SAS Macro for Generation of 2^n×3 Mixed Level Rotatable Design with Neighbor Effects (MLRDNE)

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Methodology that helps the experimenter find the input factor settings with the optimum response is called response surface methodology (RSM). These methods are used to examine the relationship between the response and the factors affecting the response. In response surface experiments, it is generally assumed that the observations are independent and are not influenced by the treatments applied in the adjacent neighboring units. Usually, in agricultural experiments the plots are arranged side by side in compact blocks, without any gaps in between. It is natural that treatments applied in one plot may spread over to nearby plots (left or right), may be after irrigation or due to the interference of nematodes and other organisms present in the soil or air. For example, in field experiments if a chemical fertilizer is applied to one plot, it may spread over to the nearby plots due to water seepage. These effects are termed as overlap effects or neighbor effects or competition effects or interference effects in the literature. Thus, overlap effects must be considered to develop an appropriate approximating relationship between the response variable and the input variables when the experimental units experience these effects from the nearby units. Further, there may be experimental situations where there are factors that are of unequal levels. Such experimental situations demand the use of mixed level response surface designs. here, it is to be noted that, a design for $2^n\times 3$ is Mixed Level Rotatable Design with Neighbor Effects (MLRDNE) if the variance of the estimated response is same for all points in the design matrix which are equi-distant from the center. Verma et al. (2021) developed a method of constructing $2^n\times 3$ Mixed Level Rotatable Design with Neighbor Effects (MLRDNE). The method of constructing a series of $2^n\times 3$ Mixed Level Rotatable Design with Neighbor Effects (MLRDNE) as discussed by Verma *et al.* (2021) is as follows:

Consider (n + 1) factors with n factors at level two each and $(n + 1)^{th}$ factor is having three levels. Arrange the combinations of $2^n\times 3$ in lexicographic order or reverse of lexicographic order. Obtain (n-1) ($2^n\times 3$) more points (runs) by circularly rotating the n columns pertaining to 2^n factorial and retaining the entries of the $(n+1)^{th}$ column as such. Adding two extra points of border units such that each end of the array has a point of the other end (i.e., treatment given in last plot is taken for the first border plot and treatment given in the first plot is taken for the last border plot) results in a MLRDNE in n($2^n\times 3$) runs along with 2 border units.

Following SAS macro using SAS 9.3 has been developed to generate the series of $2^n\times 3$ Mixed Level Rotatable Design with Neighbor Effects (MLRDNE) using the method of Verma *et al.* (2021) as discussed above. For the series of designs, n number of factors are having two levels each and n number of other factors are having three levels each. In order to execute the macro, user need to enter the **number of factors** as "**n (≥2)** = "and the **value of the coefficient of Neighbour Effects (which vary from 0 to 1)** as "**alpha ="**. If user execute the macro after entering the value of n and the value of alpha, then the macro will generate a particular class of

$2^n \times 3$ Mixed Level Rotatable Design with Neighbor Effects (MLRDNE) based on Verma *et al.* (2021) corresponding to the value of n and alpha under the heading **Mixed Level Rotatable Design with Neighbor Effects (MLRDNE).** Along with the design, the macro will also print the value of alpha as **The coefficient of Neighbour Effects (alpha),** variance of estimated parameter under the heading **Variance factor for parameter estimates** and variance of estimated response under the heading of **Variance factor for predicted response**. Once user run the macro, every time the SAS macro would also generate a word file containing the output. User can then save the word file. The code and output are as follows:

