A GENERALIZED COMPUTER PROGRAM IN FORTRAN IV FOR LISTING ALL POSSIBLE COLOR BAND PERMUTATIONS

By K. W. Duncan

INTRODUCTION

In any study program involving banding birds in such a way that each bird can be identified by its unique color band combination, an essential stage is to list all possible permutations of colors. Such a listing can be difficult and laborious to work out when a large number of bands are to be used on each bird. To reduce the laboı, recourse may be made to computer programs, such as that written by Buckley and Hancock (1968) for an IBM 1620. However, general programs capable of handling a wide variety of problems do not seem to be available in FORTRAN IV for IBM 360 computers. The

Table 1. The number of permutations of n colors taken r at a time with an aluminum band inserted into each sequence and treated as a color. This table gives solutions for the number of color bands (n) from two to 20 and for the number of color bands used on each bird (r) from one to five.

Number of colors in set (n)	Number of colors used on each bird (r)				
	1	2	3	4	5
2	4	12			
3	6	27			
4	8	48	256	1280	
5	10	75	500	3125	18750
6	12	108	864	6480	46656
7	14	147	1372	12005	100842
8	16	192	2048	20480	196608
9	18	243	2916	32805	354294
10	20	300	4000	50000	600000
11	22	363	5324	73205	966306
12	24	432	6912	103680	1492992
13	26	507	8788	142805	2227758
14	28	588	10976	192080	3226944
15	30	675	13500	253125	4556250
16	32	768	16384	327680	6291456
17	34	867	19652	417605	8519142
18	36	972	23328	524880	11337408
19	38	1083	24736	651605	14856594
20	40	1200	32000	800000	19200000

FORTRAN IV program given below has been developed for use by people with virtually no computing experience.

THE NUMBER OF PERMUTATIONS

Solutions for the maximum number of permutations of n colors taken r at a time, each sequence having an aluminum band treated as a color, have been given by Buckley and Hancock for up to 15 colors taken two and three at a time. Table 1 extends this, giving solutions for up to 20 colors taken between one and five at a time.

TABLE 2. THE TOTAL NUMBER OF PERMUTATIONS OF n COLORS TAKEN r AT A TIME EXCLUDING THOSE PERMUTATIONS WITH IDENTICAL ADJACENT COLORS AND WITH AN ALUMINUM BAND INSERTED INTO EACH SEQUENCE. THIS TABLE GIVES SOLUTIONS FOR THE NUMBER OF COLOR BANDS (n) FROM TWO TO 20 AND FOR THE NUMBER USED ON EACH BIRD (r) FROM TWO TO FIVE.

Number of colors in set (n)	Number of colors used on each bird (r)			
	2	3	4	5
2	6			
3	18	48		
4	36	144	540	
5	60	320	1600	7680
6	90	600	3750	22500
7	126	1008	7560	54432
8	168	1568	13720	115248
9	216	2304	23040	221184
10	270	3240	36450	393660
11	330	4400	55000	660000
12	396	5808	79860	1054152
13	468	7488	112320	1617408
14	546	9464	153790	2399124
15	630	11760	205800	3457440
16	720	14400	270000	4860000
17	816	17408	348160	6684672
18	918	20808	442170	9020268
19	1026	24624	554040	11967264
20	1140	28880	685900	15638520

Experience suggests that it is often advisable to avoid having two identical colors as adjacent bands since this leads to errors when inspecting birds from a distance. If such errors are likely to occur, all permutations which have adjacent bands of the same color should be excluded from the list of permutations used in the study. For instance, RED RED BLACK would not be a permitted permutation because, from a distance, it might be difficult to decide whether this is a two-band or a three-band combination. Note, however, that non-adjacent but repeated permutations such as RED BLACK RED are acceptable as these do not present any difficulty in determining the number of bands.

The formula which gives the total number of permutations of n colors taken r at a time, with an aluminum band inserted at the beginning, in between, or at the end of the series of color bands, and with all permutations having adjacent identical colors excluded is:

$$P = (r + 1).n.(n - 1)^{r-1}$$

Table 2 gives solutions for the total number of permutations using this equation.

The computer program allows the user to specify whether all possible permutations are to be listed or only the restricted set in which permutations having adjacent bands with identical colors are excluded. It also allows the user to specify both how many bands he will use on a bird and the list of colors he wishes to use. Some observers are blue-green color blind and, if so, the user-specified list can exclude either green or blue or both.

THE PROGRAM

The computer program is fully generalized, printing out either all permutations or a selected set of permutations, of a user-specified number of colors drawn from a user-specified set of colors. Between two and five colors may be drawn from the set giving, when the aluminum band is included, a total of between three and six bands per bird. The set may have between two and twenty non-repeated colors.

