RELIABILITY ANALYSIS FOR PHASED MISSION SYSTEM BY USING SIX SIGMA CONCEPTS

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ABSTRACT

Phased mission systems are a typical way to do operations in engineering. It was hard to figure out how reliable phased mission systems were in a good way. Reliability is important to figure out and make sure that a system works safely even when working conditions are complicated. When at least one active subsystem fails in any phase, the PMS is said to have failed. If all subsystems are active in all phases, the PMS reliability can be found by multiplying the mission reliability of each subsystem, it accounts for the implications of phase-dependent variable configurations by phase count. However, at some stages, certain subsystems are disabled, thus failure of any one component will not result in the failure of the whole subsystem.

The proposed method will be used on large-scale systems, and it will depend on conditional probabilities and an effective recursive formula for calculating these probabilities. Six sigma ideas are used in this proposed method. The importance of this method is similar to how the time it takes to calculate and the amount of memory it needs. Both of these things are linear in terms of the size of the system. It shows how well the proposed method works by looking at large systems from a medium scale. The proposed method makes it easy, quick, and accurate to analyze the reliability of large-scale and practical phased-mission systems. The method will be used in a MATLAB simulation environment for this project.

INDEX-TERMS: Reliability Optimization, Six Sigma Concepts, PMS

I. INTRODUCTION

Work is completed in stages through a phased mission system (PMS). There are phases between each action or procedure. PMSs find applications in the electrical power, aerospace, armament, and computer sectors. Launch, separation, and orbit are all aspects of a satellite's lifecycle that may be tracked by a mission monitoring system (PMS). If each step of the PMS process is finished successfully, then the system is functional. If all N phases of an N-phase PMS are working well, then the system may be considered dependable.

RS = P (Phase 1 is successful, Phase 2 is successful, and so on up to Phase N.) Phases 1 and 2 are successful; Phase N is also successful. The complexity of a PMS makes its dependability estimation more challenging than that of a simple system. PMS's phase-dependent structure and interdependence of component failures. The dependability of PMS has been examined for a long time. Such situations can be handled via state space models and combinatorial approaches. State space-oriented models describe system behavior using Markov chains and/or Petri nets, making them malleable and potent for modeling complex interactions between system components.

The possible number of states grows in proportion to the number of components. Analysis of PMS dependability is performed using combinatorial techniques, Boolean algebra, and decision diagrams. For PMS reliability analysis, the combinatorial technique of Binary Decision Diagram (BDD) has gained traction in recent years due to its computing efficiency and compact structural function representation. Zang et al. [9] conducted a BDD analysis of premenstrual syndrome symptoms. Tang et al. devised a BDD-based method for assessing the reliability of multimode PMSs. By using a heuristic selection approach to lessen the BDD, Mo, Reed, and colleagues improved upon Tang's method. Xing et al. and Levitin et al. both offered BDD-based solutions for PMSs that have a root cause and propagated failures.

Wang et al. and Lu et al. used BDDs with state-enumeration methods in their studies of PMSs with repairable components. Though BDD is a powerful combinatorial technique, it is challenging to examine complex systems without extensive computational effort [1, 12]. For PMS reliability analysis, we present a combinatorial analytical method.

It's the basic mechanism that does something again and over again to get somewhere (or mission). A Phased Mission System (PMS) is one in which the structure of the system (and sometimes the operational environment) evolves through time, and each stage of development is referred to as a "phase." There is an interdependency between the parts that are unique to each phase, and each phase corresponds to a certain structural arrangement.

Think of a two-phase system in which each phase contains ni components, denoted by N2.

In phase I the jth component's operational status is represented by the binary state indicator variable Xij, j1,..., ni.

If the ith phase uses the jth component, then Xij = 1. The alternative is a zero in my book.

The ith phase states of all components are repr esented by the vectors Xi = (Xi1,..., Xini), I 1,. .., N, and X = (X1,..., XN) = (X11,..., X1n1,..., XN1,..., XN11) = (X11,..., X1n2,..., XN11) = (X11,..., X1n2,..., XN11) = ((X1,..., XN1).

The system state is a binary random variable for each phase, with values set by the components of that phase.

