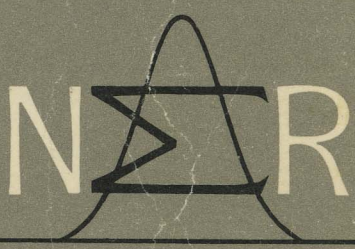
SIMULA information



NORSK REGNESENTRAL
NORWEGIAN COMPUTING CENTER
OSLO 3 - NORWAY

COMMON BASE LANGUAGE

by

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PREFACE TO THE 1968 EDITION

SIMULA 67 is a general purpose programming language developed by the authors at the Norwegian Computing Center. Compilers for this language are now implemented on a number of different computers.

The Norwegian Computing Center regards the SIMULA 67 language as its own property. The implementations have taken place under contracts with the NCC for professional assistance.

A main characteristic of SIMULA is that it is easily structured towards specialized problem areas, and hence can be used as a basis for Special Application Languages.

This report is a reference document for the SIMULA 67 Common Base. The Common Base comprises the language features required in every SIMULA 67 compiler. The "Introduction" highlights some features of the language. The following sections are intended as a precise language definition. Users manuals and textbooks will appear later.

During our development of SIMULA 67 we have benefited from ideas and suggestions from a number of colleagues. First of all we should like to mention C.A.R. Hoare whose ideas on referencing have been used and extended, S. Kubosch who has been an important source of useful comments and criticism and Mrs. I. Siguenza whose help in the typing of this report has been indispensable.

We should also like to express our gratitude to D. Belsnes, P. Blunden, J. Buxton, J.V. Garwick, Ø. Hjartøy, Ø. Hope, P. M. Kjeldaas, D. Knuth, J. Laski, A. Lunde, J. Newey, T. Noodt, K. S. Skog, C. Strachey and N. Wirth, as well as SIMULA I users who have given advice based upon their experience. Finally, the authors feel that they benefited very much from the SIMULA 67 Common Base Conference in Oslo, June 1967, and would like to thank the participants.

Oslo, May 1968

Ole-Johan Dahl Bjørn Myhrhaug Kristen Nygaard

PREFACE TO THE 1970 EDITION

This revised version contains the modifications and clarifications passed by the SIMULA Standards Group at their meeting in May 1970. Several minor errors have also been corrected.

Compilers are now available on a wide range of computers, including CD 3300, CD 3600, CD 6600, UNIVAC 1108 and IBM 360/370.

The authors would like to thank the members of the SIMULA Standards Group for their interest and help, and the typing pool and printing shop of the Norwegian Computing Center for their efficient work.

We would also like to extend our list of acknowledgements in the original preface by K. Babcicky, G. M. Birtwistle, R. Kerr and M. Woodger.

Oslo, October 1970

Ole-Johan Dahl Bjørn Myhrhaug Kristen Nygaard

1. Introduction

1.1 General purpose programming languages

High level languages, like FORTRAN, ALGOL 60 and COBOL were originally regarded as useful for two purposes:

- to provide concepts and statements allowing a precise formal description of computing processes and also making communication between programmers easier.

- to provide the non-specialist with a tool making it possible for him to solve small and medium-sized problems without specialist help.

High level languages have succeeded in these respects. However, strong new support for these languages is developing from a fresh group: those who are confronted with the task of organizing and implementing very complex, highly interactive programs, e.g. large simulation programs.

These tasks put new requirements on a language:

- in order to decompose the problem into natural, easily conceived components, each part should be describable as an individual program. The language should provide for this and also contain means for describing the joint interactive execution of these sub-programs.

- in order to relate and operate a collection of programs, the language should have the necessary powerful list processing and sequencing capabilities.

- in order to reduce the already excessive amount of debugging trouble associated with present day methods, the language should give "reference security". That is, the language and its compiler should spot and not execute invalid use of data through data referencing based on wrong assumptions.

Even if the organizational aspects of complex programming are becoming more and more important, the computational aspects must, of course, be taken care of at least as well as in the current high-level languages.

It is also evident that such a general language should be oriented towards a very wide area of use. The market cannot for long accommodate the present proliferation of languages.

1.2 Special application languages

Until now, the computer has been a powerful but frightening tool to most people. This should be changed in the years to come, and the computer should be regarded as an obvious part of the human environment. More and more people should get their capabilities increased through the availability of the "know-how" and data they need.

A condition for this development is that the demands on the computer user are reduced, which implies that communication between man and computer is made easier.

Know-how is today to a large extent made operative through "application packages" covering various fields of knowledge and methods. But these packages are in general not sufficiently flexible and expandable, and also often require specialist assistance for their use.

The future seems to be "application languages" which are problem-oriented, perhaps in the extreme. Such languages may provide the basic concepts and methods associated with the field in question and allow the user to formulate his specific problem in accordance with his own earlier training.

At the same time, such languages should be flexible in the sense that new knowledge acquired should be easily incorporated, even by the individual user.

The need for application languages is apparently in conflict with the desire for the non-proliferation of languages and for general purpose programming languages.

A solution is to design a general purpose programming language to serve as a "substrate" for the application languages by making it easy to orient towards specialized fields, and to augment it by the introduction of additional aggregated concepts useful as "building blocks" for programming.

By making the general purpose language highly standardized and available on many types of computers, the application languages also become easily transferable, and at the same time the software development costs for the computer manufacturers may be retarded from the present rapid increase.

1.3 The basic characteristics of SIMULA 67

1.3.1 Algorithmic capability

SIMULA 67 contains most features of the general algorithmic language ALGOL 60 as a subset. The reason for choosing ALGOL 60 as starting point was that its basic structure lent itself to extension. It was felt that it would be impractical for the users to base SIMULA 67 on yet another new algorithmic language, and ALGOL 60 already had a user basis, mainly in Europe.

1.3.2. Decomposition

In dealing with problems and systems containing a large number of details, decomposition is of prime importance. The human mind must concentrate; it is a requirement for precise and coherent thinking that the number of concepts involved is small. By decomposing a large problem, one can obtain component problems of manageable size to be dealt with one at a time, and each containing a limited number of details. Suitable decomposition is an absolute requirement if more than one person takes part in the analysis and programming.

The fundamental mechanism for decomposition in ALGOL 60 is the block concept. As far as local quantities are concerned, a block is completely independent of the rest of the program. The locality principle ensures that any reference to a local quantity is correctly interpreted regardless of the environment of the block.

The block concept corresponds to the intuitive notion of "sub-problem" or "sub-algorithm" which is a useful unit of decomposition in orthodox application areas.

A block is a formal description, or "pattern", of an aggregated data structure and associated algorithms and actions. When a block is executed, a dynamic "instance" of the block is generated. In a computer, a block instance may take the form of a memory area containing the necessary dynamic block information and including space for holding the contents of variables local to the block.

A block instance can be thought of as a textual copy of its formal description, in which local variables identify pieces of memory allocated to the block instance. Any inner block of a block instance is still a "pattern", in which occurrences of non-local identifiers, however, identify items local to textually enclosing block instances. Such "bindings" of identifiers non-local to an inner block remain valid for any subsequent dynamic instance of that inner block.

The notion of block instances leads to the possibility of generating several instances of a given block which may co-exist and interact, such as, for example, instances of a recursive procedure. This further leads to the concept of a block as a "class" of "objects", each being a dynamic instance of the block, and therefore conforming to the same pattern.

An extended block concept is introduced through a "class" declaration and associated interaction mechanism such as "object references" (pointers), "remote accessing", "quasi-parallel" operation, and block "concatenation".

Whereas ALGOL 60 program execution consists of a sequence of dynamically nested block instances, block instances in SIMULA 67 may form arbitrary list structures. The interaction mechanisms which are introduced, serve to increase the power of the block concept as a means for decomposition and classification.

1.3.3 Classes

A central new concept in SIMULA 67 is the "object". An object is a self-contained program (block instance), having its own local data and actions defined by a "class declaration". The class declaration defines a program (data and action) pattern, and objects conforming to that pattern are said to "belong to the same class".

If no actions are specified in the class declaration, a class of pure data structures is defined.

Example

```
class order (number); integer number;
    begin integer number of units, arrival date;
          real processing time;
    end;
```

A new object belonging to the class "order" is generated by an expression such as

"new order (103)"

and as many "orders" may be introduced as desired.

The need for manipulating objects and relating objects to each other makes it necessary to introduce list processing facilities (as described below).

A class may be used as "prefix" to another class declaration, thereby building the properties defined by the prefix into the objects defined by the new class declaration.

Examples:

```
order class batch order;
   begin integer batch size;
         real setup time;
   end;

order class single order;
   begin real setup time, finishing time,weight; end;

single order class plate;
   begin real length, width; end;
```

New objects belonging to the "sub-classes" - "batch order" "single order" and "plate" all have the data defined for "order", plus the additional data defined in the various class declarations. Objects belonging to the class "plate" will, for example, comprise the following pieces of information: "number", "number of units", "arrival date", "processing time", "setup time", "finishing time", "weight", "length" and "width".

If actions are defined in a class declaration, actions conforming to this pattern may be executed by all objects belonging to that class. The actions belonging to one object may all be executed in sequence, as for a procedure. But these actions may also be executed as a series of separate subsequences, or "active phases". Between two active phases of a given object, any number of active phases of other objects may occur.

SIMULA 67 contains basic features necessary for organizing the total program execution as a sequence of active phases belonging to objects. These basic features may be the foundation for aggregated sequencing principles, of which the class SIMULATION is an example.

1.3.4 Application language capability

SIMULA 67 may be oriented towards a special application area by defining a suitable class containing the necessary problem-oriented concepts. This class can then be used as prefix to the program by the user interested in this problem area.

The unsophisticated user may restrict himself to using the aggregated, problem-oriented and familiar concepts as constituent "building blocks" in his programming. He may not need to know the full SIMULA 67 language, whereas the experienced programmer at the same time has the general language available, and he may extend the "application language" by new concepts defined by himself.

As an example, in discrete event system simulation, the concept of "simulated system time" is commonly used. SIMULA 67 is turned into a simulation language by providing the class "SIMULATION" as a part of the language,

(in this case provided with the compilers).
In the class declaration

```
class SIMULATION;
   begin ..... end;
```

a "time axis" is defined, as well as two-way lists (which may serve as queues), and also the class "process" which gives an object the property of having its active phases organized through the "time axis".

A user wanting to write a simulation program starts his program by

```
SIMULATION begin .....
```

in order to make all the simulation capabilities available in his program. If he himself wants to generate a special-purpose simulation language to be used in job-shop analysis, he may write:

```
SIMULATION class JOBSHOP;
   begin ..... end;
```

and between "begin" and "end" define the building blocks he needs, such as

```
process class crane;
   begin ..... end;

process class machine;
   begin procedure datacollection; .....
   .....
   end;
etc.
```

The programmer now compiles this class, and whenever he or his colleagues want to use SIMULA 67 for jobshop simulation, they may write in their program

```
JOBSHOP begin .....
```

thereby making available the concepts of both "SIMULATION" and "JOBSHOP".

This facility requires that a mechanism for the incorporation of separately compiled classes is available in the compiler (see section 15).

1.3.5 List processing capability

When many objects belonging to various classes do co-exist as parts of the same total program, it is necessary to be able to assign names to individual objects, and also to relate objects to each other, e.g. through binary trees and various other types of list structures. A system class, "SIMSET", introducing circular two-way lists is a part of the language.

Hence basic new types, "references", are introduced. References are "qualified", which implies that a given reference only may refer to objects belonging to the class mentioned in the qualification (or belonging to subclasses of the qualifying class).

Example:

```
ref(order)next, previous;
```

The operation of making a reference denote a specified object is written ":-" and read "denotes".

Example:

```
next :- new order (101); previous :- next;
```

or (also valid since "plate" is a subclass of "order")

```
next :- new plate(50);
```

Data belonging to other objects may be referred to and used by "remote accessing", utilizing a special "dot notation".

Example:

```
if next.number ≥ previous.number then .....;
```

comparing the "number" of the "order" named "next" with the "number"of the "order" named "previous".

The "dot notation" gives access to individual pieces of information. "Group access" is achieved through "connection statements".

Example:

```
inspect next when plate do begin ..... end;
```

In the statement between begin and end all pieces of information contained in the "plate" referenced by "next" may be referred to directly.

1.3.6 String handling

SIMULA 67 contains the new basic type "character". The representation of characters is implementation defined.

In order to provide the desired flexibility in string handling, a compound type called "text" is introduced. The "text" concept is closely associated with input/output facilities.

1.3.7 Input/output

ALGOL 60 has been seriously affected by the lack of standardized input/output and string handling. Clearly a general purpose programming language should have great flexibility in these areas. Consequently, input/output are defined and made a standardized part of SIMULA 67.

1.4 Standardization

For a general purpose programming language it is of paramount importance that while the language is uniquely defined and at the same time under strict control, it may be extended in the future.

This is achieved by the SIMULA Standard Group, consisting of representatives for firms and organizations having responsibility for SIMULA 67 compilers. The statutes lay down rigid rules to provide for both standardization and future extensions.

The SIMULA definition which is required to be a part of any SIMULA 67 system is named the "SIMULA 67 Common Base Definition".

1.5 Language definition

The language definition given in the following sections must be supplemented by the formal definition of ALGOL 60 [1]. The syntactic definitions given in this report are to be understood in the following way.

1) Syntactic classes referred to, but not defined in this report, refer to syntactic definitions given in [1].

2) Definitions in this report of syntactic classes defined in [1] replace the corresponding definitions given in [1].

3) Any construction of the form

   <ALGOL some syntactic class>

   stands for the list of alternative direct productions of <some syntactic class> according to the definition given in [1].

4) The comment conventions given in [1] is extended in that the convention for "end-comment" is replaced by:

   {end <any sequence not containing ;, end, else, when or otherwise>} → {end }

2. Class declarations

2.1 Syntax

```
<declaration> ::= <ALGOL declaration>|
                  <class declaration>|
                  <external declaration>
<class identifier> ::= <identifier>
<prefix> ::= <empty>|
             <class identifier>
<virtual part> ::= <empty>|
                   virtual: <specification part>
<class body> ::= <statement>|
                 <split body>
<initial operations> ::= begin|
                         <blockhead>;|
                         <initial operations><statement>;
<final operations> ::= end|
                       ; <compound tail>
<split body> ::= <initial operations>
                 inner <final operations>
<class declaration> ::= <prefix><main part>
<main part> ::= class <class identifier>
                <formal parameter part>;
                <value part><specification part>
                <virtual part><class body>
```

2.2 Semantics

A class declaration serves to define the class associated with a class identifier. The class consists of "objects" each of which is a dynamic instance of the class body.

An object is generated as the result of evaluating an object generator, which is the analogy of the "call" of a function designator, see section 4.3.2.2.

A class body always acts like a block. If it takes the form of a statement which is not an unlabelled block, the class body is identified with a block of the form

begin; S end

when S is the textual body. A split body acts as a block in which the symbol "inner" represents a dummy statement.

