Patuxent Wildlife Research Center

CONTRAST - A general program for the analysis of several survival or recovery rate estimates.

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Introduction

Several statistical procedures have recently become available for the estimation of rates of survival and recovery from banding and band recovery data for animal populations (e.g., White 1983, Conroy and Williams 1984, Brownie et al. 1985). In spite of the sophistication of these models, there has been comparatively little discussion regarding tests for multiple comparisons of these rates, and the standard method remains the z-test discussed by Brownie et al. (1985). Sauer and Williams (1989) recently described a general procedure for the comparison of several rate estimates that incorporates associated variance and covariance estimates. The method requires matrix multiplication and inversion, which may limit its use among biologists.

In this user's manual, we describe a computer program to implement the methods of Sauer and Williams (1989). We also provide some guidelines for its use in multiple comparisons of rate data, and illustrate the use of the program with several examples. We discuss the method and its application using survival rates (denoted by the symbol s), as we believe that the program will be used primarily for the analysis of survival rates. However, the method can be used for tests about any rates (or other parameters) for which estimates and their associated variances and covariances are available.

An expanded version of this user's manual (Hines and Sauer 1989) can be obtained from the authors.

Multiple comparisons of rate estimates

Brownie et al. (1985) discussed a z test for comparison of survival rates, which tests a simple hypothesis of form:

Ho: $c_1s_1 + c_2s_2 + c_3s_3 + \ldots + c_ns_n = 0$,

where the $c_1, c_2, \ldots, c_n$ comprise a contrast., a series of constants with the constraint that the sum of the $c_i = 0$. Most commonly, the c_i are used to categorize the survival rates into 2 groups, which then are tested using a z-test. If the null hypothesis is true, z is asymptotically a standard normal variate and critical values can be found in many statistical texts (e.g., Snedecor and Cochran 1980).

The z-test is widely applicable to a variety of hypotheses, in that simple contrasts can be used to specify groupings of survival rates. However, it is more difficult to specify the contrasts for composite hypotheses, such as a test for differences among >2 groups of survival rates. The z test is limited to separate tests defined by the selection of a single contrast. Composite hypothesis of form:

Ho : $s_1 = s_2 = s_3 = \ldots = s_n$,

with n > 2, cannot be specified by a single contrast. To test this composite hypothesis, Sauer and Williams (1989) suggested an asymptotically chi-square quadratic form.

For the composite hypothesis, the null hypothesis is rejected with probability if the observed chi-square is greater than a tabular critical value of chi-square with degrees of freedom determined by the choice of the contrast matrix C (for the simple hypothesis, df = n - 1) and significance level alpha.

Computation of the Contrast Matrix C

The hypothesis to be tested is determined by the structure of matrix C. In general, C is composed of n - 1 algebraically independent rows (i.e., it is of full rank), each of which specifies a contrast. To test the hypothesis (3), we use a matrix of dimension n - 1 x n with elements:

$c_{i,j}$ = 1 - 1/n for i = j,

= - 1/n for i not= j.

In the above, each row of the matrix is a contrast that defines a simple hypothesis to compare the survival rate corresponding to element (1 - 1/n) to all other survival rates (corresponding to elements -1/n). However, any grouping of contrasts can be used to form the rows of C, and the same computed value for the chi-square test will be produced, as long as C is a full-rank matrix. If the overall hypothesis is rejected, at least one of the survival rates differ from the others.

In general, we can also test any simple hypothesis using the chi-square test. The c's can be used to group the survival rates into 2 categories, which can then be tested using the chi-square test with C = [c_1, c_2 , . . . , c_n]. Note that the C used in this test is a vector (i.e., it only contains 1 row). The resulting chi-square is tested using df = 1. The matrix C therefore can be used to test both simple hypotheses and composite hypotheses, that require several constrasts to specify. In CONTRAST, we provide the option of defining a single contrast, and also allow specification of groupings of >2 mean survival rates for testing of composite hypotheses.

In Analysis of Variance procedures, there are many a-priori and a-posteriori methods of specifying which group means differ from the remaining means (Snedecor and Cochran 1980, Neter and Wasserman 1974). Many of these methods use contrasts to place the means into groups for testing for differences as in simple hypotheses. In the case of survival rates, we also use contrasts to construct simple hypothesis tests, and we here provide some quidelines for multiple comparisons of survival rates after the overall hypothesis (3) is rejected.

