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MATLAB Program for Simulating the Performance Measures of Continuous Sampling Plans

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ABSTRACT

This paper explains the MATLAB program for designing different types of Continuous Sampling Plans. The designed Continuous Sampling Plans are of the type CSP-1, CSP-2, CSP-3 and CSP-5. The program mainly developed are for evaluating the performance measures like Average amount of Inspection *E(I)* and Average Outgoing Quality *(AOQ)*, probability of acceptance of the lot P_A and the parameters like clearance number *'i'* and sampling fraction *'f'* of the plans. In this work, MATLAB R 2007b version is used for the simulation.

Keywords: MATLAB program; Continuous Sampling Plan; Average amount of Inspection; Average Outgoing Quality; probability of acceptance of the lot.

1. INTRODUCTION

MATLAB is a programming language developed by Math Works. It started out as a matrix programming language where linear algebra programming was simple. It can be run both under interactive sessions and as a batch job. MATLAB (matrix laboratory) is a fourth-generation high-level programming language and interactive environment for numerical computation, visualization and programming. It allows matrix manipulations; plotting of functions and data; implementation of algorithms; creation of user interfaces; interfacing with programs written in other languages, including C, C++, Java, and FORTRAN; analyze data; develop algorithms; and create models and applications. It has numerous built-in commands and math functions that help in mathematical calculations, generating plots, and performing numerical methods. It is an interactive program for numerical computation and data visualization. The command used in MATLAB are entered by typing it at the MATLAB prompt'>>' on the Command Window[7].

1.1. Continuous Sampling Plans

Continuous Sampling Plans were introduced by Dodge (1943) for the inspection of continuous flow of discrete products with the aim to sort the production in order to get the fraction non-conforming below a given upper bound. This is achieved by alternating sequences of 100 percent screening and sampling inspections controlled by two parameters i and f [6]. Further generalization of Dodge basic CSP-1 procedure was made by Dodge and Torrey, Liberman and Solomon, Guthire and Johns, Sackrowitz and others. Characteristics of these plans were extensively investigated by many authors. This CSP-1 plan is the simplest and most commonly used single level Continuous Sampling Plan. The other Continuous Sampling Plans namely, CSP-2 and CSP-3 have been developed by Dodge and Torrey as the generalizations of Dodge's basic CSP-1, CSP-2, CSP-3 and a multiple level, CSP-F, CSP-T and CSP-5 contain some differences due to the implementation and the theoretic foundation between them[1].

1.2. Performance Measures of Continuous Sampling Plans

Performance of any sampling plan is measured using certain criteria. The basic and most powerful discriminatory measure is operating characteristic (OC) curve of the sampling plan or scheme. Further, other measures such as average outgoing quality limit, average sample number, average total inspection, average run length etc, are used for assessing the performance of the sampling plans or scheme.

2. MATLAB PROGRAM FOR DESIGNING CSP-1 PLAN

The MATLAB program for simulating the parameters like the clearance number *'i'*, and the sampling frequency *'f'* and performance measures like *AOQ* and *E(I)* of CSP-1 plan are developed[2]. Also program is developed for plotting the graph of the performance measures *AOQ* and *E(I).*