For a given object the formal parameters, the quantities specified in the virtual part, and the quantities declared local to the class body are called the "attributes" of the object. A declaration or specification of an attribute is called an "attribute definition".

Specification (in the specification part) is necessary for each formal parameter. The parameters are treated as variables local to the class body. They are initialized according to the rules of parameter transmission, (see section 8.2). Call by name is not available for parameters of class declarations. The following specifiers are accepted:

<type>, array, and <type> array.

Attributes defined in the virtual part are called "virtual quantities". They do not occur in the formal parameter list. The virtual quantities have some properties which resemble formal parameters called by name. However, for a given object the environment of the corresponding "actual parameters" is the object itself, rather than that of the generating call. See section 2.2.3.

Identifier conflicts between formal parameters and other attributes defined in a class declaration are illegal.

The declaration of an array attribute may in a constituent subscript bound expression make reference to the formal parameters of the class declaration.

Example:

The following class declaration expresses the notion of "n-point Gauss integration" as an aggregated concept.

```
class Gauss (n); integer n;
   begin array W,X[1:n];
      real procedure integral(F,a,b); real procedure F;
                                      real a,b;
        begin real sum, range; integer i;
           range := (b-a) ×0.5;
           for i := 1 step 1 until n do
           sum := sum + F(a+range×(X[i]+1))×W[i];
           integral := range × sum;
        end integral;
      comment compute the values of the elements of
              W and X as functions of n;
      ..........
   end Gauss;
```

The optimum weights W and abcissae X can be computed as functions of n. By making the algorithm part of the class body, the evaluation and assignment of these values can be performed at the time of object generation. Several "Gauss" objects with different values of n may co-exist. Each object has a local procedure "integral" for the evaluation of the corresponding n-point formula. See also examples of section 6.1.2.2 and section 7.1.2.

2.2.1 Subclasses

A class declaration with the prefix "C" and the class identifier "D" defines a subclass D of the class C. An object belonging to the subclass consists of a "prefix part", which is itself an object of the class C, and a "main part" described by the main part of the class declaration. The two parts are "concatenated" to form one compound object. The class C may itself have a prefix.

Let C_1, C_2, ..., C_n be classes such that C_1 has no prefix and C_k has the prefix C_{k-1} ($k = 2, 3, ..., n$). Then C_1, C_2, ..., C_{k-1} is called the "prefix sequence" of C_k ($k = 2, 3, ..., n$). The subscript k of C_k ($k = 1, 2, ..., n$) is called the "prefix level" of the class. C_i is said to "include" C_j if $i \leq j$, and C_i is called a "subclass" of C_j if $i > j$ ($i, j = 1, 2, ..., n$). The prefix level of a class D is said to be "inner" to that of a class C if D is a subclass of C, and "outer" to that of C if C is a subclass of D. The figure 2.1 depicts a class hierarchy consisting of five classes, A, B, C, D and E:

```
    class A .......;
A class B .......;
B class C .......;
B class D .......;
A class E .......;
```

A capital letter denotes a class. The corresponding lower case letter represents the attributes of the main part of an object belonging to that class. In an implementation of the language, the object structures shown in Fig. 2.2 may indicate the allocation in memory of the values of those attributes which are simple variables.

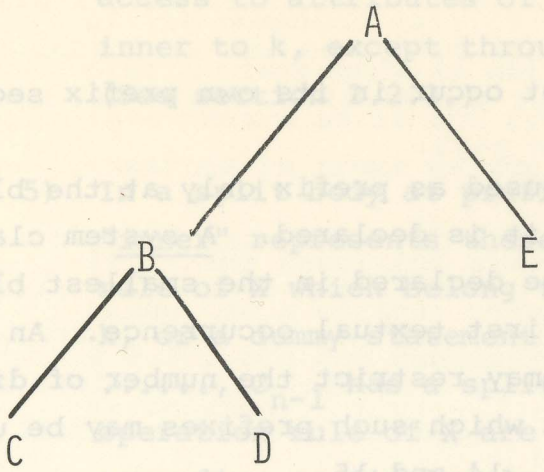


Fig. 2.1

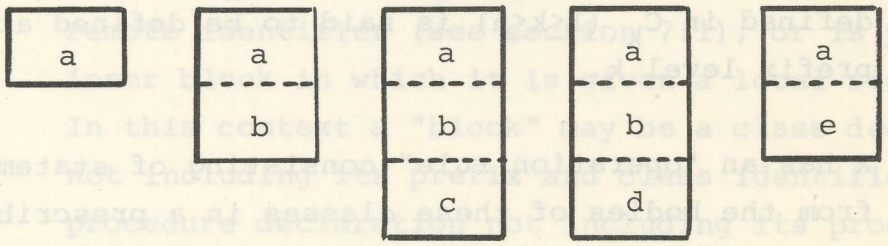


Fig. 2.2

The following restrictions must be observed in the use of prefixes:

1) A class must not occur in its own prefix sequence.

2) A class can be used as prefix only at the block level at which it is declared. A system class is considered to be declared in the smallest block enclosing its first textual occurrence. An implementation may restrict the number of different block levels at which such prefixes may be used. See sections 11, 14 and 15.

2.2.2 Concatenation

Let C_n be a class with the prefix sequence C_1, C_2, ..., C_{n-1}, and let X be an object belonging to C_n. Informally, the concatenation mechanism has the following consequences.

1) X has a set of attributes which is the union of those defined in C_1, C_2, ..., C_n. An attribute defined in C_k ($1 \leq k \leq n$) is said to be defined at prefix level k.

2) X has an "operation rule" consisting of statements from the bodies of these classes in a prescribed order. A statement from C_k is said to belong to prefix level k of X.

3) A statement at prefix level k of X has access to all attributes of X defined at prefix levels equal to or outer to k, but not directly to attributes "hidden" by conflicting definitions at levels $\leq k$. These "hidden"attributes may be accessed through use of procedures or this).

4) A statement at prefix level k of X has no immediate access to attributes of X defined at prefix levels inner to k, except through virtual quantities. (See section 2.2.3.)

5) In a split body at prefix level k, the symbol "inner" represents those statements in the operation rule of X which belong to prefix levels inner to k, or a dummy statement if k = n. If none of C_1, ..., C_{n-1} has a split body the statements in operation rule of X are ordered according to ascending prefix levels.

A compound object could be described formally by a "concatenated" class declaration. The process of concatenation is considered to take place prior to program execution. In order to give a precise description of that process, we need the following definition.

An occurrence of an identifier which is part of a given block is said to be "uncommitted occurrence in that block", except if it is the attribute identifier of a remote identifier (see section 7.1), or is part of an inner block in which it is given a local significance. In this context a "block" may be a class declaration not including its prefix and class identifier, or a procedure declaration not including its procedure identifier. (Notice that an uncommitted identifier occurrence in a block may well have a local significance in that block.)

The class declarations of a given class hierarchy are processed in an order of ascending prefix levels. A class declaration with a non-empty prefix is replaced by a concatenated class declaration obtained by first modifying the given one in two steps.

1. If the prefix refers to a concatenated class declaration, in which identifier substitutions have been carried out, then the same substitutions are effected for uncommitted identifier occurrences within the main part.

2. If now identifiers of attributes defined within the main part have uncommitted occurrences within the prefix class, then all uncommitted occurrences within the main part of these identifiers are systematically changed to avoid name conflicts. Identifiers corresponding to virtual quantities defined in the prefix class are not changed.

The concatenated class declaration is defined in terms of the given declaration, modified as above, and the concatenated declaration of the prefix class.

1. Its formal parameter list consists of that of the prefix class followed by that of the main part.

2. Its value part, specification part, and virtual part are the unions (in an informal but obvious sense) of those of the prefix class and those of the main part. If the resulting virtual part contains more than one occurrence of some identifier, the virtual part of the given class declaration is illegal.

3. Its class body is obtained from that of the main part in the following way, assuming the body of the prefix class is a split body. The begin of the block head is replaced by a copy of the block head of the prefix body, a copy of the initial operations of the prefix body is inserted after the block head of the main part and the end of the

compound tail of the main part is replaced by a copy of the compound tail of the prefix body. If the prefix class body is not a split body, it is interpreted as if the symbols ";inner" were inserted in front of the end of its compound tail.

If in the resulting class body two matching declarations for a virtual quantity are given (see section 2.2.3), the one copied from the prefix class body is deleted.

The declaration of a label is its occurrence as the label of a statement.

Examples:

```
class point (x,y); real x,y;
   begin ref (point) procedure plus (P); ref (point) P;
                 plus :- new point (x+P.x, y+P.y);
   end point;
```

An object of the class point is a representation of a point in a cartesian plane. Its attributes are x,y and plus, where plus represents the operation of vector addition.

```
point class polar;
   begin real r,v;
         ref (polar) procedure plus (P); ref (point) P;
               plus :- new polar (x+P.x, y+P.y);
     r:= sqrt (x↑2+y↑2);
     v:= arctg (x,y);
end polar;
```

An object of the class polar is a "point" object with the additional attributes r,v and a redefined plus operation. The values of r and v are computed and assigned at the time of object generation. ("arctg" is a suitable non-local procedure.)

2.2.3 Virtual quantities

Virtual quantities serve a double purpose:

1) to give access at one prefix level of an object to attributes declared at inner prefix levels, and

2) to permit attribute redeclarations at one prefix level valid at outer prefix levels.

The following specifiers are accepted in a virtual part:

label, switch, procedure and <type> procedure.

A virtual quantity of an object is either "unmatched" or is identified with a "matching" attribute, which is an attribute whose identifier coincides with that of the virtual quantity, declared at the prefix level of the virtual quantity or at an inner one. The matching attribute must be of the same kind as the virtual quantity. At a given prefix level, the type of the matching quantity must coincide with or be subordinate to (see Section 3.2.5) that of the virtual specification and that of any matching quantity declared at any outer prefix level.

It is a consequence of the concatenation mechanism that a virtual quantity of a given object can have at most one matching attribute. If matching declarations have been given at more than one prefix level of the class hierarchy, then the one is valid which is given at the innermost prefix level outer or equal to that of the main part of the object. The match is valid at all prefix levels of the object equal or inner to that of the virtual specification.

Example:

The following class expresses a notion of "hashing", in which the "hash" algorithm itself is a "replaceable part". "error" is a suitable non-local procedure.

```
class hashing (n); integer n;
  virtual: integer procedure hash;
    begin integer procedure hash (T); value T; text T;
        begin integer i;
            L: if T.more then
                begin i := i+rank (T.getchar);
                    go to L;
                end;
                hash := i - (i ÷ n × n);
        end hash;
      text array table [0:n-1]; integer entries;
       integer procedure lookup (T,old); name old;
                          value T; Boolean old; text T;
            begin integer i;
                  i:= hash(T);
              L: if table[i] == notext then
                  begin table[i] :- T; entries :=
                                        entries+1; end
                  else if table [i] = T then
                       old := true
                  else if entries = n then
                          error("hash table
                                filled completely")
                  else begin i := i+1;
                             if i = n then i := 0;
                             go to L
                       end;
                  lookup := i;
            end lookup;
  end hashing;
```

```
hashing class ALGOL hash;
    begin integer procedure hash(T); value T;
                                     text T;
        begin integer i; character c;
        L:  if T.more then
            begin c := T.getchar;
                if c ≠ '_' then
                    i := i + rank(c);
            go to L;
            end;
          hash := i-(i ÷ n × n);
        end hash;
    end ALGOL hash;
```

3. Types and variables

3.1 Syntax

```
<type declaration> ::= <type><type list>
<array declaration> ::= array <array list>|
                        <type> array <array list>
<type> ::= <value type>|
           <reference type>
<value type> ::= integer|
                 real|
                 Boolean|
                 character
<reference type> ::= <object reference>|
                     text
<object reference> ::=  ref (<qualification>)
<qualification> ::= <class identifier>
```

3.2 Semantics

The syntax for type declaration represents a deviation from ALGOL 60, in that own is not a part of SIMULA 67.

A "value" is a piece of information interpreted at run time to represent itself. Examples of values are: an instance of a real number, an object, or a piece of text. A "reference" is a piece of information which identifies a value, called the "referenced" value. The distinction between a reference and the referenced value is determined by context.

The reference concept corresponds to the intuitive notion of a "name" or a "pointer". It also reflects the addressing capability of computers: in certain simple cases a reference could be implemented as the memory address of a stored value.

For computer efficiency the reference concept is not introduced in its full generality. In particular, there is no reference concept associated with any value type.

A variable local to a block instance is a memory device whose "contents" is either a value or a reference, according to the type of the variable. A value type variable has a value which is the contents of the variable. A reference type variable is said to have a value which is the one referenced by the contents of the variable. The contents of a variable may be changed by an appropriate assignment operation, see section 6.1.

3.2.1 Object references

Associated with an object there is a unique "object reference" which identifies the object. And for any class C there is an associated reference type ref (C). A quantity of that type is said to be qualified by the class C. Its value is either an object, or the special value none which represents "no object". The qualification restricts the range of values to objects of classes included in the qualifying class. The range of values includes the value none regardless of the qualification.

3.2.2 Characters

A character value is an instance of an "internal character". For any given implementation there is a one-one mapping between a subset of internal characters and external ("printable") characters. The character sets (internal and external) are implementation defined.

3.2.2.1 Collating sequence

The set of internal characters is ordered according to an implementation defined collating sequence. The collating sequence defines a one-one mapping between internal characters and integers expressed by the function procedures:

integer procedure rank(c); character c;
whose value is in the range [0,N-1], where N is the number of internal characters, and

character procedure char(n); integer n;
The parameter value must be in the range [0,N-1], otherwise a run time error is caused.

Example:

Most character codes are such that the digits (0-9) are character values which are consecutive and in ascending order with respect to the collating sequence. Under this assumption, the expressions

"rank(c) - rank('0')" and "char(rank('0')+i)"

provide implementation independent conversion between digits and their arithmetic values.

3.2.2.2 Character subsets

Two character subsets are defined by the standard non-local procedures:

Boolean procedure digit(c); character c;
which is true if c is a digit, and

Boolean procedure letter(c); character c;
which is true if c is a letter.

3.2.3 Text

A text value is an ordered sequence, possibly empty, of internal characters. The number of characters is called the "length" of the text. A non-empty text value is either a "text object", or it is part of a longer character sequence which is a text object.

A text reference identifies a text value. Certain properties of a text reference are represented by procedures accessible through remote accessing (the dot notation). The text concept is further described in section 10.

3.2.4 Initialization

Any declared variable is initialized at the time of entry into the block to which the variable is local. The initial contents depends on the type of the variable.

real	0.0
integer	0
Boolean	false
character	implementation defined
object reference	none
text	notext (see section 10)

3.2.5 Subordinate types

An object reference is said to be "subordinate" to a second object reference if the qualification of the former is a subclass of the class which qualifies the latter.

A proper procedure is said to be of "type universal". Any type is subordinate to the universal type. (Cf. sections 2.2.3, 8.2.2 and 8.2.3.)

