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Model predictive control of cash balance in a cash concentration and disbursements system

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Abstract

This paper presents a Model Predictive Control (MPC) for a revenue account belonging to a cash concentration and disbursements system, based on the application of inventory policies to the cash balance. Dynamic Programming (DP) is used for the prediction model by including a standard forecasting model for uncertainty. Moreover, a band for the uncertainty is established to narrow the input of the DP model, together with a stabilizing regulator in cascade fashion using a linear feedback gain. This combination allows determining a range for the system stability regardless of the size of the prediction horizon. The reference signal used is a sawtooth function, which conveniently adapts to the inventory policy (s, S). Theoretically, and through simulation, it is shown that the proposed controller meets the control objective. Furthermore, the results achieved are equivalent to those obtained by using a traditional inventory control model by directly applying the (s, S) strategy with periodic review, which supports the conclusions in Lee and Wong [44], Wong and Lee [71] and Lee [42] regarding the limited effectiveness when ADP is applied together with MPC. However, the method leaves open the possibility of obtaining promising results if some complexity elements (e.g. delay) are added to model.
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Keywords: Model predictive control; Dynamic programming; Cash balance; Inventory control

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1. Introduction

A cash concentration and disbursements system (CCDS) is a concept commonly used by companies as part of cash management, and of planning and controlling current assets. It is applied in companies whose structure is scattered in different regions nationally, as agencies or distributors. Through agencies or distributors, the cash collection is performed and payments of supplies or services required for operation are channeled. The aim of the system is to concentrate cash money in a main bank account in order to have complete control of cash and provide greater investment opportunities, when there are surpluses large amounts of money. In other words, to maximize the availability of cash not invested in fixed assets or inventories, and thus, avoid the risk of insolvency while improving profitability. As required, revenue bank accounts are designated in which all cash coming from the collection is deposited. Similarly, disbursement bank accounts are allocated to cover paychecks issued to suppliers and other commitments. According to a pre-established policy the cash in revenue accounts is transferred periodically to the main account, and from there, the necessary cash amounts are transferred to the accounts of disbursement with the purpose of cover the demand for cash. This paper is framed in a research addressing the problem of CCDS as a dynamic system in which various elements participate and, among them, monetary flows. The objective is centralize the cash management decisions to make the best use of cash surpluses and cover deficits effectively and efficiently. For a company, the key aspect is focused on making a suitable scheduling of the cash transfers between the different accounts, that is, establish the control actions expressed through the transfers frequency and the amounts transferred according to a predetermined policy. This issue has been addressed in different ways in literature as discussed below.

Different researchers have addressed the subject of CCDS. In this regard, see the researches of Anvari and Mohan [4], Stone and Hill [60,61], Anvari [1], Anvari and Goyal [3] and Anvari [2]. These and other studies have based their argument on inventory policies applied to cash balances to propose their models and management policy, whose origin is in Baumol [7], Tobin [67] and Miller and Orr [52,53]. Similarly, Girgis [39] and Eppen and Fama [32,33], separately use a mathematical programming approach to present cash forecasting models under uncertainty. Furthermore, Marquis and Witte [50] examine the implications on the demand for cash in order to lower the average or variability of money transfers, using a stochastic decision model for selecting an optimal cash management program. Nevertheless, Sethi and Thompson [58] were those who introduced modern control theory applied to the field of finance. Their formulation aims to control the level of a firm's cash balances to meet its demand for cash, raising the problem in terms of terminal value optimization. Subsequently, several authors also focused their proposals on cash management as an optimal control problem. This is how, Vasconcellos [68] applies a general operational approach that joins the forecasting methods and optimal control theory applied to financial planning problems. Premachandra [55] uses the diffusion approximation technique to model a cash management problem in which two types of accounts (cash balance and a portfolio of marketable securities) are involved. The aim of this study is to determine the optimal values for the return point and the upper control limit that minimizes the overall cost of managing the cash. On the other hand, Bar-Ilan et al. [6], present a general model of cash management, viewed as an impulse control problem for a stochastic money flow process. They consider impulse control band (ICB) policies, which are characterized by two trigger levels and two target levels, with which if a condition is satisfied, it is possible to find an ICB policy that minimizes the expected discounted total cost associated with the cash flow. Baccarin [5] studies the optimal control of a multidimensional cash management system in which the cash

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