Reliability Optimization Using Genetic Algorithm

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ABSTRACT

This paper presents an advancement model that distinguishes the kinds of segment upgrades and the degree of exertion spent on those enhancements to augment at least one execution measures (e.g., framework dependability or accessibility) exposed to requirements (e.g., cost, weight) within the sight of vulnerability about the part disappointment rates. An issue explicit Genetic Algorithm (GA) is created to examine arrangement equal framework and to decide the ideal plan setup. Past plans of the issue have understood limitations concerning the kind of excess permitted the quantity of accessible segments decisions and in the case of blending of segments are permitted.

Keyword: Reliability, redundancy, cost

NOTATIONS

R_1 = Reliability of Input transducer

R_2 = Reliability of Functional group G_1

R_3 = Reliability of Functional group G_2

R_4 = Reliability of Output transducer

R_s = Reliability of whole control system

c_i = Cost of each components

w_i = Weight of each components

X_1, X_2, X_3, X_4 = Redundancy required for each of above mentioned components

INTRODUCTION

In the structure procedure, a framework intended to meet it utilitarian necessity as well as intended to play out its capacity effectively. The dependable exhibition of a framework for crucial different conditions is of most extreme significance in numerous mechanical, military and regular daily existence circumstances. The appropriateness of performing unmistakable errands is essentially dictated by the dependability and nature of the framework. Reliability of a system is defined as the probability of achieving the required input-output function within specified limits. Due to increase complexity, sophistication and automation in modern system, system reliability tends to decrease. Generally, the reliability of the constituent components of the system is not sufficient to meet the system reliability. It can be increased by incorporating the following methods:[1, 2, 3]

1. Reducing the complexity of the system.
2. Increasing the reliability of the components by product improvement program.
3. Using structural redundancy.

The employment of the structural redundancy at subsystem level, keeping specific system topology, can provide theoretically unit system reliability. It is definite that the use of the redundancy scheme increases the system reliability, but on the other hand, system weight, cost, power requirement etc. increases. The various types of redundancy schemes can be grouped into two categories:

- Active Redundancy
- Dynamic Redundancy

The use of active redundancy results in less stresses in the load components if load sharing exists, and thereby provides higher system reliability than the dynamics redundancy. The active redundancy can be classified as parallel, series-parallel, parallel-series.

Dynamic Redundancy type of redundancy is also called as standby redundancy. This system has the same as a mixed series-parallel system. However, when a system standby system is used, the parallel M series subsystem is not all active at the same time. Realization of standby redundancy requires a fault detecting and switching device, which make it possible to locate the faulty component and replace it by the standby component. If the fault detecting and switching device is perfect, i.e. highly reliable, theoretically it enables to achieve system reliability close to unity [2].

A number of optimization techniques have been developed for optimizing the system reliability. These techniques are broadly classified into three categories:[4, 5]

1. Approximate technique
2. Exact technique
3. Heuristic technique

Genetic Algorithms (GAs) are a stochastic global search method that mimics the process of natural evolution. The

Evolutionary Algorithms differ substantially from more traditional search and optimization methods. The most significant differences are:[6, 7, 8]

- Evolutionary Algorithms search a populace of focuses in equal, not a solitary point.
- Evolutionary Algorithms don't require derivative data or other auxiliary information; just the objective function and relating fitness levels impact the bearings of search.
- Evolutionary Algorithms use probabilistic transition rules, not deterministic ones.
- Evolutionary Algorithms are generally more straight forward to apply.

Evolutionary Algorithms can give various potential answers for a given issue. An answer calculation for this issue depends on GA search. GA includes the assessment of a populace of arrangements that are amended over progressive ages. Every arrangement is spoken to in the populace by the vector. The hybrid and change administrators are utilized to present new imminent plan arrangements every age. Hybrid includes the choice of parent arrangement vectors and the recombination of those vectors to create new forthcoming arrangements. Parent determination is irregular, however one-sided by the ordinal target work positioning inside a present populace. Arrangements that have been seen to be better are more probable than be picked. Transformation includes the expansion or evacuation of segments as per a pre-chosen change rate. The separating administrator includes the determination of the arrangements with the most noteworthy target work from among the earlier populace and the recently framed arrangements.

