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# Solvability of boundary value problems of nonlinear fractional differential equations

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## Abstract

In this paper, we study the existence of multiple positive solutions for the nonlinear fractional differential equation boundary value problem  $D_{0+}^{\alpha} u(t) + f(t, u(t)) = 0$ ,  $0 < t < 1$ ,  $u(0) = u(1) = u'(0) = 0$ , where  $2 < \alpha \leq 3$  is a real number,  $D_{0+}^{\alpha}$  is the Riemann-Liouville fractional derivative. By the properties of the Green's function, the lower and upper solution method and the Leggett-Williams fixed point theorem, some new existence criteria are established. As applications, examples are presented to illustrate the main results.

**MSC:** 34A08; 34B18

**Keywords:** fractional differential equation; boundary value problem; positive solution; fractional Green's function; fixed point theorem; lower and upper solution method

## 1 Introduction

Fractional differential equations have been of great interest. It is caused both by the intensive development of the theory of fractional calculus itself and by the applications. Apart from diverse areas of mathematics, fractional differential equations arise in rheology, dynamical processes in self-similar and porous structures, fluid flows, electrical networks, viscoelasticity, chemical physics, and many other branches of science; see [1–5]. Recently, there have appeared some papers dealing with the existence of solutions of fractional differential equations by the use of techniques of nonlinear analysis (fixed point theorems, Leray-Schauder theory, Adomian decomposition method, etc.); see [6–9]. Especially, boundary value problems for fractional differential equations have attracted considerable attention; see [10–31]. As is well known, the aim of finding solutions to boundary value problems is of main importance in various fields of applied mathematics. Recently, there seems to be a new interest in the study of the boundary value problems for fractional differential equations.

Bai and Lü [28] studied the following two-point boundary value problem of fractional differential equations:

$$\begin{aligned} D_{0+}^{\alpha} u(t) + f(t, u(t)) &= 0, \quad 0 < t < 1, \\ u(0) = u(1) &= 0, \end{aligned}$$

where  $1 < \alpha \leq 2$  is a real number and  $D_{0+}^{\alpha}$  is the standard Riemann-Liouville fractional derivative. They obtained the existence of positive solutions by means of the Krasnosel'skii fixed point theorem and the Leggett-Williams fixed point theorem.

# Solvability Of Nonlinear Equations And Boundary Value Problems

**Padhraic Smyth**



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The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts.

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