A-priori Tests:

As in ANOVA-based multiple comparison tests, it is often of interest to examine additional simple or composite hypothesis that were defined before the overall test was conducted. Although CONTRAST can be used to specify any combination of contrasts, it is important to note that, for a-priori tests of simple hypotheses to be independent, the contrasts to be tested must be orthogonal. If the contrasts are not orthogonal, the Chi-square value for the composite test based upon the 2 contrasts will not be equal to the sum of the Chi-square values from the separate tests. If the contrasts are orthogonal, however, the composite Chi-square can be partitioned into the Chi-square values of the simple hypotheses.

A-posteriori Tests:

It is often the case that "unplanned" comparisons become necessary after the original test is conducted. While these tests are legitimate to conduct, some sort of adjustment of the alpha levels is necessary to maintain the overall level of experimentwise error (Neter and Wasserman 1974). We use the Bonferroni approach of using alpha/m as the significance level for the unplanned comparisons, where m is the number of contrasts tested. We leave it to the user to appropriately modify significance levels for both unplanned comparisons and one-sided tests.

Program specifications

CONTRAST was written on an IBM PS/2 using the Ryan McFarland FORTRAN compiler (and the 8087 emulator library), so the math coprocessor is not required. The program should run on all IBM-PC compatible computers. The program currently is set up to compare up to 50 survival rates, and takes up less than 256K of memory. However, the size of the program depends upon the maximum number of survival rates. For those who have a FORTRAN77 compiler, the maximum number of survival rates can be decreased or increased by changing all occurrences of 'IDIM=50' to 'IDIM=XX' in the source code, where XX is the desired number of survival rates.

Use of the Program

As an introduction to the use of the program, we will present the responses to a simple application. We want to first test the null hypothesis that 3 survival rates are equal, then test the hypothesis that the first survival rate is equal to the mean of the second and third survival rates.

Sample Data:

```
S' = [ 0.25  0.30  0.35 ]
 =  [   0.0002500        0            0        ]
    [         0          0.000625     0        ]
    [         0          0            0.000100 ]    .
```

For the overall Chi-square:

```
C = [    2/3    - 1/3     - 1/3   ]
    [  - 1/3      2/3     - 1/3   ]
```

Chi-square = 6.80, 2 degrees of freedom (reject Ho, $P < 0.035$).

For the test of Ho: $s_1 = (s_2 + s_3)/2$:

```
C = [2  -1  -1]
```

Chi-square = 2.08, 1 degree of freedom (do not reject H_o, $P > 0.14$).

Responses and data to be entered are enclosed by carrots <>. The right carrot indicates use of the return (or enter) key. Comments are delimited by pound (#) symbols.

To run the program, enter the name CONTRAST at the prompt. It will respond with:

```
Program CONTRAST [07/17/89]
   Tests hypotheses about survival or recovery rates.
   Method: See Sauer & Williams (1989) Generalized
           Procedures For Testing Hypotheses About
           Survival Or Recovery Rates., J. Wildl.
           Manage. 53:137-142.

   Results from this program will be saved in a file
   called CONTRAST.OUT.  If the survival rates and
```

```
   variance-covariance matrix are entered via the
   keyboard, they will be saved in a file called
   CONTRAST.TMP.  This file may be used as input to
   CONTRAST in later runs.

Enter input filename("CON" for keyboard input):<CON>

    #If a filename was entered at this line, the program  #
    #would have taken all later data input and any        #
    #additional input (e.g., contrasts) from the file.    #
    #After all data are read from this input file, the    #
    #program reverts to interactive input.                #
    #Sample input file for this example:                  #
    #EXAMPLE DATA                                         #
    #3                                                    #
    #2                                                    #
    #.25                                                  #
    #.30                                                  #
    #.35                                                  #
    #.0025                                                #
    #0,.000625                                            #
    #0,0,.0001                                            #
    #1                                                    #
    #1,2,2                                                #
    #2                                                    #
    #2,-1,-1                                              #

Enter title to identify contrast:
:<EXAMPLE DATA>
Enter number of survival rates(N):<3>

Enter 1 if you will be entering standard errors,
   or 2 if you will be entering the variance-covariance matrix.

#Here is sample input for choice 1.#

Choice (1 or 2):<1>
Enter S,SE(          1):<.25,.05>
Enter S,SE(          2):<.30,.025>
Enter S,SE(          3):<.35,.01>

#Here is sample input for choice 2.#

Choice (1 or 2):<2>

ENTER S(          1):<.25>
ENTER S(          2):<.30>
ENTER S(          3):<.35>

Since the variance-covariance matrix is symmetric, only the lower left half
needs to be entered.
 ie.  var(S1)
      cov(S2,S1)  var(S2)
      cov(S3,S1)  cov(S3,S2)  var(S3) ...

Enter row      1 of the variance-covariance matrix (          1 values):
?<.0025>
Enter row      2 of the variance-covariance matrix (          2 values):
?<0,.000625>
Enter row      3 of the variance-covariance matrix (          3 values):
?<0,0,.0001>

#The program then prints the data and the results for the overall test.#

Survival rates and variance-covariance matrix will be
```