The MATLAB program is

```
clc
% clf
clear all
p1=input ('value of p1'); k=1;
for p=0:0.01:1
% if (p>p1) q(k) =1-p;
i (k) = (1-p)/(p-p1);
f(k) = (q(k)·∧(i(k)+1))/(i(k)*p1*q(k))·∧ (i(k)+1));
Pa(k) = ((f (k)* q(k))+(1-f(k))*q(k)·∧ i(k))/(f(k)+(1-f(k))*q(k)·∧ i(k)); AOQ(k) = ((1-f(k)) *p(k)*q(k)·∧ i(k))/(f(k)+(1-f(k))*q(k)·∧ i(k));
E (K) = (1-(f(k)*q(k)+(1-f(k))*q(k)·∧ i(k))/((f(k)*p(k)+(1-f(k))*p(k)*q(k)·∧ i(k)) k=k+1;
% else
```

```
end
figure; % subplot (5, 1, 1) stem (i)
title (‘Plot for i’)
figure; % subplot (5, 1, 2)
stem (f)
title (‘Plot for F’)
figure; % subplot (5, 1, 3)
stem (Pa)
title (‘Plot for Pa’)
figure; % subplot (5, 1, 4) stem (AOQ)
title (‘Plot for AOQ’) figure; % subplot (5, 1, 5) stem (E)
title (‘Plot for E’)
filename = ‘variable value· xls’; xlswrite (filename, i)
filename = ‘variable value· xls’; xlswrite (filename, f, 2) filename = ‘variable value· xls’; xlswrite (filename, Pa, 3) filename = ‘variable value· xls’; xlswrite (filename, AOQ, 4) filename = ‘variable value· xls’; xlswrite (filename, E, 5)
```

3. MATLAB PROGRAM FOR DESIGNING CSP-2 PLAN

The MATLAB program for simulating the parameters like the clearance number *’i’*, and the sampling frequency *’f’*, performance measures like *AOQ* and *E(I)* and graphical representation of the performance measures of CSP-2 plan are developed and as follows[3]

The MATLAB program is clc % clf

```
clear all
p1   = input (‘value of p1’); k=1;
for p=0:0.01:1
% if (p > p1) q(k) =1-p;
i(k) = (1-p)/(p-p1);
f(k)=q(k)·∧(i(k)+1)*(2-q(k)·∧ i(k)/(i(k)*p1 +(q(k))·∧(i(k)+1))*(2-q(k))·∧ i(k)); Pa(k)=(q(k)·∧ i(k))*(2-q(k)·∧ i(k))/(f(k)*(1-(q(k)·∧ i(k))*(1-q(k)·∧ i(k))+ (2-q(k)·∧ i(k))*(q(k)·∧ i(k));
AOQ(k)= p(k)*(1-f(k))/f(k)+(1-f(k))*(q(k)·∧ i(k)) (2-q(k)·∧ i(k)); E(K)=(1-q(k)·∧ i(k))/(p(k)*q(k)·∧ i(k)));
k=k+1;
% else end
figure; % subplot (5, 1, 1)
stem (i)
title (‘Plot for i’)
figure; % subplot (5, 1, 2) stem (f)
title (‘Plot for F’)
figure; % subplot (5, 1, 3)
stem (Pa)
title (‘Plot for Pa’)
```

```
figure; % subplot (5, 1, 4) stem (AOQ)
title ('Plot for AOQ') figure; % subplot (5, 1, 5) stem (E)
title ('Plot for E')
filename = 'variable value· xls'; xlswrite (filename, i)
filename = 'variable value· xls'; xlswrite (filename, f, 2) filename = 'variable value· xls';
xlswrite (filename, Pa, 3) filename = 'variable value· xls'; xlswrite (filename, AOQ, 4)
filename = 'variable value· xls'; xlswrite (filename, E, 5)
```

4. MATLAB PROGRAM FOR DESIGNING CSP-3 PLAN

The MATLAB program for simulating the parameters like the clearance number *'i'*, and the sampling frequency *'f'*, performance measures like *AOQ* and *E(I)* and graphical representation of the performance measures of CSP-3 plan are developed and as follows[4]

