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A FORTRAN 77 Program and User's Guide for the Statistical Analyses of Scatterplots to Identify Important Factors in Large-Scale Simulations

Michael J. Shortencarier and Jon C. Helton

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A FORTRAN 77 Program and User's Guide for the Statistical Analyses of Scatterplots to Identify Important Factors in Large-Scale Simulations

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Abstract

A description and user's guide are given for a computer program, PATTRN, developed at Sandia National Laboratories for use in sensitivity analyses of complex models. This program is intended for use in the analysis of input-output relationships in Monte Carlo analyses when the input has been selected using random or Latin hypercube sampling. Procedures incorporated into the program are based upon attempts to detect increasingly complex patterns in scatterplots and involve the detection of linear relationships, monotonic relationships, trends in measures of central tendency, trends in measures of variability, and deviations from randomness. The program was designed to be easy to use and portable.

Acknowledgements

The authors would like to express their appreciation to Curt Storlie, a graduate student in the Department of Mathematics at Arizona State University, and to Judy Rollstin and Jim Emery of GRAM, Incorporated for their extensive efforts in the verification, validation, and review of both this document and the computer program described herein. The authors would also like to thank Jack Kleijnen of Tilburg University in The Netherlands and Steve Hora of the University of Hawaii at Hilo for their work in the assembly and development of the algorithms used in the computer program.

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1. INTRODUCTION

This document serves as a user's guide for Version 1.00 of the PATTRN computer program. PATTRN receives two different input data files from two different sources: sampled input variable values generated by a statistical sampling program, and model outputs generated by executing a computer model. PATTRN attempts to identify any relationships that may exist between the input variables and model outputs by performing user-specified statistical tests and calculations and then reporting the results in a user-specified format and structure. A third input file contains the user parameters that specify these calculations and formats.

This user's guide identifies PATTRN's sponsors and its expert consultants (Section 1), describes the code's functions (Section 2), provides recommended user training (Section 3), outlines the code's statistical basis (Section 4), its capabilities and limitations (Section 5), describes user interactions (Section 6), input files (Section 7), error messages (Section 8), output files (Section 9), appropriate references (Section 10), and provides examples of relevant input and output files in its appendices (Section 11). The appendices in Section 11 also contain further descriptions of the statistical basis.

1.1 Software Identifier

Code Name: PATTRN – A program to detect relationships between sampled input variables and computer model outputs.

WIPP Prefix: PTN

Version: 1.00

Platform: FORTRAN 77 for Open VMS, version 7.1, on DEC Alpha.

1.2 Points of Contact

Code Consultant: Mickey Shortencarier
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Code Sponsor: Mickey Shortencarier
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2. FUNCTIONAL REQUIREMENTS

This section contains functional requirements of the PATTRN program. These requirements are:

- R.1 – This code will calculate Partial Correlation Coefficients as described in Kleijnen and Helton (1999).
- R.2 – This code will calculate Partial Rank Correlation Coefficients as described in Kleijnen and Helton (1999).
- R.3 – This code will calculate Standardized Regression Coefficients as described in Kleijnen and Helton (1999).
- R.4 – This code will calculate Standardized Rank Regression Coefficients as described in Kleijnen and Helton (1999).
- R.5 – This code will perform the Correlation Coefficients test as described in Kleijnen and Helton (1999).
- R.6 – This code will perform the Rank Correlation Coefficients test as described in Kleijnen and Helton (1999).
- R.7 – This code will perform the Common Means test as described in Kleijnen and Helton (1999) using either the raw data or natural logarithms for the dependent variable.
- R.8 – This code will perform the Common Locations test as described in Kleijnen and Helton (1999).
- R.9 – This code will perform the Common Medians test as described in Kleijnen and Helton (1999).
- R.10 – This code will perform the Common Variances test as described in Kleijnen and Helton (1999) using either the raw data or natural logarithms for the dependent variable.
- R.11 – This code will perform the Common Interquartiles test as described in Kleijnen and Helton (1999).
- R.12 – This code will perform the Statistical Independence test as described in Kleijnen and Helton (1999).

- R.13 – This code will perform the Friedman test as described in Appendix C.
- R.14 – This code will perform the Differences of Ranks test as described in Appendix C.
- R.15 – This code will calculate p-values for all of the tests using the formal statistical techniques as described in Kleijnen and Helton (1999).
- R.16 – This code will calculate p-values for all of the tests using the Monte Carlo simulation as described in Kleijnen and Helton (1999).
- R.17 – This code will calculate the Top-Down Correlations as described in Kleijnen and Helton (1999).
- R.18 – This code will calculate the p-values for the Top-Down Correlations as described in Kleijnen and Helton (1999).

3. REQUIRED USER TRAINING AND/OR BACKGROUND

PATTRN is primarily a statistical analysis code. Users should have a basic understanding of introductory statistics, sampling methods, and sensitivity analysis.

To exercise PATTRN, users should have basic knowledge of Open VMS and the Digital Command Language, and should have access to a DEC Alpha with an Open VMS, version 7.1, operating system, or their functional equivalents.

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4. DESCRIPTION OF THE MODELS AND METHODS

4.1 Sensitivity Analysis

Problems involving physical processes are often difficult to solve. Computer models of physical processes are created in attempts to generate problems that are easier to solve. The computer model becomes a black box in that it takes a series of input variables and generates one or more outputs. Sensitivity analysis attempts to identify any relationships between the input variables and the model outputs. Knowing which input variables have the most influence on the model outputs helps the analyst validate and verify the computer model and also identify those input variables that may require further investigation.

Input variables may be sampled from known distributions to create vectors of values to be used as inputs to the computer model. The computer model then generates outputs such that there is a one-to-one correspondence between a particular vector of input variables and a particular vector of model outputs. Regression analysis is typically used to determine which input variables are influencing the model outputs by identifying those input variables that have the strongest linear relationship with the model outputs. There are occasions when the relationship is not linear but monotonic. In these instances rank regression analysis can be used to identify strong monotonic relationships between input variables and model outputs. A suite of sensitivity analysis tools exists in the form of computer programs that perform these tasks. The LHS program (Iman and Shortencarier, 1984) generates vectors of input variable values. The STEPWISE program (Iman, Davenport, Frost, and Shortencarier, 1980) and the PCCSRC program (Iman, Shortencarier, and Johnson, 1985) perform regression analyses.

Often however, the relationships between input variables and model outputs are not linear or even monotonic. Regression analyses can fail to identify these kinds of relationships no matter how strong they may be. What is needed in these cases is a method that can detect a relationship or a pattern between input variables and model outputs. One such method, called pattern detection, is described in the sections that follow.

4.2 Pattern Detection

Pattern detection attempts to detect patterns by determining how different a scatterplot is from a random pattern. A scatterplot is the result of plotting an input variable on the x-axis and the corresponding model output on the y-axis and a random pattern is the result of pairing the input variable values randomly with the model output values. If the scatterplot appears linear or monotonic, then regression analyses should identify that input variable as contributing to that model output. There are instances when the scatterplot will show a definite pattern yet the regression analyses will not include the input variable as important. In addition, since the input variable has been sampled from a known distribution and the model output may also assume a distribution, the scatterplot may show a definite pattern even when there is no relationship between the input variable and the model output. In this case the pattern on the scatterplot is the result of the marginal distributions of the input variable and model output. A pattern detection method must be able to detect this situation as well as detect relationships.

Plotting the data in probability space should remove the effects of the marginal distributions and prevent a pattern that is based solely on the marginal distributions of the input variable and the model output from being spuriously detected. A grid can be set up in probability space where the area of each cell contains equal probability. To plot a particular ordered pair (x, y), one needs to determine in which probability interval along the x-axis the x value falls and in which probability interval along the y-axis the y value falls. This grid may be one-dimensional, along either the x-axis or y-axis, or two-dimensional.

After each point has been assigned to a particular probability cell, several statistical tests can be performed to determine if the resulting assignments are significantly different from a random pattern. There are also some statistical tests that may be performed that do not require that the data be transformed into probability space. A number of these tests have been incorporated into a single computer program, PATTRN, which is the subject of this user's guide. PATTRN will become part of the suite of sensitivity analysis tools mentioned in Section 4.1.

These statistical tests are performed by first calculating a test statistic and then determining the p-value associated with that test statistic. The p-value gives the significance of the test statistic and is calculated using either formal statistical techniques or Monte Carlo simulations. The algorithms used to calculate the test statistics are described in Kleijnen and Helton (1999). The algorithms used to calculate the p-values via formal statistical techniques are found in Press et al. (1989) and those used to calculate the p-values via Monte Carlo simulations are described in Kleijnen and Helton (1999).

4.3 Terminology and Conventions

In the sections that follow, the term "independent variables" refers to the input variables, the term "dependent variables" refers to the model outputs, and the terms "user parameters" and "keywords" are used interchangeably.

This program was developed following the lifecycle methodology prescribed by the Nuclear Waste Management Program (NWMP) Software Quality Assurance requirements. NWMP users of this program should refer to the user's manual stored in the NWMP Central Files.

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5. CAPABILITIES AND LIMITATIONS OF THE SOFTWARE

5.1 Capabilities

PATTRN's capabilities include the calculating partial correlation coefficients and standardized regression coefficients on both raw and rank-transformed data, performing tests to detect relationships between input variables and model outputs, reporting the results of these calculations and tests in a user-specified format, and producing scatterplots and plots of the cumulative distribution functions of the model outputs. The user may also define new variables that are functions of the input variables or the model outputs.

