Abstract
The intent of this paper is to show how to use SAS/IML software through the use of an example. Multivariate control charts for both location and variability are used as the example.

Fully documented code is shown utilizing many of the facets of SAS/IML, including graphics, reading SAS data sets into IML, functions and printing of results. A table comparing some sample commands of PROC MATRIX to that of IML is also provided.

Introduction
The IML in the title "SAS/IML" stands for Interactive Matrix Language. The software itself allows the user to perform operations on individual values, vectors and matrices, produce graphics, and store IML code in modules to be invoked later. This paper will demonstrate the above functions in an example that produces multivariate controls charts.

About the Example
Today's emphasis on quality requires people involved in day-to-day processes to use among other techniques statistical process controls. One of these techniques used in situations when the quality characteristics being measured are dependent on the multivariate control chart. For example, the multivariate version of the univariate XBAR chart is based on the Hotelling T-Square statistic. The multivariate version of the Sigma chart can be based on the logarithm of the determinant of the covariance matrix. Shown below are the formulas of the points to be plotted and their control limits. More information on the theory of these versions can be found in References (1) and (2), respectively.

\[
T^2 \text{ Control Chart} \\
T^2 = n(x-X)'S^{-1}(x-x) \\
\text{where } x \text{ is a } p \times 1 \text{ matrix of period averages} \\
S \text{ is the within variance-covariance matrix} \\
x \text{ is a } p \times 1 \text{ matrix of grand averages} \\
\text{UCL } T^2 \left| a_p,n-1 \right| = p(n-1) / p \cdot \gamma_{a_p,n-p} \\
\log |S| \text{ Control Chart} \\
Y_i = \log |S_i| \\
\text{where } |S_i| \text{ is the determinant of the sample variance-covariance matrix for the } i\text{-th period} \\
LCL, UCL = \bar{y} \pm 3 \bar{S} \\
\text{where } \bar{y} = \frac{1}{m} \sum_{i=0}^{m} y_i \\
\bar{S} = \left[ \frac{1}{m-1} \sum_{i=0}^{m} (y_i - \bar{y})^2 \right]^{1/2}
\]

Details
The code listed in the appendix will now be examined closely. First, there are two major parts of this code. Part one, which is shown in the first 10 lines will be discussed later. Part two is the actual IML code and will be discussed now.

To invoke IML, the statement is simply PROC IML:

\[
\text{The next statement START; signals to SAS the beginning of a module. To end the collection of statements into the module a FINISH; statement is used. Between the first START; and FINISH; statements is the code that computes the statistics necessary for the control charts. This code is explained next to each line of code in the appendix. Some of the code is very similar to PROC MATRIX; however a few basic functions have changed.}
\]

The table below points out some of these differences.

<table>
<thead>
<tr>
<th>Comparison of PROC IML and PROC MATRIX Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>X = [1 2 3 4 5 6] , a 2x3 matrix</td>
</tr>
<tr>
<td>PROC IML</td>
</tr>
<tr>
<td>PROC MATRIX</td>
</tr>
<tr>
<td>Matrix X</td>
</tr>
<tr>
<td>ROW Averages</td>
</tr>
<tr>
<td>Division</td>
</tr>
<tr>
<td>Transpose</td>
</tr>
<tr>
<td>Getting SAS READ INTO X;</td>
</tr>
<tr>
<td>Dataset</td>
</tr>
</tbody>
</table>

The next set of START; and FINISH; statements are for the graphics. Graphics capability does not exist in PROC MATRIX. The commands, although not
similar to SAS/GRAF commands, perform very much the same functions. For example, you can place text anywhere on the screen with different heights, colors, fonts, angles, and rotation. Also, points and/or lines can be drawn with or without axes.

The first ten lines of the code which are MACRO statements make the control chart program code look very much like ordinary SAS code. The MACRO code used is called STATEMENT STYLE MACRO’s, and a discussion can be found in either the SAS User’s Guide: Basics, Version 5 manual.

Once the code shown in the appendix (without the comments on the right) is typed into a file on the VM system called IMLMULT SASMACRO A, then the program can be invoked by typing the following:

```sas
PROC QC DATA=dataset;
    T2S SUBGRP=6 GRPSIZE=' ALPHA=
```

The DATA= and ALPHA= are options. The user simply supplies both the number of subgroups and group size that characterizes the data.

Example

Shown below is an example that contains six subgroups each of size 7.

cmiss filedef z disk iilmult sasmacro a;
%include z;

data a;
    input x1-x4;
    cards;
    50 33 14 2
    46 36 10 2
    51 33 17 5
    55 35 13 2
    48 31 16 2
    52 34 14 2
    65 28 46 25
run;
```
title h=2 c=green f=xswiss 'Multivariate Control Charts';
goptions device=gddmpcgs;
proc qc data=a;
    t2s subgrp=6 grpsize=7 alpha=.99;
```

Output

Shown below is the output from the above example:

![Multivariate Control Charts](image)

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Appendix

/* Statement Style Macro to Simulate a PROC Call */
/* Statement Style Macros for Multivariate */
/* T-Square Control Chart and Log Determinant */
/* Number of Sub-Groups and Sample Size Must Be */
/* Specified, also Program Title. */
/* Begins Collection of Statements into a Module */
/* Dose All Obs From SAS Dataset in Matrix X */
/* Creates a Kol Matrix of 1's */
/* Picks & Returns each Sub-Group for Calculations */
/* Column Averages, Group Averages for Each Var. */
/* Form Matrix of Group Averages */
/* Group Deviations from the Group Average */
/* Group Corrected Sum of Sources */
/* Log of Determinant of Group Covariance Matrix */
/* Form Matrix of Group Log Determinants */
/* Creates a Kol Matrix of 1's */
/* Creates a Kol Matrix of Average Log Determin. */
/* Lower and Upper Control Limits for Log Determ. */
/* Pooled Covariance Matrix */
/* Grand Average of Groups ( X Double Bar ) */
/* T-Square Statistics for each Group */
/* Lower Control Limit for T-Square Control Charts */
/* Matrix of Values Ranging From 1 to # of Groups */
/* Option to Allow User Supplied Column Names */
/* Print Matrices with these Column Names */
/* Ends Collection of Statements into a Module */
/* Ends AXIS Module */
/* Begin Axes Module Graphics */
/* Set up Minimum and Maximum Values Plotted for */
/* The Yaxis for the T-Square Control Chart */
/* Run AXIS Module to Create T-Square Chart */
/* Connect T-Square Points */
/* Draw Upper Control Limit Line */
/* Set Up Minimum and Maximum Values Plotted for */
/* the Yaxis for the Log Determinant 5 Chart */
/* Run AXIS Module to Create Log Determinant 5 */
/* Connect Log Determinant 5 Points */
/* Draw Average of Log Determinant 5 Points */
/* Draw Lower Control Limit */
/* Show the Graphs */
/* Ends the AXIS Module */
/* Macro Label Used When Parameters are not Ent. */
/* End MACRO T2S */