saved in a file called CONTRAST.TMP (which can be used
as input to later runs of CONTRAST).

EXAMPLE DATA

```
Null Hypothesis: Homogeneous survival rates


Survival rates:
   0.2500   0.3000   0.3500

============== Variance-covariance matrix ===========

 0.002500

 0.000000 0.000625

 0.000000 0.000000 0.000100

                        CHI-SQUARE VALUE   =     6.8000
                        DEGREES OF FREEDOM =     2
                        PROBABILITY        =     0.0334
```

#The program then prompts for additional analyses.#

#In our example, we are comparing S(1) with S(2) and S(3).#

```
Would you like to

  1) compare survival rates with 2 or more groups
  2) enter a contrast vector to compare 2 groups of survival rates
  3) start a new problem
  4) quit

#To compare means directly, enter a 1.#

Enter 1,2,3, or 4:<1>

To compare 2 or more groups of survival rates, you must specify which
group each survival rate belongs to. When prompted for group number, enter
0 for survival rates not in the contrast, 1 for survival rates in the first
group, 2 for survival rates in the 2nd group, ...etc.

Enter a group number for each survival rate(          3 values)
?<1, 2, 2>

#The program then prints out the results for the 2 groups.#

Input group numbers:
   1  2  2

Survival rates:           #Means for the 2 groups.#
   0.2500   0.3250

 Difference between survival rates =    0.0750

============= Variance-covariance matrix ===========

 0.002500

 0.000000 0.000181

                        CHI-SQUARE VALUE   =     2.0979
                        DEGREES OF FREEDOM =     1
                        PROBABILITY        =     0.1475

#The program then prompts for the next comparison.#

Would you like to

  1) compare survival rates with 2 or more groups
```

```
  2) enter a contrast vector to compare 2 groups of survival rates
  3) start a new problem
  4) quit

Enter 1,2,3, or 4:<2>

#The same comparison can be accomplished using a contrast.#

To contrast survival rates, you must specify which survival rates are to be
compared.  To compare S(i) with S(j), enter -1 in the ith position of the
contrast vector and 1 in the jth position of the contrast vector.  For
example to compare S(2) with S(3), enter 0,-1,1 as the contrast vector.
Make sure you enter 0 in the positions which are not included in the
contrast.

Enter contrast vector (or Q to quit):<2,-1,-1>

Input contrast vector:
   2.000 -1.000 -1.000

Scaled contrast vector:
   2.000 -1.000 -1.000

Survival rates:
   0.2500   0.3250

 Difference between survival rates =    0.0750

                        CHI-SQUARE VALUE   =     2.0979
                        DEGREES OF FREEDOM =     1
                        PROBABILITY        =     0.1475

#The program then prompts for additional analyses.#

Would you like to

  1) compare survival rates with 2 or more groups
  2) enter a contrast vector to compare 2 groups of survival rates
  3) start a new problem
  4) quit

Enter 1,2,3, or 4:<4>

#Exit the program by entering a 4.  The program can be restarted by#
#entering a 3.#
```

Examples

These examples are from Sauer and Williams (1989), and illustrate both an example involving independent survival rates and a complex example that has both variances and covariances among survival rates. See Sauer and Williams (1989) for more information about the examples.

Example 1. Survival rates of mallards (From Anderson 1975, cited in Sauer and Williams [1989]).