5.2 Limitations

The PATTRN computer program was developed on a DEC Alpha using the Open VMS operating system and was written using ANSI-standard FORTRAN 77. Every attempt was made to make the code as platform independent as possible. However, certain items in the code are by their very nature platform dependent and must be adjusted before the code will run on platforms other than the DEC Alpha/Open VMS. These adjustments are described below in a general sense without platform-specific suggestions with respect to code conversion. Converting the code to a specific platform is the user's responsibility. However, it is hoped that the comments throughout the code will ease the task of code conversion.

5.2.1 Upper Limits

Program PATTRN uses the FORTRAN 77 PARAMETER statement to set upper limits that are used primarily for array dimensioning. These upper limits are:

1. The number of dependent variables, MAXDV = 10
2. The number of intervals in the grid, MAXINT = 20
3. The number of independent variables, MAXIV = 100
4. The number of observations in the sample, MAXOBS = 400
5. The number of replicates in the sample, MAXREP = 10
6. The number of random patterns, MAXRP = 10000
7. The number of tests, MAXTST = 25.

These upper limits should be satisfactory for most situations. However, if any or all of these upper limits need to be adjusted, the new values must be replaced in every program occurrence of the upper limit. The FORTRAN 77 PARAMETER statements are located near the beginning of the program routines.

5.2.2 Plotting Routines

Program PATTRN contains plotting routines that access platform-specific routines. These platform-specific routines are contained in a program library that is included in the program during link time. When the code is ported to a different platform, the plotting routines in PATTRN will have to be modified to access the platform-specific routines on the new platform. For the user's convenience, the names of these plotting routines all begin with the letters ZZPLT. Since the routines in PATTRN appear alphabetically by name, this places these plotting routines at the end of the program.

6. USER INTERACTIONS WITH THE SOFTWARE

6.1 Program Files

Each operating system has its own set of rules for naming files and the paths to those files. The path and file naming convention used in the PATTRN program is the convention specific to the Open VMS operating system. If the PATTRN program is to be run on a platform other than the DEC Alpha/Open VMS platform, then the path and file naming convention will have to be changed to reflect the path and file naming conventions of the new platform.

The PATTRN program accesses or creates up to five files. These files are described with respect to their associated FORTRAN 77 unit numbers.

UNIT 1 - This is the independent variable file. This file contains the independent variable values. The independent variable file is described in Section 7.1. The path and name of this file are specified on the IVF keyword record described in Section 7.3.2.

UNIT 2 - This is the dependent variable file. This file contains the dependent variable values. The dependent variable file is described in Section 7.2. The path and name of this file are specified on the DVF keyword record described in Section 7.3.3.

UNIT 5 - This is the user parameter file. This file contains the user parameters. The user parameter file is described in Section 7.3. This file is referred to as PATTRN\$INP in the program. A logical association must be established between PATTRN\$INP and the actual name and path of the file as it exists in the Open VMS file system. This can be done through the use of the Open VMS ASSIGN statement.

UNIT 6 - This is the output text file. This file contains the output text generated by the program and is created each time the program executes. The output text file is described in Section 9.1. This file is referred to as PATTRN\$OUT in the program. A logical association must be established between PATTRN\$OUT and the actual name and path of the file created in the Open VMS file system. This can be done through the use of the Open VMS ASSIGN statement.

UNIT 77 - This is the output plot file. This file contains the output plots, if requested, generated by the program. The output plot file is described in Section 9.2. This file is located in the same directory in which the PATTRN program is executed and is named FOR077.XXX, where XXX depends upon the type of output device selected by the user. This file is only created when plots are requested. This file is controlled by the platform-specific routines discussed in Section 5.2.2. If the PATTRN program is ported to a different platform, the name and location of the PATTRN output plot file might change.

6.2 Modifying Variable Values

Section 7.3 describes the user parameters specified to modify the independent variable values and the dependent variable values after they have been read from the independent variable file and the dependent variable file. These modifications are done through the use of FORTRAN 77 subroutines that the user must provide. These subroutines are compiled separately from the PATTRN program and then the subroutines are included in the program during link time.

6.2.1 User-Defined Independent Variables Subprogram

Figure 1 contains the FORTRAN 77 subroutine used to modify the independent variables. If this subroutine is included, it must appear exactly as listed here with the code to modify the independent variables inserted where indicated.

```
C*****
C
C SUBROUTINE UDIV GENERATES USER DEFINED INDEPENDENT VARIABLES
C
C*****
      SUBROUTINE UDIV(NOBS, NIVTMP, XNMTMP, XIVTMP)
C
C NOBS CONTAINS THE NUMBER OF OBSERVATIONS
C NIVTMP CONTAINS THE NUMBER OF INDEPENDENT VARIABLES
C XNMTMP CONTAINS THE INDEPENDENT VARIABLE NAMES
C XIVTMP CONTAINS THE INDEPENDENT VARIABLE VALUES
C
C THE FOLLOWING TWO PARAMETERS ARE REQUIRED
C
      PARAMETER (MAXIV = 100)
      PARAMETER (MAXOBS = 400)
C
C THE FOLLOWING TWO ARRAYS ARE REQUIRED
C
      CHARACTER*8 XNMTMP(MAXIV)
      DIMENSION XIVTMP(MAXOBS,MAXIV)
C
C BEGIN GENERATING USER DEFINED INDEPENDENT VARIABLES
C
      10 CONTINUE
      RETURN
      END
```

Figure 1 - User-Defined Independent Variables Subprogram

6.2.2 User-Defined Dependent Variables Subprogram

Figure 2 contains the FORTRAN 77 subroutine used to modify the dependent variables. If this subroutine is included, it must appear exactly as listed here with the code to modify the dependent variables inserted where indicated.

```
C*****
C
C SUBROUTINE UDDV GENERATES USER DEFINED DEPENDENT VARIABLES
C
C*****
      SUBROUTINE UDDV(NOBS, NDVTMP, YNMTMP, YDVTMP)
C
C NOBS CONTAINS THE NUMBER OF OBSERVATIONS
C NDVTMP CONTAINS THE NUMBER OF DEPENDENT VARIABLES
C YNMTMP CONTAINS THE DEPENDENT VARIABLE NAMES
C YDVTMP CONTAINS THE DEPENDENT VARIABLE VALUES
C
C THE FOLLOWING TWO PARAMETERS ARE REQUIRED
C
      PARAMETER (MAXDV = 10)
      PARAMETER (MAXOBS = 400)
C
C THE FOLLOWING TWO ARRAYS ARE REQUIRED
C
      CHARACTER*8 YNMTMP(MAXDV)
      DIMENSION YDVTMP(MAXOBS,MAXDV)
C
C BEGIN GENERATING USER DEFINED DEPENDENT VARIABLES
C
      10 CONTINUE
      RETURN
      END
```

Figure 2 - User-Defined Dependent Variables Subprogram

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7. DESCRIPTION OF INPUT FILES

Program PATTRN expects three input files - a file containing the independent variable values, a file containing the dependent variable values, and a file containing the user parameters or keywords.

7.1 Independent Variable File

Figure 3 shows a portion of an independent variable file that contains independent variable values. It is important that the independent variable file adheres to this format. The first three lines of the independent variable file contain header information. The first two values contained in the fourth line are the number of independent variables and the number of vectors, respectively. These values are input using a list-directed read. The lines following these values contain the names of the independent variables and each line is input using the format statement (5X,A8,4(7X,A8)). The line following the independent variable names contains more header information. The independent variable values follow and they are input by reading a blank line followed by a list-directed read based on the number of independent variables for as many times as there are vectors. Figure 3 contains the first two vectors of the independent variable file.

5

!Written by LHS2STEP 1.04 (04/19/96) on 09/05/96 15:38:54

!LHS Sampled Output from DISK\$IKE_CCA3:[PANEL.DATA.LHS]LHS2_CCGF_TRN_R1.DAT;1

75	100	1			
WGRCOR	WMICDFLG	WGRMICI	WGRMICH	WFBETCEL	
WRGSSAT	WRBRNSAT	WASTWICK	SHPRMCLY	SHPRMCON	
SHPRMSAP	SHPRMDRZ	SHPRNHAL	SHRGSSAT	SHRBRSAT	
SHBCEXP	HALPOR	HALPRM	HALCOMP	ANHPRM	
ANHCOMP	ANHBCVGP	ANRBRSAT	ANRGSSAT	ANHBCEXP	
SALPRES	BPINTPRS	BPPRM	BPCOMP	BHPERM	
BPMAP	WPRTDIAM	WTAUFAIL	CTTRANSFM	CTTRAN	
WSOLAM3S	WSOLAM3C	WSOLPU3S	WSOLPU3C	WSOLPU4S	
WSOLPU4C	WSOLU4S	WSOLU6S	WSOLU6C	WSOLTH4S	
WPHUMOX3	WOXSTAT	CCLIMSF	CFRACSP	CFRACPOR	
CMTRXPOR	CMKDU6	CMKDU4	CMKDPU3	CMKDPU4	
CMKDTM4	CMKDAM3	LHS58	LHS59	LHS60	
LHS61	LHS62	LHS63	LHS64	LHS65	
LHS66	LHS67	LHS68	LHS69	LHS70	
LHS71	LHS72	LHS73	LHS74	LHS75	

