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Abstract: In this paper we address the problem of deciding whether a water source should be used by a water utility such that the production cost as well as the penalty cost due to water shortages is minimized while certain constraints are satisfied. The problem is modeled using composition of multiple open hybrid automata while the decision logic depends on certain parameters that need to be optimized. Subsequently, infinitesimal perturbation analysis (IPA) is used to optimize these parameters. The proposed approach is non-parametric in the sense that it does not depend on any assumptions on the stochastic processes that drive the system dynamics and it can be used online to continuously adjust the control parameters even when the input processes are not stationary.

Keywords: Water systems, hybrid systems, infinitesimal perturbation analysis (IPA).

1. INTRODUCTION

In this paper we consider a water utility that needs to optimize its operation by deciding when certain water source(s) should be used in order to satisfy its customer demand. In general, a water utility may have several sources where it can obtain water, e.g, from a river, a reservoir, an underground well or a desalination plant. The water availability and production cost among the various sources varies significantly. For example, water from a dam or river may be cheaper to use, while its availability depends on the weather conditions. On the other hand, water from desalination plants is significantly more expensive, but availability is more predictable. At the same time, the water utility's decision should take into consideration quality of service and other environmental constraints. For example, customers should have a continuous supply of water while the water volume of the reservoir should remain above a certain threshold to limit possible environmental consequences.

To address this problem, currently utilities rely on decision support systems (DSS). In the literature, several approaches have been proposed that try to solve the water resource management problem. Most approaches rely on linear programming and stochastic dynamic programming. Using linear programming, Kenneth and Richard (1982) and Rani and Moreira (2010) determine optimal reservoir operations while stochastic programming is used in Kim et al. (2007) to derive optimal policies for multi-reservoir systems. In these approaches, an important challenge is to determine the parameters to be used in the formulation. For example Alemu et al. (2011) used a linear programming model based on historical operations and rules in order to investigate the value of ensemble streamflow predictions and energy price forecasts as aid to decision makers in scheduling the quantity and timing of reservoir releases for daily, weekly, and seasonal operations under regulatory specific constraints. Their DSS generates a range of optimal reservoir releases using an ensemble streamflow forecast and identifies robust operational solutions.

In another approach Koutsoyiannis et al. (2003) proposed a DSS reservoir management system that is based on two main modules. The first is a stochastic hydrological simulator and the second is a linear programming model. The stochastic simulator is responsible to generate simulations and forecasts of the hydrosystem inputs using historical data and, the linear programming model is responsible for the parameterization, simulation and optimization of the hydrosystem. Westphal et al. (2003) developed a real-time DSS for adaptive management of a reservoir system that is responsible to provide drinking water to the Boston metropolitan region. To achieve this, they used linear and nonlinear optimization algorithms for the watershed models, the reservoir hydraulic models, and the reservoir water quality model. In another work by Yingchun et al. (2013) the target was to provide solution for the water allocation in agricultural regions for irrigation purposes. In order to achieve this, authors used models for calculating quantifiably key parameters, like the crop water consumption, the agricultural water demand, and the water use efficiency. Stedinger et al. (1984) have developed a stochastic dynamic programming model which employs the best forecast of the current period's inflow to define a reservoir release policy and to calculate the expected benefits from future operations. Finally Homayounfar et al.

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