} operation delays a process until another process is ready to execute a matching \textit{receive} operation (and vice versa). If and when this happens, a \textit{communication} takes place as follows:

1. The sending process obtains a value by evaluating the output expression $e$.
2. The receiving process assigns the value to the input variable $v$.

After the communication, the sending and receiving processes proceed independently.

\textit{Communication Errors:}

1. \textit{Undefined channel reference}: A channel expression does not denote a channel.
2. \textit{Channel contention}: Two parallel processes both attempt to send (or receive) through the same channel at the same time.
3. \textit{Message type error}: Two parallel processes attempt to communicate through the same channel, but the output expression and the input variable are of different message types.

The abbreviation

\[ \text{send}(b, e_1, e_2, \ldots, e_n) \]
is equivalent to

\begin{verbatim}
begin send(b, e_1); send(b, e_2, \ldots, e_n) end
\end{verbatim}

The abbreviation

\begin{verbatim}
receive(c, v_1, v_2, \ldots, v_n)
\end{verbatim}

is equivalent to

\begin{verbatim}
begin receive(c, v_1); receive(c, v_2, \ldots, v_n) end
\end{verbatim}

\textit{Examples:}

send(out, ai)
receive(inp, aj)
send(top[i,j], 2, ai)

7 Statements

7.1 Assignment Statements

If \(x\) is a channel variable access and \(y\) is a well-defined channel expression of the same type, the effect of the assignment statement

\begin{verbatim}
x := y
\end{verbatim}

is to make the values of \(x\) and \(y\) denote the same channel.

\textit{Example:}

\begin{verbatim}
left := top[i,j]
\end{verbatim}

7.2 Procedure Statements

The \emph{restricted actual parameters} of a procedure statement are the explicit variable parameters that occur in the actual parameter list and the implicit parameters of the corresponding procedure block.

\textit{Restriction:} The restricted actual parameters of a procedure statement must be distinct entire variables (or components of such variables).

A procedure statement cannot occur in the statement part of a function block. This rule also applies to a procedure statement that denotes activation of a required procedure.
7.3 Parallel Statements

parallel-statement =
    "parallel" process-statement-list "end" .
process-statement-list =
    process-statement { "|" process-statement } .
process-statement =
    statement-sequence .

A parallel statement denotes parallel processes. Each process is denoted by a separate process statement.

The effect of a parallel statement is to execute the process statements as parallel processes until all of them have terminated.

Restriction: In a parallel statement, a target variable of one process statement cannot be a target or expression variable of another process statement.

Example:

\[
\begin{align*}
\text{parallel} & \quad \text{source}(a, c[0]); \text{sink}(a, c[p]) | \\
\text{forall } k := 1 \text{ to } p \text{ do} & \quad \text{node}(k, c[k-1], c[k]) \\
\end{align*}
\]

7.4 Forall Statements

forall-statement =
    "forall" index-variable-declaration "do"
    element-statement .
index-variable-declaration =
    variable-identifier ":=" process-index-range .
process-index-range =
    expression "to" expression .
element-statement =
    statement .

The statement

\[
\text{forall } i := e_1 \text{ to } e_2 \text{ do } S
\]

denotes a (possibly empty) array of parallel processes, called element processes, and a corresponding range of values, called process indices. The lower and upper bounds of the process index range are denoted by two expressions, \( e_1 \) and \( e_2 \), of the same
simple type (the index type). Every index value corresponds to a separate element process defined by an index variable $i$ and an element statement $S$.

The index variable declaration

$$i := e_1 \text{ to } e_2$$

introduces the index variable $i$ which is local to the element statement $S$.

A forall statement is executed as follows:

1. The expressions $e_1$ and $e_2$ are evaluated. If $e_1 > e_2$, the execution of the forall statement terminates; otherwise, step 2 takes place.

2. $e_2 - e_1 + 1$ element processes run in parallel until all of them have terminated. Each element process creates a local instance of the index variable $i$, assigns the corresponding process index to the variable, and executes the element statement $S$. When an element process terminates, its local instance of the index variable ceases to exist.

Restriction: In a forall statement, the element statement cannot use target variables.