1.000000E+00				
2.297000E-15	2.000000E+00	7.810000E-09	4.714000E-10	6.023000E-01
1.259000E-03	4.607000E-01	9.356000E-01	-1.796000E+01	-1.984000E+01
-2.035000E+01	-1.554000E+01	1.668000E-01	9.790000E-02	2.600000E-01
4.861000E-01	1.081000E-02	-2.340000E+01	1.514000E-10	-1.888000E+01
7.670000E-11	1.000000E+00	9.324000E-02	1.398000E-02	6.133000E-01
1.201000E+07	1.490000E+07	-1.102000E+01	-1.082000E+01	-1.271000E+01
2.900000E+01	6.034000E-02	9.258000E-01	3.977000E+02	3.570000E-01
-1.976000E-01	-3.910000E-01	-4.834000E-01	1.014000E-01	-2.832000E-01
-8.138000E-02	-4.570000E-01	-2.324000E-01	-1.110000E-02	5.522000E-01
1.283000E-01	9.977000E-01	1.214000E+00	4.234000E-01	1.301000E-04
1.250000E-01	2.671000E-03	4.848000E+00	3.181000E-01	1.238000E+01
4.403000E+00	1.197000E-01	8.262000E-01	7.275000E-01	3.800000E-01
8.434000E-01	5.461000E-01	5.572000E-02	3.938000E-01	2.713000E-01
1.075000E-02	9.079000E-01	6.734000E-01	8.244000E-01	9.295000E-01
2.612000E-01	6.375000E-01	7.788000E-01	9.834000E-01	6.820000E-01
6.448000E-15	0.000000E+00	9.200000E-09	8.844000E-10	2.903000E-01
1.096000E-01	2.286000E-01	4.746000E-01	-1.818000E+01	-1.964000E+01
-1.958000E+01	-1.623000E+01	1.596000E-01	3.888000E-01	2.406000E-01
9.551000E-01	4.985000E-03	-2.164000E+01	4.765000E-11	-1.883000E+01
6.285000E-11	1.000000E+00	8.087000E-02	4.879000E-02	6.096000E-01
1.227000E+07	1.234000E+07	-1.198000E+01	-1.040000E+01	-1.204000E+01
3.200000E+01	2.024000E-03	2.753000E+00	8.911000E+02	1.873000E-02
-3.821000E-01	-1.461000E-01	6.853000E-01	-4.374000E-01	-6.566000E-02
2.441000E-01	-2.272000E-01	3.276000E-02	-7.551000E-02	-4.155000E-01
1.429000E+00	6.733000E-02	2.191000E+00	6.395000E-02	8.438000E-03
1.049000E-01	1.170000E-02	6.674000E+00	1.667000E-01	8.944000E+00
8.097000E+00	3.153000E-01	6.112000E-01	5.149000E-01	1.877000E-01
5.178000E-01	3.385000E-01	4.396000E-01	4.144000E-01	2.831000E-01
4.703000E-01	1.097000E-02	1.373000E-02	1.789000E-01	6.715000E-01
2.212000E-01	2.945000E-01	1.966000E-01	9.221000E-01	8.811000E-01

Figure 3 - Example Independent Variable File

7.2 Dependent Variable File

Figure 4 shows a portion of a dependent variable file that contains dependent variable values. It is important that the dependent variable file adheres to this format. The first seven lines of the dependent variable file contain header information. The first two values contained in the eighth line are the number of dependent variables and the number of vectors, respectively. These values are input using a list-directed read. The lines following these values contain the names of the dependent variables and each line is input using the format statement (5(8X,A8)). The dependent variable values follow and they are input by reading a header line followed by a list-directed read based on the number of dependent variables for as many times as there are vectors. Figure 4 contains the first two vectors of the dependent variable file.

```
5
!   Single
! $InfoRec
! $QaRec
! $Title
! $Coords
!
!       X $XnCoord      Y $YnCoord      Z $ZnCoord
!       1              100              1
!
!       WAS PRES
!       1.0000000E+04
!       1.3920750E+07
!
!       7.9986535E+06
```

Figure 4 - Example Dependent Variable File

7.3 User Parameter File

Program PATTRN performs various statistical tests and reports the results of these tests. The program recognizes 27 keywords, which designate the desired calculations and output for an analysis. These keywords are used to specify the tests to be performed, and the format, structure and content of the output. These keywords are contained in the user parameter file.

The following rules apply:

1. All keywords must be spelled completely (no abbreviations).
2. At least one blank must follow the keyword on the record.
3. A keyword record may have no leading blanks.
4. The keyword records are a maximum of 80 characters in length.
5. The keyword records may appear in any order.
6. Not all keywords are required (some keywords are optional).

In addition, an exclamation mark, "!", in the first column of any keyword record designates that record as a comment which causes that record to be ignored. Line 1 of Table 1 gives an example of the use of the exclamation mark.

The role of each keyword will now be explained. For purposes of illustration, Table 1 contains an example setup that uses all of the keywords. The numbers that appear in the left column of Table 1 are for reference only and are not part of the keywords.

Table 1 - PATTRN Keywords

Line #	Keyword
1	! THIS IS A SAMPLE COMMENT
2	TTL THIS IS AN EXAMPLE TITLE
3	IVF [MJSHORT.PATTRN.DATA]LHSALL.TRN
4	DVF [MJSHORT.PATTRN.DATA]ALLS5.TBL
5	USER DEF IV
6	USER DEF DV
7	OBSERVATIONS 1-300
8	NUMBER OF REPLICATES 3
9	SIV 1-18 20 22-31
10	SDV 1
11	TEST CC CCMC CIQ CIQMC CL CLMC CMD CMDMC CMN CMNMC CV CVMC
12	DR DRMC FR FRMC PCC PRCC RCC RCCMC SI SIMC SRC SRRC
13	NXINT 5
14	NYINT 5
15	LOGARITHMS
16	NUMBER OF RANDOM PATTERNS 10000
17	SEED -585488632
18	ALPHA CUTOFF 0.1
19	SCATTERPLOTS 1 3 5 7 9
20	X GRID LINES
21	MD GRID LINES
22	IQ GRID LINES
23	SI GRID LINES
24	PLOTCDF
25	VERBOSE
26	VERBOSEMC 2 4 6 8
27	VERBOSECV
28	COEFFICIENTS
29	RANK COEFFICIENTS

7.3.1 TTL Keyword

The TiTLe keyword is optional. This keyword may be followed by up to 76 characters of alphanumeric data. The alphanumeric data is intended to give a brief description of the particular problem being run. This data is printed as the top line of every page of output and also across the top of each plot. The default value is all blanks. Line 2 of Table 1 gives an example of the use of this keyword.

7.3.2 IVF Keyword

The Independent Variable File keyword is required. This keyword is followed by up to 76 characters of alphanumeric data that contain the path and file name where the independent variable data are located. There is no default path and file name. The format of the independent variable data file is described in Section 7.1. Line 3 of Table 1 gives an example of the use of this keyword.

7.3.3 DVF Keyword

The Dependent Variable File keyword is required. This keyword is followed by up to 76 characters of alphanumeric data that contain the path and file name where the dependent variable data are located. There is no default path and file name. The format of the dependent variable data file is described in Section 7.2. Line 4 of Table 1 gives an example of the use of this keyword.

7.3.4 USER DEF IV Keyword

The USER DEFINED Independent Variables keyword is optional. This keyword is used to indicate that the user will be modifying the independent variables after the independent variables have been read from the independent variable file. These modifications are done through the use of a subprogram that the user has provided. The details of this subprogram are described in Section 6.2.1. The default is that no user-defined independent variables are present. Line 5 of Table 1 gives an example of the use of this keyword.

7.3.5 USER DEF DV Keyword

The USER DEFINED Dependent Variables keyword is optional. This keyword is used to indicate that the user will be modifying the dependent variables after the dependent variables have been read from the dependent variable file. These modifications are done through the use of a subprogram that the user has provided. The details of this subprogram are described in Section 6.2.2. The default is that no user-defined dependent variables are present. Line 6 of Table 1 gives an example of the use of this keyword.

7.3.6 OBSERVATIONS Keyword

The OBSERVATIONS keyword is required. This keyword is used to specify the observations in the independent variable file and the dependent variable file that will be used in the analysis. This keyword must be followed by at least one observation number. Blanks must be used to delimit the numbers and a hyphen may be used to indicate a range of numbers. This keyword may be continued to the next record but only if the next record contains a blank in the first column. Line 7 of Table 1 gives an example of the use of this keyword.

7.3.7 NUMBER OF REPLICATES Keyword

The NUMBER OF REPLICATES keyword is required for the FR and FRMC tests and may also be specified for the DR and DRMC tests (see Section 7.3.10 for a description of these tests). This keyword is used to indicate the number of replicates in the independent variable sample and the dependent variable output. The number of replicates is the number of different samples in the independent variable file and the dependent variable file. For further details on the number of replicates, see Iman and Shortencarier (1984). This keyword must be followed by a single integer. The number of observations selected with the OBSERVATIONS keyword must be an integer multiple of the number of replicates. Line 8 of Table 1 gives an example of the use of this keyword.

7.3.8 SIV Keyword

The Selected Independent Variables keyword is required. This keyword is used to select the independent variables to be included in the problem. This keyword must be followed by at least one independent variable number and these numbers must reflect any user-defined independent variables. Blanks must be used to delimit the numbers and a hyphen may be used to indicate a range of numbers. This keyword may be continued to the next record but only if the next record contains a blank in the first column. Line 9 of Table 1 gives an example of the use of this keyword.

