Available online at www.sciencedirect.com

ScienceDirect

IFAC PapersOnLine 50-1 (2017) 10154–10159

Inventory Control for a Manufacturing System under Uncertainty: Adaptive Approach

Valerii N. Azarskov*. Leonid S. Zhiteckii. Klavdia Yu. Solovchuk**. Olga A. Sushchenko*. Roman O. Lupoi****

**National Aviation University, 03058 Kiev, Ukraine (e-mail: azarskov@nau.edu.ua; sushoa@ukr.net).*
***Int. Centre of Inform. Technologies & Systems, Institute of Cybernetics, 03680 MSP, Kiev, Ukraine, (e-mail: leonid_zhiteckii@i.ua; solovchuk_ok@mail.ru; r.lupoi@ukr.net)*

Abstract: This paper deals with controlling the in-process inventories for the manufacturing system of a typical machine-building enterprise which includes the machining, the transport, the storage bunker and the assembly line. The decision-making is implemented under uncertainty associated with the absence of exact machining model assuming that machine failures are also possible. To cope with this uncertainty, the adaptive control approach is proposed. Within this approach, a new adaptive reorder policy which makes it possible to improve the performance of the inventory control system is developed. Simulation experiments are conducted to demonstrate the advantage of this policy.

Keywords: Adaptation, estimation algorithms, identifiers, inventory control, production planning and scheduling, uncertainty.

1. INTRODUCTION

The in-process inventory control problem stated several decades ago, in particular, in Buchan and Koenigsberg (1963) remains a topic of considerable and widespread interest up to now. This problem is important from both theoretical and practical point of view. Since the pioneering works (Simon, 1952; Yokoyama, 1955), the classical control theory becomes a tool for dealing with the control of manufacturing systems containing the in-process inventories. A significant breakthrough in this research area has been made in Axsater (1985), Kuntsevich (1973), Shin *et al*. (2008), Skurikhin (1972), Wiendahl and Breithaupt (2000) who studied the dynamic processes arising in typical production control systems. Their ideas were extended in Azarskov *et al*. (2006), Zhiteckii *et al*. (2007).

Recently, different approaches inspired by novel results achieved in the modern control theory have been advanced to tackle the manufacturing control problems. Among them they include linear programming and dynamic programming, robust and adaptive control concepts, genetic algorithms, ℓ_1-optimization, etc. (Aharon *et al*., 2009; Azarskov *et al*., 2013; Bauso *et al*., 2006; Boukas, 2006; Grubbstrom and Wikner, 1996; Hennet, 2003; Hoberg *et al*., 2007; Ignaciuk and Bartoszewic, 2010; Kostić, 2009; Rodrigues and Boukas, 2006; Taleizadeh *et al*., 2009; Towill *et al*., 1997).

To implement a perfect inventory control for a manufacturing system, the exact mathematical model with respect to the machining is required (Skurikhin, 1972). In practice, however, there is only approximate model of the machining that may be used in the decision-making system. Moreover, machine failures are possible, in principle. Due to these facts, there is some uncertainty when the order (reorder) policy is formed (Azarskov *et al*., 2006; Zhiteckii *et al*., 2007). The two approaches are proposed in modern control theory to deal with uncertainty: either a nonadaptive robust approach (Sanchez-Pena and Szanier, 1998) or an adaptive approach (Landau *et al*., 1997).

In this paper, the adaptive control concept is extended to cope with uncertainty in the inventory control. Its main contribution is a new adaptive control algorithm that makes it possible to improve the decision-making system via the use of a novel reorder policy formed by this system. Contrary to (Azarskov *et. al*., 2013), it does not require *a priori* information related to some bounds on uncertainty. This feature seems to be important from a practical point of view.

2. DESCRIPTION OF A BASIC INVENTORY CONTROL SYSTEM

2.1 Mathematical Model

Consider the system for controlling the so-called in-process inventory (Buchan and Koenigsberg, 1963, Chap. 22) of a typical machine-building enterprise whose production line includes the machining, the transport, the storage and the assembly line depicted diagrammatically in Fig. 1. This control system operates as follows. At the start $t = t_n := nT_0$ of each nth scheduled time interval $[t_n, t_{n+1}]$ $(n = 0, 1, 2, \ldots)$ having the same duration $T_0 = t_{n+1} - t_n$, the decision-making system sends the request about the current product stock level $H(t)$ equal to $H(t_n) := H_n$. After receiving this information, the deviation