The MATLAB program is clc

```
% clc clear all
p1= input ('value of p1 '); k =1;
for p=0:0.01:1
% if (p > p1) q(k) = 1-p;
i(k) = (1-p) / (p-p1);
r(k) = 1-q(k)·∧ i(k);
t(k) = 1+q(k)·∧ 4*(1-q(k)·∧i(k)); s(k) =1-q(k)·∧(i(k)+4);
A(k)= p*q(k)·∧(k)*(i(k)*q(k)·∧(i(k)+3)-4*(q(k)·∧3)*r(k))+(q(k)·∧i(k))*t(k)-
(i(k)*p*(q(k)·∧(i(k)-1) *t(k)));
B(k)=q(k)·∧i(k)*(i(k)*q(k)·∧(i(k)+3)-4*(q(k)·∧3)*r(k))-i(k)*(q(k)·∧(i(k)-1))*t(k);
C(k)=i(k)*s(k)*q(k)·∧(i(k)-1)+r(k)*(i(k)+4)*(q(k)·∧(i(k)+3))+4*(q(k)·∧i(k)-
(i(k)*p*q(k)·∧(i(k)-1)));
f(k)=(A(k)-p1*B(k))/(A(k)+p1*C(k));
Pa(k)=((q(k)·∧i(k))*t(k))/(f(k)*s(k)*r(k)+(q(k)·∧i(k))*t(k)+4*f(k)*p*
(q(k)·∧i(k)));
AOQ(k)=(p*(1-f(k))*(q(k)·∧i(k))*t(k))/(f(k)*s(k)*r(k)+(q(k)·∧i(k))*t(k)+4*f(k)*
P*(q(k)·∧ i(k)));
E(k)=(f(k)*r(k)*s(k))+(4*f(k)*p*q(k)·∧ i(k))/(s(k)*f(k)*p*q(k)·∧i(k));
k=k+1;
% else
% end
end
figure;% subplot (5, 1, 1)
stem (i)
title ('Plot for i')
figure; % subplot (5, 1, 2)
stem (f)
title ('Plot for f')
```

figure; %subplot (5, 1, 3)
stem (Pa)
title (‘Plot for P*a*’)
figure; % subplot (5, 1, 4) stem (AOQ)
title (‘Plot for AOQ’) figure; % subplot (5, 1, 5) stem (E)
title (‘Plot for E’)
filename = ‘variable value· xls’; xlswrite (filename, i)
filename = ‘variable value· xls’; xlswrite (filename, f, 2) filename = ‘variable value· xls’;
xlswrite (filename, Pa, 3)
filename = ‘variable value· xls’;
xlswrite (filename, AOQ, 4)
filename = ‘variable value· xls’; xlswrite (filename, E, 5)

5. MATLAB PROGRAM FOR DESIGNING CSP-5 PLAN

The MATLAB program for simulating the parameters like the clearance number *’i’*, and the sampling frequency *’f’* , performance measures like *AOQ* and *E(I)* and graphical representation of the performance measures of CSP-5 plan are developed and as follows[5]
The MATLAB program is clc;
clear all;
p1=0.3; q=0; x=0;
for p=0.1:0.1:1 if p<p1 display (invalid);
else
i = (1-p)/(p-p1); i=ceil (i);
q=1-p;
for x=1: 1: i-1;
A=-p*i*(q·∧(i-1))+q·∧i;
B = i*q·∧(i-1);
C = i*(q·∧(i-1))+(q·∧i)*(-i*q·∧(i-1)+x*q·∧(x-1))-i*(q·∧(i-1)*((q·∧i)-(q·∧x)));
f = A+p1*B/A + p1*C;
P*a*(x)=(q·∧i)/(q·∧i)+f*(1-q·∧i)+f *(q·∧i)*(q·∧i-q·∧x);
AOQ(x)= p*(1-f)*(q·∧i)/(q·∧i)+f *(1-q·∧i)+f *(q·∧i)*(q·∧i-q·∧x);
E(x)= f+1+(q·∧i)*((q·∧i)-(q·∧x))/((q·∧i)+f *(1-q·∧i)+f*(q·∧i)*(q·∧i-q·∧x)); end;
figure; % subplot (5, 1, 1) stem (i)
title (‘Plot for i')
figure; % subplot (5, 1, 2) stem (f)
title (‘Plot for f’)
figure; % subplot (5, 1, 3)
stem (P*a*)
title (‘Plot for P*a* ‘) figure; %subplot(5,1,4) stem (AOQ)
title (‘Plot for AOQ’) figure; %subplot(5,1,5) stem (E)
title (‘Plot for E’)

filename = ‘variable value· xls’; xlswrite (filename,i)
filename = ‘variable value· xls’; xlswrite (filename,f,2)
filename = ‘variable value· xls’; xlswrite (filename,Pa,3) filename = ‘variable value· xls’; xlswrite (filename,AOQ,4) filename = ‘variable value· xls’; xlswrite (filename,E,5)