4. Expressions

4.1 Syntax

```
<label> ::= <identifier>
<expression> ::= <value expression>|
                 <text value>|
                 <reference expression>|
                 <designational expression>
<value expression> ::= <arithmetic expression>|
                       <Boolean expression>|
                       <character expression>
<reference expression> ::= <object expression>|
                           <text expression>
```

4.1.2 Semantics

The syntax for label represents a restriction compared with ALGOL 60.

A value expression is a rule for obtaining a value.

A reference expression is a rule for obtaining a reference and the associated referenced value.

A designational expression is a rule for obtaining a reference to a program point.

Any value expression or reference expression has an associated type, which is textually defined. The type of an arithmetic expression is that of its value. The following deviations from ALGOL 60 are introduced; see also section 8.2.3.

1) An expression of the form

   <factor>↑<primary>

   is of type real.

2) A conditional arithmetic expression is of type integer if both alternatives are of type integer, otherwise its type is real. If necessary, a conversion of the value of the selected alternative is invoked.

4.2 Character expressions

4.2.1 Syntax

<simple character expression> ::= '<character designation>'
<variable>|
<function designator>|
(<character expression>)

<character expression>
::= <simple character expression>|
<if clause><simple character expression>
else <character expression>

4.2.2 Semantics

A character expression is of type character. It is a rule for obtaining a character value.
A character designation is either an external character or another implementation defined representation of an internal character.

4.3 Object expressions

4.3.1 Syntax

simple object expression ::= none|
<variable>|
<function designator>|
<object generator>|
<local object>|
<qualified object>|
(<object expression>)

<object expression> ::= <simple object expression> |
<if clause><simple object expression>
else <object expression>
<object generator> ::= new <class identifier>
<actual parameter part>
<local object> ::= this <class identifier>
<qualified object> ::= <simple object expression>
qua <class identifier>

4.3.2 Semantics

An object expression is of type ref (<qualification>). It is a rule for obtaining a reference to an object. The value of the expression is the referenced object or none.

4.3.2.1 Qualification

The qualification of an object expression is defined by the following rules:

1) The expression none is qualified by a fictitious class which is inner to all declared classes.

2) A variable or function designator is qualified as stated in the declaration (or specification, see below) of the variable or array or procedure in question.

3) An object generator, local object, or qualified object is qualified by the class of the identifier following the symbol "new", "this", or "qua" respectively.

4) A conditional object expression is qualified by the innermost class which includes the qualifications of both alternatives. If there is no such class, the expression is illegal.

5) Any formal parameter of object reference type is qualified according to its specification regardless of the qualification of the corresponding actual parameter.

6) The qualification of a function designator whose procedure identifier is that of a virtual quantity, depends on the access level (see section 7). The qualification is that of the matching declaration, if any, occurring at the innermost prefix level equal or outer to the access level, or if no such match exists, it is that of the virtual specification.

4.3.2.2 Object generators

An object generator invokes the generation and execution of an object belonging to the identified class. The object is a new instance of the corresponding (concatenated) class body. The evaluation of an object generator consists of the following actions:

1) The object is generated and the actual parameters, if any, of the object generator are evaluated. The parameter values and/or references are transmitted. (For parameter transmission modes, see section 8).

2) Control enters the object through its initial begin, whereby it becomes operating in the "attached" state (see section 9). The evaluation of the object generator is completed:

case a: whenever the basic procedure "detach" is executed "on behalf of" the generated object (see section 9.1), or

case b: upon exit through the final end of the object.

The value of an object generator is the object generated as the result of its evaluation. The state of the object after the evaluation is either "detached" (case a) or "terminated" (case b).

4.3.2.3 Local objects

A local object "this C" is a meaningful expression within

1) the class body of C or that of any subclass of C, or

2) a connection block whose block qualification is C or a subclass of C (see section 7.2).

The value of a local object in a given context is the object which is, or is connected by, the smallest textually enclosing block instance, in which the local object is a meaningful expression. If there is no such block the local object is illegal (in the given context). For an instance of procedure or class body "textually enclosing" means containing its declaration.

4.3.2.4 Instantaneous qualification

Let X represent any simple reference expression, and let C and D be class identifiers such that D is the qualification of X. The qualified object "X qua C" is then a legal object expression, provided that C is outer to or equal to D or is a subclass of D. Otherwise, i.e. if C and D belong to disjoint prefix sequences, the qualified object is illegal.

If the value of X is none or is an object belonging to a class outer to C, the evaluation of X qua C constitutes a run time error. Otherwise, the value of X qua C is that of X. The use of instantaneous qualification enables one to restrict or extend the range of attributes of a concatenated class object accessible through inspection or remote accessing. (See also section 7.)

4.4 Text expressions

4.4.1 Syntax

<simple text expression> ::= notext |
<variable> |
<function designator> |
<text expression>

<text expression> ::= <simple text expression> |
<if clause><simple text expression>
else <text expression>

<text value> ::= <text expression> |
<string>

4.4.2 Semantics

The constituents of a string are external characters and/or other implementation defined representations of internal characters.

A string is a text value, not a text reference. It is not a text expression, but it may occur as the right part of a text value assignment (cf. section 10.6), as an operand of a text value relation (cf. section 5.2), and as an actual parameter called by value (cf. section 8.2.1).

In an implementation the left and right string quotes may be represented by one and the same external character. In this document either symbol is represented by the symbol ".

notext designates an empty text reference.

For further information on the text concept, see section 10.

5. Relations

<relation> ::= <ALGOL relation> |
<character relation> |
<text value relation> |
<object relation> |
<reference relation>

5.1 Character relations

5.1.1 Syntax

<character relation> ::= <simple character expression>
<relational operator><simple character expression>

5.1.2 Semantics

Character values may be compared for equality and inequality and ranked with respect to the (implementation defined) collating sequence. A relation

x rel y,

where x and y are character values, and rel is any relational operator has the same truth value as the relation

rank(x) rel rank(y).

5.2 Text value relations

5.2.1 Syntax

<text value relation> ::= <text value>
<relational operator><text value>

5.2.2 Semantics

Two text values are equal if they are both empty, or if they are both instances of the same character sequence. Otherwise they are unequal.

A text value T ranks lower than a text value U if and only if they are unequal and one of the following conditions is fulfilled:

1) T is empty.
2) U is equal to T followed by one or more characters.
3) The i'th character of T ranks lower than the i'th character of U, and i (i ≥ 1) is the smallest integer such that the i'th character of T is unequal to the i'th character of U.

5.3 Object relations

5.3.1 Syntax

<object relation> ::= <simple object expression>
is <class identifier>|
<simple object expression>
in <class identifier>

5.3.2 Semantics

The operators "is" and "in" may be used to test the class membership of an object.

The relation "X is C" has the value true if X refers to an object belonging to the class C, otherwise the value is false.

The relation "X in C" has the value true if X refers to an object belonging to a class C or a class inner to C, otherwise the value is false.

5.4 Reference relations

5.4.1 Syntax

<reference comparator> ::= ==|=/=
<reference relation> ::= <object reference relation>|
<text reference relation>
<object reference relation> ::= <simple object expression>
<reference comparator><simple object expression>
<text reference relation> ::= <simple text expression>
<reference comparator><simple text expression>

5.4.2 Semantics

The reference comparators "==" and "=/=" may be used for the comparison of references (as distinct from the corresponding referenced values). Two object (text) references X and Y are said to be "identical" if they refer to the same object (text object) or if both are none (notext). In those cases the relation "X==Y" has the value true. Otherwise the value is false.

The relation "X=/=Y" is the negation of "X==Y".

Let T and U be text references. Observe that the relations "T=/=U" and "T=U" may both have the value true. Then T and U refer to physically distinct character sequences which are equal.

Reference comparators have the same priority level as the relational operators.

6. Statements

<statement> ::= <ALGOL unconditional statement>|
<conditional statement>|
<for statement>|
<connection statement>

<unlabelled basic statement> ::= <assignment statement>|
<go to statement>|
<dummy statement>|
<procedure statement>|
<activation statement>|
<object generator>

<conditional statement> ::= <ALGOL conditional statement>|
<if clause><connection statement>

For <connection statement> see section 7.2.
For <activation statement> see section 14.2.3.

6.1 Assignment statements

6.1.1 Syntax

<assignment statement> ::= <value assignment>|
<reference assignment>

<value left part> ::= <variable>|
<procedure identifier>|
<simple text expression>

<value right part> ::= <value expression>|
<text value>|
<value assignment>

<value assignment>::=
<value left part> := <value right part>

<reference left part> ::= <variable>|
<procedure identifier>

<reference right part> ::= <reference expression>|
<reference assignment>

<reference assignment> ::=
<reference left part> :- <reference right part>

6.1.2 Semantics

The operator ":=" (read: "becomes") indicates the assignment of a value to the value type variable or value type procedure identifier which is the left part of the value assignment or the assignment of a text value to the text object referenced by the left part.

The operator ":-" (read: "denotes") indicates the assignment of a reference to the reference type variable or reference type procedure identifier which is the left part of the reference assignment.

A procedure identifier in this context designates a memory device local to the procedure instance. This memory device is initialized upon procedure entry according to section 3.2.4.

The value or reference assigned is a suitably transformed representation of the one obtained by evaluating the right part of the assignment. If the right part is itself an assignment, the value or reference obtained is a copy of that of its constituent left part after that assignment operation has been completed.

Any expression which is, or is part of, the left part of an assignment is evaluated prior to the evaluation of the right part.

For a detailed description of the text value assignment, see section 10.6. There is no value assignment operation for objects.

The type of the value or reference obtained by evaluating the right part, must coincide with the type of the left part, with the exceptions mentioned in the following sections.

If the left part of an assignment is a formal parameter, and the type of the corresponding actual parameter does not coincide with that of the formal specification, then the assignment operation is carried out in two steps.

1) An assignment is made to a fictitious variable of the type specified for the formal parameter.

2) An assignment statement is executed whose left part is the actual parameter and whose right part is the fictitious variable.

The value or reference obtained by evaluating the assignment is, in this case, that of the fictitious variable.

For text reference assignment see section 10.5.

6.1.2.1 Arithmetic value assignment

In accordance with ALGOL 60, any arithmetic value may be assigned to a left part of type real or integer. If necessary, an appropriate transfer function is invoked.

Example:

Consider the statement (not a legal one in ALGOL 60):

```
X := i := Y := F := 3.14
```

where X and Y are real variables, i is an integer variable, and F is a formal parameter called by

name and specified real. If the actual parameter for F is a real variable, then X, i, Y and F are given the values 3,3,3.14 and 3.14 respectively. If the actual parameter is an integer variable, the respective values will be 3,3,3.14 and 3.

6.1.2.2 Object reference assignment

Let the left part of an object reference assignment be qualified by the class Cl, and let the right part be qualified by Cr. If the right part is itself a reference assignment, Cr is defined as the qualification of its constituent left part. Let V be the value obtained by evaluating the right part. The legality and effect of the reference assignment depend on relationships between Cr, Cl and V.

Case 1. Cl is of the class Cr or outer to Cr:
The reference assignment is legal and the assignment operation is carried out.

Case 2. Cl is inner to Cr:
The reference assignment is legal. The assignment operation is carried out if V is none or is an object belonging to the cåass Cl or innracters

class Cl or a class inner to Cl. If not, the execution of the reference assignment constitutes a run time error.

Case 3. Cl and Cr satisfy neither of the above relations:
The reference assignment is illegal.

Similar rules apply to reference assignments implicit in for clauses and the transmission of parameters.

Example 1:

Let "Gauss" be the class declared in the example of the section 2.2.

```
ref (Gauss) G5, G10;
    G5 :- new Gauss(5);  G10 :- new Gauss(10);
```

The values of G5 and G10 are now Gauss objects.
See also example 1 of section 7.1.2.

Example 2:

Let "point" and "polar" be the classes declared in the example of section 2.2.2.

```
ref (point) P1, P2; ref (polar) P3;
    P1 :- new polar (3,4); P2 :- new point (5,6);
```

Now the statement "P3 :- P1" assigns to P3 a reference to the "polar" object which is the value of P1. The statement "P3 :- P2" would cause a run time error.

6.2 For statements

6.2.1 Syntax

```
<controlled variable> ::= <simple variable>
<controlled statement> ::= <statement>
<for statement> ::= <for clause><controlled statement>|
                    <label> : <for statement>
<for clause> ::= for <controlled variable>
                    <for right part> do
<for right part> ::= :=<value for list>|
                     :-<object for list>
<value for list> ::= <value for list element>|
                     <value for list>,
                       <value for list element>
```

<object for list> ::= <object for list element>|
<object for list>,
<object for list element>
<value for list element> ::= <value expression>|
<arithmetic expression> step <arithmetic expression> until <arithmetic expression>|
<value expression> while <Boolean expression>
<object for list element> ::= <object expression>|
<object expression> while <Boolean expression>

6.2.2 Semantics

A for clause causes the controlled statement to be executed repeatedly zero or more times. Each execution of the controlled statement is preceded by an assignment to the controlled variable and a test to determine whether this particular for list element is exhausted.

Assignments may change the value of the controlled variable during execution of the controlled statement.

6.2.3 For list elements

The for list elements are considered in the order in which they are written. When one for list element is exhausted, control proceeds to the next, until the last for list element in the list has been exhausted. Execution then continues after the controlled statement.

The effect of each type of for list element is defined below using the following notation:

C: controlled variable
V: value expression
O: object expression
A: arithmetic expression
B: Boolean expression
S: controlled statement

The effect of the occurrence of expressions as for list elements may be established by textual replacement in the definitions.

α, β, σ are different identifiers which are not used elsewhere in the program. σ identifies a non-local simple variable of the same type as A_2.

1. V

```
C:= V;
S;
next for list element
```

2. A_1 step A_2 until A_3

```
C := A1;
σ := A2;
α: if σ ×(C-A3) > 0 then go to β;
S;
σ := A2;
C := C + σ;
go to α;
β: next for list element
```

3. V while B

```
α: C := V;
   if ¬ B then go to β;
   S;
   go to α;
β: next for list element
```

4. 0

```
C :- 0;
S;
next for list element
```

5. O while B

```
α: C :- O;
   if ¬ B then go to β;
   S;
   go to α;
β: next for list element
```

6.2.4 The controlled variable

The semantics of this section (6.2) is valid when the controlled variable is a simple variable which is not a formal parameter called by name, or a procedure identifier.

The cases of formal parameter called by name, procedure identifier, subscripted variable and remote identifier are presently under study by a Technical Committee appointed by the SIMULA Standards Group.

To be valid, all for list elements in a for-statement (defined by textual substitution, section 6.2.3) must be semantically and syntactically valid.

In particular each implied reference assignment in cases 4 and 5 of section 6.2.3 is subject to the rules of section 6.1.2.2.

6.2.5 The value of the controlled variable upon exit

Upon exit from the for statement, the controlled variable will have the value given to it by the last (explicit or implicit) assignment operation.