7.3.9 SDV Keyword

The Selected Dependent Variables keyword is required. This keyword is used to select the dependent variables to be included in the problem. This keyword must be followed by at least one dependent variable number and these numbers must reflect any user-defined dependent variables. Blanks must be used to delimit the numbers and a hyphen may be used to indicate a range of numbers. This keyword may be continued to the next record but only if the next record contains a blank in the first column. Line 10 of Table 1 gives an example of the use of this keyword.

7.3.10 TEST Keyword

The TEST keyword is required. This keyword is used to select the tests to be performed on the data. This keyword must be followed by at least one keyword option. The keyword options must be separated by at least one blank and must appear exactly as specified below. The keyword options may appear in any order in the record but the order in which the keyword options appear is the order in which the test results will appear in the output file. The first keyword option specified is the test result that will be used to sort all of the test results (see Section 9.1 for further description). This keyword may be continued to the next record but only if the next record contains a blank in the first column.

7.3.10.1 CC Keyword Option

The Correlation Coefficient keyword option is used to select the correlation coefficient test described in Kleijnen and Helton (1999). The p-value for this test statistic is calculated using formal statistical techniques. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.2 CCMC Keyword Option

The Correlation Coefficient Monte Carlo keyword option is used to select the correlation coefficient Monte Carlo test. This test is the same as the CC test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.3 CIQ Keyword Option

The Common InterQuartiles keyword option is used to select the common interquartiles test described in Kleijnen and Helton (1999). The p-value for this test statistic is calculated using formal statistical techniques. If this test is selected, then the NXINT keyword must be specified. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.4 CIQMC Keyword Option

The Common InterQuartiles Monte Carlo keyword option is used to select the common interquartiles Monte Carlo test. This test is the same as the CIQ test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NXINT keyword, the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.5 CL Keyword Option

The Common Location keyword option is used to select the common location test described in Kleijnen and Helton (1999). The p-value for this test statistic is calculated using formal statistical techniques. If this test is selected, then the NXINT keyword must be specified. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.6 CLMC Keyword Option

The Common Location Monte Carlo keyword option is used to select the common location Monte Carlo test. This test is the same as the CL test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NXINT keyword, the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.7 CMD Keyword Option

The Common MeDians keyword option is used to select the common medians test described in Kleijnen and Helton (1999). The p-value for this test statistic is calculated using formal statistical techniques. If this test is selected, then the NXINT keyword must be specified. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.8 CMDMC Keyword Option

The Common MeDians Monte Carlo keyword option is used to select the common medians Monte Carlo test. This test is the same as the CMD test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NXINT keyword, the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.9 CMN Keyword Option

The Common MeaNs keyword option is used to select the common means test described in Kleijnen and Helton (1999). The p-value for this test statistic is calculated using formal statistical techniques. If this test is selected, then the NXINT keyword must be specified. The LOGARITHMS keyword may be specified with this test. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.10 CMNMC Keyword Option

The Common MeaNs Monte Carlo keyword option is used to select the common means Monte Carlo test. This test is the same as the CMN test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NXINT keyword, the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. The LOGARITHMS keyword may be specified with this test. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.11 CV Keyword Option

The Common Variances keyword option is used to select the common variances test described in Kleijnen and Helton (1999). The p-value for this test statistic is calculated using formal statistical techniques. If this test is selected, then the NXINT keyword must be specified. The LOGARITHMS keyword may be specified with this test. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.12 CVMC Keyword Option

The Common Variances Monte Carlo keyword option is used to select the common variances Monte Carlo test. This test is the same as the CV test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NXINT keyword, the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. The LOGARITHMS keyword may be specified with this test. Line 11 of Table 1 gives an example of the use of this keyword option.

7.3.10.13 DR Keyword Option

The Differences of Ranks keyword option is used to select the differences of ranks test described in Section 11.3. The p-value for this test statistic is calculated using formal statistical techniques. If this test is selected, then the NUMBER OF REPLICATES keyword may be specified also. Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.14 DRMC Keyword Option

The Differences of Ranks Monte Carlo keyword option is used to select the differences of ranks Monte Carlo test. This test is the same as the DR test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NUMBER OF REPLICATES keyword may be specified also, but the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.15 FR Keyword Option

The FRiedman keyword option is used to select the Friedman test described in Section 11.3. The p-value for this test statistic is calculated using formal statistical techniques. If this test is selected, then the NUMBER OF REPLICATES keyword must be specified. Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.16 FRMC Keyword Option

The FRiedman Monte Carlo keyword option is used to select the Friedman Monte Carlo test. This test is the same as the FR test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NUMBER OF REPLICATES keyword, the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.17 PCC Keyword Option

The Partial Correlation Coefficient keyword option is used to select the partial correlation coefficient calculation described in Iman, Shortencarier and Johnson (1985). Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.18 PRCC Keyword Option

The Partial Rank Correlation Coefficient keyword option is used to select the partial rank correlation coefficient calculation described in Iman, Shortencarier and Johnson (1985). Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.19 RCC Keyword Option

The Rank Correlation Coefficient keyword option is used to select the rank correlation coefficient test described in Kleijnen and Helton (1999). The p-value for this test statistic is calculated using formal statistical techniques. Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.20 RCCMC Keyword Option

The Rank Correlation Coefficient Monte Carlo keyword option is used to select the rank correlation coefficient Monte Carlo test. This test is the same as the RCC test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.21 SI Keyword Option

The Statistical Independence keyword option is used to select the statistical independence test described in Kleijnen and Helton (1999). The p-value for this test statistic is calculated using formal statistical techniques. If this test is selected, then the NXINT keyword and the NYINT keyword must be specified. Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.22 SIMC Keyword Option

The Statistical Independence Monte Carlo keyword option is used to select the statistical independence Monte Carlo test. This test is the same as the SI test except the p-value for this test statistic is calculated using the Monte Carlo simulation described in Kleijnen and Helton (1999). If this test is selected, then the NXINT keyword, the NYINT keyword, the NUMBER OF RANDOM PATTERNS keyword and the SEED keyword must be specified. Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.23 SRC Keyword Option

The Standardized Regression Coefficient keyword option is used to select the standardized regression coefficient calculation described in Iman, Shortencarier and Johnson (1985). Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.10.24 SRRC Keyword Option

The Standardized Rank Regression Coefficient keyword option is used to select the standardized rank regression coefficient calculation described in Iman, Shortencarier and Johnson (1985). Line 12 of Table 1 gives an example of the use of this keyword option.

7.3.11 NXINT Keyword

The Number of X INTervals keyword is required for the CIQ, CIQMC, CL, CLMC, CMD, CMDMC, CMN, CMNMC, CV, CVMC, SI, and SIMC tests and for the X GRID LINES keyword. This keyword is used to specify the number of intervals of equal probability on the x-axis of the probability grid described in Kleijnen and Helton (1999). For the case of a discrete independent variable, the value of this keyword is temporarily replaced with the number of different values that the discrete independent variable assumes. Line 13 of Table 1 gives an example of the use of this keyword.

7.3.12 NYINT Keyword

The Number of Y INTervals keyword is required for the SI and SIMC tests and for the SI GRID LINES keyword. This keyword is used to specify the number of intervals of equal probability on the y-axis of the probability grid described in Kleijnen and Helton (1999). Line 14 of Table 1 gives an example of the use of this keyword.

7.3.13 LOGARITHMS Keyword

The LOGARITHMS keyword is optional. This keyword is used to specify that natural logarithms will be used in the calculations for the CMN, CMNMC, CV, and CVMC tests. These calculations are described in Kleijnen and Helton (1999). The default is that no logarithms will be used. Line 15 of Table 1 gives an example of the use of this keyword.

7.3.14 NUMBER OF RANDOM PATTERNS Keyword

The NUMBER OF RANDOM PATTERNS keyword is required for the CCMC, CIQMC, CLMC, CMDMC, CMNMC, CVMC, DRMC, FRMC, RCCMC, and SIMC tests. This keyword specifies the number of random patterns to be generated for the Monte Carlo simulation described in Kleijnen and Helton (1999). Line 16 of Table 1 gives an example of the use of this keyword.

7.3.15 SEED Keyword

The SEED keyword is required for the CCMC, CIQMC, CLMC, CMDMC, CMNMC, CVMC, DRMC, FRMC, RCCMC, and SIMC tests. This keyword is used to specify the starting value for the random number generator for the Monte Carlo simulation described in Kleijnen and Helton (1999). The starting value specified must be negative. Line 17 of Table 1 gives an example of the use of this keyword.

7.3.16 ALPHA CUTOFF Keyword

The ALPHA CUTOFF keyword is optional. This keyword is used to specify a value such that only those p-values that are less than or equal to the alpha cutoff for any selected test will be output. The alpha cutoff does not apply to the PCC, PRCC, SRC, or SRRC calculations. The default is that all p-values for all tests are output, i.e. an alpha cutoff value of 1.0. Line 18 of Table 1 gives an example of the use of this keyword.

7.3.17 SCATTERPLOTS Keyword

The SCATTERPLOTS keyword is optional. This keyword is used to specify that scatterplots will be generated for those independent variables that meet the alpha cutoff. In addition, the user may select specific independent variables for plotting whether or not the alpha cutoff is met. The selected independent variables are specified in the same manner as for the SIV keyword. The default is that no scatterplots will be generated. Line 19 of Table 1 gives an example of the use of this keyword.

7.3.18 X GRID LINES Keyword

The X GRID LINES keyword is optional. This keyword is used to specify that NXINT vertical lines representing NXINT equal probability intervals along the x-axis will be drawn on the scatterplots. These grid lines are described in Kleijnen and Helton (1999). For the case of a discrete independent variable, these grid lines are drawn so that the different values that the discrete independent variable assumes appear in separate intervals. If this keyword is specified, then the NXINT keyword must be specified. The default is that no grid lines will be drawn. Line 20 of Table 1 gives an example of the use of this keyword.