The system is in a state I during the ith phase if and only if I = i(Xi) = i(Xi1).

I = 1 if the system allows the Xi state vector, and 0 otherwise.

All the parts of the PMS contribute to a binary random variable that represents the structural importance of the PMS as a whole (the operational state of the system across all phases).

S = S (X), Y = N (Xi 1) = 1 (2)

In eq. (2), the structure function is a Boolean function that is computed from the truth tables of the individual phases.

Truth tables are configuration-specific tables that list every conceivable combination of states for each component that might indicate the system's operational status.

When S(X) is a state vector equal to 1, the system is operational, and when it is equal to 0 the system is not.

In order to do a reliable analysis of a PMS, the truth table must be cleaned up by removing any potential state combinations that cannot occur.

A failing component cannot be used in later phases system and if its components are beyond repair, the mission must be aborted.

If every step goes off without a hitch, the mission is a success.

S = Y Ni = 1 I = 1 J = 1 J

However, computing PMS reliability is more difficult than non-PMS dependability because to changes in system architecture throughout phases and failure dependency between components.

In the last several decades, PMS reliability analysis has risen to prominence as one of the most difficult problems in the fields of system reliability evaluation and maintenance engineering. Although there has been progress toward economical and effective techniques for assessing PMS dependability, it is still challenging to analyze big systems without incurring significant computing expenditure, and Intuitions regarding the system's dependability are often lost in translation when using various approaches. The PMS's dependability is tested using the survival signature. The signature of a system may be used as a trustworthy indication of its reliability. A PMS structure-function analysis may be shown in a novel survival signature. Using the hypothesized survival signature, we determine the PMS reliability. Reliability analysis based on signatures helps decouple system architecture from component failure rates. In addition to being effective, the proposed strategy is straightforward to apply. Reliability analysis is necessary for PMSs that have several failure mode components.

A component may have more than one way of breaking down. Analysis of the significance of components in PMS is a topic of study here.

II. METHODOLOGY

II.A. RELIABILITY

Depending on whom you ask, reliability can mean a lot of different things. Depending on whom you ask, this is either root cause analysis or predictive maintenance. When people discuss reliability, some people think of RCM while others think of failure elimination teams. The truth is that reliability is both a concept and a methodology, employing a wide variety of techniques to achieve its objective. Only by employing predictive maintenance, RCFA, RCM, and teams is it possible to ensure the consistent performance of mechanical systems.

The KMS (Kennecott Maintenance System) defines reliability as "the degree to which an asset, when operated in accordance with specified conditions, consistently produces the quality product or service for which it was designed." The maintenance schedule and standard operating procedures play important roles in the success of any reliability initiative. It includes topics like careful asset selection at the outset, high-quality construction, fewer breakdowns, and regular upkeep.

Reliability at Kennecott, in a nutshell, is maximizing the outcome to provide optimum value to the business through the systematic elimination of failures in the most important pieces of equipment by knowing how critical equipment failures, operating practices, and maintenance strategies are intertwined. Many Resources, including RCM Cost, AvSim+, and RCFA are used to accomplish this goal.

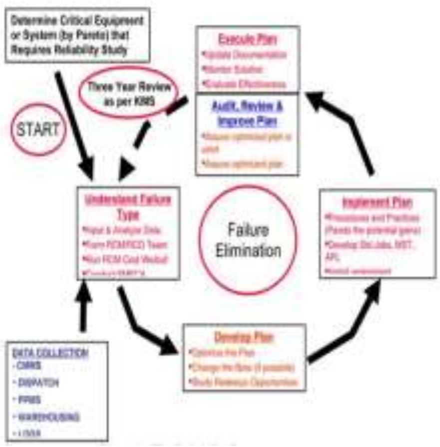

Fig.1: Reliability with sigma

II.B. SIX SIGMA

Some people see Six Sigma as nothing more than a number—3.4 defects per million possible outcomes, to be exact. The implementation of a six-sigma program does not necessitate that every process is optimized to the point where it achieves six-sigma results. In its simplest form, Six Sigma is an initiative to improve quality by minimizing sources of error.

