A
Project Report On

Economic Design of Control Chart

In partial fulfillment of the requirements of

Bachelor of Technology (Mechanical Engineering)

Submitted By

Anand Amrit Raj (Roll.No 10603003)
Session : 2009—2010

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CERTIFICATE

This is to certify that the work in this thesis report entitled "Economic Design of Control Chart" submitted by Anand Amrit Raj in partial fulfillment of the requirements for the degree of Bachelor of Technology in Mechanical Engineering Session 2009-2010 in the department of Mechanical Engineering, National Institute of Technology Rourkela,an authentic work carried out by him under my supervision and guidance.

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CONTENTS

Abstract

Control chart are widely used to establish and maintain statistical control of a process.In other words it is a tool used to monitor processes and to assure that they remain "In Control" or stable

The vital function of control chart is to find out the occurrence of assignable causes so that the necessary corrective action can be taken before a huge amount of defective product is produced. The X-bar control chart is preferred most in comparison to any other control chart technique if quality is measured on a regular scale. In the present project, we here develop the economic design of the X-bar control chart using Genetic Algorithm to determine the values of the sample size, sampling interval, width of control limits such that the expected total cost per hour is minimized. The genetic algorithms (GA) are applied to search for the optimal values of the three test parameters of the X-bar chart. In genetic algorithm we use mutation and cross-over technique to get the optimal solution. Finally, a sensitivity analysis will be carried out to investigate the effect of model parameters on the solution of the economic design.

Chapter1.

Introduction:

1.1. Control chart:

Control chart are widely used to establish and maintain statistical control of a process.In other words it is a tool used to monitor processes and to assure that they remain "In Control" or stable.

1.2. Elements Of A Control Chart:

A control chart consists of:

1. a central line, (cl)
2. an upper control limit (ucl),
3. a lower control limit and (lcl)
4.process values plotted on the chart.

1.3. Designing a Control Chart:

The obtained all process values are plotted on the chart. If the obtained process values fall within the upper and lower control limits then the process is called as "In Control." If the process values plotted fall outside the upper & lower control limits, then the process is called as "Out Of Control".

1.4. Economic Design of a Control Chart:

Almost in all production processes, we need to observe (monitor) the limit to which our products meet specifications.We can say in the most general terms, there are two "opponent /foe " of product quality:

1. facing deviations from target specifications, and
2. Undue variability around target specifications.

To find out various design parameters that minimize total economic costs,the economic design of control charts are used.The consequence of production lot size on the quality of the product can be significant. If the process goes out-of-control initially of the production run, then the entire lot will be full of more defective items. Therefore, it will be better to reduce the production cycle to decrease the fraction of defective items and,hence, improve output quality. On the other side, decrease in the production cycle may result in an increase in costs due to frequent setups. A balance must be maintained so that the total cost is minimized. The production of quality goods depends upon the operating condition of the machine tools; since, the performance of machine tools depends upon the maintenance policy. It is assumed that the cost of maintaining the equipment enhance life; therefore, an age replacement strategy is needed to minimize the cost of the system, which will simultaneously improve maintenance policy and quality control.

1.5. Genetic Algorithm:

Genetic algorithms are a particular class of evolutionary algorithms (EA) that use techniques inspired by evolutionary biology such as inheritance,mutation,selection,and crossover.

It is an approximate search technique used in computing to find exact or approximate solutions to optimization and search problems. The basic idea of GAs is designed to simulate processes in natural system necessary for evolution, specifically those that follow the principles first laid down by Charles Darwin of survival of the fittest. As such they provide an exploitation of a random search within a given search space to solve a problem.It is not only gives an alternative procedure to solving problem, it constantly outperforms other conventional procedures in most of the problems link. Many of the real world problems involved finding optimal parameters, which might prove difficult for traditional methods but ideal for GAs. Genetic algorithms are categorized as global search heuristics

Chapter 2:

Literature Review:

2.1. General intention of control chart:

Generally in any industrial processes production planning, quality control and maintenance policy are three basic and interrelated factors . The aim of production planning is to determine the optimal method for product manufacturing in order to reduce production cost, holding cost and setup cost and to guarantee that no stock-outs occur during the production cycle.In every production processes, we need to monitor the limit to which our products meet specifications. In the most general terms, there are two "foe" of product quality:

(1) facing deviations from target specifications, and

(2) Undue variability around target specifications.