CODE

```
options nodate nonumber;
%let n=2;/*number factors will be of the form ((2^n)*3)*/
%let alpha=0.5; /*Enter the value of alpha*/
ods rtf  file= 'output.rtf' startpage=no;
proc iml;
ss0=j(&n,1,2);
ss1=j(1,1,3);
ss=ss0//ss1;
*print ss;
s=ss;
a=j(max(s),nrow(s),0);
do kk=1 to nrow(s);
m=mod(s[kk, ],2);
do i=1 to s[kk, ];
do j=i to s[kk, ];
if m=1 then
            do;
            a[j,kk]=-((s[kk, ]-1)/2)+(i-1);
            end;
            else
            do;
            if -(s[kk, ]/2)+(i-1)<0 then do;
            a[j,kk]=-(s[kk, ]/2)+(i-1);
            end;
            else do;
            a[j,kk]=-(s[kk, ]/2)+i;
            end;
            end;
end;
end;
end;
*print a;
aa=j(s[1, ],1,0);
do i=1 to s[1, ];
aa[i,]=a[i,1];
end;
*print aa;
sum=1;
do j=1 to nrow(s)-1;
do i=1 to nrow(aa);
kk=repeat(aa[i,],s[j+1,],1);
```

```
if i=1 then do;
aaa=kk;
end;else do;
aaa=aaa//kk;
end;
end;
*print aaa;
sum=sum*s[j, ];
if mod(sum,2)=0 then do;
ggg=j(s[j+1, ],1,0);
do i=1 to s[j+1, ];
ggg[i,]=a[i,j+1];
end;
ggg1=ggg;
ggg2=ggg//ggg1;
hh=repeat(ggg2,sum/2,1);
aa=aaa||hh;
end;
else do;
ggg=j(s[j+1, ],1,0);
do i=1 to s[j+1, ];
ggg[i,]=a[i,j+1];
end;
ggg1=ggg*-1;
ggg2=ggg//ggg1;
hh1=repeat(ggg2,(sum-1)/2,1);
hh=hh1//ggg;
aa=aaa||hh;
end;
end;
Run_Sequence=aa*-1;
*print Run_Sequence;

kk_2=j(nrow(Run_sequence),&n,0);
do i=1 to &n;
kk_2[ ,i]=Run_sequence[ ,i];
end;
kk_21=j(nrow(Run_sequence),&n,0);
do j=1 to &n-1;
do i=1 to &n;
if i+j>&n then do;
kk_21[ ,i]=kk_2[ ,(i+j)-&n];
end;
else do;
kk_21[ ,i]=kk_2[ ,i+j];
end;
kk_22=kk_21;
end;
kk_23=kk_23//kk_22;
*print kk_22;
end;
kk_24=kk_2//kk_23;
*print kk_24;

kk_3=Run_Sequence[ ,&n+1];
kk_31=Run_Sequence[ ,&n+1];
do j=1 to &n-1;
do i=1 to &n;
kk_32=kk_31;
end;
kk_33=kk_33//kk_32;
*print kk_22;
end;
kk_34=kk_3//kk_33;
*print kk_34;
*print kk_24 kk_34;
print "Mixed Level Rotatable Design with Neighbor Effects (MLRDNE),
v=(2^&n)*3";
*print "The number of input variables (v)=(2^&n)*3";
MLRDNE=kk_24||kk_34;
ARSDIE=MLRDNE;
print MLRDNE;
xsquare=j(nrow(kk_34),ncol(kk_34),0);
do i=1 to nrow(kk_34);
do j=1 to ncol(kk_34);
xsquare[i,j]=kk_34[i,j]*kk_34[i,j];
end;
end;
*print xsquare;
b0=j(nrow(xsquare),1,1);
model=b0||kk_24||kk_34||xsquare;
*print model;
g_=i(nrow(ARSDIE));
do i= 1 to nrow(ARSDIE);
do j= 2 to nrow(ARSDIE);
if i=j then g_[i,j-1]=&alpha;
end;
end;
do i= 1 to nrow(ARSDIE)-1;
do j= 1 to nrow(ARSDIE);
if i=j then g_[i,j+1]=&alpha;
end;
end;
x1=model[nrow(model), ]//model//model[1, ];
*print g_;/*without border*/
g1=j(nrow(ARSDIE),1,0);
g1[1,1]=&alpha;
g2=j(nrow(ARSDIE),1,0);
g2[nrow(ARSDIE),1]=&alpha;
g=g1||g_||g2;
*print g;
z=g*x1;
/*print z */;
Var_beta=vecdiag(inv(z`*z));
Var_Est_Resp1=vecdiag(x1*inv(z`*z)*x1`);
Var_Est_Resp=sum(Var_Est_Resp1)/nrow(Var_Est_Resp1);
print 'The coefficient of Neighbour Effects (alpha)';
print &alpha;
print 'Variance factor for parameter estimates';
print Var_beta;
print 'Variance factor for estimated response';
print Var_Est_Resp;
ods rtf close;
quit;
```

SAS output for generation of a MLRDNE for 2^n×3

Mixed Level Rotatable Design with Neighbor Effects (MLRDNE), v=(2^2)*3

MLRDNE		
1	1	1
1	1	0
1	1	-1
1	-1	1
1	-1	0
1	-1	-1
-1	1	1
-1	1	0
-1	1	-1
-1	-1	1
-1	-1	0
-1	-1	-1
1	1	1
1	1	0
1	1	-1
-1	1	1
-1	1	0
-1	1	-1
1	-1	1
1	-1	0
1	-1	-1
-1	-1	1
-1	-1	0
-1	-1	-1

The coefficient of Neighbour Effects (alpha)

0.5

Variance factor for parameter estimates

Var_beta
0.34375
0.0166667
0.0166667
0.25
0.75

Variance factor for estimated response

Var_Est_Resp
0.3770833

Reference

Verma, A., Jaggi, S., Varghese, E., Varghese, C., Bhowmik, A., Datta, A. and Hemavathi, M. (2021). On the Construction of Mixed Level Rotatable Response Surface Designs when Experimental Unit Experiences Overlap Effects. *Communications in Statistics - Simulation and Computation*. DOI: 10.1080/03610918.2021.1890123.