Kennecott Utah Copper's Master Black Belt Aaron Breen has said, "Six Sigma is an Attitude with a Toolbox." One's outlook is that difficulties are really just advantages in disguise. The options in the toolbox can be used to effectively deal with the problems at hand. MISTAKE PROOFING, LEAN (a structured method for reducing waste in processes), and STATISTICS (data analysis for making decisions accurately, efficiently, and without emotion) are all common tools (designing process such that it is easy to do right and hard to do it wrong). To put it simply, Six Sigma is merely a method of coping with the stresses of the modern workplace. It offers a methodical plan for meeting the requirements of various clientele. Six Sigma is a methodology that employs tried-and-true methods to solve business problems. It's more methodical and organized than what came before. The structure and workflow of Six Sigma are highly hierarchical. There is a part for everyone in the organization to play, from the top brass to the assembly line workers. (Breen, 6). DMAIC is the foundation upon which the six-sigma methodology is built (Define, Measure, Analyze, Improve, Control). For centuries, statisticians have used the Greek letter sigma (0) to stand for the statistical concept of standard deviation. The standard deviation is a statistical measure of the dispersion of data around the mean. Variability within the process has been widely acknowledged as a major contributor to subpar quality ever since the time of Derning and Juran. William Smith, a reliability engineer at Motorola, is credited with coming up with the concept of Six Sigma, which is now a trademark of the company. Bill Smith created Six Sigma to address Motorola's design flaws, which were causing system failures on a regular basis. William Smith suggested aiming for Six Sigma to boost product dependability and quality. Until then, the standard deviation of a process is used to establish its lower and upper control limits (LCL and UCL). Bill Smith proposed increasing both the lower and upper bounds to the age of 60. So, the range of permissible deviations is p-60 to p+60. As a result, designers will have no choice but to create processes with as little room for error as possible.

The LCL and UCL for a three-sigma process are p-30 and p+30, respectively. The maximum allowable deviation in a three-sigma process is 0,..3.