6.2.6 Labels local to the controlled statement

The controlled statement always acts as if it were a block. Hence, labels on or defined within the controlled statement may not be accessed from without the controlled statement.

6.3 Prefixed blocks

6.3.1 Syntax

```
<block> ::= <ALGOL block>|
            <prefixed block>
<block prefix> ::=
    <class identifier><actual parameter part>
<main block> ::= <unlabelled block>|
                 <unlabelled compound>
<unlabelled prefixed block> ::=
                <block prefix><main block>
<prefixed block> ::= <unlabelled prefixed block>|
                     <label>:<prefixed block>
```

6.3.2 Semantics

An instance of a prefixed block is a compound object whose prefix part is an object of the class identified by the block prefix, and whose main part is an instance of the main block. The formal parameters of the former are initialized as indicated by the actual parameters of the block prefix. The concatenation is defined by rules similar to those of section 2.2.2.

The following restrictions must be observed:

1) A class in which reference is made to the class itself through use of "this", is an illegal block prefix.

2) The class identifier of a block prefix must refer to a class local to the smallest block enclosing the prefixed block. If that class identifier is that of a system class, it refers to a fictitious declaration of that system class occurring in the block head of the smallest enclosing block.

An instance of a prefixed block is a detached object (cf. section 9). A program is enclosed in a prefixed block (cf. section 11) and is therefore detached.

Example:

Let "hashing" be the class declared in the example of section 2.2.3. Then within the prefixed block,

```
hashing (64) begin integer procedure hash(T); value T;
                   text T; .............;
                   ..............
                 end
```

a "lookup" procedure is available which makes use of the "hash" procedure declared within the main block.

7. Remote accessing

An attribute of an object is identified completely by the following items of information:

1) the object,

2) a class which is outer to or equal to that of the object, and

3) an attribute identifier defined in that class or in any class belonging to its prefix sequence.

Item 2 is textually defined for any attribute identification. The prefix level of the class is called the "access level" of the attribute identification.

Consider an attribute identification whose item 2 is the class C. Its attribute identifier, item 3, is subjected to the same identifier substitutions as those which would be applied to an uncommitted occurrence of that identifier within the main part of C, at the time of concatenation. In that way, name conflicts between attributes declared at different prefix levels of an object are resolved by selecting the one defined at the innermost prefix level not inner to the access level of the attribute identification.

An uncommitted occurrence within a given object of the identifier of an attribute of the object is itself a complete attribute identification. In this case items 1 and 2 are implicitly defined, as respectively the given object and the class associated with the prefix level of the identifier occurrence.

If such an identifier occurrence is located in the body of a procedure declaration (which is part of the object), then, for any dynamic instance of the procedure, the

occurrence serves to identify an attribute of the given object, regardless of the context in which the procedure was invoked.

Remote accessing of attributes, i.e. access from outside the object, is either through the mechanism of "remote identifiers" ("dot notation") or through "connection". The former is an adaptation of a technique proposed in [3], the latter corresponds to the connection mechanism of SIMULA I [2].

A text reference is (itself) a compound structure in the sense that it has attributes accessible through the dot notation.

7.1 Remote identifiers

7.1.1 Syntax

```
<attribute identifier> ::= <identifier>
<remote identifier> ::=
        <simple object expression>.<attribute identifier>|
        <simple text expression>.<attribute identifier>
<identifier 1> ::= <identifier>|
                   <remote identifier>
<variable identifier 1> ::= <identifier 1>
<simple variable 1> ::= <variable identifier 1>
<array identifier 1> ::= <identifier 1>
<variable> ::= <simple variable 1>|
               <array identifier 1>[<subscript list>]
<procedure identifier 1> ::= <identifier 1>
<function designator>::=
        <procedure identifier 1><actual parameter part>
<procedure statement> ::=
        <procedure identifier 1><actual parameter part>
<actual parameter> ::= <expression>|
                       <array identifier 1>|
                       <switch identifier>|
                       <procedure identifier 1>
```

7.1.2 Semantics

Let X be a simple object expression qualified by the class C, and let A be an appropriate attribute identifier. Then the remote identifier "X.A", if valid, is an attribute identification whose item 1 is the value X and whose item 2 is C.

The remote identifier X.A is valid if the following conditions are satisfied:

1) The value X is different from none.

2) The object referenced by X has no class attribute declared at any prefix level equal or outer to that of C.

Condition 1 corresponds to a run time check which causes a run-time error if the value of X is none.

Condition 2 is an ad hoc rule intended to simplify the language and its implementations.

A remote identifier of the form

<simple text expression>.<attribute identifier>

identifies an attribute of the text reference obtained by evaluating the simple text expression, provided that the attribute identifier is one of the procedure identifiers listed in section 10.1.

Example 1:

Let G5 and G10 be variables declared and initialized as in example 1 of section 6.1.2.2. Then an expression of the form

G5.integral(.....) or G10.integral(.....)

is an approximation to a definite integral obtained by applying respectively a 5 point or a 10 point Gauss formula.

Example 2:

Let P1 and P2 be variables declared and initialized as in example 2 of section 6.1.2.2. Then the value of the expression

```
P1.plus (P2)
```

is a new "point" object which represents the vector sum of P1 and P2. The value of the expression

```
P1 qua polar.plus (P2)
```

is a new "polar" object representing the same vector sum.

7.2 Connection

7.2.1 Syntax

```
<connection block 1> ::= <statement>
<connection block 2> ::= <statement>
<when clause> ::=
                when <class identifier>do<connection block 1>
<otherwise clause> ::= <empty>|
                       otherwise<statement>
<connection part> ::= <when clause>|
                      <connection part><when clause>
<connection statement> ::=
                      inspect <object expression>
                      <connection part><otherwise clause>|
                      inspect <object expression> do
                      <connection block 2><otherwise clause>|
                      <label>:<connection statement>
```

A connection block may itself be a connection statement, which, in that case, is the largest possible connection statement.

7.2.2 Semantics

The purpose of the connection mechanism is to provide implicit definitions of the above items 1 and 2 for certain attribute identifications within connection blocks.

The execution of a connection statement may be described as follows:

1) The object expression of the connection statement is evaluated. Let its value be X.

2) If when-clauses are present they are considered one after another. If X is an object belonging to a class equal or inner to the one identified by a when-clause, the connection block 1 of this when-clause is executed, and subsequent when-clauses are skipped. Otherwise the when-clause is skipped.

3) If a connection block 2 is present it is executed, except if X is none in which case the connection block is skipped.

4) The statement of an otherwise clause is executed if X is none, or if X is an object not belonging to a class included in the one identified by any when-clause. Otherwise it is skipped.

A statement which is a connection block 1 or a connection block 2 acts as a block, whether it takes the form of a block or not. It further acts as if enclosed in a second fictitious block, called a

"connection block". During the execution of a connection block the object X is said to be "connected". A connection block has an associated "block qualification", which is the preceding class identifier for a connection block 1 and the qualification of the preceding object expression for a connection block 2.

Let the block qualification of a given connection block be C and let A be an attribute identifier defined at any prefix level of C. Then any uncommitted occurrence of A within the connection block is given the local significance of being an attribute identification. Its item 1 is the connected object, its item 2 is the block qualification C.

It follows that a connection block acts as if its local quantities are those attributes of the connected object which are defined at prefix levels outer to and including that of C. (Name conflicts between attributes defined at different prefix levels of C are resolved by selecting the one defined at the innermost prefix level.)

Example:

Let "Gauss" be the class declared in the example of section 2.2. Then within the connection block 2 of the connection statement

inspect new Gauss(5) do begin ..... end

a procedure "integral" is available for numeric integration by means of a 5 point Gauss formula.

8. Procedures and parameter transmission

8.1 Syntax

```
<procedure heading> ::= <procedure identifier>
                        <formal parameter part>;
                        <mode part><specification part>
<mode part> ::= <value part><name part>|
                <name part><value part>
<name part> ::= name <identifier list>;|
                <empty>
<specifier> ::= <type >|
                array|
                <type> array|
                label|
                switch|
                procedure|
                <type> procedure
<parameter delimiter> ::= ,
```

For actual parameter see section 7.1.1.

8.2 Semantics

With respect to procedures, SIMULA 67 deviates from ALGOL 60 on the following points:

1) Specification is required for each formal parameter.

2) The ALGOL specifier "string" is replaced by "text".

3) A "name part" is introduced as an optional part of a procedure heading to identify parameters called by name. Call by name is not the default parameter transmission mode.

4) Call by name is redefined in the case that the type of actual parameter does not coincide with that of the formal specification.

5) Exact type correspondence is required for array parameters not called by value.

There are three modes of parameter transmission: "call by value", "call by reference", and "call by name".

The default transmission mode is call by value for value type parameters and call by reference for all other kinds of parameters.

The available transmission modes are shown in fig. 8.1 for the different kinds of parameters to procedures. The upper left subtable defines transmission modes available for parameters of class declarations.

Parameter	Transmission modes		
	by value	by reference	by name
value type	D	I	O
object reference	I	D	O
text	O	D	O
value type array	O	D	O
reference type array	I	D	O
procedure	I	D	O
type procedure	I	D	O
label	I	D	O
switch	I	D	O

D: default mode O: optional mode I: illegal

fig. 8.1 Transmission modes

8.2.1 Call by value

A formal parameter called by value designates initially a local copy of the value (or array) obtained by evaluating the corresponding actual parameter. The evaluation takes place at the time of procedure entry or object generation.

The call by value of value type and value type array parameters is as in ALGOL 60.

A text parameter called by value is a local variable initialized in two steps, informally described by the statements:

```
FP :- blanks (AP.length); FP := AP;
```

where FP is the formal parameter and AP is the value of the actual parameter. Any text value is a legal actual parameter in this case.

Value specification is redundant for a parameter of value type.

There is no call by value option for object reference parameters and reference type array parameters.

8.2.2 Call by reference

A formal parameter called by reference designates initially a local copy of the reference obtained by evaluating the corresponding actual parameter. The evaluation takes place at the time of procedure entry or object generation.

A reference type formal parameter is a local variable initialized by a reference assignment

```
FP :- AP
```

where FP is the formal parameter and AP is the reference obtained by evaluating the actual parameter. The reference assignment is subject to the rules of section 6.1.2.2. Since in this case the formal parameter is a reference type variable, its contents may be changed by reference assignments within the procedure body, or within or without (by remote accessing) a class body. A string is not a legal actual parameter for a text parameter called by reference.

Although array-, procedure-, label-, and switch identifiers do not designate references to values, there is a strong analogy between references in the strict sense and references to entities such as arrays, procedures (i.e. procedure declarations), program points and switches. Therefore a call by reference mechanism is defined in these cases.

An array-, procedure-, label-, or switch parameter called by reference cannot be changed from within the procedure or class body; it will thus reference the same entity throughout its scope. However, the contents of an array called by reference may well be changed through appropriate assignments to its elements.

For an array parameter called by reference, the type associated with the actual parameter must coincide with that of the formal specification. For a procedure parameter called by reference, the type associated with the actual parameter must coincide with or be subordinate to that of the formal specification.

8.2.3 Call by name

Call by name is an optional transmission mode available for parameters to procedures. It represents a textual replacement as in ALGOL 60.

However, for an expression within a procedure body which is

1) a formal parameter called by name,

2) a subscripted variable whose array identifier is a formal parameter called by name, or

3) a function designator whose procedure identifier is a formal parameter called by name,

the following rules apply:

1) Its type is that prescribed by the corresponding formal specification.

2) If the type of the actual parameter does not coincide with that of the formal specification, then an evaluation of the expression is followed by an assignment of the value or reference obtained to a fictitious variable of the latter type. This assignment is subject to the rules of section 6.1.2. The value or reference obtained by the evaluation is the contents of the fictitious variable.

Section 6.1.2 defines the meaning of an assignment to a variable which is a formal parameter called by name, or is a subscripted variable whose array identifier is a formal parameter called by name, if the type of the actual parameter does not coincide with that of the formal specification.

Assignment to a procedure identifier which is a formal parameter is illegal, regardless of its transmission mode.

Notice that each dynamic occurrence of a formal parameter called by name, regardless of its kind, may invoke the execution of a non-trivial expression, e.g. if its actual parameter is a remote identifier.

9. Sequencing

9.1 Blocks and dynamic scopes

The constituent parts of a program execution are dynamic instances of blocks. The different kinds of blocks fall into three categories according to the possible interrelationships and states of execution of the block instances.

1) Prefixed blocks.
2) Sub-blocks, procedure bodies and connection blocks.
3) Class bodies.

A block instance is, at any given time, in one of three states of execution: "attached", "detached" or "terminated". The possible and initial states are defined in fig. 9.1.:

Block category	Possible states	Initial state
1	D	D
2	A	A
3	A,D,T	A
A: attached	D: detached	T: terminated

Fig. 9.1 Execution states

A program conforming to ALGOL 60 only contains blocks of category 2, except the outermost one which is of category 1 (see section 11). An execution of any such program is a simple dynamically nested structure.

A block instance of category 2 is in the attached state and is said to be "attached to" the smallest dynamically enclosing block instance. E.g. an instance of a procedure body is attached to the block instance containing the corresponding procedure call.

The "program sequence control", PSC, refers at any time to that program point within a block instance which is currently being executed. For brevity we shall say that the PSC is "positioned" at the program point and is "contained" in the block instance. If A is the block instance containing the PSC, then A, and any block instance dynamically enclosing A, is said to be "operating".

The entry into any block invokes the generation of an instance of that block, whereupon the PSC enters the block instance. If and when the PSC leaves a block instance of category 1 or 2 through its end or by a go to statement, that block instance is deleted.

An object (i.e., a block instance of category 3) is initially attached to the block instance containing the corresponding object generator. It may enter the detached state by executing the statement "detach" (see section 9.2.1). If and when the PSC leaves the object through its end or by a go to statement, the object becomes terminated.

A block instance is said to be "local to" the one which contains its describing text. E.g. an object belonging to a given class is local to the block instance containing the class declaration.

A block instance A is said to "enclose" a second one B if:

1) B is attached and is dynamically enclosed by A,
or

2) B is detached or terminated and is local to A or to a block instance dynamically enclosed by A,
or

3) there is a detached object C local to A or to a block instance dynamically enclosed by A, such that C encloses B.

Whenever a block instance is deleted, any block instance enclosed by it is also deleted. It is a consequence of the language structure that an object, at the time of its deletion, cannot be referenced by any computable object reference expression. The dynamic scope of an object is thus limited by that of its class declaration. However, an implementation may further reduce the effective life spans of objects by techniques such as "garbage collection".

Notice that arrays and text objects cannot, in general, be deleted together with the block instance in which they are declared.

9.2 Quasi-parallel sequencing

A program execution can be described as a tree structure whose branching nodes are instances of prefixed blocks. A subtree whose "root" is a prefixed block instance is called a "quasi-parallel system". The prefixed block instance, including block instances dynamically enclosed by it, is called the "main program" of the quasi-parallel system.