Examples:

```pascal
forall k := 1 to p do
  node(k, c[k-1], c[k])

forall i := 0 to 1 do
  forall j := 0 to 1 do
    quadtree(i, j, top[i,j])
```

7.5 Unrestricted Statements

unrestricted-statement =
  sic-clause statement .

sic-clause =
  "[" sic " ]" .

A statement $S$ is said to be unrestricted in the following cases:

1. The statement $S$ is prefixed by a sic clause.

2. The statement $S$ is a component of an unrestricted statement.
All other statements are said to be restricted.

Restricted statements must satisfy the rules labeled as restrictions in this paper. These rules restrict the use of entire variables in procedure statements, parallel statements, and forall statements to make it possible to check the disjointness of parallel processes during single-pass compilation (see 7.2, 7.3 and 7.4).

The same rules do not apply to unrestricted statements. Consequently, the programmer must prove that each unrestricted statement preserves the disjointness of parallel processes; otherwise, the semantics of unrestricted statements are beyond the scope of this paper.

Examples:

\[ \text{sic}\{ i <> j \} \]
\text{swap}(a[i], a[j])

\[ \text{sic}\{ i <> j \} \]
\text{parallel} \ a[i] := a[i] \ a[j] := a[j] \text{ end}

\[ \text{sic}\{ \text{disjoint elements } a[i] \} \]
\text{forall} \ i := 1 \text{ to } n \text{ do } a[i] := a[i]

7.6 Assume Statements

\text{assume-statement} =
\text{“assume” assumption} .
\text{assumption} =
\text{expression} .

The effect of an assume statement is to test an assumption denoted by a boolean expression. If the assumption is true, the test terminates; otherwise, program execution stops.

Example:

\text{assume} \ i <> j

8 SuperPascal versus Pascal

The following summarizes the differences between SuperPascal and Pascal.

8.1 Added Features

Table 1 lists the SuperPascal features that were added to Pascal.
8.2 Excluded Features

Table 2 lists the Pascal features that were excluded from SuperPascal.

8.3 Minor Differences

SuperPascal differs from Pascal in the following details:

1. *Program parameters* are comments only.

2. A multi-dimensional *array type* is defined in terms of one-dimensional array types.

3. The required type *string* is the only string type:

   \[
   \text{string} = \text{array}\ [1..\text{maxstring}]\ \text{of char}
   \]

   A character string with \( n \) string elements denotes a string of \( n \) characters followed by \( \text{maxstring} - n \) null characters, where

   \[2 \leq n \leq \text{maxstring}\quad \text{maxstring} = 80\quad \text{null} = \text{chr}(0)\]

   The default length \( n \) of a write parameter of type string is the number of characters (if any) which precede the first null character (if any), where \( 0 \leq n \leq \text{maxstring} \).

4. The required textfile *input* is the only input file. The file identifier is omitted from *eof* and *eoln* function designators and *read* and *readln* statements. The input file is an implicit value parameter of the eof and eoln functions and is an implicit variable parameter of the read and readln procedures (see 4.2).

5. The required textfile *output* is the only output file. The file identifier is omitted from *write* and *writeln* statements. The output file is an implicit variable parameter of the write and writeln procedures (see 4.2).

8.4 Required Identifiers

Table 3 lists the required identifiers of SuperPascal.
### Table 1: Added features

<table>
<thead>
<tr>
<th>Language concepts</th>
<th>Required identifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>channel types</td>
<td>null</td>
</tr>
<tr>
<td>structured function types</td>
<td>maxstring</td>
</tr>
<tr>
<td>parallel statements</td>
<td>string</td>
</tr>
<tr>
<td>forall statements</td>
<td>open</td>
</tr>
<tr>
<td>unrestricted statements</td>
<td>send</td>
</tr>
<tr>
<td>assume statements</td>
<td>receive</td>
</tr>
</tbody>
</table>

### Table 2: Excluded features

<table>
<thead>
<tr>
<th>Language concepts</th>
<th>Required identifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>labels</td>
<td>text</td>
</tr>
<tr>
<td>subrange types</td>
<td>input</td>
</tr>
<tr>
<td>record variants</td>
<td>output</td>
</tr>
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<td>empty field lists</td>
<td>page</td>
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<td>reset</td>
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<td>forward declarations</td>
<td></td>
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<tr>
<td>goto statements</td>
<td></td>
</tr>
<tr>
<td>with statements</td>
<td></td>
</tr>
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</table>
### Table 3: Required identifiers