7.3.19 MD GRID LINES Keyword

The MD GRID LINES keyword is optional. This keyword is used to specify that horizontal lines representing the median values of the dependent variables will be drawn on the scatterplots. These grid lines are described in Kleijnen and Helton (1999). Only one type of horizontal grid lines can be specified. The default is that no grid lines will be drawn. Line 21 of Table 1 gives an example of the use of this keyword.

7.3.20 IQ GRID LINES Keyword

The IQ GRID LINES keyword is optional. This keyword is used to specify that horizontal lines representing the interquartile ranges of the dependent variables will be drawn on the scatterplots. These grid lines are described in Kleijnen and Helton (1999). Only one type of horizontal grid lines can be specified. The default is that no grid lines will be drawn. Line 22 of Table 1 gives an example of the use of this keyword.

7.3.21 SI GRID LINES Keyword

The SI GRID LINES keyword is optional. This keyword is used to specify that NYINT horizontal lines representing NYINT equal probability intervals along the y-axis will be drawn on the scatterplots. These grid lines are described in Kleijnen and Helton (1999). Only one type of horizontal grid lines can be specified. If this keyword is specified, then the NYINT keyword must be specified. The default is that no grid lines will be drawn. Line 23 of Table 1 gives an example of the use of this keyword.

7.3.22 PLOTCDF Keyword

The PLOTCDF keyword is optional. This keyword is used to specify that plots will be generated of the cumulative distribution function (CDF) for each of the dependent variables. The default is that no CDF plots will be generated. Line 24 of Table 1 gives an example of the use of this keyword.

7.3.23 VERBOSE Keyword

The VERBOSE keyword is optional. This keyword is used to specify that a detailed summary of the formal statistical techniques used to calculate the p-values for each test will be written to the output file for those independent variables that meet the alpha cutoff. This keyword should only be used in conjunction with the CC, CIQ, CL, CMD, CMN, CV, DR, FR, RCC, or SI tests. The default is that no detailed summary will be written. Line 25 of Table 1 gives an example of the use of this keyword.

7.3.24 VERBOSEMC Keyword

The VERBOSEMC keyword is optional. This keyword is used to specify that intermediate results from the test statistic p-value calculations using the Monte Carlo simulation described in Kleijnen and Helton (1999) will be written to the output file. This keyword may be followed by at least one random pattern number. Blanks must be used to delimit the numbers and a hyphen may be used to indicate a range of numbers. This keyword may be continued to the next record but only if the next record contains a blank in the first column. This keyword may only be used in conjunction with the CCMC, CIQMC, CLMC, CMDMC, CMNMC, CVMC, DRMC, FRMC, RCCMC, or SIMC tests. These intermediate results contain the (x,y) pairings for those random patterns specified by the user, the random pattern test statistics, and the bracketing values for the p-value calculations. If no random pattern numbers are specified with this keyword, then only the random pattern test statistics and bracketing values will be written to the output file. For the CCMC and for the RCCMC tests, only the magnitude of the test statistics is displayed instead of the signed test statistics as they would appear in the detailed test summaries. This keyword is included primarily as a verification and validation aid. Care should be exercised in specifying this keyword as it causes a great deal of information to be written to the output file. The default is that no intermediate results will be written. Line 26 of Table 1 gives an example of the use of this keyword.

7.3.25 VERBOSECV Keyword

The VERBOSECV keyword is optional. This keyword is used to specify that intermediate results from the test statistic calculations for the common variances test will be written to the output file. This keyword may only be used in conjunction with the CV or CVMC tests. This keyword is included primarily as a verification and validation aid. Care should be exercised in specifying this keyword as it causes a great deal of information to be written to the output file. The default is that no intermediate results will be written. Line 27 of Table 1 gives an example of the use of this keyword.

7.3.26 COEFFICIENTS Keyword

The COEFFICIENTS keyword is optional. This keyword is used to specify that a summary of the CC test, the PCC calculation, and the SRC calculation will be written to the output file for those independent variables that meet the alpha cutoff. The default is that no summary will be output. Line 28 of Table 1 gives an example of the use of this keyword.

7.3.27 RANK COEFFICIENTS Keyword

The RANK COEFFICIENTS keyword is optional. This keyword is used to specify that a summary of the RCC test, the PRCC calculation, and the SRRC calculation will be written to the output file for those independent variables that meet the alpha cutoff. The default is that no summary will be output. Line 29 of Table 1 gives an example of the use of this keyword.

Figure 5 shows a user parameter file that contains user parameters. This file is constructed from the user parameters and follows the guidelines in this section.

```
TTL E2:WAS_SATB @ 1E4 YRS S5 INCLUDED VARIABLES
IVF [MJSHORT.PATTRN.BFSA]LHSALL.TRN
DVF [MJSHORT.PATTRN.BFSA]ALLS5SATB.TBL
OBSERVATIONS 1-300
NUMBER OF REPLICATES 3
USER DEF IV
SIV 1-18 20 22-26 30
SDV 1
TEST RCC CL SI FR
NXINT 5
NYINT 5
ALPHA CUTOFF 0.05
SCATTERPLOTS 1 3 5 7 9
VERBOSE
COEFFICIENTS
RANK COEFFICIENTS
```

Figure 5 - Example User Parameter File

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8. ERROR MESSAGES

If no errors occur during the execution of the PATTRN program, then the character string "PATTRN" is displayed on the monitor and the program terminates normally. Errors that occur during the execution of the PATTRN program cause the program to abort. Information displayed on the monitor is limited to a character string that contains the name of the PATTRN routine in which the error occurred or was detected. Error messages generated by the PATTRN program are written to the output text file described in Section 9.1. Each line of any error message generated by the PATTRN program is preceded by the character string "*****". These error messages provide sufficient explanation to identify and correct any errors. The user response to these error messages can simply be to correct the errors and rerun the program.

The user parameter file is read and processed first by the program. Error checks contained in the program ensure that the user parameters have been properly specified, and that the user parameters are complete and not in conflict with each other. The independent variable file and dependent variable file are read and processed next by the program. Once again error checks contained in the program ensure that these files are properly formatted and the data contained in these files are not in conflict with each other. Errors detected while these files are being opened are handled by the ERR keyword in their FORTRAN 77 OPEN statements. Errors that occur during the generation of the output plot file are handled internally by the platform-specific routines described in Section 5.2.2.

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9. DESCRIPTION OF OUTPUT FILES

Program PATTRN produces two output files. The first file is the output text file and it contains the results requested in the user parameter file. The results are formatted as specified in the user parameter file. The output text file may also contain any error messages generated by PATTRN as described in Section 8. The second file is the output plot file and it contains the scatterplots and cumulative distribution plots as requested in the user parameter file.

9.1 *Output Text File*

The output text file from program PATTRN contains several different sections. The number and type of sections in the output text file will vary depending upon the selection of the user parameters. The figures that follow each contain a separate section of the output text file and each possible section of the output text file has been represented.

9.1.1 User Parameter Section

Figure 6 contains the user parameter section of the output text file from program PATTRN. This section contains the values for all user parameters for this particular run of the program.

```
E2:WAS_SATB @ 1E4 YRS  S5 INCLUDED VARIABLES

THE INDEPENDENT VARIABLES ARE FOUND IN
[MJSHORT.PATTRN.BFSA]LHSALL.TRN
THE DEPENDENT VARIABLES ARE FOUND IN
[MJSHORT.PATTRN.BFSA]ALLS5SATB.TBL
USER DEFINED INDEPENDENT VARIABLES WILL BE GENERATED
USER DEFINED DEPENDENT VARIABLES WILL NOT BE GENERATED
THE NUMBER OF INDEPENDENT VARIABLES SELECTED IS 25
THE SELECTED INDEPENDENT VARIABLE NUMBERS ARE
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
 16  17  18  20  22  23  24  25  26  30
THE NUMBER OF DEPENDENT VARIABLES SELECTED IS 1
THE SELECTED DEPENDENT VARIABLE NUMBERS ARE
  1
THE NUMBER OF TESTS SELECTED IS 4
THE SELECTED TESTS WILL BE SORTED BASED ON RCC
THE SELECTED TESTS WILL APPEAR AS FOLLOWS:
RCC  CL  SI  FR
THE NUMBER OF CELLS IN THE X DIRECTION IN THE GRID IS 5
THE NUMBER OF CELLS IN THE Y DIRECTION IN THE GRID IS 5
LOGARITHMS WILL NOT BE USED FOR THE CMN AND CV TESTS
MONTE CARLO SIMULATIONS WILL NOT BE PERFORMED
THE NUMBER OF RANDOM PATTERNS USED IN BUILDING THE CCDF IS 0
THE SEED FOR THE RANDOM NUMBER GENERATOR IS 0
THE ALPHA CUTOFF IS 5.0000E-02
SCATTERPLOTS WILL BE GENERATED FOR THOSE INDEPENDENT VARIABLES
THAT MEET THE ALPHA CUTOFF
THE NUMBER OF SCATTERPLOTS SELECTED IS 5
SCATTERPLOTS ARE SELECTED FOR INDEPENDENT VARIABLE NUMBERS
  1   3   5   7   9
X GRID LINES WILL NOT BE PLOTTED
Y GRID LINES WILL NOT BE PLOTTED
CDFs WILL NOT BE PLOTTED FOR THE DEPENDENT VARIABLES
A DETAILED TEST SUMMARY WILL BE GENERATED
A MONTE CARLO SUMMARY WILL NOT BE GENERATED
A COMMON VARIANCES SUMMARY WILL NOT BE GENERATED
A COEFFICIENT SUMMARY WILL BE GENERATED
A RANK COEFFICIENT SUMMARY WILL BE GENERATED
THE NUMBER OF INDEPENDENT VARIABLES IN THE INDEPENDENT VARIABLE FILE IS 75
AFTER GENERATING USER DEFINED INDEPENDENT VARIABLES
  THE NUMBER OF INDEPENDENT VARIABLES IS 75
THE NUMBER OF DEPENDENT VARIABLES IN THE DEPENDENT VARIABLE FILE IS 1
THE NUMBER OF OBSERVATIONS SELECTED IS 300
THE NUMBER OF REPLICATES IN THE SELECTED OBSERVATIONS IS 3
```

Figure 6 - User Parameter Section

9.1.2 Test Results Section

Figure 7 contains the test results section of the output text file from program PATTRN. This section contains the independent variable numbers, the independent variable names, the p-values and the ranks of the p-values for each independent variable whose p-value met the alpha cutoff for any of the user-selected tests. The results are presented in the order that the user selected the tests and are sorted based on the p-values from the first user-selected test.