A quasi-parallel system has an associated "system level", which is the number of prefixed block instances enclosing its main program. The program as a whole is a quasi-parallel system at system level zero.

A quasi-parallel system consists of system "components" which are the main program and any detached object, including block instances dynamically enclosed by the object, whose smallest enclosing instance of a prefixed

block is the main program. The components of a quasi-parallel system are said to be "detached" at the system level of the quasi-parallel system.

Any system component has an associated "local sequence control", LSC. Associated with any quasi-parallel system is an "outer sequence control", OSC. The OSC at system level zero coincides with the PSC. The OSC of a system at level k ($k \geq 1$) coincides with the LSC of that component at system level k-1 which encloses the given system.

For any given quasi-parallel system, one and only one of its components is said to be "active". The LSC of that component coincides with the OSC of the quasi-parallel system.

An instance of a prefixed block is initially active, i.e. it contains the OSC of its own quasi-parallel system. The OSC of a system may move from one component to another as the result of statements described below. The LSC of a component not containing the OSC remains positioned at the program point at which the OSC left the object the last time.

At any given time, there exists a sequence of system components $X_0, X_1, \ldots\ldots, X_n$ such that:

1) X_k is active at system level k ($k = 0,1,\ldots,n$).
2) X_k is enclosed by X_{k-1} ($k = 1,2,\ldots,n$).
3) There is no quasi-parallel system enclosed by X_n.

This sequence is called the "operating chain". System components on the operating chain all contain the PSC and are therefore said to be operating. The LSC of a system component remains fixed as long as it is not a member of the operating chain.

9.2.1 The detach statement

Let the smallest operating block instance be X.

If X is an attached object, a detach statement has the following effects:

1) The object becomes detached at the system level of the smallest enclosing prefixed block instance, its LSC positioned at the end of the statement.

2) The PSC returns to the block instance to which X was attached and resumes operations after the object generator which caused the generation of X. A reference to X is the result of that expression.

If X is a detached object which is component of a quasi-parallel system S, a detach statement operates as follows:

1) The OSC of S leaves X. As a consequence X is removed from the operating chain. Its LSC remains positioned at the end of the statement.

2) The OSC of S enters the main program of S at the current position of its LSC. As a consequence the main program of S and possibly system components at system levels higher than that of S become operating.

If X is an instance of a prefixed block, a detach statement has no effect.

If X is any block instance other than an object or a prefixed block instance, execution of a detach statement constitutes an error.

9.2.2 The resume statement

"resume" is formally a procedure with one object reference parameter qualified by a fictitious class including all classes.

Let the actual parameter of a resume statement reference a detached object Y, which is a component of a quasi-parallel system S. It is a consequence of the language conventions that Y can only be referenced from within a block instance which is or is enclosed by a component X of S. X is currently operating. The resume statement has the following effects:

1) The OSC of S leaves X. As a consequence X and any operating components at higher system levels are removed from the operating chain. The LSC of each component remains at the end of the resume statement.

2) The OSC of S enters Y at the current position of its LSC. As a consequence Y, and possibly a sequence of components at higher system levels, become operating.

If the actual parameter of a resume statement does not refer to a detached object, its execution constitutes an error.

9.2.3 Object "end"

The effect of the PSC passing through the final end of an object is the same as that of a detach statement, except that the object becomes terminated, not detached, and thus loses its LSC.

9.2.4 go to statements

A designational expression defines a block instance and a program point local to this block instance.

A go to statement leading to a block instance is valid if and only if this block instance is operating. This restriction implies that a go to statement leading out of a detached object must also lead out of the smallest enclosing prefixed block. The restriction further implies that a go to statement leading to a connected label is valid if and only if the connected object is also operating. The go to statement will lead to the label in the operating block instance.

Block instances left through a go to statement become terminated.

10. The type "text"

Cf. sections 3.2.3, 4.4.2, 5.2 and 5.4.

10.1 Text attributes

The following procedures are attributes of any text reference. They may be accessed by remote identifiers of the form

<simple text expression>.<procedure identifier>

integer procedure length	(cf. 10.2)
text procedure main	(cf. 10.2)
integer procedure pos	(cf. 10.3)
procedure setpos	(cf. 10.3)
Boolean procedure more	(cf. 10.3)
character procedure getchar	(cf. 10.3)
procedure putchar	(cf. 10.3)
text procedure sub	(cf. 10.7)
text procedure strip	(cf. 10.7)
integer procedure getint	(cf. 10.9)
real procedure getreal	(cf. 10.9)
integer procedure getfrac	(cf. 10.9)
procedure putint	(cf. 10.10)
procedure putfix	(cf. 10.10)
procedure putreal	(cf. 10.10)
procedure putfrac	(cf. 10.10)

In the following section "X" denotes a text reference unless otherwise is specified.

10.2 "length" and "main"

integer procedure length;

The value of "X.length" is the number of characters of the text value referenced by X (cf. section 3.2.3). "notext.length" is equal to zero.

text procedure main;

"X.main" is a reference to the text object which is, or contains, the text value referenced by X (cf. section 3.2.3).

"notext.main" is identical to "notext".

The following relations are true for any text reference X.

X.main.length ≥ X.length
X.main.main == X.main

10.3 Character access

The characters of a text are accessible one at a time. Any text reference contains a "position indicator", which identifies the currently accessible character, if any, of the referenced text object. The position indicator of a given text reference X is an integer in the range [1,X.length+1].

The position indicator of notext is equal to 1. A text reference obtained by calling any system defined text procedures(i.e. main, sub and strip) has its position indicator equal to 1.

The position indicator of a given text reference may be altered by the procedures "setpos", "getchar", and "putchar" of the text reference. Also any of procedures defined in sections 10.9 and 10.10 may alter the position indicator of the text reference which contains the procedure.

Position indicators are ignored and left unaltered by text reference relations, text value relations and text value assignments.

The following procedures are facilities available for character accessing. They are oriented towards sequential access.

integer procedure pos;

The value of "X.pos" is the current value of the position indicator of the text reference X.

procedure setpos(i); integer i;

The effect of "X.setpos(i)" is to assign the integer i to the position indicator of X, if i is in the range [1,X.length+1]. Otherwise the value X.length+1 is assigned.

Boolean procedure more;

The value of "X.more" is true if the position indicator is in the range [1,X.length]. Otherwise the value is false.

character procedure getchar;

The value of "X.getchar" is a copy of the currently accessible character of X, provided that the current value of X.more is true. Otherwise the evaluation constitutes a run time error. In the former case the position indicator of X is increased by one after the copying operation.

procedure putchar(c); character c;

The effect of "X.putchar(c)" is to replace the currently accessible character of X by a copy of the character c provided that the current value of X.more is true.

Otherwise the execution constitutes a run time error. In the former case the position indicator of X is increased by 1 after the replacement operation.

Example:

```
procedure compress(T); text T;
begin text U;  character c;
      T.setpos(1);  U :- T;
      for c := c while U.more do
      begin c := U.getchar;
            if c ≠ '_' then T.putchar(c)
      end;
      for c := c while T.more do T.putchar('_')
end compress;
```

The procedure will rearrange the characters of the text value referenced by its parameter. The non-blank characters are collected in the leftmost part of the text and the remainder, if any, is filled with the blank characters. Since the parameter is called by reference, its position indicator is not altered. The character constant '_' represents a blank character value.

10.4 Text generation

The following basic procedures are available for text object generation. The procedures are non-local.

```
text procedure blanks(n); integer n;
```

The reference value is a new text object of length n, filled with blank characters. If n=0, the reference value is notext. For n<0, a run-time error will occur.

```
text procedure copy (T); value T; text T;
```

The referenced value is a new text object, which is a copy of the text value which is (or is referenced by) the actual parameter.

Example:

The statement "T :- copy ("ABC")", where T is a text variable, is equivalent to the compound statement

```
begin T :- blanks(3); T := "ABC" end
```

10.5 Text reference assignment

Syntax, see section 6.1.

A text reference assignment causes a text reference to be assigned as the new contents of the left part. The text reference is a copy of the one which is obtained by evaluating the right part (see section 6.2), and includes a copy of its position indicator.

If X is a text variable and Y is a text reference, then after the execution of the reference assignment "X :- Y", the relations "X == Y" and "X.pos = Y.pos" both have the value true.

10.6 Text value assignment

Syntax, see section 6.1.

Let the left part of a text value assignment be a text of length Ll, and let the right part be of length Lr. If the right part is itself a text value assignment, Lr is defined as the length of its constituent left part.

The effect of the text value assignment depends on the relationship between Ll and Lr.

Ll = Lr : The character contents of the right part text are copied to the left part text.

Ll > Lr : The character contents of the right part text are copied to the first Lr characters of the left part text. The remaining Ll-Lr characters of the left part text are filled with blanks.

Ll < Lr : The statement constitutes a run time error.

The effect of a text value assignment is implementation defined if the left part and right part refer to overlapping texts.

The position indicators of the left and the right parts are ignored and remain unchanged.

If X and Y are non-overlapping texts of the same length then after the execution of the value assignment "X := Y", the relation "X = Y" is true.

10.7 Subtexts

Two procedures are available for referencing subtexts.

text procedure sub(i,n); integer i,n;

Let i and n be integers such that i ≥ 1, n ≥ 0, and i + n ≤ X.length+1. Then the expression "X.sub(i,n)" refers to that part of the text value X whose first

character is character number i of X, and which contains n consecutive characters. The position indicator of the text reference is equal to 1, and defines a local character numbering within the subtext. The position indicator of X is ignored and not altered. In the exceptional case n = 0, the reference obtained is notext. If i and n do not satisfy the above conditions, a run time error is caused.

If legal, the Boolean expressions

X.sub(i,n).sub(j,m) == X.sub(i+j-1,m),

and n ≠ 0⊃X.main == X.sub(i,n).main

both have the value true.

text procedure strip;

The expression "X.strip" is equivalent to "X.sub(1,n)", where n is the smallest integer such that the remaining characters of X, if any, are blanks.

Let X and Y be text references. Then after the value assignment "X := Y", if legal, the relation

X.strip = Y.strip

has the value true.

10.8 Numeric text values

10.8.1 Syntax

<EMPTY> ::=
<DIGIT> ::= 0|1|2|3|4|5|6|7|8|9
<DIGITS> ::= <DIGIT>|<DIGITS><DIGIT>
<BLANKS> ::= <EMPTY>|<BLANKS><BLANK>

```
<SIGN> ::= <EMPTY>|+|-
<SIGN PART> ::= <BLANKS><SIGN><BLANKS>
<INTEGER ITEM >::= <SIGN PART><DIGITS>
<FRACTION >::= .<DIGITS>
<DECIMAL ITEM> ::= <INTEGER ITEM>|
                   <SIGN PART><FRACTION>|
                   <INTEGER ITEM><FRACTION>
<EXPONENT> ::= 10<INTEGER ITEM>
<REAL ITEM >::= <DECIMAL ITEM>|
                <SIGN PART><EXPONENT>|
                <DECIMAL ITEM><EXPONENT>
<GROUPS> ::= <DIGITS>|
             <GROUPS><BLANKS><DIGITS>
<GROUPED ITEM> ::= <SIGN PART><GROUPS>|
                   <SIGN PART>.<GROUPS>|
                   <SIGN PART><GROUPS>.<GROUPS>
<NUMERIC ITEM> ::= <REAL ITEM>|
                   <GROUPED ITEM>
```

10.8.2 Semantics

The syntax applies to sequences of characters, i.e. to text values. <BLANK> stands for a blank character.

A numeric item is a character sequence which is a production of <NUMERIC ITEM>. "Editing" and "de-editing" procedures are available for the conversion between arithmetic values and text values which are numeric items, and vice versa.

10.9 "De-editing" procedures

A de-editing procedure of a given text reference X operates in the following way:

1) The longest numeric term, if any, of a given form is located, which is contained in X and contains the first character of X. (Notice that leading blanks are accepted as part of any numeric item.)

2) If no such numeric item is found, a run time error is caused.

3) Otherwise the numeric item is interpreted as a number.

4) If that number is outside a relevant implementation defined range, a runtime error is caused.

5) Otherwise an arithmetic value is computed, which is equal to or approximates that number.

6) The position indicator of X is made one greater than the position of the last character of the numeric item.

The following de-editing procedures are available.

integer procedure getint;

The procedure locates an INTEGER ITEM. The function value is equal to the corresponding integer.

real procedure getreal;

The procedure locates a REAL ITEM. The function value is equal to or approximates the corresponding number. If the number is an integer within an implementation defined range, the conversion is exact.

integer procedure getfrac;

The procedure locates a GROUPED ITEM. In its interpretation of the GROUPED ITEM the procedure

will ignore any BLANKS and a possible decimal point. The function value is equal to the resulting integer.

10.10 Editing procedures

Editing procedures of a given text reference X serve to convert arithmetic values to numeric items. After an editing operation, the numeric item obtained, if any, is right adjusted in the text X and preceded by as many blanks as necessary to fill the text. The final value of the position indicator of X is equal X.length+1.

A positive number is edited without a sign, a negative number is edited with a minus sign immediately preceding the most significant character. Leading non-significant zeros are suppressed, except possibly in an EXPONENT.

If X is identical to notext, a runtime error is caused. Otherwise if the text value is too short to contain the resulting numeric item, an "edit overflow" is caused. Then an implementation defined character sequence is edited into the text. In addition, an appropriate warning will be given after the completion of a program execution if an edit overflow has occurred.

```
procedure putint(i); integer i;
```

The value of the parameter is converted to an INTEGER ITEM which designates an integer equal to that value.

```
procedure putfix(r,n); real r; integer n;
```

The resulting numeric item is an INTEGER ITEM if n = 0 or a DECIMAL ITEM with a FRACTION of n digits if n > 0. It designates a number equal to the value of r

or an approximation to the value of r, correctly rounded to n decimal places. If n < 0, a run time error is caused.

procedure putreal(r,n); real r; integer n;

The resulting numeric item is a REAL ITEM containing an EXPONENT with a fixed implementation defined number of characters. The EXPONENT is preceded by a SIGN PART if n = 0, or by an INTEGER ITEM with one digit if n = 1, or if n > 1, by a DECIMAL ITEM with an INTEGER ITEM of 1 digit only, and a fraction of n-1 digits. If n < 0 a run time error is caused.

In putfix and putreal, the numeric item designates that number of the specified form which differs by the smallest possible amount from the value of r or from the approximation to the value of r.

procedure putfrac(i,n); integer i,n;

The resulting numeric item is a GROUPED ITEM with no decimal point if n <= 0, and with a decimal point followed by total of n digits if n > 0. Each digit group consists of 3 digits, except possibly the first one, and possibly the last one following a decimal point. The numeric item is an exact representation of the number $i.10^{-n}$.

The editing and de-editing procedures are oriented towards "fixed field" text manipulation.

