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Genetic algorithm optimisation of a class of inventory control systems

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Abstract

The paper describes a procedure for optimising the performance of an industrially designed inventory control system. This has the three classic control policies utilising sales, inventory and pipeline information to set the order rate so as to achieve a desired balance between capacity, demand and minimum associated stock level. A first step in optimisation is the selection of appropriate "benchmark" performance characteristics. Five are considered herein and include inventory recovery to "shock" demands; in-built filtering capability; robustness to production lead-time variations; robustness to pipeline level information fidelity; and systems selectivity. A genetic algorithm for optimising system performance, via these five vectors is described. The optimum design parameters are presented for various vector weightings. This leads to a decision support system for the correct setting of the system controls under various operating scenarios. The paper focuses on a single supply chain interface, however the methodology is also applicable to complete supply chains.

Keywords: Inventory control; Optimisation; Simulation; Ordering algorithms

1. Introduction

Burbidge's Law of Industrial Dynamics states that "If demand is transmitted along a series of inventories using stock control ordering, then the amplitude of demand variation will increase with each transfer" [1]. This results in excessive inventory, production, labour, capacity and learning curve costs, due to unnecessary fluctuations in perceived demand [2]. One major cause is the time lag between a decision to make or order a unit of inventory and the realisation of that order [3]. It has long been understood (from knowledge of controller design), that the way to minimise this effect is to design the decision appropriately using control theory techniques to customise the response of the production/distribution decision [4]. This implies that the decision has a known structure and there are a number of such generic structures in use. A generic production/distribution control algorithm, termed the Automatic Pipeline Inventory and Order Based Production Control System (APIOBPCS) can be expressed in words as follows: "Production targets are

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Nomenclature

$\bar{T}p$	production WIP gain.
ω	frequency (rads/time period)
λ_a	normalised parameter $= (Ta/Tp)$
λ_i	normalised parameter $= (Ti/Tp)$
ω_N	noise bandwidth
Δt	simulation time increment
AINV	actual inventory holding
APIOBPCS	automatic pipeline, inventory and order based production control system.
AVCON	average consumption
COMRATE	completion rate
CONS	consumption or market demand
CSL	customer service levels
DINV	desired inventory holding
DSS	decision support system
DWIP	desired work in progress
E	error
EINV	error in inventory holding
EWIP	error in work in progress
ITAE	integral of time * absolute error
ORATE	order rate
PR	robustness to production lead-time variations
s	laplace operator, and (S) normalised Laplace operator
SV	systems selectivity
t	time
Ta	consumption averaging time constant
Ti	inverse of inventory based production control law gain
Tp	production lag time constant
Tw	inverse of WIP based production control law gain
WIP	work in progress
WIPR	robustness to pipeline level information fidelity

equal to demand averaged over Ta time units (the demand policy), plus a fraction, Ti, of the inventory deficit in stores (the inventory policy), plus a fraction, Tw, of the WIP deficit (the WIP policy)". We usually express the model in continuous control form. However, the discrete version is also available, if preferred [5].

The model can also be expressed in block diagram form as shown in Fig. 1 [6]. The block diagram describes, in a form suitable for building a simulation model, the controllers that are used to place production orders. It is also representative of Sterman's work [3], (where a simplified model of a beer production/distribution system was used to convince senior executives that they did not fully understand the concept of the supply chain, especially the effect of system structure on system behaviour). His heuristics can be directly related to the control parameters Ta, Tw and Ti, via mathematical manipulation [7]. It should also be noted that by appropriate selection of system parameters the model can cover a wide spectrum of supply philosophies ranging from make-to-stock to make-to-order.