E2:WAS_SATB @ 1E4 YRS S5 INCLUDED VARIABLES

DEPENDENT VARIABLE (# : NAME) IS 1 : WAS_SATB

INDEP VAR	RCC		CL		SI		FR	
# : NAME	RANK	P-VAL	RANK	P-VAL	RANK	P-VAL	RANK	P-VAL
30 : BHPERM	1.0	0.0000	1.0	0.0000	2.0	0.0000	1.0	0.0000
6 : WRGSSAT	2.0	0.0000	2.0	0.0000	1.0	0.0000	4.0	0.0789
20 : ANHPRM	3.0	0.0001	3.0	0.0001	3.0	0.0002	6.0	0.0908
13 : SHPRNHAL	4.0	0.0225	8.0	0.1528	10.0	0.2278	2.0	0.0224
17 : HALPOR	5.0	0.0269	12.0	0.3437	7.0	0.1328	7.0	0.0981
4 : WGRMICH	8.0	0.1842	4.0	0.0059	5.0	0.0564	14.0	0.3779
14 : SHRGSSAT	11.0	0.3784	25.0	0.9424	17.5	0.7885	3.0	0.0485
7 : WRBRNSAT	13.0	0.4950	6.0	0.0270	9.0	0.2128	15.0	0.4583
10 : SHPRMCON	19.0	0.6549	5.0	0.0202	12.0	0.4075	21.0	0.6689
23 : ANRBR SAT	20.0	0.6645	13.0	0.3977	4.0	0.0495	20.0	0.6063

Figure 7 - Test Results Section

9.1.3 Importance Orderings Section

Figure 8 contains the importance orderings section of the output text file from program PATTRN. This section contains the rankings of the p-values, called importance orderings, for all independent variables that met the alpha cutoff for any of the user-selected tests. For example, the third column in Figure 8 contains the ranks of the p-values for the independent variable ANHPRM for the user-selected tests RCC, CL, SI, and FR. The results are presented in the order that the user selected the tests and are sorted based on the results of the first user-selected test.

```
E2:WAS_SATB @ 1E4 YRS  S5 INCLUDED VARIABLES

DEPENDENT VARIABLE (# : NAME) IS  1 : WAS_SATB

IMPORTANCE ORDERINGS FOR INDEP VARS VS TESTS

RCC      1.0   2.0   3.0   4.0   5.0   8.0   11.0  13.0  19.0  20.0
CL       1.0   2.0   3.0   8.0  12.0   4.0  25.0   6.0   5.0  13.0
SI       2.0   1.0   3.0  10.0   7.0   5.0  17.5   9.0  12.0   4.0
FR       1.0   4.0   6.0   2.0   7.0  14.0   3.0  15.0  21.0  20.0

          30     6     20     13     17     4     14     7     10     23

LEGEND - INDEP VAR # : NAME
          30 : BHPERM
           6 : WRGSSAT
          20 : ANHPRM
          13 : SHPRNHAL
          17 : HALPOR
           4 : WGRMICH
          14 : SHRGSSAT
           7 : WRBRNSAT
          10 : SHPRMCON
          23 : ANRBRNSAT
```

Figure 8 - Importance Orderings Section

9.1.4 Top-Down Correlation Section

Figure 9 contains the top-down correlation section of the output text file from program PATTRN. This section contains the matrices of top-down correlation coefficients and their associated p-values. These top-down correlation results are described in Kleijnen and Helton (1999). The results are presented in the order that the user selected the tests.

```
E2:WAS_SATB @ 1E4 YRS  S5 INCLUDED VARIABLES
DEPENDENT VARIABLE (# : NAME) IS  1 : WAS_SATB
TOP-DOWN CORRELATION MATRIX
```

CL	0.894		
SI	0.730	0.760	
FR	0.807	0.574	0.296
RCC	CL	SI	

```
E2:WAS_SATB @ 1E4 YRS  S5 INCLUDED VARIABLES
DEPENDENT VARIABLE (# : NAME) IS  1 : WAS_SATB
TOP-DOWN CORRELATION MATRIX P-VALUES
```

CL	0.004		
SI	0.014	0.011	
FR	0.008	0.043	0.187
RCC	CL	SI	

Figure 9 - Top-Down Correlation Section

9.1.5 Scatterplots Section

Figure 10 contains the scatterplots section of the output text file from program PATTRN. This section contains lists of those scatterplots of independent variables versus dependent variables that will be included in the scatterplot file. These lists include all the independent variables that met the alpha cutoff for any user-selected test, sorted based on the results of the first user-selected test, and also those independent variables that the user selected that did not meet the alpha cutoff for any user-selected test.

```
E2:WAS_SATB @ 1E4 YRS  S5 INCLUDED VARIABLES

DEPENDENT VARIABLE (# : NAME) IS    1 : WAS_SATB

SCATTERPLOTS WILL BE GENERATED FOR THE FOLLOWING INDEPENDENT
VARIABLES (# : NAME) WHICH MET THE ALPHA CUTOFF 5.0000E-02

    30 : BHPRM
     6 : WRGSSAT
    20 : ANHPRM
    13 : SHPRNHAL
    17 : HALPOR
     4 : WGRMICH
    14 : SHRGSSAT
     7 : WRBRNSAT
    10 : SHPRMCON
    23 : ANRBRSAT

E2:WAS_SATB @ 1E4 YRS  S5 INCLUDED VARIABLES

DEPENDENT VARIABLE (# : NAME) IS    1 : WAS_SATB

SCATTERPLOTS HAVE BEEN SELECTED FOR THE FOLLOWING INDEPENDENT
VARIABLES (# : NAME)

     1 : WGRCOR
     3 : WGRMICI
     5 : WFBETCEL
     9 : SHPRMCCLY
```

Figure 10 - Scatterplots Section

9.1.6 Coefficients Section

Figure 11 contains the coefficients section of the output text file from program PATTRN. This section contains the results of the CC test, the SRC calculations, and the PCC calculations. The results are listed for each independent variable that met the alpha cutoff for the CC test and are sorted based on the p-values from the CC test.

```
E2:WAS_SATB @ 1E4 YRS S5 INCLUDED VARIABLES
COEFFICIENTS SUMMARY FOR DEPENDENT VARIABLE (# : NAME) 1 : WAS_SATB

INDEP VAR      CC      SRC      PCC
# : NAME      P-VAL  RANK  VALUE  RANK  VALUE  RANK  VALUE
30 : BHPERM    0.0000   1.0  0.6029   1.0  0.5923   1.0  0.6812
20 : ANHPRM    0.0000   2.0  0.2929   2.0  0.2950   2.0  0.4198
17 : HALPOR    0.0006   3.0  0.1980   4.0  0.1888   4.0  0.2832
1 : WGRCOR     0.0017   4.0 -0.1810   3.0 -0.1891   3.0 -0.2840
6 : WRGSSAT    0.0081   5.0 -0.1530   5.0 -0.1447   5.0 -0.2211
2 : WMICDFLG   0.0214   6.0 -0.1329   6.0 -0.1357   6.0 -0.2044
```

Figure 11 - Coefficients Section

9.1.7 Rank Coefficients Section

Figure 12 contains the rank coefficients section of the output text file from program PATTRN. This section contains the results of the RCC test, the SRRC calculations, and the PRCC calculations. The results are listed for each independent variable that met the alpha cutoff for the RCC test and are sorted based on the p-values from the RCC test.

```
E2:WAS_SATB @ 1E4 YRS S5 INCLUDED VARIABLES
RANK COEFFICIENTS SUMMARY FOR DEPENDENT VARIABLE (# : NAME) 1 : WAS_SATB

INDEP VAR      RCC      SRRC      PRCC
# : NAME      P-VAL  RANK  VALUE  RANK  VALUE  RANK  VALUE
30 : BHPERM    0.0000   1.0  0.5989   1.0  0.5904   1.0  0.7011
6 : WRGSSAT    0.0000   2.0 -0.4113   2.0 -0.3997   2.0 -0.5534
20 : ANHPRM    0.0001   3.0  0.2299   3.0  0.2260   3.0  0.3518
13 : SHPRNHAL  0.0225   4.0 -0.1319   5.0 -0.1148   5.0 -0.1870
17 : HALPOR    0.0269   5.0  0.1280   4.0  0.1315   4.0  0.2136
```

