

Existence of solutions for Caputo fractional boundary value problems with integral conditions

WENJUN LIU and HEFENG ZHUANG

ABSTRACT.

In this paper, we investigate the existence results for Caputo fractional boundary value problems with integral conditions. Our analysis relies on Banach's contraction principle, Leray-Schauder nonlinear alternative, Boyd and Wong fixed point theorem, and Krasnoselskii's fixed point theorem. As applications, some examples are provided to illustrate our main results.

Acknowledgments. This work was supported by the National Natural Science Foundation of China (Grant No. 11301277), the Natural Science Foundation of Jiangsu Province (Grant No. BK20151523), the Six Talent Peaks Project in Jiangsu Province (Grant No. 2015-XCL-020), and the Qing Lan Project of Jiangsu Province.

REFERENCES

- [1] Abbas, S. and Benchohra, M., *Partial hyperbolic differential equations with finite delay involving the Caputo fractional derivative*, Commun. Math. Anal., **7** (2009), No. 2, 62–72
- [2] Agarwal, R. P., Benchohra, M. and Hamani, S., *A survey on existence results for boundary value problems of nonlinear fractional differential equations and inclusions*, Acta Appl. Math., **109** (2010), No. 3, 973–1033
- [3] Agarwal, R. P., Hristova, S. and O'Regan, D., *Stability of solutions to impulsive Caputo fractional differential equations*, Electron. J. Differential Equations, **2016**, Paper No. 58, 22 pp.
- [4] Ahmad, B. and Sivasundaram, S., *Existence and uniqueness results for nonlinear boundary value problems of fractional differential equations with separated boundary conditions*, Commun. Appl. Anal., **13** (2009), No. 1, 121–127
- [5] Ahmad, B. and Sivasundaram, S., *On four-point nonlocal boundary value problems of nonlinear integro-differential equations of fractional order*, Appl. Math. Comput., **217** (2010), No. 2, 480–487
- [6] Anguraj, A. et al., *On new existence results for fractional integro-differential equations with impulsive and integral conditions*, Comput. Math. Appl., **66** (2014), No. 12, 2587–2594
- [7] Bai, Z. and Lü, H., *Positive solutions for boundary value problem of nonlinear fractional differential equation*, J. Math. Anal. Appl., **311** (2005), No. 2, 495–505
- [8] Balachandran, K. and Trujillo, J. J., *The nonlocal Cauchy problem for nonlinear fractional integrodifferential equations in Banach spaces*, Nonlinear Anal., **72** (2010), No. 12, 4587–4593
- [9] Benchohra, M., Graef, J. R. and Hamani, S., *Existence results for boundary value problems with non-linear fractional differential equations*, Appl. Anal., **87** (2008), No. 7, 851–863
- [10] Benchohra, M., Hamani, S., and Ntouyas, S. K., *Boundary value problems for differential equations with fractional order and nonlocal conditions*, Nonlinear Anal., **71** (2009), No. 7-8, 2391–2396
- [11] Boyd, D. W. and Wong, J. S. W., *On nonlinear contractions*, Proc. Amer. Math. Soc., **20** (1969), 458–464
- [12] Cabada, A. and Hamdi, Z., *Nonlinear fractional differential equations with integral boundary value conditions*, Appl. Math. Comput., **228** (2014), 251–257
- [13] Cabada, A. and Wang, G., *Positive solutions of nonlinear fractional differential equations with integral boundary value conditions*, J. Math. Anal. Appl., **389** (2012), No. 1, 403–411
- [14] Chen, D. and Liu, W., *Chaotic behavior and its control in a fractional-order energy demand-supply system*, J. Comput. Nonlinear Dynam., **11** (2016), No. 6, Art. 061010, 7 pp.

Received: 29.09.2016; In revised form: 04.05.2017; Accepted: 11.05.2017

2010 Mathematics Subject Classification. 34A08, 35A01, 35A02.

Key words and phrases. *Rational differential equations, integral conditions, fixed point theorem, existence.*

Corresponding author: Wenjun Liu; wjliu@nuist.edu.cn

- [15] Chen, K., Liu, W. and Park, J., *Modified models for love and their dynamical properties*, Miskolc Math. Notes, **17** (2016), No. 1, 119–132
- [16] Granas, A. and Dugundji, J., *Fixed point theory*, Springer Monographs in Mathematics, Springer, New York, 2003
- [17] Guezane-Lakoud, A., Hamidane, N. and Khaldi, R. *Existence and uniqueness of solution for a second order boundary value problem*, Commun. Fac. Sci. Univ. Ank. Sér. A1 Math. Stat., **62** (2013), No. 1, 121–129
- [18] Krasnoselskiĭ, M. A., *Two remarks on the method of successive approximations*, Uspehi Mat. Nauk (N.S.), **10** (1955), No. 1(63), 123–127
- [19] Li, Y.-N., Sun, H.-R. and Feng, Z., *Fractional abstract Cauchy problem with order $\alpha \in (1, 2)$* , Dyn. Partial Differ. Equ., **13** (2016), No. 2, 155–177
- [20] Liu, W., Wen, W. and Park, J., *Hermite-Hadamard type inequalities for MT-convex functions via classical integrals and fractional integrals*, J. Nonlinear Sci. Appl., **9** (2016), No. 3, 766–777
- [21] Podlubny, I., *Fractional differential equations*, Mathematics in Science and Engineering, 198, Academic Press, San Diego, CA, 1999
- [22] Qarout, D., Ahmad, B. and Alsaedi, A., *Existence theorems for semi-linear Caputo fractional differential equations with nonlocal discrete and integral boundary conditions*, Fract. Calc. Appl. Anal., **19** (2016), No. 2, 463–479
- [23] Sithiwiratham, T., Tariboon, J. and Ntouyas, S. K., *Three-point boundary value problems of nonlinear second-order q -difference equations involving different numbers of q* , J. Appl. Math., **2013**, Art. ID 763786, 12 pp.
- [24] Sun, Y. and Yan, K., *Existence of solutions for fractional differential equation three-point boundary value problems*, J. Appl. Anal. Comput., **6** (2016), No 4, 939–949
- [25] Thongsalee, N., Ntouyas, S. K. and Tariboon, J., *Nonlinear Riemann-Liouville fractional differential equations with nonlocal Erdelyi-Kober fractional integral conditions*, Fract. Calc. Appl. Anal., **19** (2016), No. 2, 480–497
- [26] Zhang, S., *The existence of a positive solution for a nonlinear fractional differential equation*, J. Math. Anal. Appl., **252** (2000), No. 2, 804–812

NANJING UNIVERSITY OF INFORMATION SCIENCE AND TECHNOLOGY

COLLEGE OF MATHEMATICS AND STATISTICS

NANJING 210044, CHINA

E-mail address: wjliu@nuist.edu.cn

E-mail address: hfzhuang11@163.com