III. Simulation Results

➢ The Subsystem Reliability Algorithm

Here, we provide an all-encompassing approach for assessing the component's robustness. As noted in Section 3, this approach cannot be used until the conditional reliabilities of the components (pj values) are known. The algorithm's computing complexity is equal to the mean value of the vector m = [m1, m2, mM] (n mM). This method has many similarities with another one that was recently presented in [11]. As a result, with a few adjustments, the MATLAB code provided in [11] may be used to calculate the subsystem reliabilities.

```
Inputs: n, M, k = [k1, k2 ..., kM], p = [p1, p2 ...,
pM] Output: Subsystem reliability: Ri

Calculate the vector m = [m1, m2,... , mM]
                    // for i =1 to M: mi = n-ki+1
for j = 1 to M do
    pG > pj; pF > 1 — pG          // where: pi = qi
    if (pF == 0) continue          // skip the iteration j
pZ > [1,0, ... 0]; m0 > 1   // means: pZ0 = 1
                    // pZ means: previous Z vector

    Pr0 > (pG)^n
    for i = 0 to n do
        Pr > Pr0; Zi > O
        for a = 0 to min{i, mj-1 -1} do
            Zi > Zi + pZa × Pr
            Pr > Pr/pF × (i-a)/(n-a)
                                   // for next a
    end for
        Pr0 > Pr0 × (n-i)/(i+1) × pG/pF
    end for                        // for next i
    pZ > Z
end for                  // set pZ to Z = [Z0, ..., Zn]

Subsystem Reliability: R > Σ_{i=0}^{mM -1} Zi
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Fig.2: Algorithm for Subsystem Reliability Evaluation

An automobile is a complicated system involving three key components. Breaking, torque, and acceleration are taken into consideration. Six sigma implements the proposed method. In this process, reliability analysis for each component, each phase, and each subsystem. There are so many outcomes in large-scale systems because the system is so complex. The proposed six sigma is a quality improvement strategy that analyses the number of flaws in a present process and seeks to reduce them systematically in order to achieve high reliability. Demonstration of the method: It uses a straightforward example to illustrate the proposed approach. As an Effortless Illustration Think of a made-up version of PMS with 3 causes (A, B, C) and 4 phases. Subsystems' total component counts are shown in Table 1. For those unfamiliar, Weibull is taken to be the default distribution for component failure times in each subsystem. Baseline distribution parameters are context specific.

Table 1: Subsystem Parameters

Subsystem	#Comp.	Baseline Distribution	Distribution Parameters	
ID	*n*	*F*	*η*	*β*
A	4	Weibull	1000	2
B	3	Weibull	2000	1.5
C	5	Weibull (Exponential)	5000	1

Table 2 displays the phase lengths and the values of the subsystem parameters (k and alpha) that vary with the phase.

Table 2*:* Parameters and Prerequisites that Vary by Phase

Phase		Phase 1	Phase 2	Phase 3	Phase 4
Duration		10	30	40	20
Phase-Dependent Subsystem Parameters					
Subsystem *A*	*k*	2	0 (Idle)	3	1
	α	1	0.2	2	1.2
Subsystem *B*	*k*	1	2	0 (Idle)	2
	α	1	2	0	0.25
Subsystem *C*	*k*	3	4	3	2
	α	1	4	3	2

During phases 2 and 3, subsystems A and B are put on hold. As a result, in these stages, zero operational components are required for these subsystems. Subsystem-components A, are at risk of failure even though it is inactive in phase 2. Because alpha=0.2 for the A-subsystem, this is the case. The proposed procedure begins with an assessment of the reliability of each mission component. Using equations (1) through (5), we determine the conditional reliabilities of subsystem components: A's p = [p1, p2, p3, p4] = [0.9999, 0.9998, 0.9911, 0.9948]. Based on the data in Table 2, we know that for