Figure 12 - Rank Coefficients Section

9.1.8 Verbose Section

Figure 13 contains a representative portion of the verbose section of the output text file from program PATTRN. This section contains the detailed summaries of the formal statistical techniques used to calculate the p-values for each user-selected test. The detailed summaries contain the test statistic, the p-value for the test statistic, the degrees of freedom, if any, used in calculating the p-value, and the rank of the p-values for each independent variable that met the alpha cutoff for that user-selected test. The results are sorted based on the p-values for that user-selected test. The detailed summaries are presented in the order that the user selected the tests.

```
E2:WAS_SATB @ 1E4 YRS S5 INCLUDED VARIABLES  
  
DETAILED TEST SUMMARY FOR DEPENDENT VARIABLE (# : NAME) 1 : WAS_SATB  
  
DETAILED TEST SUMMARY FOR TEST S1  
  
INDEP VAR  
# : NAME          RANK   STATISTIC  P-VALUE   DF  
6 : WRGSSAT       1.0    254.1666   0.0000    16  
30 : BHPRM        2.0    137.8334   0.0000    16  
20 : ANHPRM       3.0     43.8333   0.0002    16  
23 : ANRBR SAT    4.0     26.3333   0.0495    16
```

Figure 13 - Verbose Section

9.2 *Output Plot File*

The plot file from program PATTRN may contain scatterplots and cumulative distribution function plots depending upon which user parameters are specified. The figures that follow contain examples of these plots.

9.2.1 Scatterplots

The scatterplots from program PATTRN may contain several different types of grid lines. Recall that only one type of horizontal grid lines can be specified for a set of scatterplots.

9.2.1.1 Scatterplot with No Grid Lines

Figure 14 contains a scatterplot with no grid lines. Scatterplots containing no grid lines are useful for simply illustrating the data or to aid in interpreting the results from the CC, CCMC, DR, DRMC, FR, FRMC, RCC, and RCCMC tests as well as the PCC, PRCC, SRC, and SRRC calculations.

Figure 14 - Scatterplot with No Grid Lines

9.2.1.2 Scatterplot with X Grid Lines

Figure 15 contains a scatterplot with NXINT vertical lines that represent NXINT intervals of equal probability along the x-axis. The NXINT intervals of equal probability are based on the marginal distribution of the independent variable named in the x-axis label. Recall that for the case of a discrete independent variable, these grid lines are drawn so that the different values that the discrete independent variable assumes appear in separate intervals. Scatterplots containing these grid lines are useful for interpreting the results from the CL, CLMC, CMN, CMNMC, CV, and CVMC tests.

Figure 15 - Scatterplot with X Grid Lines

9.2.1.3 Scatterplot with X Grid Lines and MD Grid Lines

Figure 16 contains a scatterplot with the X grid lines described in Section 9.2.1.2 and with a horizontal line that represents the median of the dependent variable. The median is based on the marginal distribution of the dependent variable named in the y-axis label. Scatterplots containing these grid lines are useful for interpreting the results from the CMD and CMDMC tests.

Figure 16 - Scatterplot with X grid Lines and MD Grid Lines

9.2.1.4 Scatterplot with X Grid Lines and IQ Grid Lines

Figure 17 contains a scatterplot with the X grid lines described in Section 9.2.1.2 and with horizontal lines that represent the interquartile range of the dependent variable. The interquartile range is based on the marginal distribution of the dependent variable named in the y-axis label. Scatterplots containing these grid lines are useful for interpreting the results from the CIQ and CIQMC tests.

Figure 17 - Scatterplot with X Grid Lines and IQ Grid Lines

9.2.1.5 Scatterplot with X Grid Lines and SI Grid Lines

Figure 18 contains a scatterplot with the X grid lines described in Section 9.2.1.2 and with NYINT horizontal lines that represent NYINT intervals of equal probability along the y-axis. The NYINT intervals of equal probability are based on the marginal distribution of the dependent variable named in the y-axis label. Scatterplots containing these grid lines are useful for interpreting the results from the SI and SIMC tests.

Figure 18 - Scatterplot with X Grid Lines and SI Grid Lines

9.2.2 Cumulative Distribution Function Plots

Figure 19 contains a plot of the cumulative distribution function of a selected dependent variable.

Figure 19 - Cumulative Distribution Function Plot of Dependent Variable

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10. REFERENCES

Iman, R.L., and M.J. Shortencarier. 1984. *A FORTRAN 77 Program and User's Guide for the Generation of Latin Hypercube and Random Samples for Use with Computer Models*. SAND83-2365. Albuquerque, NM: Sandia National Laboratories.

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Iman, R.L., M.J. Shortencarier, and J.D. Johnson. 1985. *A FORTRAN 77 Program and User's Guide for the Calculation of Partial Correlation and Standardized Regression Coefficients*. SAND85-0044. Albuquerque, NM: Sandia National Laboratories.

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Press, W.H., B.P. Flannery, S.A. Teukolsky, and W.T. Vetterling. 1989. *Numerical Recipes: The Art of Scientific Computing (FORTRAN Version)*. New York, NY: Cambridge University Press.

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11. APPENDICES

This section contains three appendices. Appendix A contains the user parameter file for a typical PATTRN run and Appendix B contains the output text file from a typical PATTRN run. Appendix C contains the descriptions of the Friedman test and the differences of ranks test. Appendix C was written by Professor Steve Hora of the Business Administration and Economics Division at the University of Hawaii at Hilo.

11.1 Appendix A - Typical PATTRN User Parameter File

Figure 20 contains the user parameter file for a typical PATTRN run.

```
! TITLE CARD
TTL PATTRN EXAMPLE RUN FOR USERS GUIDE
! FILE CONTAINING INDEPENDENT VARIABLE VALUES
IVF [MJSHORT.PATTRN.BFSA]LHSALL.TRN
! FILE CONTAINING DEPENDENT VARIABLE VALUES
DVF [MJSHORT.PATTRN.BFSA]ALLS1.TBL
! SPECIFY NUMBER OF OBSERVATIONS IN SAMPLE
OBSERVATIONS      1-300
! SELECT INDEPENDENT VARIABLES
SIV 1-18 20 22-26
! SELECT DEPENDENT VARIABLES
SDV 1
! SELECT TESTS
TEST SI SIMC CIQ CL DR CMN
! SPECIFY GRID SIZE
NXINT      5
NYINT      5
! SPECIFY MONTE CARLO SIMULATION PARAMETERS
NUMBER OF RANDOM PATTERNS      10000
SEED -585531083
! SPECIFY OUTPUT PARAMETERS
ALPHA CUTOFF 0.1
COEFFICIENTS
```

Figure 20 - Typical PATTRN User Parameter File

11.2 Appendix B - Typical PATTRN Output Text File

Figure 21 contains the output text file from a typical PATTRN run.

```
PATTRN EXAMPLE RUN FOR USERS GUIDE

THE INDEPENDENT VARIABLES ARE FOUND IN
[MJSHORT.PATTRN.BFSA]LHSALL.TRN
THE DEPENDENT VARIABLES ARE FOUND IN
[MJSHORT.PATTRN.BFSA]ALLS1.TBL
USER DEFINED INDEPENDENT VARIABLES WILL NOT BE GENERATED
USER DEFINED DEPENDENT VARIABLES WILL NOT BE GENERATED
THE NUMBER OF INDEPENDENT VARIABLES SELECTED IS 24
THE SELECTED INDEPENDENT VARIABLE NUMBERS ARE
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
 16  17  18  20  22  23  24  25  26
THE NUMBER OF DEPENDENT VARIABLES SELECTED IS 1
THE SELECTED DEPENDENT VARIABLE NUMBERS ARE
  1
THE NUMBER OF TESTS SELECTED IS 6
THE SELECTED TESTS WILL BE SORTED BASED ON SI
THE SELECTED TESTS WILL APPEAR AS FOLLOWS:
  SI   SIMC  CIQ   CL   DR   CMN
THE NUMBER OF CELLS IN THE X DIRECTION IN THE GRID IS 5
THE NUMBER OF CELLS IN THE Y DIRECTION IN THE GRID IS 5
LOGARITHMS WILL NOT BE USED FOR THE CMN AND CV TESTS
MONTE CARLO SIMULATIONS WILL BE PERFORMED
THE NUMBER OF RANDOM PATTERNS USED IN BUILDING THE CCDF IS 10000
THE SEED FOR THE RANDOM NUMBER GENERATOR IS      -585531083
THE ALPHA CUTOFF IS 1.0000E-01
SCATTERPLOTS WILL NOT BE GENERATED
CDFs WILL NOT BE PLOTTED FOR THE DEPENDENT VARIABLES
A DETAILED TEST SUMMARY WILL NOT BE GENERATED
A MONTE CARLO SUMMARY WILL NOT BE GENERATED
A COMMON VARIANCES SUMMARY WILL NOT BE GENERATED
A COEFFICIENT SUMMARY WILL BE GENERATED
A RANK COEFFICIENT SUMMARY WILL NOT BE GENERATED
THE NUMBER OF INDEPENDENT VARIABLES IN THE INDEPENDENT VARIABLE FILE IS 75
THE NUMBER OF DEPENDENT VARIABLES IN THE DEPENDENT VARIABLE FILE IS 1
THE NUMBER OF OBSERVATIONS SELECTED IS 300
THE NUMBER OF REPLICATES IN THE SELECTED OBSERVATIONS IS 1
```

