Model Predictive Control of a Forecasting Production System with Deteriorating Items

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ABSTRACT

The authors consider in this paper an integrated forecasting production system of the tracking type. The demand rate during a certain period depends on the demand rate of the previous period. Also, the demand rate depends on the inventory level. Items on the shelves are subject to deterioration. Using a model predictive control approach, the authors obtain the optimal production rate, the optimal inventory level, the optimal demand rate, and the optimal objective function value, explicitly in terms of the system parameters. A numerical example is presented.

Keywords: Deterioration, Forecasting, Model Predictive Control, Production Planning Systems, Target

1. INTRODUCTION

Production planning and demand forecasting are two problems that have been abundantly considered in the literature. However, consideration of these two problems separately may lead to suboptimal solutions. The integration of interrelated models in a single integrated model is a common solution that many authors have chosen. Production planning models have thus been integrated with pricing, scheduling, maintenance, distribution, quality, etc.

For example, Abid and Tadj (2011) consider an integrated production inventory model where raw materials, as well as items, are subject to deterioration. They develop an exact formula for the total inventory cost per unit of time and derive the optimal production schedule.

To capture interactions between pricing, sales, and lead times, Upasani and Uzsoy (2014) develop an integrated model for dynamic pricing and production planning for a single product under workload-dependent lead times.

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Khan et al. (2014) provide an integrated mathematical model for determining an optimal vendor–buyer inventory policy by accounting for quality inspection errors at the buyer’s end and learning in production at the vendor’s end. The objective is to minimize the joint annual cost incurred in the supply chain.

Fitouhi and Nourelfath (2014) integrate noncyclical preventive maintenance with tactical production planning in multistate systems. The maintenance policy suggests noncyclical preventive replacements of components and minimal repair on failed components. The model gives simultaneously the appropriate instants for preventive maintenance and production planning decisions. It determines an integrated lot-sizing and preventive maintenance strategy of the system that minimizes the sum of preventive and corrective maintenance costs, setup costs, holding costs, backorder costs, and production costs, while satisfying the demand for all products over the entire horizon.

Lee and Kim (2014) develop an integrated production–distribution model to determine an optimal policy with both deteriorating and defective items under a single-vendor single-buyer system. The optimal numbers of delivery after incorporating deterioration and defectiveness into one model are found by maximizing the supply chain profit.

Chu et al. (2015) propose a new method for integrating planning and scheduling problems under production uncertainties. The integrated problem is formulated into a bi-level program. The planning problem is solved in the upper level, while the scheduling problems in the planning periods are solved under uncertainties in the lower level. The planning and scheduling problems are linked via service level constraints. To solve the integrated problem, a hybrid method is developed, which iterates between a mixed-integer linear programming solver for the planning problem and an agent-based reactive scheduling method.

For a recent review of some integrated production planning models we direct the reader to Hadidi et al. (2012).

Although production planning has been integrated with many areas, there is one area that did not receive much attention. Recently, Hedjar et al. (2012) introduced the following integrated forecasting-production system:

\[ D(k+1) = aI(k) + bD(k) \]  

(1.1)

where \( I(k) \) is the inventory level at time \( k \) and \( D(k) \) is the demand rate at time \( k \). This model combines two pertinent observations.

The first one is an observation that has been made decades ago, that the inventory level affects customer behavior; see e.g. Levin et al. (1972) and Silver and Peterson (1985). It has been observed that the presence of more quantities of the same product tends to attract more customers. In other words, the demand rate may be influenced by the inventory levels. The second part of model (1.1) incorporates the forecasting component into the production planning problem. It is assumed that the production rate at time \( k \) is used to predict the demand at time \( (k+1) \).

The brief literature review we conduct in the next section shows the efforts researchers put in looking for optimal ways to produce demand forecasts. As mentioned earlier, to avoid suboptimal solutions, the forecasting and production planning problems should not be treated separately. Therefore, we consider in this paper such an integrated problem. While Hedjar et al. (2012) study that problem using an optimal control approach, we want to study the same
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