subsystem-A, k = [k1, k2, k3, k4] = [2, 0, 3, 1]. Using the data in Tables 1 and 2, we get the values 4 for both n and M. Subsystem-mission A's dependability may be determined as follows using the algorithm: RA = 0.9995. In a similar vein, we may calculate the mission reliabilities of the remaining subsystems as follows: RB = 0.9998, RC = 0.9933. Total system mission dependability is determined by multiplying the mission reliabilities of its constituent parts. Thus, RPMS = 0.9926. for a technique to reliably quantify these minuscule CPU durations. The CPU time for solving this issue is 1.68E-4 seconds. For example, the mission's 200 phases serve as a demonstration of efficiency. Time spent in phase j can be calculated as rj = 1 + mod (j, 10). Therefore, t = 1,100 is the total time of the mission. There are one hundred individual modules making up the whole system. There is ni = (5+i) parts in subsystem i. Therefore, there are a total of 5,550 parts to the system. Results: CPU time = 1.23 seconds; RPMS = 0.99998; mission unreliability = 2.33E-5.

Initialization of the project and syncing process

In this process, each point can be applied to clustering then evaluate the baseline distribution and hierarchical clustering and dendrogram. A typical method for grouping data is hierarchical clustering. It organizes items into groups so that they are related to one another yet different from those from other groups. A dendrogram is a hierarchical tree that graphically represents clusters. Hierarchical clustering groups data over a number of sizes by constructing a cluster tree or dendrogram. The tree is a multilevel hierarchy in which clusters at one level are joined as clusters at the following level. Six Sigma is a quality improvement strategy that analyzes the number of faults in a current process and seeks to systematically eliminate them in order to attain high reliability.

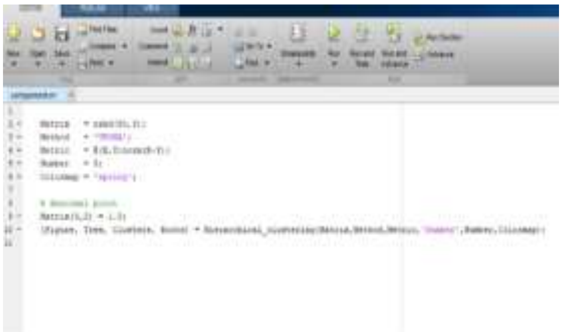

Fig.3: This diagram depicts the processing loading component required to achieve the six-sigma process.

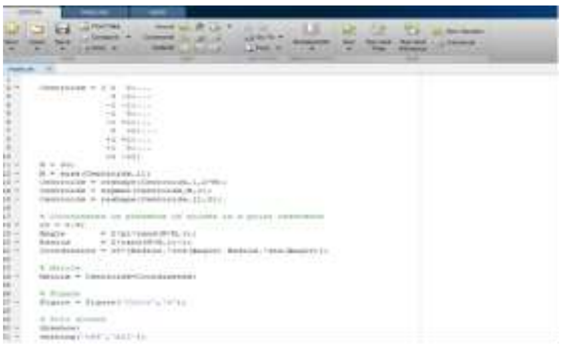

Fig.4: This figure represents the overall process of six sigma and PMS in a large-scale system.

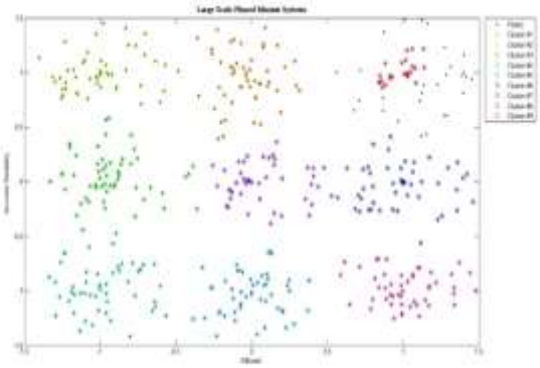

Figure.5: This diagram illustrates the cluster applied in each point used in large-scale systems.

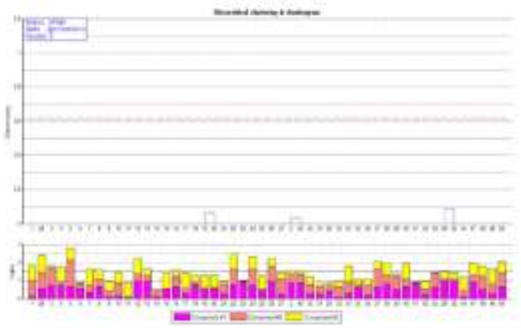

Figure.6: This figure represents a hierarchal clustering and also represents the component on a level basis.

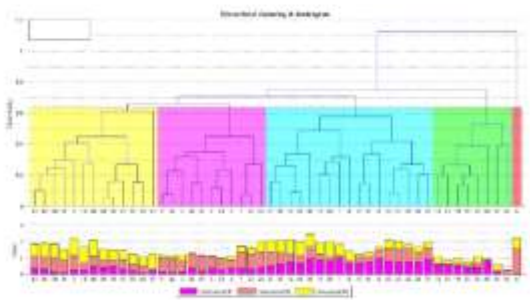

Figure.7: These diagrams show hierarchical clustering, which is the process of grouping components into clusters and applying them to a large-scale system. Clustering allows us to subgroup components.

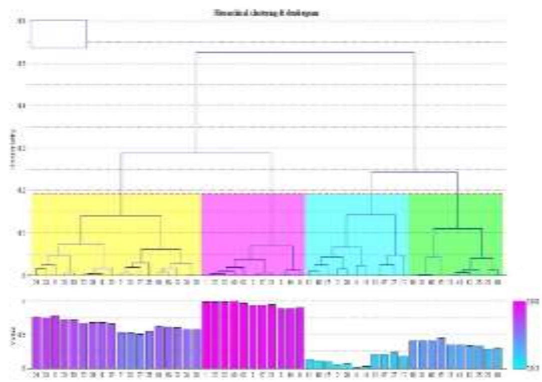

Figure.8: The six sigma utilized in the hierarchical clustering component yielded great reliability in this case.

IV. CONCLUSION

Numerical examples validate the effectiveness of the suggested methodology in evaluating PMS model reliability. The technique takes into consideration failure rates and the long-term damaging repercussions of such failures. Show that the approach works even if the phase durations are unpredictable, backup systems aren't perfect, and there is a gap in fault coverage. The proposed method allows for a quick and precise analysis of the dependability of large-scale and practical PMS models. It is straightforward to incorporate the method with optimization algorithms for locating economical system configurations. Take into account components that can be in a few different states, subsystems that don't all have the same components, and components and subsystems that can be fixed.

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