<table>
<thead>
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<th>abs</th>
<th>maxint</th>
<th>round</th>
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<tbody>
<tr>
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<td>sqrt</td>
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</tr>
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<td>receive</td>
<td>writeln</td>
</tr>
<tr>
<td>ln</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 8.5 Syntax Summary

The following grammar defines the complete syntax of *SuperPascal*.

```plaintext
program =
  program-heading " ; " program-block ". " .
program-heading =
  "program" program-identifier [ "(" program-parameters ")" ] .
program-parameters =
  parameter-identifier { "," parameter-identifier } .
program-block =
  block .
block =
  [ constant-definitions | [ type-definitions ]
    [ variable-declarations ] [ routine-declarations ]
  ] statement-part .
constant-definitions =
  "const" constant-definition ";" { constant-definition ";" } .
canstant-definition =
  constant-identifier "=" constant .
constant =
  [ sign ] unsigned-constant .
sign =
  "+" | "-" .
type-definitions =
  "type" type-definition ";" { type-definition ";" } .
type-definition =
```

---
type-identifier “=” new-type.

new-type =
  enumerated-type | array-type | record-type | channel-type.

enumerated-type =
  “(” constant-identifier-list “)”.

constant-identifier-list =
  constant-identifier { “,” constant-identifier }.

array-type =
  "array" index-range "of" type-identifier.

index-range =
  “[” constant “..” constant “]”.

record-type =
  "record" field-list "end".

field-list =
  record-section { “;” record-section } [ “;” ].

record-section =
  field-identifier-list “:” type-identifier.

field-identifier-list =
  field-identifier { “,” field-identifier }.

channel-type =
  “∗” “(” message-type-list “)”.

message-type-list =
  type-identifier { “,” type-identifier }.

variable-declarations =
  “var” variable-declaration “;” { variable-declaration “;” }.

variable-declaration =
  variable-identifier-list “:” type-identifier.

variable-identifier-list =
  variable-identifier { “,” variable-identifier }.

routine-declarations =
  routine-declaration | procedure-declaration.

routine-declaration =
  function-declaration | procedure-declaration.

function-declaration =
  function-heading “;” function-block.

function-heading =
  “function” function-identifier [ formal-parameter-list ]
  “:” type-identifier.

formal-parameter-list =
  “(” formal-parameters “)”.