Example:

```
text Tr, type, amount, price, payment;
integer pay, total;
Tr :- blanks (80); type :- Tr.sub (1,10);
amount :- Tr.sub(20,5); price :- Tr.sub (30,6);
payment :- Tr.sub (60,10);
.....
if type.strip = "order" then
begin pay := amount.getint × price.getfrac;
      total := total + pay;
      payment.putfrac (pay,2)
end
```

11. Input-Output

The semantics of certain I/O facilities will rely on the intuitive notion of "files" ("data sets"), which are collections of data external to the program and organized in a sequential or addressable manner. We shall speak of a "sequential file" or a "direct file" according to the method of organization.

Examples of sequential files are:

- a batch of cards
- a series of printed lines
- input from a keyboard
- data on a tape

An example of a direct file is a collection of data items on a drum, or a disc, with each item identified by a unique index.

The individual logical unit in a file will be called an "image". Each "image" is an ordered sequence of characters.

I/O facilities are introduced through block prefixing. For the purpose of this presentation, this collection of facilities will be described by a class called "BASICIO". The class is not explicitly available in any users program.

The program acts as if it were enclosed in the following block:

```
BASICIO (n) begin
                inspect SYSIN do
                inspect SYSOUT do
                <program>
            end
```

where n is an integer constant representing the length of a printed line as defined for the particular implementation.

Within the definition of the I/O semantics, identifiers in CAPITAL LETTERS represent quantities which are not accessible in a user program. A series of dots is used to indicate that actual coding is either found elsewhere, described informally, or implementation defined.

The overall organization of "BASICIO" is as follows:

```
class BASICIO (LINELENGTH); integer LINELENGTH;
   begin ref (infile) SYSIN;
         ref (infile) procedure sysin;
                      sysin :- SYSIN;
         ref (printfile) SYSOUT;
         ref (printfile) procedure sysout;
                         sysout :- SYSOUT;
         class FILE ...................;
         FILE class infile ...........;
         FILE class outfile ..........;
         FILE class directfile .......;
         outfile class printfile .....;

         SYSIN :- new infile ("SYSIN");
         SYSOUT :- new printfile ("SYSOUT");
         SYSIN.open (blanks(80));
         SYSOUT.open(blanks(LINELENGTH));
         inner;
         SYSIN.close;
         SYSOUT.close;
    end BASICIO;
```

The integer "LINELENGTH" represents the implementation defined number of characters in a printed line.

"SYSIN" and "SYSOUT" represent a card-oriented standard input unit and a printer-oriented standard output unit. A program may refer to the corresponding file objects through "sysin" and "sysout" respectively. Most attributes of these file objects are directly available as a result of the implied connection blocks enclosing the program.

The files "SYSIN" and "SYSOUT" will be opened and closed within "BASICIO", i.e. outside the program itself.

11.1 The class "FILE"

11.1.1 Definition

```
class FILE(NAME,.....); value NAME; text NAME; .....
    virtual: procedure open, close;
    begin text image;
            Boolean OPEN;
            procedure setpos(i); integer i;
                      image.setpos(i);
            integer procedure pos;
                      pos := image.pos;
            Boolean procedure more;
                      more := image.more;
            integer procedure length;
                      length := image.length;
      ..........
    end FILE;
```

11.1.2 Semantics

Within a program, an object of a subclass of "FILE" is used to represent a file. The following four types are predefined:

"infile" representing a sequential file where input operations (transfer of data from file to program) are available.

"outfile" representing a sequential file where output operations (transfer of data from program to file) are available.

"directfile" representing a direct file with facilities for both input and output.

"printfile" (a subclass of outfile) representing a sequential file with certain facilities oriented towards line printers.

An implementation may restrict, in any way, the use of these classes for prefixing or block prefixing. System defined subclasses may, however, be provided in an implementation.

Each FILE object has a text attribute "NAME". It is assumed that this text value identifies an external file which, through an implementation defined mechanism, remains associated with the FILE object. The effect of several file objects representing the same (external) file is implementation defined.

The variable "image" is used to reference a text value which acts as a "buffer", in the sense that it contains the external file image currently being processed. An implementation may require that "image", at the time of an input or output of an image, refers to a whole text object.

The procedures "setpos", "pos", "more" and "length" are introduced for reasons of convenience.

A file is either "open" or "closed", as indicated by the variable "OPEN". Input or output of images may only take place on an open file. A file is initially closed (except SYSIN and SYSOUT as seen from the program).

The procedures "open" and "close" perform the opening and closing operations on a file. Since the procedures are virtual quantities, they may be redefined completely (i.e. at all access levels) for objects belonging to special purpose subclasses of infile, outfile, etc.

These procedures will be implementation defined, but they must conform to the following pattern.

```
procedure open (T,....); text T; .....
begin if OPEN then ERROR;
      OPEN := true;
      image :- T;
      .........
end open;

procedure close (....); .....
begin
      OPEN := false;
      ............
      image :- notext
end close;
```

The procedures may have additional parameters and additional effects.

11.2 The class "infile"

11.2.1 Definition

```
FILE class infile; virtual: Boolean procedure endfile;
                            procedure inimage;
begin procedure open ...;
                    begin ....;
                      ENDFILE := false;
                      image := notext;
                      setpos(length+1)
                    end open;
      procedure close .....;
                    begin ....;
                      ENDFILE := true
                    end;
      Boolean ENDFILE;
      Boolean procedure endfile; endfile := ENDFILE;
      procedure inimage;
                    begin
                      if ENDFILE then ERROR;
                      .....;
                      setpos(1)
                    end;
      character procedure inchar;
                    begin if ¬ more then
                            begin inimage; if ENDFILE then ERROR
                            end;
                            inchar := image.getchar
                    end inchar;
      Boolean procedure lastitem;
                  begin
                  L:  if ENDFILE then lastitem := true else
                      begin
                      M: if ¬ more then
                           begin inimage;
                             go to L;
                           end;
                           if inchar = '_' then go to M else
                                                setpos(pos-1);
                      end;
                end lastitem;
```

```
integer procedure inint;
    begin text T;
        if lastitem then ERROR;
        T :- image.sub(pos,length-pos+1);
        inint := T.getint;
        setpos(pos+T.pos-1)
    end inint;
real procedure inreal; .......;
integer procedure infrac; .......;
text procedure intext(w); integer w;
    begin text T; integer m;
        T :- blanks (w);
        for m := 1 step 1 until w do
            T.putchar(inchar);
        intext :- T;
    end intext;
.....; ENDFILE := true; ....
end infile;
```

11.2.2. Semantics

An object of the class "infile" is used to represent a sequentially organized input file.

The procedure "inimage" performs the transfer of an external file image into the text "image". A run time error occurs if the text is notext or is too short to contain the external image. If it is longer than the external image, the latter is left adjusted and the remainder of the text is blank filled. The position indicator is set to one.

If an "end of file" is encountered, an implementation defined text value is assigned to the text "image" and the variable "ENDFILE" is given the value true. A call on "inimage" when ENDFILE has the value true is a run time error.

The procedure "open" will give ENDFILE the value false and set "image" to blanks. Otherwise it conforms to the pattern of section 11.1.2.

The procedure "endfile" gives access to the value of the variable ENDFILE.

The remaining procedures provide mechanisms for "item oriented" input, which treat the file as a "continuous" stream of characters with a "position indicator" (pos) which is relative to the first character of the current image.

The procedure "inchar" gives access to and scans past the next character.

If the remainder of the file contains one or more non-blank characters, "lastitem" has the value false, and the position indicator of the file is set to the first non-blank character.

The procedures "inreal" and "infrac" are defined in terms of the corresponding de-editing procedures of "image". Otherwise the definition of either procedure is analogous to that of "inint". These three procedures will scan past and convert a numeric item containing the first non-blank character and contained in one image, excepting an arbitrary number of leading blanks.

The expression "intext(n)" where n is a non-negative integer is a reference to a new text of length n containing the next n characters of the file. "pos" is moved to the following character.

The procedures "inchar" and "intext" may both give access to the contents of the image which corresponds to an "end of file".

Example:

The following piece of program will input a matrix by columns. It is assumed that consecutive elements are separated by blanks or contained in different images. The last element of each column should be followed immediately by an asterisk.

```
begin array a[1:n,1:m] integer i,j;
      procedure error; ......;
      for j := 1 step 1 until m do
      begin for i := 1 step 1 until n-1 do
            begin a[i,j] := inreal;
            if (if sysin.more then inchar ≠ '_' else false)
            then error
            end;
            a[n,j] := inreal;
            if inchar ≠ '*' then error;
next: end;.....;
end
```

11.3 The class "outfile"

11.3.1 Definition

```
FILE class outfile; virtual: procedure outimage;
begin procedure open .......;
                  begin ......; setpos(1); end;
      procedure close .....;
                  begin ...;
                        if pos ≠ 1 then outimage;
                  end close;
      procedure outimage;
                  begin if ¬ OPEN then ERROR;
                        .....;
                        image := notext;
                        setpos(1)
                  end outimage;
      procedure outchar(c); character c;
                  begin if ¬ more then outimage;
                        image.putchar(c)
                  end outchar;
```

```
        text procedure FIELD(w); integer w;
            begin if w ≤ 0 ∨ w > length then ERROR;
                  if pos + w - 1 > length then outimage;
                  FIELD :- image.sub(pos,w);
                  setpos(pos+w)
            end FIELD;
        procedure outint(i,w); integer i,w;
            FIELD(w).putint(i);
        procedure outfix(r,n,w); real r; integer n,w;
            FIELD(w).putfix(r,n);
        procedure outreal(r,n,w); real r; integer n,w;
            FIELD(w).putreal(r,n);
        procedure outfrac(i,n,w); integer i,n,w;
            FIELD(w).putfrac(i,n);
        procedure outtext(T); value T; text T;
            FIELD(T.length) := T;
        .....
    end  outfile;
```

11.3.2 Semantics

An object of the class "outfile" is used to represent a sequentially organized output file.

The transfer of an image from the text "image" to the file is performed by the procedure "outimage". The procedure will react in an implementation defined way if the image length is not appropriate for the external file. The text is cleared to blanks and the position indicator is set to 1, after the transfer.

The procedure "close" will call "outimage" once if the position indicator is different from 1. Otherwise it conforms to the pattern of section 11.1.2.

The procedure "outchar" treats the file as a "continuous" stream of characters.

The remaining procedures provide facilities for "item-oriented" output. Each item is edited into a subtext of "image", whose first character is the one identified by the position indicator of "image", and of a specified width. The position indicator is advanced by a corresponding amount. If an item would extend beyond the last character of "image", the procedure "outimage" is called implicitly prior to the editing operation.

The procedures "outint", "outfix", "outreal" and "outfrac" are defined in terms of the corresponding editing procedures of "image". They have an additional integer parameter which specifies the width of the subtext into which the item will be edited.

For the procedure "outtext", the item width is equal to the length of the text parameter. Notice that this parameter is called by value, which means that a text value is an acceptable actual parameter of "outtext".

11.4 The class "directfile"

Note: The definition of "directfile" is presently under study by a Technical Committee appointed by the SIMULA Standards Group.

11.4.1 Definition

```
FILE class directfile; virtual: Boolean procedure endfile;
                               procedure locate,inimage,outimage;
begin integer LOC;
      integer procedure location; location := LOC;
      procedure locate(i); integer i;
        begin if ¬OPEN then ERROR;
                 .....;
                 LOC := i
        end locate;
      procedure open .....;
        begin
                 .......;
                 setpos(1);
                 locate(1);
        end open;
      procedure close .....;
      Boolean procedure endfile; .....;
      procedure inimage;
        begin .....;
                 locate (LOC+1);
                 setpos(1)
        end inimage;
      procedure outimage;
        begin .....;
                 locate (LOC+1);
                 image := notext;
                 setpos(1)
        end outimage;
```

```
        character procedure inchar .....;
        Boolean procedure lastitem .....;
        integer procedure inint ........;
        real procedure inreal ..........;
        integer procedure infrac .......;
        text procedure intext ..........;
        procedure outchar ..............;
        text procedure FIELD ...........;
        procedure outint ...............;
        procedure outfix ...............;
        procedure outreal ..............;
        procedure outfrac ..............;
        procedure outtext ..............;
        .........
    end directfile;
```

11.4.2 Semantics

An object of the class "directfile" is used to represent an external file in which the individual images are addressable by ordinal numbers.

The variable "LOC" normally contains the ordinal number of an external image. The procedure "location" gives access to the current value of LOC. The procedure "locate" may be used to assign a given value to the variable. The assignment may be accompanied by implementation defined checks and possibly by instructions to an external memory device associated with the given file.

The procedure "open" will locate the first image of the file. Otherwise it conforms to the rules of section 11.1.2.

The procedure "endfile" may have the value true only if the current value of LOC does not identify an image of the external file. The procedure is implementation defined.

The procedure "inimage" will transfer into the text "image" a copy of the external image currently identified by the variable LOC, if there is one. Then the value of LOC is increased by one through a "locate" statement. If the file does not contain an image with an ordinal number equal to the value of LOC, the effect of the procedure "inimage" is implementation defined. The procedure is otherwise analogous to that of section 11.2.

The procedure "outimage" will transfer a copy of the text value "image" to the external file, thereby adding to the file an external image whose ordinal number is equal to the current value of LOC. A run time error occurs if the file cannot be made to contain the image. If the file contains another image with the same ordinal number, that image is deleted. The value of LOC is then increased by one through a "locate" statement. The procedure "outimage" is otherwise analogous to that of section 11.3.

The remaining procedures are analogous to the corresponding procedures of section 11.2 and 11.3.

11.5 The class "printfile"

11.5.1 Definition

```
outfile class printfile;
begin integer LINES PER PAGE, SPACING, LINE;
    integer procedure line; line := LINE;
    procedure lines per page (n); integer n;
                LINES PER PAGE := n;
    procedure spacing(n); integer n;
                SPACING := n;
```

```
    procedure eject(n); integer n;
      begin if ¬ OPEN then ERROR;
            if n > LINES PER PAGE then n := 1;
            ...;
            LINE := n;
      end eject;
    procedure open ... ;
       begin ..... ; setpos(1); eject(1)end
    procedure close ... ;
      begin ... ;
            if pos ≠ 1 then outimage;
            SPACING := 1;
            eject (LINES PER PAGE);
            LINES PER PAGE := ... ;
            LINE := 0
      end;
    procedure outimage;
      begin if ¬ OPEN ∨ image == notext then ERROR;
            if LINE > LINES PER PAGE then eject (1);
            comment output the image on the line
                    denoted by LINE;
            LINE := LINE + SPACING;
            image : = notext;
            setpos (1);
       end;
    LINES PER PAGE := ... ;
    SPACING := 1;
end printfile;
```

11.5.2 Semantics

An object of the class "printfile" is used to represent a printer-oriented output file. The class is a subclass of "outfile". A file image represents a line on the printed page.