The calculation proceeds for a pre-decided greatest number of ages or until no extra improvement is watched. The GA approach doesn't ensure that the ideal arrangement is found, yet GA has been exhibited to deliver generally excellent outcomes and reliably locate the ideal arrangement. It has been seen that the standard deviation of the last GA arrangements is extremely low; consequently, exhibiting sound combination capacities. There are a few strategies accessible to take care of numerous target issues with any mix of straight/nonlinear destinations or imperatives. These heuristics can be applied to numerous target issues effectively without adjusting the issue to accomplish Pareto ideal arrangements. [7, 8, 9]

STATEMENT OF PROBLEM no. 1

We consider a feedback control system as shown in figure consisting of an input transducer with two function groups denoted by $G_1(s)$, $G_2(s)$ and feedback loop. The feedback loop has output transducer. For successful operation of the system; each component must be in proper working condition. Reliability of the error detector is assumed to be unity. The unreliability, cost and weight, for each component are given in table. It is required to maximize the reliability of the control system by using redundant components. The incremental cost and weight of the system must not exceed 560 and 30 units respectively. From design consideration, it is known that at the most, each stage may have ten redundant components.

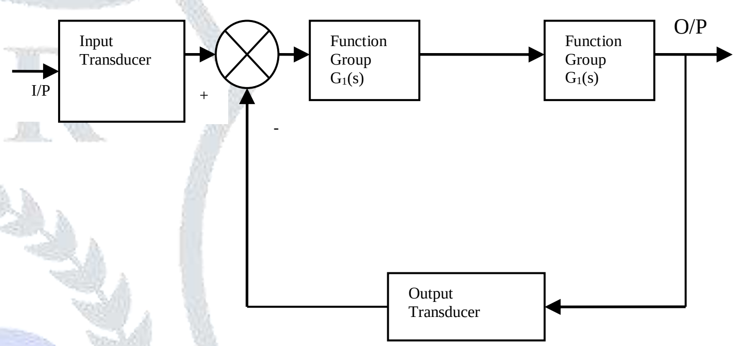

Figure 1 – A Close Loop Control System

Table: 1

Component	Unreliability	Cost	Weight	Reliability
Input Transducer	0.19	11.0	1.0	0.81
Function Group $G_1(s)$	0.33	25.0	1.0	0.67
Function Group $G_2(s)$	0.28	32.0	1.0	0.72
Output Transducer	0.18	43.0	1.0	0.82

Mathematical Formulation (Series Redundancy)

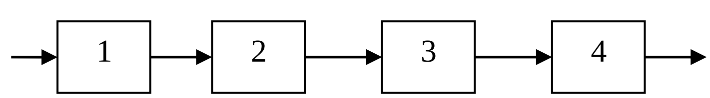

Figure 2 - A logical diagram for feedback control system

From figure 2 we can obtain the overall reliability of the system, which is given by [2, 10, 11, 12]

$R_s=[1-(1-R_1)^{x1}][1-(1-R_2)^{x2}][1-(1-R_3)^{x3}][1-(1-R_4)^{x4}]$

Also total cost (g_1) and weight (g_2) are given by

$$g_1= c_1x_1+c_2x_2+c_3x_3+c_4x_4$$

$$g_2= w_1x_1+w_2x_2+w_3x_3+w_4x_4$$

$$R_s=\prod_{j=1}^{4} [1-(1-R_j)^{xj}]$$

Subjected to

$$g_1=\sum_{j=1}^{4} c_jx_j \leq 560$$

$$g_2=\sum_{j=1}^{4} w_jx_j \leq 30$$

where, $x_j \geq 1$, j=1, 2, 3, 4 are integers

Mathematical Formulation (Parallel Redundancy)

From figure 3 we can obtain the overall reliability of the system, which is given by [2, 10, 11, 12]