The program will solve more than one problem following compilation, if so desired. To make it as machine-independent as possible, the FORTRAN used avoids sophisticated but machine-dependent features. The minimum requirement for this program (on a 360/44) is 3264 bytes of core storage (HICORE - 32901) and the machine should have a line printer, a card reader and a card punch although the latter can be excluded if cards 41, 42, 95 and 96 are removed. Canterbury's IBM 360/44 designates the card reader as '5', the line printer as '6' and the card punch as '7'. Other models in the 360 series use other designations. To make the program compatible with these designations, users of other models need only change the three cards, 13, 14 and 15. Data is fed into the machine on standard 80 column cards. The program will accept multiple data decks (problems) but any one data deck must have the following structure:

Card type 1 Headings

One card per problem. Used to identify the data deck. Anything punched (alphabetic or numeric characters) between columns 1 to 80 on this card will be reproduced in output.

Card type 2 Specifications

One card per problem punched as follows:

Col. 1-5 n, the number of colors to be read in (integer; right-justified).

Col. 6-10 r, the number of colors to be selected (integer; right-justified).

Col. 15 ϕ (zero or blank) if output on cards is not required; 1 if output on cards is required.

Col. 20 ϕ if a list of all permutations (repeats allowed) is required. 1 if a restricted list (excluding identical, adjacent colors) only is required.

Card type 3 Variable format

One card per problem. Include this card *only* if 1 was punched in column 15 of card type 2. In other cases leave out. This card controls the format on the output cards — a suitable card would be (k(A4,1X)) where k = r + 1.

Card type 4 Specified color list

One card per problem. Specify the colors which make up the set. Allow four card columns per color and punch the colors as words, starting in column 1 and continuing for as many columns as are necessary. The total number of colors specified (four column words) must be the same as the first number specified on card type 2.

Card type 5 Termination card

One card per problem. If this is the last problem to be solved, punch a number in column 1 to 5. In other cases, leave this card blank.

SPECIMEN INPUT

```
TEST DATA FOR BANDING PROGRAM
bbb10bbbb3bbbb1bbbb1
(4(A4, 1X) )
REDbGRENYELLBLUEPINKWHITBLCKGREY
   ORANTURQ
bb999
```

OUTPUT

```
   TEST DATA FOR BANDING PROGRAM

 A RESTRICTED LIST OF 3240 PERMUTATIONS WILL BE
PRINTED
   1  ALUM...RED...GREN...RED.....................
   2  RED...ALUM...GREN...RED.....................
   3  RED...GREN...ALUM...RED.....................
   .    .     .     .     .

   .    .     .     .     .
3240  TURQ...ORAN...TURQ...ALUM..................
   END OF SELECTION 1
   END OF RUN
```

Note that the output listing distinguishes between 'full' and 'restricted' sets — the total number of permutations is given for both cases.

The author cannot assume responsibility for the use of the program but, since it has been tested under a wide variety of conditions, little trouble should be experienced by other users. Card decks punched in either BCD or EBCDIC code will be made available on request.

SUMMARY

The table presented by Buckley and Hancock (1968) giving the total number of permutations from a set of color bands drawing two or three bands at a time, has been extended to those cases where four or five bands are drawn at a time. In addition, a table is given of the maximum number of permutations in which those permutations having adjacent, identical colors are rejected.

A generalized computer program is given, written in FORTRAN IV for IBM 360 machines. This program lists all combinations of n color bands taken r at a time where n and r are specified by the user. An aluminum band is automatically included in the listing. The total number of color bands can be from two to 20 according to user option, and the number of bands selected is optionally between two and five. An option is available which rejects all permutations having identical adjacent colors from the output listing. Output is either on the line printer or on the line printer and card punch, according to user option. Object time formats are used to control the output on cards so that these are under the control of the user and may be varied. The minimum core size required for the program is 3264 bytes.

ACKNOWLEDGEMENTS

My thanks are due to J. A. Mills who brought to my attention the need for this program and tested it once it was written. I would also like to thank my wife for reading and criticising the manuscript.

LITERATURE CITED

Buckley, P. A. and J. T. Hancock, Jr. 1968. Equations for estimating and a simple computer program for generating unique color and aluminum band sequences. *Bird-Banding,* **39:** 123-129.

Department of Zoology, University of Canterbury, Private Bag, Christchurch, New Zealand.