The variable "LINES PER PAGE" indicates the maximum number of physical lines that will be

printed on each page, including intervening blank lines. An implementation defined value is assigned to the variable at the time of object generation, and when the printfile is closed. The procedure "lines per page" may be used to change the value. If the parameter to "lines per page" is zero, "LINES PER PAGE" is reset to the same implementation defined value as at the time of object generation. The effect is implementation defined if the parameter is less than zero.

The variable "SPACING" represents the value by which the variable "LINE" will be incremented after the next printing operation. The variable is set equal to 1 at the time of object generation and when the printfile is closed. Its value may be changed by the procedure "spacing". A call on the procedure "spacing" with a parameter less than zero or greater than "LINES PER PAGE" constitutes an error. The effect of a parameter to "spacing" which is equal to zero may be defined by an implementation either to mean successive printing operations on the same physical line, or to be an error.

The variable "LINE" indicates the ordinal number of the next line to be printed, provided that no implicit or explicit "eject" statement occurs. Its value is accessible through the procedure "line". Note that the value of "LINE" may be greater than "LINES PER PAGE". The value of "LINE" is zero when the file is not open.

The procedure "eject is used to position to a certain line identified by the parameter, n.

The following cases can be distinguished:

n ≤0: ERROR
n >LINES PER PAGE: Equivalent to eject (1)
n ≤LINE: Position to line number n on the next page
n >LINE: Position to line number n on the current page.

The tests above are performed in the given sequence.

The procedure "outimage" operates according to the rules of section 11.3. In addition, it will update the variable "LINE".

The procedure "open" and "close" conform to the rules of section 11.1. In addition, "open" will position to the top of a page, and "close" will output the current value of "image" if "pos" is different from one and reset "LINE", "SPACING" and "LINES PER PAGE".

12. Random drawing

12.1 Pseudo-random number streams

All random drawing procedures of SIMULA 67 are based on the technique of obtaining "basic drawings" from the uniform distribution in the interval <0,1>.

A basic drawing will replace the value of a specified integer variable, say U, by a new value according to an implementation defined algorithm. As an example, the following algorithm may be suitable for binary computers:

$$U_{i+1} = \text{remainder } ((U_i \times 5^{2p+1}) \div 2^n)$$

where U_i is the i'th value of U, n is an integer related to the size of a computer word and p is a positive integer. It can be proved that, if U_o is a positive odd integer, the same is true for all U_i and the sequence U_o, U_1, U_2, ... is cyclic with period 2^{n-2}. (The last two bits of U remain constant, while the other n-2 take on all possible combinations).

The real numbers $u_i = U_i \times 2^{-n}$ are fractions in the range <0,1>. The sequence u_1, u_2, ... is called a "stream" of pseudo-random numbers, and u_i (i = 1,2, ...) is the result of the i'th basic drawing in the stream U. A stream is completely determined by the initial value U_o of the corresponding integer variable. Nevertheless, it is a "good approximation" to a sequence of truly random drawings.

12.2 Random drawing procedures

The following procedures all perform a random drawing of some kind. Unless it is explicitly stated otherwise, the drawing is effected by means of one single basic drawing, i.e. the procedure has the side effect of advancing the specified stream by one step. The necessary type conversions are effected for the actual parameters, with the exception of the last one. The latter must always be an integer variable specifying a pseudo-random number stream.

1. Boolean procedure draw (a,U); name U; real a;
   integer U;

   The value is true with the probability a, false with the probability 1 - a. It is always true if a ≥ 1 and always false if a ≤ 0.

2. integer procedure randint (a,b,U); name U;
   integer a,b,U;

   The value is one of the integers a, a+1, ..., b-1, b with equal probability. If b < a, the call constitutes an error.

3. real procedure uniform (a,b,U); name U; real a,b;
   integer U;

   The value is uniformly distributed in the interval [a,b>. If b < a, the call constitutes an error.

4. real procedure normal (a,b,U); name U;
   real a,b; integer U;

   The value is normally distributed with mean a and standard deviation b. An approximation formula may be used for the normal distribution function.

(See M. Abramowitz & I. A. Stegun (ed): Handbook of Mathematical Functions, National Bureau of Standard Applied Mathematics Series No. 55, p. 952 and C. Hastings formula (26.2.23) on p. 933.)

5. real procedure negexp (a,U); name U; real a; integer U;

The value is a drawing from the negative exponential distribution with mean 1/a, defined by -ln(u)/a, where u is a basic drawing. This is the same as a random "waiting time" in a Poisson distributed arrival pattern with expected number of arrivals per time unit equal to a.

6. integer procedure Poisson (a,U); name U; real a; integer U;

The value is a drawing from the Poisson distribution with parameter a. It is obtained by n+1 basic drawings, u_i, where n is the function value. n is defined as the smallest non-negative integer for which

$$\prod_{i=0}^{n} u_i < e^{-a}$$

The validity of the formula follows from the equivalent condition

$$\sum_{i=0}^{n} -\ln(u_i)/a > 1$$

where the left hand side is seen to be a sum of "waiting times" drawn from the corresponding negative exponential distribution.

When the parameter a is greater than some implementation defined value, for instance 20.0, the value may be approximated by entier (normal (a,sqrt (a),U)+0.5) or, when this is negative, by zero.

7. real procedure Erlang (a,b,U); name U; integer U; real a,b;

The value is a drawing from the Erlang distribution with mean 1/a and standard deviation $1/(a\sqrt{b})$. It is defined by b basic drawings u_i, if b is an integer value,

$$-\sum_{i=1}^{b} \frac{\ln(u_i)}{ab}$$

and by c+1 basic drawings u_i otherwise, where c is equal to entier (b),

$$-\left(\sum_{i=1}^{c} \frac{\ln(u_i)}{ab}\right) - \left(\frac{(b-c)\ \ln\ (u_{c+1})}{ab}\right)$$

both a and b must be greater than zero.
The last formula represents an approximation.

8. integer procedure discrete (A,U); name U; real array A; integer U;

The one-dimensional array A, augmented by the element 1 to the right, is interpreted as a step function of the subscript, defining a discrete (cumulative) distribution function. The array is assumed to be of type real.

The function value is an integer in the range [lsb, usb+1], where lsb and usb are the lower and upper subscript bounds of the array. It is defined as the smallest i such that A[i]> u, where u is a basic drawing and A [usb+1] = 1.

9. real procedure linear (A,B,U); name U;
real array A,B; integer U;

The value is a drawing from a (cumulative) distribution function F, which is obtained by linear interpolation in a non-equidistant table defined by A and B, such that A[i] = F(B[i]).

It is assumed that A and B are one-dimensional real arrays of the same length, that the first and last elements of A are equal to 0 and 1 respectively and that A[i] $\geq$ A[j] and B [i]> B [j] for i > j. If any of these conditions are not satisfied, the effect is implementation defined.

The steps in the function evaluation are:

1. draw a uniform <0,1> random number, u.

2. determine the lowest value of i, for which A[i-1] $\leq$ u $\leq$ A[i]

3. compute D= A[i] - A[i-1]

4. if D= 0: linear = B[i-1]
if D$\neq$ 0: linear = B[i-1] + $\frac{(B[i] - B[i-1])}{D}$ (u-A[i-1])

10. integer procedure histd (A,U); name U; real array A;
integer U;

The value is an integer in the range [lsb,usb], where lsb and usb are the lower and upper subscript bounds of the one-dimensional array A. The latter is interpreted as a histogram defining the relative frequencies of the values.

13. Utility procedures

The following procedure is defined:

```
procedure histo (A,B,c,d); real array A,B; real c,d;
```

It will update a histogram defined by the one-dimensional arrays A and B according to the observation c with the weight d. A[lba+i] is increased by d, where i is the smallest integer such that c $\leq$ B[lbb+i]and lba and lbb are the lower bounds of A and B respectively. If the length of A is not one greater than that of B the effect is implementation defined. The last element of A corresponds to those observations which are greater than all elements of B.

14. System classes

Two additional system-defined classes are available:

class SIMSET; .....;

and

SIMSET class SIMULATION; .....;

The class SIMSET introduces list processing facilities corresponding to the "set" concept of SIMULA I [2]. The class SIMULATION further defines facilities analogous to the "process" concept and sequencing facilities of SIMULA I.

The two classes are available for prefixing or block prefixing at any block level of a program. Such a prefix or block prefix will act as if an appropriate declaration of the system class were part of the block head of the smallest block enclosing the first textual occurrence of the class. An implementation may restrict the number of block levels at which such prefixes or block prefixes may occur in any one program.

In the following definitions, identifiers in capital letters, except "SIMSET" and "SIMULATION", represent quantities not accessible to the user. A series of dots is used to indicate that the actual coding is found in another section.

14.1 The class "SIMSET"

The class "SIMSET" contains facilities for the manipulation of circular two-way lists, called "sets".

14.1.1 General structure

14.1.1.1 Definition

```
class SIMSET;
   begin class linkage; .......;
      linkage class head ; ......;
      linkage class link; ......;
   end SIMSET;
```

14.1.1.2 Semantics

The reference variables and procedures necessary for set handling are introduced in standard classes declared within the class "SIMSET". Using these classes as prefixes, their relevant data and other properties are made parts of the objects themselves.

Both sets and objects which may acquire set membership have references to a successor and a predecessor. Consequently they are made subclasses of the "linkage" class.

The sets are represented by objects belonging to a subclass "head" of "linkage". Objects which may be set members belong to subclasses of "link" which is itself another subclass of "linkage".

14.1.2 The class "linkage"

14.1.2.1 Definition

```
class linkage;
   begin ref (linkage) SUC, PRED;

         ref (link) procedure suc;
             suc :- if SUC in link then SUC
                                   else none;

         ref (link) procedure pred;
              pred :- if PRED in link then PRED
                                      else none;
   end linkage;
```

14.1.2.2 Semantics

The class "linkage" is the common denominator for "set heads" and "set members".

"SUC" is a reference to the successor of this linkage object in the set, "PRED" is a reference to the predecessor.

The value of "SUC" and "PRED" may be obtained through the procedures "suc" and "pred". These procedures will give the value "none" if the designated object is not a "set" member, i.e. of class "link" or a subclass of "link".

The attributes "SUC" and "PRED" may only be modified through the use of procedures defined within "link" and "head". This protects the user against certain kinds of programming errors.

14.1.3 The class "link"

14.1.3.1 Definition

```
linkage class link;
   begin procedure out;
      if SUC =/= none then
         begin SUC.PRED :- PRED;
               PRED.SUC :- SUC;
               SUC :- PRED :- none
         end out;

      procedure follow(X); ref (linkage)X;
      begin out;
         if X =/= none then
            begin if X.SUC =/= none then
               begin PRED :- X;
                     SUC :- X.SUC;
                     SUC.PRED :- X.SUC :-
                        this linkage
               end
            end
      end follow;

      procedure precede(X); ref (linkage)X;
         begin out;
            if X =/= none then
               begin if X.SUC =/= none then
                  begin SUC :- X;
                        PRED :- X.PRED;
                        PRED.SUC :- X.PRED :-
                           this linkage
                  end
               end
         end precede;
```

```
procedure into(S); ref (head)S;
          precede (S);
end link;
```

14.1.3.2 Semantics

Objects belonging to subclasses of the class "link" may acquire set membership. An object may only be a member of one set at a given instant.

In addition to the procedures "suc" and "pred", there are four procedures associated with each "link" object: "out", "follow", "precede" and "into".

The procedure "out" will remove the object from the set (if any) of which it is a member. The procedure call will have no effect if the object has no set membership.

The procedures "follow" and "precede" will remove the object from the set (if any) of which it is a member and insert it in a set at a given position. The set and the position are indicated by a parameter which is inner to "linkage". The procedure call will have the same effect as "out" (except for possible side effects from evaluation of the parameter) if the parameter is "none" or if it has no set membership and is not a set head. Otherwise the object will be inserted immediately after ("follow") or before ("precede") the "linkage" object designated by the parameter.

The procedure "into" will remove the object from the set (if any) of which it is a member and insert it as the last member of the set designated by the parameter. The procedure call will have the same effect as "out" if the parameter has the value "none" (except for possible side effects from evaluation of the actual parameter).

14.1.4 The class "head"

14.1.4.1 Definition

```
linkage class head;
   begin ref (link) procedure first; first :- suc;

         ref (link) procedure last; last :- pred;

         Boolean procedure empty;
               empty := SUC == this linkage;

         integer procedure cardinal;
               begin integer I; ref (linkage)X;
                     X :- this linkage;
                     for X :- X.suc while X =/= none do
                           I := I+1;
                     cardinal := I
               end cardinal;

         procedure clear;
               begin ref (link)X;
                     for X :- first while X =/= none do X.o
               end clear;
         SUC :- PRED :- this linkage
   end head;
```

14.1.4.2 Semantics

An object of the class "head", or a subclass of "head" is used to represent a set. "head" objects may not acquire set membership. Thus, a unique "head" is defined for each set.

The procedure "first" may be used to obtain a reference to the first member of the set, while the procedure "last" may be used to obtain a reference to the last member.

The Boolean procedure "empty" will give the value true only if the set has no members.

The integer procedure "cardinal" may be used to count the number of members in a set.

The procedure "clear" may be used to remove all members from the set.

The references "SUC" and "PRED" will initially point to the "head" itself, which thereby represents an empty set.

14.2 The class "SIMULATION"

The system class "SIMULATION" may be considered an "application package" oriented towards simulation problems. It has the class "SIMSET" as prefix, and set-handling facilities are thus immediately available.

The definition of "SIMULATION" which follows is only one of many possible schemes of organization of the class. An implementation may choose any other scheme which is equivalent from the point of view of any user's program.

In the following sections the concepts defined in SIMULATION are explained with respect to a prefixed block, whose prefix part is an instance of the body of SIMULATION or of a subclass. The prefixed block will act as the main program of a quasi-parallel system which may represent a "discrete-event" simulation model.

14.2.1 General structure

14.2.1.1 Definition

```
SIMSET class SIMULATION;
begin link class EVENT NOTICE(EVTIME,PROC);
          real EVTIME; ref(process)PROC;
      begin ref(EVENT NOTICE) procedure suc;
            suc :- if SUC is EVENT NOTICE then SUC
                                          else none;

          ref(EVENT NOTICE) procedure pred;
              pred :- PRED;

          procedure RANK(BEFORE); Boolean BEFORE;
          begin ref (EVENT NOTICE)P;
                P :- SQS.last;
                for P :- P while P.EVTIME > EVTIME do
                              P :- P.pred;
                if BEFORE then begin
                for P :- P while P.EVTIME = EVTIME do
                              P :- P.pred end;
                follow(P)
          end RANK;
      end EVENT NOTICE;
      link class process;
      begin ref (EVENT NOTICE)EVENT; ..... end process;
      ref (head) SQS;
```

```
        ref (EVENT NOTICE) procedure FIRSTEV;
            FIRSTEV :- SQS.first;

        ref (process) procedure current;
            current :- FIRSTEV.PROC;

        real procedure time; time := FIRSTEV.EVTIME;

        procedure hold .....;
        procedure passivate .....;
        procedure wait .....;
        procedure cancel .....;
        procedure ACTIVATE .....;
        procedure accum .....;
        process class MAIN PROGRAM .....;
        ref (MAIN PROGRAM) main;

        SQS :- new head;
        main :- new MAIN PROGRAM;
        main.EVENT :- new EVENT NOTICE (0,main);
        main.EVENT.into(SQS)
    end SIMULATION;
```

14.2.1.2 Semantics

When used as a prefix to a block or a class, "SIMULATION" introduces simulation-oriented features through the class "process" and associated procedures.

