Algorithms

J. WEGSTEIN, Editor

ALGORITHM 154
COMBINATION IN LEXICOGRAPHICAL ORDER

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```
procedure COMB1 (n,r,I); integer n, r; integer array I;
comment The distinct combinations of the first n integers
   taken r at a time are generated in I in lexicographical order
   starting with an initial combination of the r integers 1, 2, ··· ,
   r. Each call of the procedure, after the first, must have in I
   the previous generated combination. The Boolean variable
   first is nonlocal to COMB1 and must be true before the first call.
   Thereafter first remains false until all combinations have been
   generated. When calling COMB1 with I containing n − r + 1,
   n − r + 2, ··· , n, I is left unchanged and first is set true;
begin integer s, j;
  if first then begin for j := 1 step 1 until r do
    I[j] := j;
    first := false;  go to EXIT end;
  begin if I[r] < n then begin I[r] := I[r] + 1;  go to EXIT
         end;
    for j := r step −1 until 2 do
      if I[j−1] < n − r + j − 1 then
        begin I[j−1] := I[j−1] + 1;
          for s := j step 1 until r do
            I[s] := I[j−1] + s − (j−1);  go to EXIT end end;
  first := true;
EXIT : end
```

ALGORITHM 155
COMBINATION IN ANY ORDER

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```
procedure COMB2 (m,M,n,r,s,S,TOTAL); integer array m,
          M, S; integer n, r, s,TOTAL;
comment Each call of COMB2 generates a distinct combina-
   tion S, (if possible) of the n integer values of J taken r (r>1)
   at a time if J consists of m[1] integers each equal to M[1], and
   m[2] integers each equal to M[2], and so on, there being s integers
   available. TOTAL must be set to zero before the first call of
   COMB2 and thereafter TOTAL is increased by one after each
   new combination is generated. To speed up the machine opera-
   tion arrange the s integers in M such that m[1] ≧ m[2] ≧ ··· ≧
   m[s];
begin integer i, j, t, p;  own integer array J[1:n], I[1:r];  own
Boolean first;
  if TOTAL = 0 then begin
    t := 1;  p := 0;
    for j := 1 step 1 until s do
      begin p := p + m[j];
        for i := t step 1 until p do
          begin J[i] := M[j];
            t := t + 1 end end;
              first := true end;
  1:  COMB1 (n,r,I);
      if first then go to EXIT;
        if I[1] = 1 then go to 2 else go to 3;
  2:  for j := 2 step 1 until r do
      if (J[I[j]]=J[I[j]−1]) ∧ (I[j]>I[j−1]+1) then go to 1;
        go to 4;
  3:  if J[I[1]] = J[I[1]−1] then go to 1 else go to 2;
  4:  for j := 1 step 1 until r do
        S[j] := J[I[j]];
      TOTAL := TOTAL + 1;
EXIT:  end
```