formal-parameters =
  formal-parameter-section { “;” formal-parameter-section }.
formal-parameter-section =
    [ "var" ] variable-declaration .
function-block =
    block .
procedure-declaration =
    procedure-heading ";;" procedure-block .
procedure-heading =
    "procedure" procedure-identifier [ formal-parameter-list ] .
procedure-block =
    block .
statement-part =
    compound-statement .
compound-statement =
    "begin" statement-sequence "end" .
statement-sequence =
    statement { ";;" statement } .
statement =
    empty-statement | assignment-statement | procedure-statement | if-statement |
    while-statement | repeat-statement | for-statement | case-statement |
    compound-statement | parallel-statement | forall-statement | unrestricted-statement |
    assume-statement .
empty-statement = .
assignment-statement =
    left-part "::=" expression .
left-part =
    variable-access | function-identifier .
procedure-statement =
    procedure-identifier [ actual-parameter-list ] .
actual-parameter-list =
    "(" actual-parameters ")" .
actual-parameters =
    actual-parameter { "," actual-parameter } .
actual-parameter =
    expression | variable-access | write-parameter .
write-parameter =
    expression [ ":;" expression ]
if-statement =
    "if" expression "then" statement
    [ "else" statement ].
while-statement =
   "while" expression "do" statement .
repeat-statement =
   "repeat" statement-sequence "until" expression .
for-statement =
   "for" control-variable "::=" expression
   ( "to" | "downto" ) expression "do" statement .
case-statement =
   "case" expression "of" case-list "end" .
forall-statement =
   "forall" index-variable-declaration "do"
   element-statement .
expression =
   simple-expression
   [ relational-operator simple-expression ] .
relational-operator =
   "<" | "=" | ">" | "<=" | "<>" | ">=" .
simple-expression =
   entire-variable .
process-statement =
   process-statement-list "end" .
process-index-range =
   expression "to" expression .
index-variable-declaration =
   variable-identifier "::=" process-index-range .
forall-statement =
   "forall" index-variable-declaration "do"
   element-statement .
assume-statement =
   "assume" expression .
unrestricted-statement =
   "[" "sic" "]" statement .
case-statement =
   "case" expression "of" case-list "end" .
case-list =
   case-list-element { ";" case-list-element } [ ";" ] .
case-list-element =
   case-constant { ";" case-constant } "::" statement .
case-constant =
   constant .
process-index-range =
   expression "to" expression .
index-variable-declaration =
   variable-identifier "::=" process-index-range .
control-variable =
   entire-variable .
parallel-statement =
   "parallel" process-statement-list "end" .
parallel-statement-list =
   process-statement { "|" process-statement } .
process-statement =
   statement-sequence .
case-statement =
   "case" expression "of" case-list "end" .
case-list =
   case-list-element { ";" case-list-element } [ ";" ] .
case-list-element =
   case-constant { ";" case-constant } "::" statement .
case-constant =
   constant .
process-index-range =
   expression "to" expression .
index-variable-declaration =
   variable-identifier "::=" process-index-range .
for-statement =
   "for" control-variable "::=" expression
   ( "to" | "downto" ) expression "do" statement .
case-statement =
   "case" expression "of" case-list "end" .
case-list =
   case-list-element { ";" case-list-element } [ ";" ] .
case-list-element =
   case-constant { ";" case-constant } "::" statement .
case-constant =
   constant .
parallel-statement =
   "parallel" process-statement-list "end" .
process-statement-list =
   process-statement { "|" process-statement } .
process-statement =
   statement-sequence .
for-statement =
   "for" control-variable "::=" expression
   ( "to" | "downto" ) expression "do" statement .
case-statement =
   "case" expression "of" case-list "end" .
case-list =
   case-list-element { ";" case-list-element } [ ";" ] .
case-list-element =
   case-constant { ";" case-constant } "::" statement .
case-constant =
   constant .
parallel-statement =
   "parallel" process-statement-list "end" .
process-statement-list =
   process-statement { "|" process-statement } .
process-statement =
   statement-sequence .
for-statement =
   "for" control-variable "::=" expression
   ( "to" | "downto" ) expression "do" statement .
case-statement =
   "case" expression "of" case-list "end" .
case-list =
   case-list-element { ";" case-list-element } [ ";" ] .
case-list-element =
   case-constant { ";" case-constant } "::" statement .
case-constant =
   constant .
parallel-statement =
   "parallel" process-statement-list "end" .
process-statement-list =
   process-statement { "|" process-statement } .
process-statement =
   statement-sequence .
unrestricted-statement =
   "[" "sic" "]" statement .
assume-statement =
   "assume" expression .
expression =
   simple-expression
   [ relational-operator simple-expression ] .
relational-operator =
   "<" | "=" | ">" | "<=" | "<>" | ">=" .
simple-expression =
   entire-variable .
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[ sign ] term { adding-operator term }.
adding-operator =
   “±” | “−” | “or”.
term =
   factor { multiplying-operator factor }.
multiplying-operator =
   “∗” | “/” | “div” | “mod” | “and”.
factor =
   function-designator | variable-access |
   unsigned-constant | (“ expression “) |
   “not” factor.
function-designator =
   function-identifier [ actual-parameter-list ].
variable-access =
   entire-variable { component-selector }.
entire-variable =
   variable-identifier.
component-selector =
   field-selector | indexed-selector.
field-selector =
   “.” field-identifier.
indexed-selector =
   “[“ index-expressions “]”.
index-expressions =
   expression { “,” expression }.
unsigned-constant =
   character-string | unsigned-real |
   unsigned-integer | constant-identifier.
character-string =
   “” string-elements “”.
string-elements =
   string-element { string-element }.
string-element =
   string-character | apostrophe-image.
apostrophe-image =
   “”.
unsigned-real =
   unsigned-integer real-option.
real-option =
fractional-part =
   digit-sequence.
scaling-part =
    “e” scale-factor .
scale-factor =
    [ sign ] unsigned-integer .
unsigned-integer =
    digit-sequence .
digit-sequence =
    digit { digit } .
identifier =
    letter { letter | digit } .

Acknowledgements

I thank Jonathan Greenfield and Peter O’Hearn for their helpful comments.

References