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APPENDIX 1 — The program

```
C     BANDING                                                                      BAND0010
C        THIS PROGRAM COMPUTES ALL POSSIBLE COMBINATIONS OF COLOURED BANDS          BAND0020
C        TAKEN UP TO 5 AT A TIME FROM A TOTAL OF UP TO 20 COLOURS.                  BAND0030
C        AN ALUMINIUM BAND IS INSERTED IN EACH COMBINATION.  NO SUBROUTINES         BAND0040
C        ARE REQUIRED                                                               BAND0050
C        K. W. DUNCAN — ZOOLOGY DEPT. UNIV. OF CANTERBURY NEW ZEALAND               BAND0060
C        ********************************************************************** BAND0070
         DIMENSION IB (14), FMT (20), IA (20), HEAD (20), IC (17)                   BAND0080
         INTEGER*4 IA, IB, IC, IAL, HEAD, NOUGHT, FMT, DOT                          BAND0090
         DATA NOUGHT/4H    /, IAL/4HALUM/, DOT/4H.. ./                              BABD0100
C        ********************************************************************** BAND0110
C        CHANGE FOLLOWING CARDS TO SUIT TERMINAL REF. NO.                           BAND0120
         IREAD = 5                                                                  BAND0130
         IPRINT = 6                                                                 BAND0140
         IPUNCH = 7                                                                 BAND0150
C        ********************************************************************** BAND0160
       1 FORMAT (4I5)                                                               BAND0170
       2 FORMAT (20I4)                                                              BAND0180
      13 FORMAT (1H1, 20A4)                                                         BAND0190
      19 FORMAT (1H0, I12, 17 (3H. . . , A4) )                                      BAND0200
      20 FORMAT (18H0END OF SELECTION , I3)                                         BAND0210
      21 FORMAT (11H0END OF RUN)  ............................................ BAND0220
      22 FORMAT (1H0, I2, 41H COLOURS WILL BE SELECTED FROM A LIST OF, I2, 8H C     BAND0230
        1 OLOURS)                                                                   BAND0240
      62 FORMAT (50H1NUMBER OF SELECTIONS GREATER THAN LIST OF COLOURS/             BAND0250
        1 11H TERMINATED)                                                           BAND0260
      61 FORMAT (14H0FULL LIST OF , I8, 29H PERMUTATIONS WILL BE PRINTED)           BAND0270
      82 FORMAT (20 H0RESTRICTED LIST OF , I8, 29H PERMUTATIONS WILL BE PRINTED     BAND0280
        1)                                                                          BAND0290
     801 FORMAT (58H0NUMBER SPECIFIED TO BE SELECTED OUTSIDE PERMISSIBLE RAN        BAND0300
        1 GE/15H0RUN TERMINATED)                                                    BAND0310
C        ********************************************************************** BAND0320
         NUM = 0                                                                    BAND0330
     900 NUM = NUM + 1                                                              BAND0340
         ICOUNT = 0                                                                 BAND0350
         READ (IREAD, 2, END = 999) HEAD                                            BAND0360
         READ (IREAD, 1) NCOL, NSEL, IOPT, IRJ                                      BAND0370
         IF (NSEL-NCOL) 60, 60, 61                                                  BAND0380
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61   WRITE (IPRINT, 62)                                  BAND0390
     STOP                                                BAND0400
60   IF (IOPT) 3, 3, 4                                   BAND0410
 4   READ (IREAD, 2) FMT                                 BAND0420
 3   READ (IREAD, 2) (IA(I), I = 1, NCOL)                BAND0430
     NTOT = NSEL*2 + 1                                   BAND0440
     WRITE (IPRINT, 13) HEAD                             BAND0450
     WRITE (IPRINT, 22) NSEL, NCOL                       BAND0460
     IF (IRJ) 70, 70, 80                                 BAND0470
70   IPP = (NSEL + 1)*NCOL**NSEL                         BAND0480
     WRITE (IPRINT, 81) IPP                              BAND0490
     GO TO 83                                            BAND0500
80   IPP = (NSEL + 1)*NCOL*( (NCOL-1)**(NSEL-1))         BAND0510
     WRITE (IPRINT, 82) IPP                              BAND0520
83   DO 6 I = 1, 11                                      BAND0530
 6   IB (I) = NOUGHT                                     BAND0540
     I1 = 0                                              BAND0550
     I2 = 0                                              BAND0560
     I3 = 0                                              BAND0570
     I4 = 0                                              BAND0580
     I5 = 0                                              BAND0590
17   I1 = I1 + 1                                         BAND0600
     IB(2) = IA(I1)                                      BAND0610
16   I2 = I2 + 1                                         BAND0620
     IF (IRJ) 15, 15, 14                                 BAND0630
14   IF (I2-I1) 15, 38, 15                               BAND0640
15   IB (4) = IA (I2)                                    BAND0650
     IF (NSEL-2) 800, 11, 439                            BAND0660
439  I3 = I3 + 1                                         BAND0670
     IF (IRJ) 23, 23, 24                                 BAND0680
24   IF (I3-I2) 23, 39, 23                               BAND0690
23   IB (6) = IA (I3)                                    BAND0700
     IF (NSEL-3) 11, 11, 25                              BAND0710
25   I4 = I4 + 1                                         BAND0720
     IF (IRJ) 26, 26, 27                                 BAND0730
27   IF (I4-I3) 26, 43, 26                               BAND0740
26   IB (8) = IA (I4)                                    BAND0750
     IF (NSEL-4) 11, 11, 28                              BAND0760
28   I5 = I5 + 1                                         BAND0770
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      IF (IRJ) 29, 29, 37                                    BAND0780
37    IF (I5-I4) 29, 44, 29                                  BAND0790
29    IB (10) = IA (I5)                                      BAND0800
      IF (NSEL-5) 11, 11, 800                                BAND0810
11    DO 100 K = 1, NTOT, 2                                  BAND0820
      IB (K) = IAL                                           BAND0830
      M = 0                                                  BAND0840
      DO 40 I = 1, NTOT                                      BAND0850
      IF (IB(I)-NOUGHT) 41, 40, 41                           BAND0860
41    M = M + 1                                              BAND0870
      IC (M) = IB (I)                                        BAND0880
40    CONTINUE                                               BAND0890
      ICOUNT = ICOUNT + 1                                    BAND0900
      MO = M + 1                                             BAND0910
      DO 42 JJ = MO, 17                                      BAND0920
42    IC (JJ) = DOT                                          BAND0930
      WRITE (IPRINT, 19) ICOUNT, (IC (JJ), JJ = 1, 17)       BAND0940
      IF (IOPT) 100, 100, 8                                  BAND0950
8     WRITE (IPUNCH, FMT) (IC(J), J = 1, M)                  BAND0960
100   IB (K) = NOUGHT                                        BAND0970
10    GO TO (800, 38, 39, 43, 44, 800), NSEL                 BAND0980
44    IF (I5-NCOL) 28, 43, 43                                BAND0990
43    I5 = 0                                                 BAND1000
      IF (I4-NCOL) 25, 39, 39                                BAND1010
39    I4 = 0                                                 BAND1020
      IF (I3-NCOL) 439, 38, 38                               BAND1030
38    I3 = 0                                                 BAND1040
      IF (I2-NCOL) 16, 45, 45                                BAND1050
45    I2 = 0                                                 BAND1060
      IF (I1 - NCOL) 17, 46, 46                              BAND1070
46    WRITE (IPRINT, 20) NUM                                 BAND1080
      READ (IREAD, 1) IP                                     BAND1090
      IF (IP) 900, 900, 999                                  BAND1100
999   WRITE (IPRINT, 21)                                     BAND1110
      STOP                                                   BAND1120
800   WRITE (IPRINT, 801)                                    BAND1130
      STOP                                                   BAND1140
      END                                                    BAND1150
```