2.2. Common approach:

The common approach to monitor online quality is very transparent, simply extract samples of a certain size from the running production process. We then produce line charts of the variability in those samples, and consider their closeness to target specifications. If a trend emerges in those lines, or if samples fall outside pre-specified limits, then we declare the process to be out of control and take action to find the cause of the problem.These types of charts are sometimes also called as Shewhart control charts.

2.3. Interpreting the chart:

The most ideal display actually consists two charts; one is called an *X bar chart***,** the other is called an *R chart*.
In both charts, the horizontal axis represents the different samples; the vertical axis for the X-bar chart represents the means for the characteristic of interest; the vertical axis for the R chart represents the ranges. For example,suppose we wanted to control the diameter of piston rings that we are manufacturing. The center line(CL) in the X-bar chart would represent the desired standard size (e.g., diameter in millimeters) of the rings, while the center line in the R chart would represent the acceptable (within-specification) range of rings within samples; thus, this latter chart is a chart of the variability of the process (the larger the variability, the larger the range). In addition to the center line, a typical chart includes two additional horizontal lines to represent the upper and lower control limits (*UCL, LCL*, respectively).

generally, the individual points in the chart, representing the samples, are joined by a line. If this line goes outside the upper or lower control limits or exhibits systematic patterns across consecutive samples, then a quality problem may potentially exist.

2.4.Building Control Limits:

One could randomly determine when to consider a process out-of control (that is, outside the UCL-LCL range), it is general practice to apply statistical principles to do so. Elementary Concepts discusses the idea of the sampling distribution, and the characteristics of the normal distribution.

Example.

If we want the mean of a variable to be controlled ,as the size of piston rings. Under the assumption that the mean (and variance) of the process does *not* change, the successive sample means will be spreaded normally around the actual mean. However, without going into much details related to the derivation of this formula, we also know (because of the central limit theorem, and thus approximate normal distribution of the means; see, for example, Hoyer and Ellis, 1996) that the distribution o fmeans will have a standard deviation of *Sigma* (the standard deviation of individual data points or measurements) over the square root of*n* (the sample size). It follows that approximately 95% of the sample meanswill fall within the limits ± *1.96 * Sigma/Square Root(n).*

. In practice, it is common to replace the 1.96with 3 (so that the interval will include approximately 99% of the samplemeans), and to define the upper and lower control limits as plus and minus 3sigma*limits*, respectively.

General case:

The common principle for building up control limits just described applies to all control charts. After deciding on the characteristic we want to control, for example, the standard deviation, we estimate the expected variability of the respective characteristic in samples of the size we are about to take. Those estimates are then used to buildup the control limits on the chart.

2.5. Common Types of Charts:

According to the type of quality characteristic the types of charts are often classified that they are supposed to monitor: The quality controlcharts are of two types i.e control charts for *variables* and control charts for *attributes.* Specifically, the following charts are commonly constructed for controlling variables:

Charts for controlling variable:

X-bar chart:

The sample *means* are plotted in this chart in order to control the mean value of a variable (e.g., size of piston rings, strength ofmaterials, etc.).

S chart: In this chart the sample *standard deviations* are plotted in order to control the variability of a variable

R chart: In this chart, The sample *ranges* are plotted in this chart, in order to control the variability of a variable..

S2 chart:** The sample *variances* are plotted I n this chart, in order to control the variability of a variable.

<u>The following charts are commonly constructed for controlling quality characteristics that represent *attributes* of the product</u>

.

P chart:

W e plot the percent of defectives (per batch, per
day, per machine, etc.) in this chart, as in the U chart. but, the control limits in this chart are not depend on the distribution of rare events but rather on the binomial distribution (of proportions). That is why , this chart is most
applicable to conditions where the occurrence of defectives is not rare (e.g.,we expect the percent of defectives to be more than 5% of the total number of units produced).

.

C chart:

We plot the *number of defectives* (per batch, perday, per machine, per 100 feet of pipe, etc.) in this chart,. This chart assumes rareness the defects of the quality attribute and Poisson distribution is the base for computing the control limits in this chart .

U chart:

We plot the *rate of defective* in this chart*s*, that is, the number of defectives divided by the number of units inspected (the *n*; e.g., feet ofpipe, number of batches). like the C chart, this chart does not require a constant number of units, and it can be used, for example, when the batches(samples) are of different sizes.