The variable "SQS" refers to a "set" which is called the "sequencing set", and serves to represent the system time axis. The members of the sequencing set are event notices ranked according

to increasing values of the attribute "EVTIME". An event notice refers through its attribute "PROC" to a "process" object, and represents an event which is the next active phase of that object, scheduled to take place at system time EVTIME. There may be at most one event notice referencing any given process object.

The event notice at the "lower" end of the sequencing set refers to the currently active process object. The object can be referenced through the procedure "current". The value of EVTIME for this event notice is identified as the current value of system time. It may be accessed through the procedure "time".

14.2.2 The class "process"

14.2.2.1 Definition

```
link class process;
begin ref (EVENT NOTICE)EVENT;
      Boolean TERMINATED;

      Boolean procedure idle; idle := EVENT == none;

      Boolean procedure terminated;
         terminated := TERMINATED;

      real procedure evtime;
         if idle then ERROR
                 else evtime := EVENT.EVTIME;

      ref (process) procedure nextev;
         nextev :- if idle then none else
                   if EVENT.suc == none then none
                   else EVENT.suc.PROC;
```

```
        detach;
        inner;
        TERMINATED := true;
        passivate;
        ERROR
    end process;
```

14.2.2.2 Semantics

An object of a class prefixed by "process" will be called a process object. A process object has the properties of "link" and, in addition, the capability to be represented in the sequencing set and to be manipulated by certain sequencing statements which may modify its "process state". The possible process states are: active, suspended, passive and terminated.

When a process object is generated it immediately becomes detached, its LSC positioned in front of the first statement of its user-defined operation rule. The process object remains detached throughout its dynamic scope.

The procedure "idle" has the value true if the process object is not currently represented in the sequencing set. It is said to be in the passive or terminated state depending on the value of the procedure "terminated". An idle process object is passive if its LSC is at a user defined prefix level. When the LSC passes through the final end of the user-defined part of the body, it proceeds to the final operations at the prefix level of the class "process", and the value of the procedure "terminated" becomes true. (Although the process state "terminated" is not strictly equivalent to the corresponding basic concept defined in section 9, an implementation may treat a terminated process object as

terminated in the strict sense). A process object currently represented in the sequencing set is said to be "suspended", except if it is represented by the event notice at the lower end of the sequencing set. In the latter case it is active. A suspended process is scheduled to become active at the system time indicated by the attribute EVTIME of its event notice. This time value may be accessed through the procedure "evtime". The procedure "nextev" will reference the process object, if any, represented by the next event notice in the sequencing set.

14.2.3 Activation statements

14.2.3.1 Syntax

```
<activator> ::= activate|
                reactivate
<activation clause> ::= <activator><object expression>
<simple timing clause> ::=
                at <arithmetic expression>|
                delay <arithmetic expression>
<timing clause> ::= <simple timing clause>|
                    <simple timing clause> prior
<scheduling clause> ::= <empty>|
                        <timing clause>|
                        before <object expression>|
                        after <object expression>
<activation statement> ::= <activation clause>
                           <scheduling clause>
```

14.2.3.2 Semantics

An activation statement is only valid within an object of a class included in SIMULATION, or within a prefixed block whose prefix part is such an object.

The effect of an activation statement is defined as being that of a call on the sequencing procedure "ACTIVATE" local to SIMULATION.

```
procedure ACTIVATE(REAC,X,CODE,T,Y,PRIOR);
    value CODE; ref(process)X,Y; Boolean REAC,PRIOR;
    text CODE; real T;
```

The actual parameter list is determined from the form of the activation statement, by the following rules.

1. The actual parameter corresponding to "REAC" is true if the activator is reactivate, false otherwise.

2. The actual parameter corresponding to "X" is the object expression of the activation clause.

3. The actual parameter corresponding to "T" is the arithmetic expression of the simple timing clause if present, otherwise it is zero.

4. The actual parameter corresponding to "PRIOR" is true if prior is in the timing clause false if it is not used or there is no timing clause.

5. The actual parameter corresponding to "Y" is the object expression of the scheduling clause if present, otherwise it is none.

6. The actual parameter corresponding to "CODE" is defined from the scheduling clause as follows:

scheduling clause	actual parameter
empty	"direct"
at arithmetic expression	"at"
delay arithmetic expression	"delay"
before object expression	"before"
after object expression	"after"

14.2.4 Sequencing procedures

14.2.4.1 Definitions

```
procedure hold(T); real T;
   inspect FIRSTEV do
   begin if T > 0 then EVTIME := EVTIME + T;
         if suc =/= none then
         begin if suc. EVTIME < EVTIME then
               begin out; RANK (false);
                     resume(current)
               end
         end
   end hold;

procedure passivate;
   begin inspect current do
         begin EVENT.out; EVENT :- none end;
         if SQS.empty then ERROR
                      else resume (current)
   end passivate;

procedure wait(S); ref (head)S;
   begin current.into(S); passivate end wait;

procedure cancel(X); ref (process)X;
   if X == current then passivate else
   inspect X do if EVENT =/= none then
      begin EVENT.out; EVENT :- none end cancel;
```

```
procedure ACTIVATE(REAC,X,CODE,T,Y,PRIOR); value CODE;
   ref (process)X,Y; Boolean REAC,PRIOR; text CODE;
                                          real T;
   inspect X do if ¬ TERMINATED then
   begin ref (process)Z; ref (EVENT NOTICE)EV;
         if REAC then EV :- EVENT
         else if EVENT =/= none then go to exit;
         Z :- current;
         if CODE = "direct" then
direct:  begin EVENT :- new EVENT NOTICE (time,X);
                EVENT.precede(FIRSTEV)
         end direct
         else if CODE = "delay" then
         begin T := T + time; go to at end delay
         else if CODE = "at" then
at:      begin if T < time then T := time;
                if T = time ∧ PRIOR then go to direct;
         EVENT :- new EVENT NOTICE(T,X);
         EVENT.RANK(PRIOR)
         end at
   else if (if Y == none then true else Y.EVENT == none)
   then EVENT :- none else
   begin if X == Y then go to exit;
         comment reactivate X before/after X;
         EVENT :- new EVENT NOTICE (Y.EVENT.EVTIME,X);
         if CODE = "before" then EVENT.precede(Y.EVENT)
                            else EVENT.follow(Y.EVENT)
   end before or after;
   if EV =/= none then
   begin EV.out; if SQS.empty then ERROR end;
   if Z =/= current then resume (current);
exit: end ACTIVATE;
```

14.2.4.2 Semantics

The sequencing procedures serve to organize the quasi-parallel operation of process objects in a simulation model. Explicit use of the basic sequencing facilities (detach,resume) should be avoided within SIMULATION blocks.

The statement "hold(T)", where T is a real number greater than or equal to zero, will halt the active phase of the currently active process object, and schedule its next active phase at the system time "time + T". The statement thus represents an inactive period of duration T. During the inactive period the LSC stays within the "hold" statement. The process object becomes suspended.

The statement "passivate" will stop the active phase of the currently active process object and delete its event notice. The process object becomes passive. Its next active phase must be scheduled from outside the process object. The statement thus represents an inactive period of indefinite duration. The LSC of the process object remains within the "passivate" statement.

The procedure "wait" will include the currently active process object in a referenced set, and then call the procedure "passivate".

The statement "cancel(X)", where X is a reference to a process object, will delete the corresponding event notice, if any. If the process object is currently active or suspended, it becomes passive. Otherwise the statement has no effect. The statement "cancel(current)" is equivalent to "passivate".

The procedure "ACTIVATE" represents an activation statement, as described in section 14.2.3. The effects of a call on the procedure are described in terms of the

corresponding activation statement. The purpose of an activation statement is to schedule an active phase of a process object.

Let X be the value of the object expression of the activation clause. If the activator is activate the statement will have no effect (beyond that of evaluating its constituent expressions) unless the X is a passive process object. If the activator is reactivate and X is a suspended or active process object, the corresponding event notice is deleted (after the subsequent scheduling operation) and, in the latter case, the current active phase is terminated. The statement otherwise operates as an activate statement.

The scheduling takes place by generating an event notice for X and inserting it in the sequencing set. The type of scheduling is determined by the scheduling clause.

An empty scheduling clause indicates direct activation, whereby an active phase of X is initiated immediately. The event notice is inserted in front of the one currently at the lower end of the sequencing set and X becomes active. The system time remains unchanged. The formerly active process object becomes suspended.

A timing clause may be used to specify the system time of the scheduled active phase. The clause "delay T", where T is an arithmetic expression, is equivalent to "at time + T". The event notice is inserted into the sequencing set using the specified system time as ranking criterion. It is normally inserted after any event notice with the same system time; the symbol "prior" may, however, be used to specify insertion in front of any event notice with the same system time.

Let Y be a reference to an active or suspended process object. Then the clause "before Y" or "after Y" may be used to insert the event notice in a position defined relation to (before or after) the event notice of Y. The generated event notice is given the same system time as that of Y. If Y is not an active or suspended process object, no scheduling will take place.

Example:

The statements

```
activate X
activate X before current
activate X delay 0 prior
activate X at time prior
```

are equivalent. They all specify direct activation.

The statement

```
reactivate current delay T
```

is equivalent to "hold(T)".

14.2.5 The main program

14.2.5.1 Definition

```
process class MAIN PROGRAM;
begin L:  detach; go to L end MAIN PROGRAM;
```

14.2.5.2 Semantics

It is desirable that the main program of a simulation model, i.e. the SIMULATION block instance, should respond to the sequencing procedures of section 14.2.4 as if it were itself a process object. This is accomplished by having a process object of the class "MAIN PROGRAM" as a permanent component of the quasi-parallel system.

The process object will represent the main program with respect to the sequencing procedures. Whenever it becomes operative, the PSC (and OSC) will immediately enter the main program as a result of the "detach" statement (cf. section 9.2.1). The procedure "current" will reference this process object whenever the main program is active.

A simulation model is initialized by generating the MAIN PROGRAM object and scheduling an active phase for it at system time zero. Then the PSC proceeds to the first user-defined statement of the SIMULATION block.

14.2.6 Utility procedures

14.2.6.1 Definition

```
procedure accum (a,b,c,d); name a,b,c;
          real a,b,c,d;
begin a := a + c  × (time - b);
      b := time; c := c + d
end accum;
```

14.2.6.2 Semantics

A statement of the form "accum (A,B,C,D)" may be used to accumulate the "system time integral" of the variable C, interpreted as a step function of system time. The integral is accumulated in the variable A. The variable B contains the system time at which the variables were last updated. The value of D is the current increment of the step function.

15. Separate compilation

If an implementation permits user-defined procedure and class declarations to be separately compiled, then a program should have means of making reference to such declarations as external to the program.

The following additional declarations are recommended as an optional part of the Common Base.

15.1 Syntax

```
<external item> ::= <external identifier>|
                    <identifier> = <external identifier>
<external list> ::= <external item>|
                    <external list>,<external item>
<external declaration> ::=
        external procedure <external list>|
        external <type> procedure <external list>|
        external  class <external list>
```

15.2 Semantics

An external identifier is an identification with respect to an "operating system" of a separately compiled declaration.

An external item introduces a local identifier for such a declaration. The local identifier may or may not be identical to the corresponding external identifier.

An external declaration represents a copy of each of the separately compiled procedures or class declarations identified by its external list. Each copy is modified by replacing occurrences of the original procedure or class identifier by occurrences of the given local identifier.

16. Common Base restrictions

The following language restrictions are part of the SIMULA 67 Common Base.

1) System defined procedures may not be transmitted as parameters.

2) Only <type> parameters may be called by name.

3) An arithmetic assignment statement must conform to the rules of ALGOL 60.

4) A class should be defined textually before all its subclasses.

5) In the hardware representation of the language, there should be at least one space between a colon and a minus sign in an array declaration.

Restriction 1 may be relevant in order to obtain maximum efficiency in implementations of system defined procedures. Restrictions 2 and 3 may simplify the extension of existing ALGOL 60 implementations Restriction 4 is relevant in order to make one-pass compilation possible.

17. Recommended extensions

The extensions given in this section are recommended for inclusion in SIMULA Common Base implementations by the SIMULA Standards Group.

17.1 While statement

17.1.1 Syntax

```
<statement> ::= <Common Base statement>|<while statement>
<conditional statement>
            ::= <Common Base conditional statement>|
                <if clause><while statement>
<while statement>
            ::= while <Boolean expression> do <statement>|
                <label>:<while statement>
```

17.1.2 Semantics

A while statement causes a statement to be executed zero or more times.

The Boolean expression is evaluated. When true, the statement following do is executed and control returns to the beginning of the while statement for a new test of the Boolean expression.

When the expression is false, control passes to after the while statement.

17.2 "prev"

The following procedure is recommended to be local to the class "linkage":

```
ref(linkage) procedure prev;
             prev :- PRED;
```

The procedure enables a user to access a set head from its first member.

18. Features being investigated

The SIMULA Standards Group appoint a Technical Committee to study features needing clarification or which may possibly be new recommended extensions.

The following features are currently being investigated:

- For statements in which the controlled variable is a variable called by name, procedure identifier, subscripted variable or remote identifier.
- class directfile
- reference parameters
- the procedure "call"
- syntax of blocks and statements
- syntax of conditional expressions
- hardware representation standards

A closer description of these features is given in [4] and [5].

19. References

1 P. Naur (Ed.): Revised Report on the Algorithmic Language ALGOL 60. CACM., vol. 6, No. 1, 1963, pp 1-17.

2 O-J. Dahl, K. Nygaard: "SIMULA - A Language for Programming and Description of Discrete Event Systems. Introduction and User's Manual." Norwegian Computing Center, Oslo.

3 C.A.R. Hoare: "Record Handling." Lectures delivered at the NATO Summer School, Villard-de-Lans, September 1966 (Academic Press.)

4. Proposals circulated to Standards Group Members before the Annual Meeting in May 1970.

5. "Minutes from Annual Meeting of SIMULA Standards Group May 1970"
Publication No. S-18, July 1970, Norwegian Computing Center, Oslo.

20. Alphabetic index of syntactical units

For each syntactical unit, the section of definition is given. AR indicates that the definition is found in the "revised" ALGOL report [1]. The numbers of the sections in this document where the syntactical unit is referenced, are indicated in parentheses. A reference in the same section as the definition is not indicated. The metalanguage brackets < and > have been removed from the syntactic units.

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