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2017.08.1762

$$e_n := r^0 - H_n \qquad \text{(in units)} \tag{1}$$

of H_n from the required level of safety stock value, r^0, is determined. Next, it places the order (reorder), θ_n, defining the product volume to be produce during the planning interval $t_n \le t \le t_{n+1}$ in accordance with the rule

$$\theta_n = \begin{cases} \theta_{\max} & \text{if } \theta_n^{c} > \theta_{\max}, \\ \theta_n^{c} & \text{if } 0 \le \theta_n^{c} \le \theta_{\max}, \\ 0 & \text{if } \theta_n^{c} < 0, \end{cases} \qquad \text{(in units)} \tag{2}$$

where $\theta_{\max}$ denotes maximum order size which might be satisfied at $t \in [t_n, t_{n+1}]$ by introducing all available manufacturing capacity, and θ_n^{c} is defined by a given order policy. Usually (Kuntsevich, 1973; Skurikhin, 1972) θ_n^{c} is specified by

$$\theta_n^{c} = e_n \qquad \text{(in units).} \tag{3}$$

The expression (2) together with (1) and (3) implies that if $H_n > r^0$ then $\theta_n = 0$ because the order quantity θ_n cannot be negative. Note that (3) corresponds to the simplest order policy.

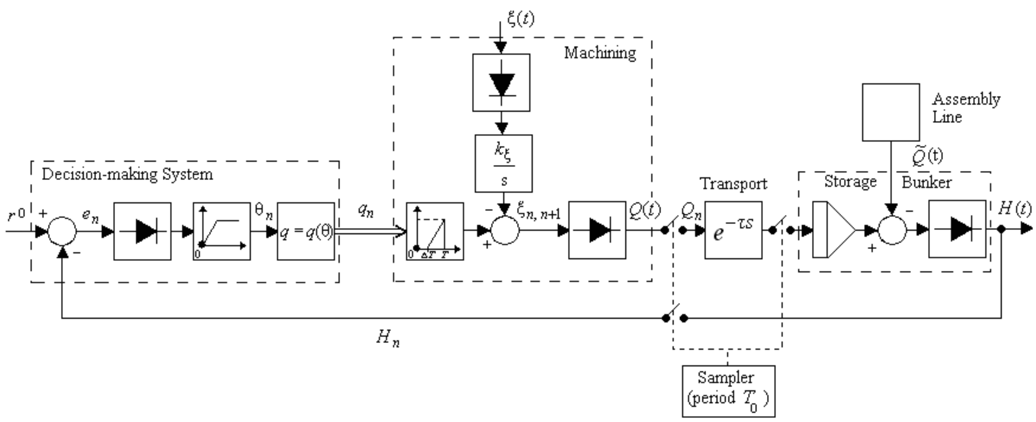

Fig. 1. Configuration of the basic inventory control system.

Based on the value of θ_n, the decision-making system determines the production capacity q_n necessary to produce the order quantity θ_n. This capacity may be expressed as

$$q_n = q(\theta_n) \tag{4}$$

with some vector-valued operator q. Equation (4) gives formally an operation schedule for each machine.

The product fabricated by machining to the end of time interval $[t_n, t_{n+1}]$ is

$$Q_{n+1} = P_{n,\, n+1}(q_n) - \xi_{n,\, n+1} \qquad \text{(in units)} \tag{5}$$

where $P_{n,n+1}$ represents, in general, the time-varying operator. $\xi_{n,n+1}$ may be understood as an additive non-negative noise $(\xi_{n,\,n+1} \ge 0)$ caused by the machine failure during a time range $\Delta T \le \Delta T_{\max} < T_0$. It is assumed that $\xi_{n,n+1}$ is an irregular bounded variable.

As in Azarskov *et al*. (2006), Skurikhin (1972) and Zhiteckii *et al*. (2007), it is assumed that all the product whose quantity Q_{n+1} is delivered through the intermediate transport to the storage at the time instant $t = t_{n+1} + \tau$ with some time delay $\tau < T_0$. The product is taken from the storage bunker on the demands coming from the assembly line with a rate $k(t) \ge 0$. Thus, for all time the stock level $H(t)$ varies so that it decreases "continuously" until the lot of size Q_{n+1} arrives to the storage when $H(t)$ increases step-wise. Fig. 2 illustrates such a typical inventory history over the time interval $[t_{n+1}, t_{n+2}]$.

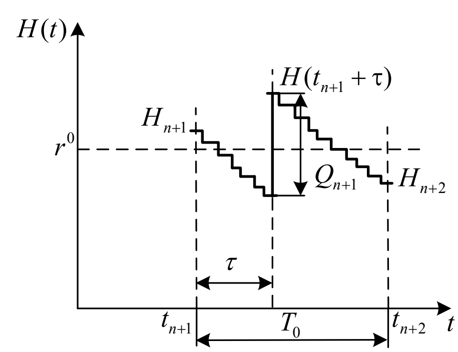

Fig. 2. Inventory level.

The lot size $\nabla\tilde{Q}_{n+1,\,n+2}$ taken on the demand of the assembly line from storage bunker during the period $t_{n+1} \le t \le t_{n+2}$ is

$$\nabla\tilde{Q}_{n+1,\,n+2} = \int_{t_{n+1}}^{t_{n+2}} k(t)\, dt \qquad \text{(in units)} \tag{6}$$