Np chart:
We plot the number of defectives (per batch, per day, per machine) in this chart, as in the C chart. However, the control limits in this chart are not depend on the distribution of rare events, but rather on the binomial distribution. Hence, this chart should be used if the occurrence of defectives is not rare (e.g., they occur in more than 5% of the units inspected). For example, we may use this chart to control the number of units produced with minor flaws.

All of these charts can be adapted for short production runs (short run charts), and for multiple process streams

Chapter3

3.1AN ECONOMIC DESIGN CONTROL CHART

1 BY TUKEY

2 MSE

3.11 BY TUKEY

3.11a INTRODUCTION

During any production process whenever an assignable cause occurs, variation in process occurs always which result in defective items. It is very easy to find out variation in process by using the technique of control chart and then the bulk of defective products can be decreased by smooth repairing process.

Presently , control charts are of many types;suitable control charts must be taken according to sampling techniques and monitoring procedures, when process is monitored. A lot of producers in the field of electronics uses an approach of destructive testing in order to measure the observations of process. The sample is destructed and inspected and not send to the market soon after this test . Generally, for such product's monitoring process , only one sample is selected to measure the observation so as to decrease the cost.To monitor the process mean most of the destructive testing procedures adopt individual control charts

3.11b The setup of this chart:

It is an individual control chart which applies the principle of Box plot to set up its control limits.

The setup of Tukey's chart is as follows:

Step 1. first quartile Q1 and the third quartile Q3.was calculated

Step 2. Inter-Quartile Range (IQR; IQR=Q3- Q1).were calculated

Step 3. to construct upper-control limit (UCL) and lower-controllimit (LCL). following equation were used.

$$LCL = Q1 - K*IQR$$
$$UCL = Q3 + K*IQR \qquad (1)$$

Where parameter k determines the width of control limits and its default is 1.5 [1]. An area of a control chart between UCL and LCL is referred as in-control region. When an observation falls within this area the process is determined to be an in-control process. When an observation falls outside the control limits, the process is determined to be a mean-shift occurrence.

So this was his setup creating process or techniques.
The above mentioned three steps are gives the quartile details .His setup can be used to bring the process from out of control to in control process ,so it was one of the most effective technique in this field of economic design of control charts

3.2 MSE

3.2a Introduction

In any process control techniques it is necessary to control simultaneously , both the shift of means and the drift of variation. Generally, it is done by X-bar and R charts. White and Schroeder (1987) provided the use of a simultaneous control chart. Spiring and Cheng (1998) given a combined control method, the MSE chart.
The vitality of this control chart is that the target value is used instead of the process mean. As per Taguchi's viewpoint, any deviation from the target value results in a kind of loss. The control method of this kind reflects that the intention of quality management is not only to satisfy specifications, but to improve quality consistently in order to reduce the customers losses. The mean square error (MSE) used as the control variable in MSE control chart.

3.2b MSE process

It can be defined as the mean of squared deviations between the observed and the target value.
i.e

$$\text{MSE} = \sum_{i=1}^{n} \frac{(X_i - T)^2}{n}$$

Where T is the target value, X1,X……… Xn is a random sample of size n from an in-control process.we know varience

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}\left(X_i - \overline{X}\right)^2$$

Therefore,

$$\text{MSE} = \sum_{i=1}^{n} \frac{(X_i - \overline{X})^2}{n} + (\overline{X} - T)^2 = \frac{n-1}{n}S^2 + (\overline{X} - T)^2,$$

This statistical theory of the MSE chart was discussed in Spiring and Cheng (1998). The design parameters of the control chart are: the sample size, n; the sample interval,
h; and the width of the control limits of the MSE chart, k, which are determined by reducing the cost brought in the control process and the loss faced by the customers.

In present years, sufficient research has been devoted to the economic design of control charts. Mostly they were depend on the model by Duncan which was reconstructed by Montgomery (1980), butthere was a common problem
survive in all of those models. They considered all types of costs invested in the production process.
The variation drift and the shift from the target can result in the Customers losses.The consumers always expect that the quality characteristic should be close to the aimed value. A kind of Loss is faced if there is a deviation from the target value . The economic design model of the MSE chart given here deals with all costs invest both in production and in consumption .It include the cost of the sampling, cost of testing, cost related with the search for and the possible
corrective action of the assignable causes, and the loss brought or faced by the customers.

Chapter4

4.1METHODOLOGY

4.1a MEANS AND CONTROL LIMIT FORMULAS.