ALGORITHM 156
ALGEBRA OF SETS

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```
procedure INOUT (A,n,SUM); real array A; integer n;
          real SUM;
comment SUM = Σ1 Ai − Σ2 AiAj + Σ3 AiAjAk − ··· ±
   A1A2 ··· An is formed where the symbols Σ1 , Σ2 , Σ3 , ··· ,
   Σn−1 stand for summation of the possible combinations of the
   numbers A1 , A2 , ··· , An taken one, two, three, ··· , (n−1)
   at a time;
   begin real j, part, T;  integer i, r;  integer array I[1:n];
   Boolean first;
     r := SUM := 0;  j := − 1;
   B:  first := true;  r := r + 1;  part := 0;
   A:  COMB1 (n,r,I);
         if first then begin j := −1 × j;  part := j × part;
           SUM := SUM + part;
           if r < n then go to B else go to EXIT end;
         T := 1;
         for i := 1 step 1 until r do
           T := A[I[i]] × T;
         part := part + T;  go to A;
EXIT:  end
```

ALGORITHM 157
FOURIER SERIES APPROXIMATION

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```
procedure FOURIER (N,f,a,b);  real array f, a, b;  integer N;
comment Fourier determines 2N+1 constants ap (p=0,1,···,N),
   bp (p=1,2,···,N) in such a way that the equations fn = 1/2ao +
   Σ(p=1..N) (ap cos 2πnp/(2N+1) + bp sin 2πnp/(2N+1)) are satisfied,
   where the fn are given numbers. The fn may be thought of as the
   2N+1 values of a function f(x) at the points xn = 2πn/(2N+1).
   The method used to generate ap , bp was formulated by G.
   Goertzel in "Mathematical Methods for Digital Computers"
   (John Wiley and Sons, Inc., 1960);
begin real array S, C[1:2], u[0:2];  real TEMP, pi;
  integer p, i;
  pi := 3.14159265;  C[2] := 1;  S[2] := 0;
  C[1] := cos(2×pi/(2×N+1));
  S[1] := sin(2×pi/(2×N+1));
  for p := 0 step 1 until N do
    begin u[1] := u[2] := 0;
      for i := 2 × N step −1 until 1 do
        begin u[0] := f[i] + 2 × C[2] × u[1] − u[2];
          u[2] := u[1];  u[1] := u[0]end;
    a[p] := 2/(2×N+1) × (f[0]+u[1]×C[2]−u[2]);
    b[p] := 2/(2×N+1) × u[1] × S[2];
    TEMP := C[1] × C[2] − S[1] × S[2];
    S[2] := C[1] × S[2] + S[1] × C[2];
    C[2] := TEMP end end
```

ALGORITHM 158 (ALGORITHM 134, REVISED) EXPONENTIATION OF SERIES

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```
procedure SERIESPWR (A,B,P,N); value A, P, N;
            array A, B; integer N;
comment This procedure calculates the first N coefficients
  B[i] of the series g(x) = f(x) ↑ P given the first N coefficients
  of the series

        f(x) = 1 + ∑ A[i] × x ↑ i     (i=1,2,−,−,N).

  P may be any real number. Setting P := 0 gives the coefficients
    for LN(g(x));
  begin integer i, k;
  real P, S;
    if P = 0 then B[1] = A[1];
else B[1] := P × A[1];
  for i := 2 step 1 until N do
  begin S := 0;
    for k := 1 step 1 until i − 1 do
    S := S + (P×(N−k)−k) × B[k] × A[N−k];
    B[i] := P × A[i] + (S/i)
      end for i;
end  SERIESPWR
```

ALGORITHM 159 DETERMINANT

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```
real procedure Determinant (X,n);
value n; integer n; array X;
comment Determinant calculates the determinant of the n-by-
  n square matrix X, using the combinatorial definition of the
  determinant. This algorithm is intended as an example of a
  recursive procedure which is somewhat less trivial than Factorial
  (Algorithm 33);
begin real D; integer i; Boolean array B[1:n];
  procedure Thread (P,e,i);
    value P, e, i; real P; integer e, i;
    if i > n then D := D + P × (−1) ↑ e else if P ≠ 0 then
      begin integer j, f;
        f := 0;
        for j := n step −1 until 1 do
          if B[j] then f := f + 1 else
            begin
              B[j] := true;
              Thread (P×X[i,j],e+f,i+1);
              B[j] := false;
            end of loop;
        end of Thread;
  for i := 1 step 1 until n do
    B[i] := false;
  D := 0;
  Thread (1,0,1);
  Determinant := D;
end Determinant;
```

CERTIFICATION OF ALGORITHM 79 DIFFERENCE EXPRESSION COEFFICIENTS

[Thomas Giamo, *Comm. ACM*, Feb. 1962]

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The procedure was translated into FORTRAN and run on the CDC 1604. Reasonable accuracy was obtained for $k = 0, 4 \leqq n \leqq 12$. For increasing n and increasing k, the accuracy diminished. It was found that the execution time increased rapidly as n was increased. For $k = 0$, the following results were obtained:

n	*Approximate Number of Machine Operations*
4	1.3×10^3
6	6.9×10^3
8	3.8×10^4
10	1.8×10^5
12	8.6×10^5

The author indicated in a letter that the procedure was developed for use with small n and small k.