$R_s=1-[[(1-R_1)^{x1}][(1-R_2)^{x2}][(1-R_3)^{x3}][(1-R_4)^{x4}]]$

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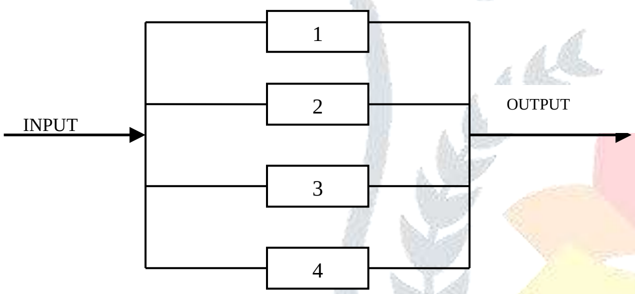

Figure 3 - A logical diagram for feedback control system

$$g_1= c_1x_1+c_2x_2+c_3x_3+c_4x_4$$

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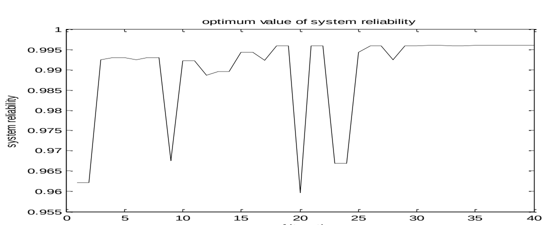


Figure 4 – Reliability of the Control System (Series Redundancy)

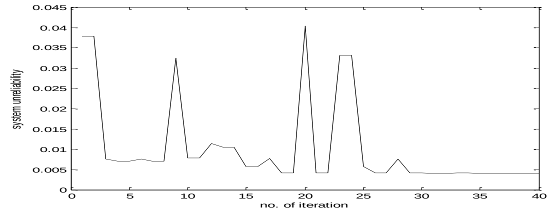


Figure 5 – Unreliability of the Control System (Series Redundancy)

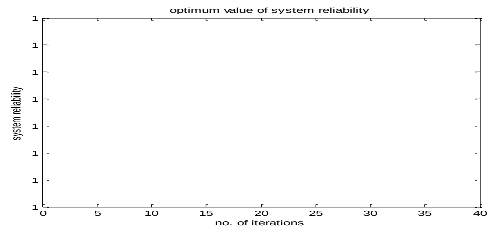


Figure 6 – Reliability of the Control System (Parallel Redundancy)

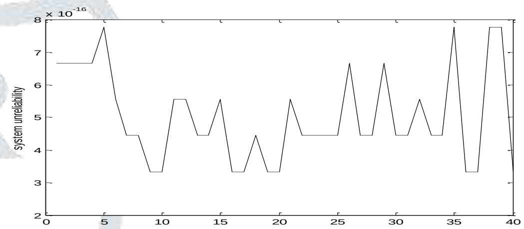


Figure 7 – Unreliability of the Control System (Parallel Redundancy)

STATEMENT OF PROBLEM no. 2

We consider a feedback control system as shown in figure consisting of an input transducer with two function groups denoted by $G_1(s)$, $G_2(s)$ and feedback loop. The feedback loop has output transducer. For successful operation of the system; each component must be in proper working condition. Reliability of the error detector is assumed to be unity. The unreliability, cost and weight, for each component are given in table. It is required to maximize the reliability of the control system by using redundant components. The incremental cost and weight of the system must not exceed 560 and 30 units respectively. From design consideration, it is known that at the most, each stage may have ten redundant components.

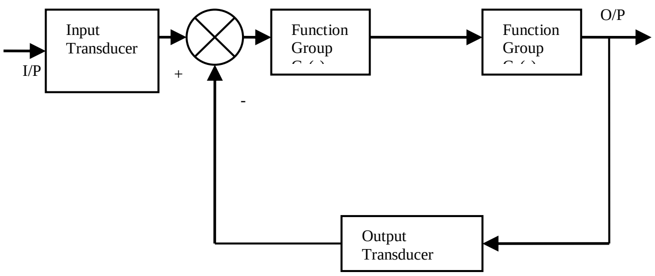
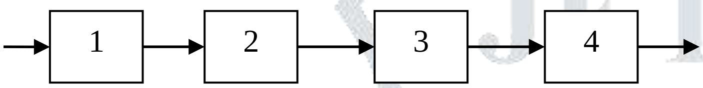