Figure 21 - Typical PATTERN Output Text File

PTTRN EXAMPLE RUN FOR USERS GUIDE

DEPENDENT VARIABLE (# : NAME) IS 1 : WAS_PRES

INDEP VAR	SI		SIMC		CIQ		CL	
# : NAME	RANK	P-VAL	RANK	P-VAL	RANK	P-VAL	RANK	P-VAL
2 : WMICDFLG	1.0	0.0000	1.5	0.0000	1.0	0.0000	1.0	0.0000
17 : HALPOR	2.0	0.0000	1.5	0.0000	2.0	0.0000	2.0	0.0000
1 : WGRCOR	3.0	0.0003	3.0	0.0002	16.5	0.6626	3.0	0.0000
20 : ANHPRM	4.0	0.0049	4.0	0.0050	3.0	0.0007	4.0	0.0187
22 : ANHBCVGP	5.0	0.0194	5.0	0.0219	24.0	1.0000	16.0	0.7686
10 : SHPRMCON	7.0	0.1487	7.0	0.1503	4.0	0.0250	11.0	0.4878
3 : WGRMICI	13.0	0.3239	13.0	0.3285	5.0	0.0595	23.0	0.9649
23 : ANRBR SAT	17.0	0.4765	17.0	0.4803	22.0	0.9197	7.0	0.2710
26 : SALPRES	21.0	0.7554	21.0	0.7607	6.0	0.0880	13.0	0.5672

PTTRN EXAMPLE RUN FOR USERS GUIDE

DEPENDENT VARIABLE (# : NAME) IS 1 : WAS_PRES

INDEP VAR	DR		CMN	
# : NAME	RANK	P-VAL	RANK	P-VAL
2 : WMICDFLG	1.0	0.0000	1.0	0.0000
17 : HALPOR	2.0	0.0000	2.0	0.0000
1 : WGRCOR	18.0	0.6678	3.0	0.0000
20 : ANHPRM	12.0	0.4484	4.0	0.0195
22 : ANHBCVGP	16.0	0.5793	18.0	0.8062
10 : SHPRMCON	14.0	0.4837	10.0	0.4099
3 : WGRMICI	5.0	0.1415	23.0	0.9705
23 : ANRBR SAT	3.0	0.0493	8.0	0.3034
26 : SALPRES	20.0	0.7620	13.0	0.6283

Figure 21 – Typical PATTRN Output Text File (continued)

PATTRN EXAMPLE RUN FOR USERS GUIDE

DEPENDENT VARIABLE (# : NAME) IS 1 : WAS_PRES

IMPORTANCE ORDERINGS FOR INDEP VARS VS TESTS

SI	1.0	2.0	3.0	4.0	5.0	7.0	13.0	17.0	21.0
SIMC	1.5	1.5	3.0	4.0	5.0	7.0	13.0	17.0	21.0
CIQ	1.0	2.0	16.5	3.0	24.0	4.0	5.0	22.0	6.0
CL	1.0	2.0	3.0	4.0	16.0	11.0	23.0	7.0	13.0
DR	1.0	2.0	18.0	12.0	16.0	14.0	5.0	3.0	20.0
CMN	1.0	2.0	3.0	4.0	18.0	10.0	23.0	8.0	13.0
	2	17	1	20	22	10	3	23	26

LEGEND - INDEP VAR # : NAME

2 : WMICDFLG
 17 : HALPOR
 1 : WGRCOR
 20 : ANHPRM
 22 : ANHBCVGP
 10 : SHPRMCON
 3 : WGRMICI
 23 : ANRERSAT
 26 : SALPRES

PATTRN EXAMPLE RUN FOR USERS GUIDE

DEPENDENT VARIABLE (# : NAME) IS 1 : WAS_PRES

TOP-DOWN CORRELATION MATRIX

SIMC	0.959				
CIQ	0.843	0.794			
CL	0.946	0.903	0.844		
DR	0.760	0.708	0.831	0.800	
CMN	0.946	0.903	0.844	1.000	0.800
SI	SIMC	CIQ	CL	DR	

PATTRN EXAMPLE RUN FOR USERS GUIDE

DEPENDENT VARIABLE (# : NAME) IS 1 : WAS_PRES

TOP-DOWN CORRELATION MATRIX P-VALUES

SIMC	0.003				
CIQ	0.009	0.012			
CL	0.004	0.005	0.008		
DR	0.016	0.023	0.009	0.012	
CMN	0.004	0.005	0.008	0.002	0.012
SI	SIMC	CIQ	CL	DR	

Figure 21 – Typical PATTRN Output Text File (continued)

PATTRN EXAMPLE RUN FOR USERS GUIDE

COEFFICIENTS SUMMARY FOR DEPENDENT VARIABLE (# : NAME) 1 : WAS_PRES

INDEP VAR		CC		SRC		PCC	
# : NAME	P-VAL	RANK	VALUE	RANK	VALUE	RANK	VALUE
2 : WMICDFLG	0.0000	1.0	0.7124	1.0	0.7234	1.0	0.8642
17 : HALPOR	0.0000	2.0	0.4483	2.0	0.4651	2.0	0.7469
1 : WGRCOR	0.0000	3.0	0.2762	3.0	0.2460	3.0	0.5113
20 : ANHPRM	0.0241	4.0	0.1302	4.0	0.1277	4.0	0.2953
26 : SALPRES	0.0855	5.0	0.0993	6.0	0.0639	6.0	0.1526

Figure 21 – Typical PATTRN Output Text File (continued)

11.3 Appendix C - Two Tests Based Upon Ranks

Two tests for identifying relationships between outputs and inputs are presented in this appendix. The first test is the Friedman test. This test is appropriate for cases where replicated samples are available. The second test is the Differences of Ranks test. This test is applicable either to single samples or to replicated samples. For each test the samples may be generated either by Latin hypercube sampling or by simple Monte Carlo sampling.

Friedman Test

Let (Y_{ij}, X_{ij}) be an output-input pair, where $i = 1, \dots, n$ indicates the item in the sample and $j = 1, \dots, m$ indicates the sample number. Thus, there are $n \times m$ such pairs in an m replicate design with n observations in each sample. The Friedman test can be applied to test for independence of the output values from the input values. It is not necessary that the Y_{ij} , for $i = 1, \dots, n$, be independent, only exchangeable. Denote by R_{ij} the rank among the Y_{ij} in the j^{th} sample of the output value paired with the input value having the rank i among the X_{ij} in the j^{th} sample. R_{ij} is then the rank of the concomitant of Y_{ij} . It is important to remember that the ranks are assigned within samples and not between samples so that in the absence of ties R_{ij} ranges from 1 to n . The layout of the ranks then is

Sample	Rank(X_{ij}) = 1	Rank(X_{ij}) = 2	Rank(X_{ij}) = 3	...	Rank(X_{ij}) = n
1	R_{11}	R_{21}	R_{31}	...	R_{n1}
2	R_{12}	R_{22}	R_{32}	...	R_{n2}
$\vdots$	$\vdots$	$\vdots$	$\vdots$	...	$\vdots$
M	R_{1m}	R_{2m}	R_{3m}	...	R_{nm}

The distribution of the Friedman test statistic arises from the assumption that the ranks within a sample are a random permutation. The test statistic is given by

$$T = (m-1) [B - mn(n+1)^2 / 4] / (A - B)$$

Where

$$A = \sum_{i=1}^n \sum_{j=1}^m R_{ij}^2 \text{ and } B = \frac{1}{m} \sum_{i=1}^n \left(\sum_{j=1}^m R_{ij} \right)^2$$

The statistic T is compared to the F distribution with $n-1$ and $(m-1)(n-1)$ degrees of freedom.

The Friedman test is particularly appropriate for replicated Latin hypercube samples. It appears to be the only commonly used test with assumptions that fit this situation. The test is sensitive to having similar output values being associated with similar input values. The test does not require a linear relationship or monotonic relationship to exist for detection. The test is therefore useful for a broad range of alternatives but the power of the test is moderate.

Differences of Ranks Test

The differences of ranks test (DR) is a new test formulated to apply in situations where the sampling is Latin hypercube, and, as with the Friedman test, it is applicable with simple Monte Carlo sampling. Unlike the Friedman test, the differences of ranks test can be applied to a single sample.

Denote by R_i the rank of the output Y having the X input with the rank i among the input values. The layout is

Rank(X_i) = 1	Rank(X_i) = 2	Rank(X_i) = 3	...	Rank(X_i) = n
Rank(Y_i) = R_1	Rank(Y_i) = R_2	Rank(Y_i) = R_2	...	Rank(Y_i) = R_n

The DR test statistic is

$$S = \frac{Q - [n(n^2 - 1)/6]}{\sqrt{n^5 \sigma_n}} \text{ where } Q = \sum_{i=1}^{n-1} (R_{i+1} - R_i)^2$$

and σ_n is given in the following table for various n :

$n = 3$	4	5	6	7	8	9	10	$10 < n \leq 40$	$40 < n$
0.091	0.117	0.130	0.138	0.143	0.147	0.150	.152	$(1/6) - (.136/n)$	1/6

Under the null hypothesis of independence between Y and X , the test statistic asymptotically has a standard normal distribution. The rejection area is in the left tail so that large negative values of S indicate dependence.

The DR test statistic uses the notion that when the output values are reordered according to an important input variable, one should observe systematic behavior in the Y values. Values of the output that are near one another will tend to reduce Q .

The differences of ranks test is sensitive to a wide range of type of dependence between X and Y . It does not require a linear or even a monotonic relationship.

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