APPENDIX 2

Adaptation to basic Fortran-IV

The following program modifications are required for computers with a basic FORTRAN-IV compiler:

1. Replace card 9 with:
   INTEGER HEAD, DOT
2. Remove card 10.
3. Insert the following card between cards 35 and 36:
   READ (IREAD, 2) IAL, DOT, NOUGHT
4. Replace card 36 with:
   READ (IREAD, 2) (HEAD(I), I = 1,20)
5. Remove cards 41 and 42 and replace with:
   60 CONTINUE
6. Replace card 96 with:
   8 WRITE (IPUNCH, 2) (IC(J), J = 1,M)
7. The first card in the data deck must be punched as follows:
   ALUM. . . .

   This card is in addition to the other data cards described earlier.

The author thanks the staff of the Computer Centre of the University of Otago for their help and cooperation in testing this version on their IBM-360/30.

RED-WINGED BLACKBIRDS WINTERING IN A DECOY TRAP

By Harold E. Burtt and Maurice L. Giltz

We have operated a large decoy trap on the University Farm in Columbus, Ohio, since 1963. It is a common occurrence for a banded bird to re-enter the trap, i.e., "repeat" many times in the course of a few weeks (Burtt and Giltz 1970a). Such behavior in winter is infrequent. However, we had 15 Cowbirds (*Molothrus ater*) "winter" in the trap in 1965-66. A similar phenomenon with Redwings (*Agelaius phoeniceus*) in the winter of 1970-71 is reported herewith. There was little snowfall until early February and we were able to operate the trap daily.