1.FOR X BAR CHART

a.Central line (CL) ***\sum_{i=1}^{n} xbar i/n***

b.Upper control limit (UCL) ***X(double bar)+ AzR(bar)***

c.Lower control limit (LCL) ***X(double bar)- AzR(bar***

2. *FOR R BAR CHART*

a.Central line (CL)

$\sum_{i=1}^{n} R i/n$

b.Upper control limit (UCL) D4R(bar))

c.Lower control limit (LCL) D3R(bar)

4.1b.FACTORS FOR X BAR AND R CHARTS

The factord for x bar nad r chart has been listed in the provided tables, where a2 ,d3,d4 are control char constants.these can be refered as the standard values or ranges

SAMPLSIZE	A2	D3	D4
2	1.880	0	3.267
3	1.023	0	2.575
4	0.729	0	2.282
5	0.577	0	2.115
6	0.483	0	2..004
7	0.419	0.076	1.924

d1	d2	d3	d4	d5	d6	d7	d8

4.1c AN EXAMPLE

In a capability study of a lathe machine used in turning a shaft to a dia. of 24.75(+/-)0.1 mm.with a sample size of six consecutive pieces were taken each day for 8 days.The dia.in mm recorded are as follows:

24.77	***24.80***	***24.77***	***24.79***	***24.75***	***24.78***	***24.76***	***24.76***
24.80	***24.70***	***24.78***	***24.76***	***24.78***	***24.76***	***24.78***	***24.77***
24.78	***24.76***	***24.77***	***24.79***	***24.78***	***24.73***	***24.75***	***24.77***
24.73	***24.70***	***24.77***	***24.74***	***24.77***	***24.76***	***24.76***	***24.72***
24.76	***24.81***	***24.80***	***24.82***	***24.76***	***24.74***	***24.81***	***24.78***
24.75	***24.77***	***24.74***	***24.76***	***24.79***	***24.78***	***24.80***	***24.78***

Construct X bar and R chart for the process . Given A2=0.48,

D4=2.D3=0

SOLUTION:

1.FOR XBAR CHART

a. central line, (CL) =x (double bar)=24.8

b. an upper control limit, (UCL) =24.83

c. a lower control limit and (LCL) =24.77

d. range(R bar) =0.07

2.FOR R CHART

a. central line, (CL) = range(R bar) =0.07

b. an upper control limit, (UCL) =0.14

c. a lower control limit and (LCL =0

Chapter 5

5.1ANALYSING THE PROBLEM WITH GENETIC ALGORITHMS

5.1aDEFINATION OF GENETIC ALGORITHM

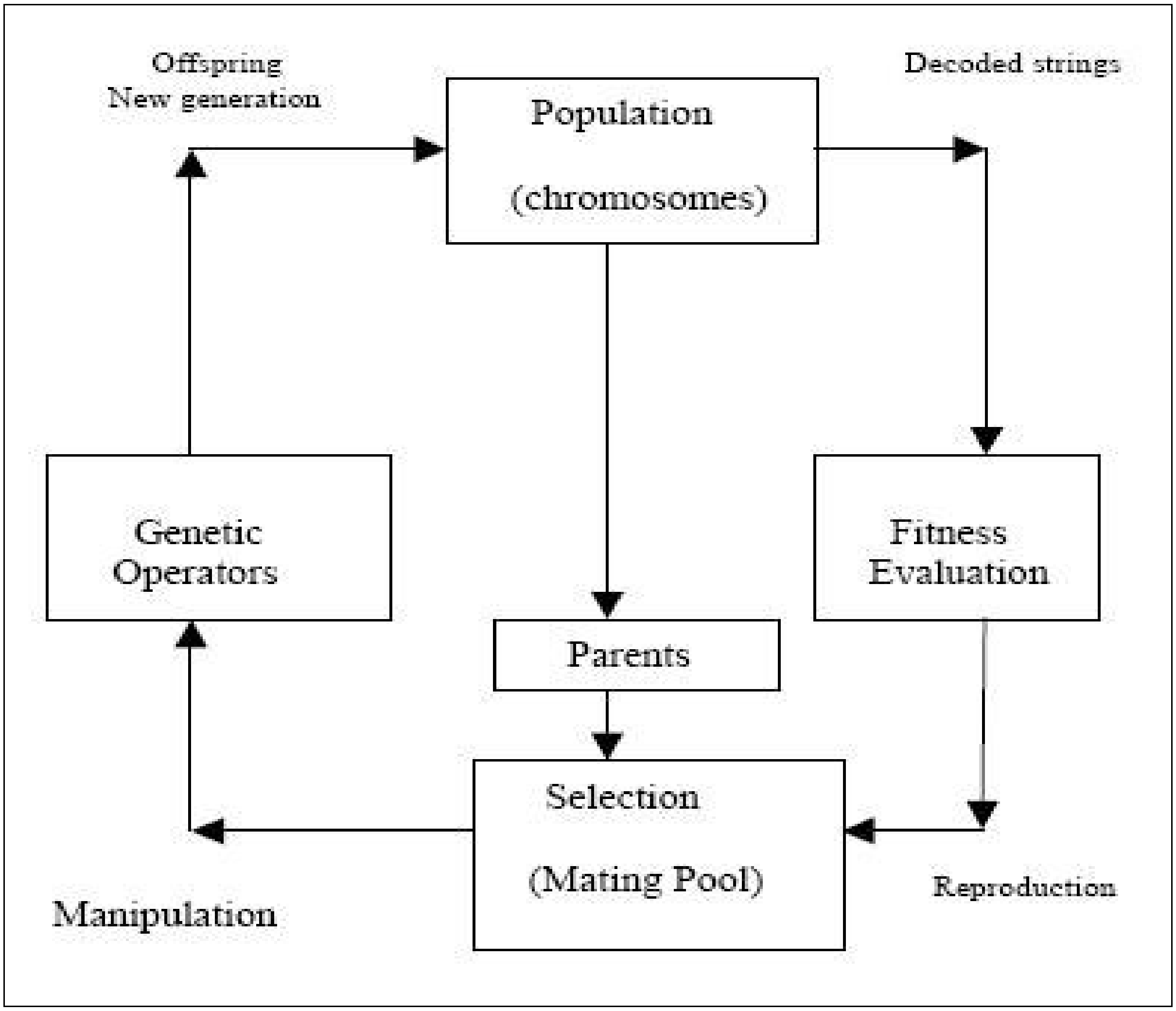
A genetic algorithm (GA) is a variant of stochastic beam search in which coming generation or successor states are generated by combining two parent states ,rather than by modifying a single state .

GAs begin- with a set of k randomly generated states called the population .Each state ,or individual ,is represented as a string over a finite alphabet – most commonly a string of 0s and1s

51bGENETIC ALGORITHAMS COMPONENTS

1 Principles Encoding (gene, chromosome)
2 Initialization method (creation)
3 Parents selection (reproduction)
4 Genetic operators (mutation, recombination)
5 Evaluation function (environment)
6 Termination condition