CERTIFICATION OF ALGORITHM 96 ANCESTOR [Robert W. Floyd, *Comm. ACM*, June, 1962]

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* Work supported by the U.S. Atomic Energy Commission

The body of this procedure was tested on the LGP-30 using the Dartmouth translator. After inclosing conditional statements in **begin end** brackets (apparently necessary for this translator), the procedure operated satisfactorily for the following matrices:

n=5, Time: 8′15″

FTTFF		FTTTT
FFFFT		FFFFT
FFFTF	→	FFFTT
FFFFT		FFFFT
FFFFF		FFFFF

$n = 6$, Time: 13′15″

FTTFFF		FTTTTT
FFFTFF		FFFTFT
FFFFTF	→	FFFTFT
FFFFFT		FFFFFT
FFFFFF		FFFFFF

$n = 9$, Time 31′2″

FTTFFFFFF		FTTTTTTTT
FFFFTFFFF		FFFFTTTTF
FFFTTFFFF		FFFTTTTTT
FFFFFFFFT		FFFFFTTTT
FFFFFTTFF	→	FFFFFTTTF
FFFFFFFTF		FFFFFFFTF
FFFFFFFTF		FFFFFFFTF
FFFFFFFFF		FFFFFFFFF
FFFFFTTFF		FFFFFTTTF

The correctness of these results was confirmed by inspection of the network diagrams.

CERTIFICATIONS OF ALGORITHMS 117 and 118 MAGIC SQUARE (ODD AND EVEN ORDERS)

[D. M. Collison, *Comm. ACM*, Aug. 1962]

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The statement within the **Booleon procedure** *beta* should be changed from

$x[r,a]$:= **if** h **then** $[nn-a\times n+r)$ **else** $(a\times n+1-r)$;

to

$x[r,a]$:= **if** h **then** $(nn-a\times n+r)$ **else** $(a\times n+1-r)$;

The procedures were then tested on magic squares of order 3 to 17 inclusive without fault.

REMARK ON ALGORITHM 133 RANDOM [Peter G. Behrenz, *Comm. ACM 11*, Nov. 1962]

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Algorithm 133 was translated into Fortran II for the IBM 1620 and run successfully. The starting value was changed to 21 348 759 609 and significant results followed.

For $N = 500$ and 1000, the resulting values were: 0.4990157688, 0.4986269653 and 0.3318717863, 0.3290401482.

Note on the Proof of the Non-existence of a Phrase Structure Grammar for ALGOL 60

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The proof of the non-existence of a phrase structure grammar for Algol 60 by Robert W. Floyd [*Comm. ACM 5* (Sept. 1962)] depends on the assumption that a syntactically correct Algol program must be a block. The concept of "program" is defined ambiguously in the Algol Report, as pointed out by Naur [1], but it is generally accepted that a program is defined as a self-contained statement. If this definition is taken, Floyd's proof becomes incomplete in that it ignores the fact that the following are syntactically correct Algol programs:

(1) **begin**; **end**
(2) **begin end**
(3) ⟨dummy statement⟩

The proof can be easily extended to include these cases. Writing (as in the notation of Floyd's proof) P_i as the concatenation of the strings $QR^{(i)}ST^{(i)}U$ and taking P_i as the string

begin real $x^{(n)}$; $x^{(n)} := x^{(n)}$ **end**

it is apparent that if P_0 is the string

begin; **end**

then Q is the string **begin**
R " " " **real** $x^{(n)}$
S " " " ;
T " " " $x^{(n)} := x^{(n)}$
U " " " **end**

and thus it follows that P_2 is the string

begin real $x^{(n)}$ **real** $x^{(n)}$; $x^{(n)} := x^{(2n)} := x^{(n)}$ **end**

which is not a syntactically correct program.

If P_0 is the string

begin end

then since S cannot be a null string (it is defined as a proper substring of RST), S must be either the string

begin

or the string

end.

In either case, Q, R, T and U can be derived and it follows that P_2 is not a syntactically correct program.

Lastly, it is obvious that P_0 cannot be the null string since S cannot be null. Hence P_0 cannot be any of the substrings of P_1 that are programs but not blocks.

A further small point about the proof might be worthy of note. The assumption that all variables must be declared implies that the version of Algol being considered contains no standard functions (such as carriage return, *pi*). This latter assumption can be made without loss of generality.

REFERENCE

1. Naur, P. Remark concerning the Definition of a Program. ALGOL Bulletin No. 10.