Input data file:

```
DATA FROM ANDERSON (1975)                    #Header.#
6                                            #Number of survival
rates.#
1                                            #Input format type.#
.766,.076                                    #Survival rate 1, SE.#
.675,.025                                    #Survival rate 2, SE.#
.676,.010                                    #Survival rate 3, SE.#
.758,.099                                    #Survival rate 4, SE.#
.632,.016                                    #Survival rate 5, SE.#
.577,.026                                    #Survival rate 6, SE.#
2                                            #Enter a contrast vector#
-1 1 0 0 0 0                                 #Contrast 1            #
2                                            #Enter a contrast vector#
-0.6 -0.6 0.4 0.4 0.4 0                      #Contrast 2            #
2                                            #Enter a contrast vector#
-0.167 -0.167 -0.167 -0.167 -0.167  0.833   #Contrast 3            #
```

Program Output:

```
 DATA FROM ANDERSON (1975)
```

```
 Null Hypothesis: Homogeneous survival rates


 Survival rates:
    0.7660   0.6750   0.6760   0.7580   0.6320   0.5770

 ============== Variance-covariance matrix ===========

  0.005776

  0.000000 0.000625

  0.000000 0.000000 0.000100

  0.000000 0.000000 0.000000 0.009801

  0.000000 0.000000 0.000000 0.000000 0.000256

  0.000000 0.000000 0.000000 0.000000 0.000000 0.000676

                         CHI-SQUARE VALUE   =    19.0758
                         DEGREES OF FREEDOM =     5
                         PROBABILITY        =     0.0019

#In Sauer and Williams (1989), 3 orthogonal contrasts were tested.#

#Contrast 1.#

 Input contrast vector:
   -1.000  1.000  0.000  0.000  0.000  0.000

 Scaled contrast vector:
   -1.000  1.000  0.000  0.000  0.000  0.000

 Survival rates:
    0.6750   0.7660

  Difference between survival rates =    0.0910

                         CHI-SQUARE VALUE   =     1.2937
                         DEGREES OF FREEDOM =     1
                         PROBABILITY        =     0.2554

#Contrast 2.#

 Input contrast vector:
   -0.600 -0.600  0.400  0.400  0.400  0.000

 Scaled contrast vector:
   -3.000 -3.000  2.000  2.000  2.000  0.000

 Survival rates:
    0.6887   0.7205

  Difference between survival rates =    0.0318

                         CHI-SQUARE VALUE   =     0.3714
                         DEGREES OF FREEDOM =     1
                         PROBABILITY        =     0.5423

#Contrast 3.#

 Input contrast vector:
   -0.167 -0.167 -0.167 -0.167 -0.167  0.833

 Scaled contrast vector:
   -1.000 -1.000 -1.000 -1.000 -1.000  5.000

 Survival rates:
    0.5770   0.7014

  Difference between survival rates =    0.1244

                         CHI-SQUARE VALUE   =    11.5633
                         DEGREES OF FREEDOM =     1
                         PROBABILITY        =     0.0007
```

Example 2. Mourning dove data from the Eastern Management Unit (Sauer and Williams 1989).

Input data file:

```
MOURNING DOVE DATA FROM THE EASTERN MANAGEMENT UNIT   #Header.#
8                              #Number of survival rates.#
2                              #Data entry type.#
.3135                          #Survival rate 1.#
.3619                          #Survival rate 2.#
.4677                          #Survival rate 3.#
.3964                          #Survival rate 4.#
.3627                          #Survival rate 5.#
.2589                          #Survival rate 6.#
.1774                          #Survival rate 7.#
.1007                          #Survival rate 8.#
.00714            #Row 1 of lower triangle of Variance-Covariance
matrix.#
-.00168,.00376                      #Row 2 of ".#
0,-.00103,.00523                    #Row 3 of ".#
0,0,-.00237,.00434                  #Row 4 of ".#
.00168,-.00194,0,0,.00425           #Row 5 of ".#
0,.00056,-.00073,0,0,.00190         #Row 6 of ".#
0,0,.00106,-.00090,0,0,.00067       #Row 7 of ".#
0,0,0,.00036,0,0,0,.00031           #Row 8 of ".#
2                                   #Enter a contrast vector.#
1.0 1.0 1.0 1.0 -1.0 -1.0 -1.0 -1.0 #Contrast 1.#
2                                   #Enter a contrast vector.#
-1.0 -1.0 1.0 1.0 0 0 0 0           #Contrast 2.#
2                                   #Enter a contrast vector.#
0 0 0 0 -1.0 -1.0 1.0 1.0           #Contrast 3.#
```