5.1cCYCLE OF EVOLUTION



5.2GENERAL APPROACH IN GENETIC ALGORITHM

A. Generation of data pool

B. Evaluation of fitness function.

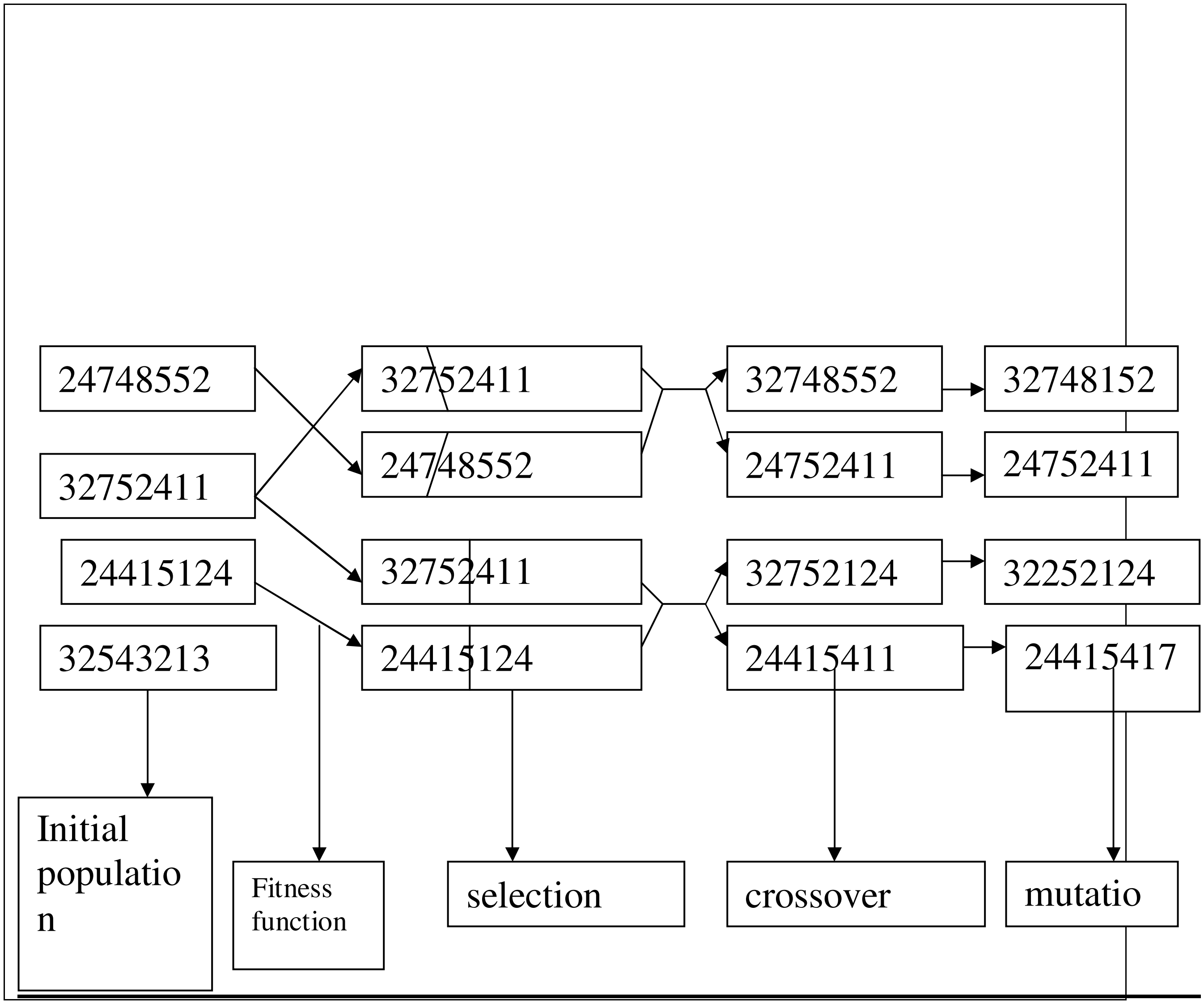
C. Selecting parents from data pool, using fitness function.

D. Cross- over at random points.

E. Mutation (generally after 10—15 iterations)

F. Finding the fittest child according to fitness function

5.3AN EXAMPLE



EXPLAINATION

For each pair to be mated , a cross over at random point is chosen from the positions in the strings. Above figure shows the cross over points are after the third digit in the first pair and after the fifth digit in the second pair .The offspring themselves are created by crossing over the parent strings at the cross over point . For instance ,the first child of the first pair gets the first three digit from the first parent and the remaining digits from the second parent ,whereas the second child get the first three digits from the second parent and the rest from the first parent.

Genetic Algorithm : Outline

1 [Start] Generate random population of *n* chromosomes (suitable solutions for the problem)
2 [Fitness] Evaluate the fitness *f(x)* of each chromosome *x* in the population

3 [New population] Create a new population by repeating following steps until the new population is complete

4 [Selection] Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected)

5 [Crossover] With a crossover probability cross over the parents to form a new offspring (children). If no crossover was performed, offspring is an exact copy of parents.

6 [Mutation] With a mutation probability mutate new offspring at each locus (position in chromosome).
7 [Accepting] Place new offspring in a new population

8[Replace] Use new generated population for a further run of algorithm

9 [Test] If the end condition is satisfied, stop, and return the best solution in current population
10 [Loop] Go to step 2

Genetic Algorithm Parameters

:
Two basic parameters of genetic algorithm are -mutation and crossover probability.

A. Probability of mutation states how often will be parts of chromosome mutated. If mutation is not there, offspring is taken after crossover without any change. If mutation is performed, part of chromosome is changed.Whole chromosome is changed, if mutation probability is hundred percent .and nothing is changed if it is zero percent.Mutation is made to prevent falling GA into local extreme, but it should not take place very often, otherwise GA will infact change to random search.

