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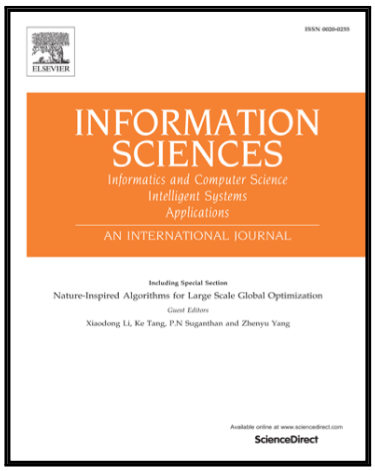

On the Solution of Fuzzy Fractional Optimal Control Problems with the Caputo Derivative

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ACCEPTED MANUSCRIPT

On the Solution of Fuzzy Fractional Optimal Control Problems with the Caputo Derivative

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Abstract. This paper presents an extension to fractional optimal control problems with ambiguity. As the ambiguity is modeled with fuzzy method, we encounter with a fuzzy fractional optimal control problem. The objective in fuzzy fractional optimal control problem is to determine the best possible fuzzy control which satisfies the related fuzzy fractional dynamic systems and minimizes the fuzzy performance index. Here, the fractional derivative is described in the Caputo sense. To find the solution, first we state some definitions and prove some required theorems. Then, we employ the obtained result to determine the necessary conditions. Furthermore, we show that the obtained necessary optimality conditions become sufficient by considering some extra assumptions. Finally, some examples are presented for more illustration of the subject.

Keywords: Fuzzy Fractional derivative, Fuzzy fractional calculus, Fuzzy fractional optimal control, Fuzzy fractional differential equations, generalized Hakahara differentiability, Fuzzy integral.

1. Introduction

In general, Fractional calculus deals with the generalization of differentiation and integration of non-integer orders. In recent years, Fractional calculus has played a significant role in several sciences such as physics, chemistry, biology, electronics, and control theory.

Fractional Optimal Control Problems (FOCPs) are optimal control problems associated with fractional dynamic systems. As defined in Agrawal [2], a Fractional Dynamic System (FDS) is a system whose dynamics is described by Fractional Differential Equations (FDEs). It has been demonstrated that Fractional Order Differential Equations (FODEs) model dynamic systems and processes more accurately than integer order differential equations [9, 12, 22, 29, 30, 32]. Therefore, the solution of FDEs and the problem containing FDEs with analytical and numerical schemes are of growing interest.

The fractional optimal control theory is a novel topic in mathematics. FOCPs may be defined in terms of different types of fractional derivatives. But the most important types of fractional derivatives are the Riemann-Liouville and the Caputo fractional derivatives. Several papers dealing with fractional order control have been presented in [1-6, 10, 18, 19, 24, 28, 33].

It is notable to mention that the uncertainty is inherent in most real-world systems. Fuzzy set theory is a powerful tool for modeling uncertainty and for processing vague or subjective information in mathematical models, which has been applied to a wide variety of real problems. Fuzzy fractional optimal control problems (FFOCPs) are fractional optimal control problems with ambiguity, which could appear,

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