A genetic algorithm for optimal joint inspection and maintenance of stochastic degrading systems

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1 Introduction

In reliability studies, there are situations where failures of a component can only be detected through inspections. The purpose of inspections is then to identify whether the component is in a working state or not, and thereby to plan and carry out necessary maintenance actions if needed.

In recent decades, maintenance problems have received a great attention and several works have been developed in the literature. Early works are those initiated by Barlow et al. [1]. Barlow et al. [1] introduced an inspection policy where the objective is to minimize the average total cost of inspection activities. An algorithm based on a recurrence relation is proposed to calculate the optimal inspection dates. Several extensions of the work by Barlow et al. [1] have been proposed in the literature. According to Munford and Shahani [2], a nearly optimal inspection policy has been suggested and an approximate solution to that of Barlow et al. [1] is proposed. The policy developed in Munford and Shahani [2] has been exploited in the work by Munford and Shahani [3] to solve the same problem while considering the particular case where the system lifetime isWeibull distributed. In Munford and Shahani [3], numerical and empirical methods are used to solve the problem initially investigated in Munford and Shahani [2]. On the basis of the works by Munford and Shahani [2, 3]; Tadikamalla [4] proposed methods to derive the optimal inspection dates for a system whose lifetime is gamma distributed. In Grall et al. [5], an inspection maintenance optimization model is proposed to derive the optimal inspection schedule as well as the optimal replacement threshold for a system whose degradation process follows a Gamma distribution. Badía et al. [6] proposed an inspection/maintenance policy while taking into account the nature of the information gathered from inspection. The objective in Badía et al. [6] is to minimize the average total cost per unit of time induced by costs of inspection and maintenance actions. In [2], Chouikhi et al. proposed a Nelder–Mead method to solve the inspection/maintenance optimization problem while taking into account the impact of the production system degradation on the environment.

The majority of existing optimization of inspection and maintenance problems are solved on the basis of numerical procedures. Solutions derived are then either optimal or near optimal. These later are obtained by assumptions added to the initial model. In the present work, the primary objective is to propose an heuristic based-approach to compute a near optimal inspection and maintenance planning for a stochastic degrading system. A Genetic algorithm is then developed to solve the inspection/maintenance optimization initially introduced in by Munford and Shahani [2]. The results obtained are then compared to those obtained in the literature.

2 The joint inspection and maintenance optimization model

The joint inspection and maintenance optimization problem studied in the present work considers a random failure system operating in infinite time horizon. Distribution and reliability functions of the system lifetime are respectively denoted by F(t) and R(t). The system is replaced by a new one at failure. Failures are however detected only by inspection. The objective consists then on finding the optimal inspection schedule Tk (k=1, 2, ...) which minimizes the total expected cost C(T1,...,Tk) of inspections and replacement [3]:

$$C_1(T_1, T_2, ...) \equiv \sum_{k=0}^{\infty} \int_{T_k}^{T_{k+1}} [C_1(k+1) + C_2(T_{k+1} - t)] dF(t) + C_3$$

$$= \sum_{k=0}^{\infty} [C_1 + C_2(T_{k+1} - T_k)] \overline{F}(T_k) - C_2\mu + C_3,$$

where C_1, C_2 and C_3 are cots of, respectively, inspection, downtime and replacement, and μ is the expected lifetime of the system. The downtime cost C_3 is the loss cost per unit of time corresponding to the time the system spent in its down state between a failure and its detection at the new inspection date.

To avoid the computational burden of computing the optimal inspection schedule, a GA is proposed in the present paper. The results are compared to an existing asymptotic approach which is initially introduced by Munford and Shahani [2]. According to the work by [2], the above cost objective function is approximated as:

$$C_1(p) = \frac{C_1}{p} + C_2 \sum_{k=1}^{\infty} T_k q^{k-1} p - C_2\mu + C_3$$

where the parameter p (q=1-p) represents the probability that the system fails in the interval $[T_{k-1}, T_k]$ given that it survives until the $(k-1)^{th}$ inspection time, i.e.

$$p = \frac{F(T_k) - F(T_{k-1})}{\overline{F}(T_{k-1})}$$

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