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Stability and Optimal Control for Uncertain Continuous-time Singular Systems

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Abstract

In this paper, problems of stability in measure and optimal control are considered for an uncertain continuous-time singular system which can be described by uncertain differential equations. Singular system is assumed to be regular and impulse-free. Under some given assumptions, the existence and uniqueness of the solution, and stability in measure of the singular system are presented. Then, by applying the principle of optimality and uncertainty theory, the equation of optimality for the optimal control model subject to the uncertain singular system is obtained. In the end of Section 3 to Section 5, three examples are given to illustrate the results obtained.

Keywords: Uncertain continuous-time singular system, Stability in measure, Optimal control, Equation of optimality

1 Introduction

The study of optimal control greatly attracted the attention of many mathematicians because of the necessity of strict expression form in optimal control theory. In last several decades, optimal control theory has achieved plenty of developments not only in theory [1] but also in applications such as economics, production engineering and management [2]. An optimal control problem for a given system is to choose the best decision such that an objective function is optimized. As is well-known, this problem has very important applications in practice.

From 1970s many researchers began to investigate stochastic optimal control problem, such as in Merton [3] for finance. In recent decades, the study of stochastic optimal control has been made considerable advances, for example, Fleming and Rishel [4], Harrison [5], Karatzas [6] and Cairns [7] studied optimal control problems of Brownian motion or stochastic differential equations and applications in finance and engineering. One of the main methods to study optimal control is based on dynamic programming. The utilization of dynamic programming in optimization over Ito's process was discussed in Dixit and Pindyck [8].

The complexity of the real world makes the events we face uncertain in various forms. Lots of human uncertainty does not behave like randomness, such as the price of a new stock, oil filed reserves and bridge strength. In order to deal with these phenomena, an uncertainty theory was established in 2007 [9] and refined by Liu [10] in 2010 as a branch of axiomatic mathematics for modeling human uncertainty. Furthermore, Liu [11] introduced uncertain process and canonical process as counterparts of stochastic process and Wiener process, respectively. Then the concept of uncertain differential equation was presented in 2008 [11].

As we all know, stability of a system is a very fundamental and important problem in optimal control theory. For uncertain systems, Liu [12] introduced the concept of stability in measure in 2009, and then a sufficient condition concerning stability in measure was established by Yao [14]. In 2014, Liu [16] proposed the definition of almost surely stability and also presented a sufficient condition for judging this stability. Yao [17] defined stability in mean, and studied the contact between stability in mean and stability in measure, and then gave a sufficient condition about stability in mean. These three different stabilities can be employed to describe the internal characters of uncertain systems in different aspects, respectively. In 2015, Tao and Zhu [18] investigated attractivity and stability of uncertain differential systems. These results on stability and attractivity have provided solid theoretical basis for studying optimal control problem of uncertain systems.

Based on uncertain differential equation, Zhu [19] investigated the excepted value model of uncertain optimal control problem in 2010. Employing Bellman's principle of optimality, he obtained an equation of

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