Program output:

```
 MOURNING DOVE DATA FROM THE EASTERN MANAGEMENT UNIT


 Null Hypothesis: Homogeneous survival rates


 Survival rates:
    0.3135   0.3619   0.4677   0.3964   0.3627   0.2589   0.1774   0.1007

 ============== Variance-covariance matrix ===========

  0.007140

 -0.001680 0.003760

  0.000000-0.001030 0.005230

  0.000000 0.000000-0.002370 0.004340

  0.001680-0.001940 0.000000 0.000000 0.004250

  0.000000 0.000560-0.000730 0.000000 0.000000 0.001900

  0.000000 0.000000 0.001060-0.000900 0.000000 0.000000 0.000670

  0.000000 0.000000 0.000000 0.000360 0.000000 0.000000 0.000000 0.000310

                        CHI-SQUARE VALUE   =   180.7535
                        DEGREES OF FREEDOM =     7
                        PROBABILITY        =     0.0000

#In this example, we test 3 non-orthogonal contrasts.#
#Note that the program does not adjust the probability levels for the#
#multiple comparison.                                               #

#Contrast 1.#

 Input contrast vector:
    1.000  1.000  1.000  1.000 -1.000 -1.000 -1.000 -1.000

 Scaled contrast vector:
    4.000  4.000  4.000  4.000 -4.000 -4.000 -4.000 -4.000

 Survival rates:
    0.3849   0.2249
```

```
  Difference between survival rates =    0.1599

                       CHI-SQUARE VALUE   =    23.7163
                       DEGREES OF FREEDOM =     1
                       PROBABILITY        =     0.0000

#Contrast 2.#

 Input contrast vector:
   -1.000 -1.000  1.000  1.000  0.000  0.000  0.000  0.000

 Scaled contrast vector:
   -2.000 -2.000  2.000  2.000  0.000  0.000  0.000  0.000

 Survival rates:
    0.4320   0.3377

  Difference between survival rates =    0.0943

                       CHI-SQUARE VALUE   =     2.4676
                       DEGREES OF FREEDOM =     1
                       PROBABILITY        =     0.1162

#Contrast 3.#

 Input contrast vector:
    0.000  0.000  0.000  0.000 -1.000 -1.000  1.000  1.000

 Scaled contrast vector:
    0.000  0.000  0.000  0.000 -2.000 -2.000  2.000  2.000

 Survival rates:
    0.1391   0.3108

  Difference between survival rates =    0.1718

                       CHI-SQUARE VALUE   =    16.5487
                       DEGREES OF FREEDOM =     1
                       PROBABILITY        =     0.0000
```

Acknowledgments

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SOFTWARE INVENTORY FORM

A. TITLE.

CONTRAST: A program for the analysis of several survival or recovery rate estimates.

B. FUNCTION.

Sauer and Williams (J. Wildl. Manage 53:137-142, 1989) recently described a general procedure for the comparison of several rate estimates that incorporates associated variance and covariance estimates. We describe a computer program to implement this method. We also provide some guidelines for its use in multiple comparisons of rate data, and illustrate the use of the program with several examples. We believe that the program will be used primarily for the analysis of survival rates. However, the method can be used for tests about any rates (or other parameters) for which estimates and their associated variances and covariances are available.

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D. USERS.

X Management X Other (Instructional)

X Research

X Extension

E. SOFTWARE STATUS.

Became operational 1 April 1989

Was last revised 15 August 1989

Revision is anticipated N/A

F. SOFTWARE SOURCE.

X Original

G. TECHNICAL KNOWLEDGE NEEDED TO INTERPRET RESULTS.

Knowledge of basic statistics is necessary.

H. HARDWARE AND SOFTWARE REQUIREMENTS.

1. Machine classification: 1. Micro

(note: program written on micro. May require modification for use on mainframes and minis.)

2. < 256K needed.

3. Operating system is DOS.

I. OTHER TECHNICAL NOTES.

1. Solution technique: See Sauer and Williams (1989, cited above).

2. Other notes: See user documentation.