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Preventive maintenance and upgrade system: Optimizing the whole performance system by components' replacement or rearrangement

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Abstract

A decision-making model for reassembling different deteriorating subsystems and components of a complex system from used and new parts is proposed. The objective is to find the proper reassembly policies in a period of time so as to maximize the systems' overall performance values, under limited budget, and reassembly and compatibility constraints. Environmental gains are incurred from these policies, since the used components' life cycle, at least in some cases, is extended instead of ending by entering the waste stream. A stochastic dynamic programming approach is proposed, and an example in the case of personal computers is presented.

Keywords: Reassembly; Benchmarking; Deteriorating components; Stochastic dynamic programming

1. Introduction

A complex system consists of subsystems and components, some or all of which may deteriorate over time at different rates due to technical or technological reasons. Consequently, their operating value as well as the operating value of the whole system deteriorates. In the case of a set of systems composed of identical or similar such subsystems and components, a recommended policy may be to periodically reassemble the systems using used subsystems and components, in order to attain better overall operating systems' value, taking compatibility and cost constraints into consideration. The reassembly policy should take also into account the fact that some components may fail and they should be replaced by new ones.

Research related to aspects of this problem has been reported in the literature regarding maintenance, reliability and scheduling applications. In Zafiropoulos and Dialynas (2004), a computational methodology was presented in order to obtain the optimal system structure of electronic devices by using single or multi-objective optimization approaches, while considering reliability and cost constraints. An optimization approach was developed using a simulated annealing algorithm. In Ferrer (1997), the economics of PC remanufacturing were studied and some experimental results concerning the values of the components of a PC, which

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deteriorate as time increases, are presented. The (monetary) values of the PCs' components are decreasing functions of time, i.e. $V = V_0 t^{-a}$, where V_0 is the component's value at $t = 0$, t is computed in periods (months) and $a > 0$. In Voutsinas and Pappis (2002), the case of PC remanufacturing was examined. The components' values deteriorate over time and the objective was to find the optimal sequence of components' remanufacturing in order to maximize their total remaining value. A heuristic algorithm was implemented, which yielded near-optimal solutions.

Reassembling subsystems and components represents a special case of closed loop supply chains management (Guide et al., 2005), i.e. supply chains involving the reuse of products and materials. The need of companies to optimally utilize their limited resources has increased during the past few years due to several reasons. Provided that high-technology components and subsystems have short life cycles, a reuse policy, along with the financial gains, contributes to a more sustainable environment (Krikke et al., 2002; Bloemhof-Ruwaard et al., 2004).

The development and diffusion of new technology affects the reuse of components and subsystems, either in the case of components of the same generation or in the case of using older technologies in next generation systems or vice versa (Linton and Bhattacharya, 2003). If there is a likelihood of rapid technological obsolescence, purchasing new equipment may not be the proper option. Skipping a generation of technology and using some new components or subsystems for replacing old ones can be proved to be a better choice until the budget for a more advanced technology is available. For example, in the case of consumable parts like one-time-use cameras, the products are sent back to the retailer (or manufacturer) immediately after their use. Then the consumable parts of the product can be replaced by new components, while the durable parts are kept in the product. Xerox is using components from copier machines that are at the end of their lease in manufacturing new copiers.

This kind of "remanufacturing" provides manufacturers and/or retail users with an incentive to recover available older products from the market for use in the next generation ones. Some fields where this might appear are military aircraft and ships, telecommunications, the semiconductor industry and cellular telephony (Savaskan et al., 2000).

Especially, in the case of home PC users where D-I-Y (do-it-yourself) assembly is very popular, subsystems' reassignment can be very effective (Hendrickson et al., 2003). Consumers have shown a considerable unwillingness to throw away old electronic products. Instead, computers are often stockpiled in storerooms. One option could be the reassignment of the PC from one owner to another without extensive modifications or no modifications at all. Moreover, in the absence of upgrading needs for most equipment, reuse is a viable option. Most PC subsystems are designed to last well beyond the useful life of the overall system. This is awkward, since the whole system sits often idle, while its subsystems could be reassigned, and the purchaser will not pay much more to replace for nondamaged components that will eventually outlast the system.

In this paper, a decision-making model is defined for reassembling different subsystems and components of a set of systems from used and off-the-shelf items. Specific policies are set up with regards to the needs for upgrading (no permanent components' damage) and replacement (permanent components' damage).

The objective is to find the proper reassembly policies in a time horizon so as to maximize the overall performance values of the systems, under limited budget, reassembly and compatibility constraints. A stochastic dynamic programming approach is proposed in order to tackle this problem and an example in the case of personal computers is presented.

The remainder of this paper is structured as follows: In Section 2, the problem is described. In Section 3, a formal model based on a stochastic dynamic programming approach is proposed. In Section 4, some preliminary results of an illustrative example in the case of personal computers are presented. The paper is concluded with Section 4.

2. Description of the problem

Consider a set with n systems. Each system has m components, each one of which is assigned a value, based on its importance and role in the system. The components deteriorate at different rates and have different importance for the system. The problem is to find the proper policies in a time horizon consisting of N discrete periods, which maximize the overall performance value of the n systems,