Figure 8 – A Close Loop Control System

Table: 2

Component	Unreliability	Cost	Weight	Reliability
Input Transducer	0.69	11.0	1.0	0.31
Function Group $G_1(s)$	0.78	25.0	1.0	0.22
Function Group $G_2(s)$	0.87	32.0	1.0	0.13
Output Transducer	0.70	43.0	1.0	0.30

Mathematical Formulation (Series Redundancy)



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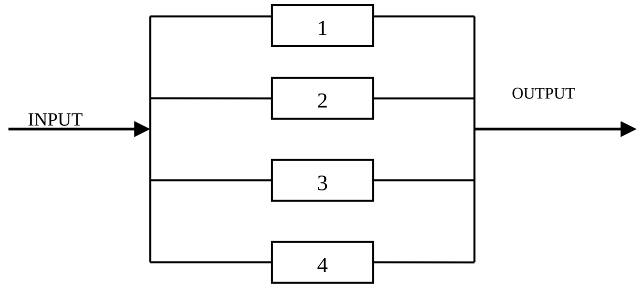

Figure 10 - A logical diagram for feedback control system

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Subjected to

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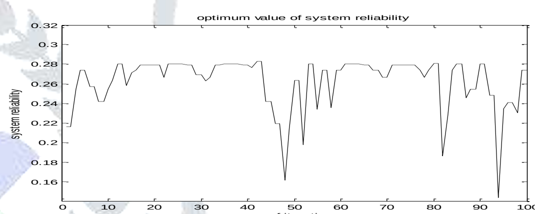

Figure 11 – Reliability of the Control System (Series Redundancy)

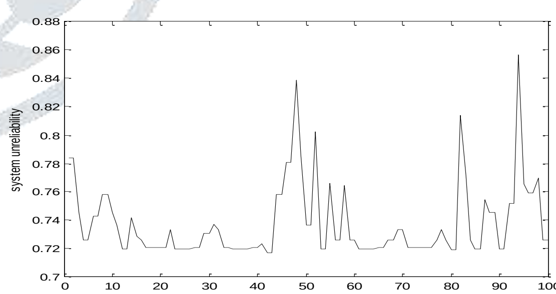

Figure 12 – Unreliability of the Control System (Series Redundancy)

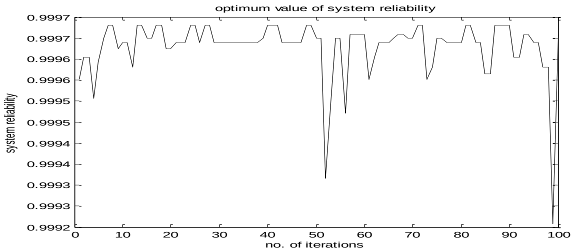

Figure 13 – Reliability of the Control System (Parallel Redundancy)

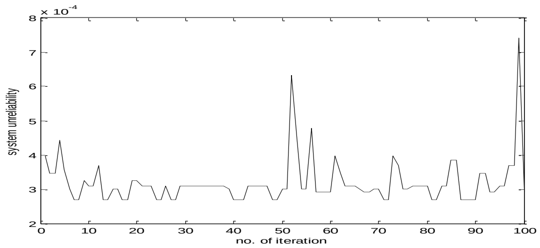

Figure 14 – Unreliability of the Control System (Parallel Redundancy)

RESULT ANALYSIS:

The following results are obtained by the use of Genetic Algorithm (GA). Figure 4 shows the reliability obtained using series redundancy which is 0.9954. The redundancy required for each component is X_1=5, X_2=3, X_3=4, X_4=4. Figure 6 shows the reliability obtained using parallel redundancy which is approximately 1.000. The redundancy required for each component is X_1=5, X_2=6, X_3=6, X_4=4, but by seeing the unreliability in Figure 7 we can say that reliability is not exactly 1.000.

CONCLUSION:

The result of Genetic Algorithm is being compared with Series redundancy and Parallel redundancy. Here it was found that for getting good reliability, Parallel Redundancy should be adopted. Here only the parallel and series redundancy allocation problem is taken, other redundancy allocation can also be taken.

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