B. **Probability of crossover** states how often will be crossover performed.If crossover is not there, offspring is completely a copy of parents. If crossover is there, offspring is made from parts of parents' chromosome. If probability of crossover is hundred percent ,then all offspring will take place by crossover. If it will be zero all new generation is made from exact copies of chromosomes from old population (but it does not mean that the new generation is the same!).
Generally crossover is made in hope that new chromosomes will have good parts of old chromosomes and may be the new chromosomes will be better. However it is good to leave some part of population survive to comming generation.
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54 A GENETIC ALGORITHM

Function GENETIC-ALGORITHM(population,FITNESS-FN)returns an individual
Inputs: *population.* a set of individuals
FITNESS-FN,a function that measures the fitness of an individual

repeat

```
new_population---------------      empty set
loop for I from 1 to SIZE(population)do
    x-------RANDOM-SELECTION( population, FITNESS-FN)
    Y------- RANDOM-SELECTION( population, FITNESS-FN)
    Child--------REPRODUCE(x,y)
    If  (small random probability) then child ----MUTATE(child)
    Add child to new – population
  Population------- new –population
 until some individual is fit enough , or enough time has elapsed
return the best individual in population , according to FITNESS-FN
```

```
function  REPRODUCE(x,y) returns an individual
   inputs: x,y   parent individuals

n------LENGTH (x)
c------random number from 1 to n
return APPEND(SUSTRING(x,1,c), SUBSTRING(y, c+1 , n))
-
```

Expected time between the jth to j+1th samplings
for the process shift to occur is

τ =1-(1+ λh) exp (-λh) / λ(1-exp(λh))…………………(1)
The expected cost per hour, denoted by E(C),
incurred by the process is:

E (C) = E (TC)/E(T)…………………………………(2)

The economic design of Tukey's control chart is really used to find out values of h and k so that E(C) may be minimized.

En example

Taking

a) $\lambda = 0.04$.
b) A shift size of about 2 ($\delta = 2$).
c) The time from searching an assignable cause to the repair process to normal state is about 1 hour (D=1).
d) The sampling, inspection and plotting cost is one (a1=1).
e) The cost of searching a mean shift cause and of the repairing process is25 (a2=25)
f) The cost of a false alarm occurrence is 50 (a3=50).
g) The cost of loss per hour caused by the continuous operation is $100 (a4=100).

RESULTS AND DISCUSSION

Once the given parameters have been applied to Eq.(2). This means that sampling will be performed each (h) hours,and the control limit width of Tukey’s control chart should be set at (k), as the probability of false alarm is($P(\delta = 0)$) . the probability of detecting process mean shift is δ accordingly, the expected cost per hour is E(C)11.18

Using ga for Tukey's control chart

		h	k	Type 1 error	power	E(C)
δ	1	0.233	1.21	0.037	0.018	19.25
	1.5	0.231	1.32	0.011	0.133	14.06
	2	0.216	0.32	0.009	0.277	11.18
	3	0.426	1.42	0.007	0.534	7.01
λ	0.01	0.623	1.67	0.000	0.321	1.26
	0.04	0.266	1.22	0.010	0.277	11.18
	0.1	0.177	1.27	0.013	0.372	19.26
	0.5	0.213	1.39	0.012	0.265	52.26
D	0.5	0.324	037	0.004	0263	8.43
	1	0.423	1.72	0.013	0.119	11.18
	2	0.188	1.31	0.005	0.390	14.12
	10	0.543	1.04	0.012	0.159	35.62
a1	0.11	0.123	1.65	0.003	0.022	6.78
	1	0.234	1.37	0.001	0.176	11.18
	11	1.322	0.51	0.035	0.522	17.40
a2	2.4	0.321	1.53	0.012	0.321	9.26
	25	0.352	1.11	0.017	0.505	11.18
	250	0.243	1.62	0.016	0.293	20.36
a3	5	0.342	0.16	0.148	0.501	7.12
	50	0.235	1.09	0.018	0.178	11.18
	500	0.275	1.04	0.014	0.123	16.17
a4	10	0.254	1.18	0.023	0.382	2.18
	100	1.033	1.47	0.017	0.311	11.18
	1000	0.451	1.22	0.101	0.317	60.33

CONCLUSION

Here in this thesis have seen different types of control chart technique of different measures, We also have analyze the different improved techniques given by different scientists and scholars.

The expected cost per hour is obtained as 11.18 is quite appreciable. So we can conclude that Genetic Algorithm is a very nice technique for the optimization of cost for X-bar chart.

CHAPTER 6

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