6. CONSTRUCTION OF TABLE VALUES

The table values for the performance measures like Average amount of Inspection *E(I)* and Average Outgoing Quality *(AOQ)* and the parameters like clearance number *’i’* and sampling fraction *’f’* of the continuous sampling plans of the type CSP-1, CSP-2 and CSP-3 corresponding to given values of process average and AOQL using the designed MATLAB program are shown in Table:1.

Table:1

	AOQL (%)								
Incoming process average	0.01			0.02			0.03		
	CSP 1	CSP 2	CSP 3	CSP1	CSP 2	CSP 3	CSP 1	CSP 2	CSP 3
0.01	98 0.1213 27.20	101 0.1952 29.02	0.9615			0.9259			0.8929
0.02	98 0.1213 50.0	101 0.1952 49.96		97 0.0253 15.60	99 0.0456 15.93	0. 9406 0.0594			0.8947
0.03	48 0.3167 66.67	53 0.4159 66.52	98 0.9987 5.884	97 0.0253 33.33	99 0.0456 33.33		97 0.0063 10.87	97 0.0124 11.04	0.9471 33
0.04	32 0.4482 75.00	36 0.5473 74.81	48 0.1591 5.7268	48 0.1235 50.00	51 0.1891 49.94	97 4.1233	97 0.0063 25.00	97 0.0124 25.00	0.9471 33
0.05	24 0.5387 80.00	27 0.6338 79.81	32 0.0957 5.81	32 0.2252 60.00	35 0.3125 59.89	48 2.43	48 0.0538 40.00	49 0.0938 39.98	96 0.0472 4
0.06	19 0.6069 83.33	22 0.6879 83.14	24 0.0745 5.8438	24 0.3118 66.70	26 0.4171 66.51	32 0.172 6.903	31 0.1281 50.00	33 0.1949 49.94	48 4.066
0.07	16 0.6527 85.72	18 0.7345 85.53	19 0.0657 71.04	19 0.3864 71.04	21 0.4903 71.25	24 0.9865 6.0371	23 0.2008 57.10	25 0.2844 57.04	31 4.285
0.08	13 0.7030 87.5	16 0.7591 87.33	16 0.0630 5.8267	15 0.4621 75.00	18 0.5406 14.81	19 0.7476 6.060	18 0.2709 62.6	20 0.3616 62.37	23 4.2558
0.09	11 0.7393 88.90	14 0.7846 88.73	13 0.0645 5.7984	13 0.5067 77.8	15 0.5963 77.57	15 0.7024 5.9801	15 0.3271 66.7	17 0.4182 66.51	18 4.1907
.1	10 0.7583 90.00	12 0.8110 89.84	14 1.0705 5.7649	11 0.5566 80.00	13 0.6367 79.8	13 0.7802 6.0124	13 0.3723 70.00	15 0.4610 69.84	15 4.2835
.11	9 0.7780	11 0.7393	10 1.0832	10 0.5839	12 0.6580	11 2.0775	11 0.4252	13 0.5083	13 4.4875

Illustration

For given values of process average = 0.05 and AOQL = 0.01, the values obtained corresponding to CSP-1 plan from Table:1 are clearance number *'i'* = 24, sampling fraction *'f'* = 0.5387 and the average amount of inspection *E(I)* = 80. Similarly for CSP-2 plan, clearance number *'i'* = 27, sampling fraction *'f'* = 0.6338 and the average amount of inspection *E(I)* = 79.81 and for CSP-3 plan, clearance number *'i'* = 32, sampling fraction *'f'* = 0.0957 and the average amount of inspection *E(I)* = 5.81.

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