Srivastava, Hari Mohan; Mohammed, Pshtiwan Othman; Guirao, Juan L. G.; Hamed, Y. S.

**Link theorem and distributions of solutions to uncertain Liouville-Caputo difference equations.** (English) [Zbl 07495842]

*Discrete Contin. Dyn. Syst., Ser. S* 15, No. 2, 427-440 (2022)

Summary: We consider a class of initial fractional Liouville-Caputo difference equations (IFLCDEs) and its corresponding initial uncertain fractional Liouville-Caputo difference equations (IUFLCDEs). Next, we make comparisons between two unique solutions of the IFLCDEs by deriving an important theorem, namely the main theorem. Besides, we make comparisons between IUFLCDEs and their $\varrho$-paths by deriving another important theorem, namely the link theorem, which is obtained by the help of the main theorem. We consider a special case of the IUFLCDEs and its solution involving the discrete Mittag-Leffler. Also, we present the solution of its $\varrho$-paths via the solution of the special linear IUFLCDE. Furthermore, we derive the uniqueness of IUFLCDEs. Finally, we present some test examples of IUFLCDEs by using the uniqueness theorem and the link theorem to find a relation between the solutions for the IUFLCDEs of symmetrical uncertain variables and their $\varrho$-paths.

**MSC:**

39A13 Difference equations, scaling ($q$-differences)
39A12 Discrete version of topics in analysis
26A33 Fractional derivatives and integrals
39A60 Applications of difference equations
33E12 Mittag-Leffler functions and generalizations

**Keywords:**

Liouville-Caputo difference equations; uncertainty theory; Mittag-Leffler functions

**Full Text:** [DOI]

**References:**

1. F. Atici; P. Eloe, A transform method in discrete fractional calculus, Internat. J. Differ. Equ., 2, 165-176 (2007)
2. Ö. Akgündüller; S. Paşalı Atmaca, Discrete normal vector field approximation via time scale calculus, Appl. Math. Nonlinear Sci., 5, 349-360 (2020) - doi:10.2478/amns.2020.1.00033
3. T. Abdeljawad and D. Baleanu, Discrete fractional differences with nonsingular discrete Mittag-Leffler kernels, *Adv. Differ. Equ.*, 2016 (2016) - Zbl 1419.34211
4. T. Abdeljawad, Fractional difference operators with discrete generalized Mittag-Leffler kernels, Chaos Soliton Fract., 126, 315-324 (2019) - Zbl 1448.39032 - doi:10.1016/j.chaos.2019.06.012
5. T. Abdeljawad and D. Baleanu, Monotonicity results for fractional difference operators with discrete exponential kernels, *Adv. Differ. Equ.*, 2017 (2017) - Zbl 1422.39048
6. T. Abdeljawad; F. Jarad; A. Atangana; P. O. Mohammed, On a new type of fractional difference operators on h-step isolated time scales, J. Fract. Calc. & Nonlinear Sys., 1, 46-74 (2021)
7. B. Ahmad; M. Alghanmi; A. Alsaeidi; H. M. Srivastava; S. K. Ntouyas, The Langevin equation in terms of generalized Liouville-Caputo derivatives with nonlocal boundary conditions involving a generalized fractional integral, Mathematics, 7, 1-10 (2019)
8. T. Abdeljawad, On delta and nabla caputo fractional differences and dual identities, *Discrete Dyn. Nat. Soc.*, 2013 (2013) - Zbl 1417.26002
9. T. Abdeljawad, Dual identities in fractional difference calculus within Riemann, *Adv. Differ. Equ.*, 2013 (2013) - Zbl 1369.39005
10. T. Abdeljawad, Different type kernel $h$-fractional differences and their fractional $h$-sums, Chaos Solit. Fract., 116, 146-56 (2018) - Zbl 1442.39032 - doi:10.1016/j.chaos.2018.09.022
11. M. Bohner and A. C. Peterson, *Advances in Dynamic Equations on Time Scales*, Birkhäuser, Boston, 2003.
12. M. Bohner and S. G. Georgiev, *Multivariable Dynamic Calculus on Time Scales*, Springer, Cham, 2016. - Zbl 1475.26001
13. L. L. Huang; G. C. Wu; D. Baleanu; H. Y. Wang, Discrete fractional calculus for interval-valued systems, Fuzzy Sets Syst.
[14] C. Goodrich and A. C. Peterson, "Discrete Fractional Calculus," Springer, Berlin, 2015.

[15] B. Liu, "Uncertainty Theory: A Branch of Mathematics for Modeling Human Uncertainty," Springer, Berlin, Germany, 2010.

[16] L.-L. Huang; D. Baleanu; Z.-W. Mo; G.-C. Wu, Fractional discrete-time diffusion equation with uncertainty: Applications of fuzzy discrete fractional calculus, Physica A Stat. Mech. Appl., 508, 166-175 (2018) · doi:10.1016/j.physa.2018.03.092

[17] A. Khan, H. M. Alshehri, T. Abdeljawad and Q. M. Al-Mdallal, Stability analysis of fractional nabla difference COVID-19 model, "Results Phys.", 22 (2021), 103888.

[18] A. A. Kilbas, H. M. Srivastava and J. J. Trujillo, "Theory and Applications of Fractional Differential Equations," North-Holland Mathematics Studies, 204, Elsevier Science B.V., Amsterdam, 2006.

[19] C. Lizama, The Poisson distribution, abstract fractional difference equations, and stability, Proc. Amer. Math. Soc., 145, 3809-3827 (2017) · Zbl 1308.39001 · doi:10.1090/proc/12895

[20] Z.-Y. Liu, T.-C. Xia and J.-B. Wang, Image encryption technique based on new two-dimensional fractional-order discrete chaotic map and Menezes-Vanstone elliptic curve cryptosystem, "J. Comput. Appl.", 376 (2020), 112884. · Zbl 1436.39007

[21] Q. Lu and Y. Zhu, Comparison theorems and distributions of solutions to uncertain fractional difference equations, "J. Comput. Appl.", 376 (2020), 112884. · Zbl 1459.39013

[22] Q. Lu, Y. Zhu and Z. Lu, Uncertain fractional forward difference equations for Riemann-Liouville type, "Adv. Differ. Equ.", 2019 (2019). · Zbl 1459.39014 · doi:10.1155/2020/6598682

[23] P. O. Mohammed, A generalized uncertain fractional forward difference equations of Riemann-Liouville type, J. Math. Res., 11, 43-50 (2019)

[24] P. O. Mohammed, F. K. Hamasalh and T. Abdeljawad, Difference monotonicity analysis on discrete fractional operators with discrete generalized Mittag-Leffler kernels, "Adv. Differ. Equ.", 2021 (2021).

[25] P. O. Mohammed, T. Abdeljawad, F. Jarad, Y.-M. Chu, Existence and uniqueness of uncertain fractional backward difference equations of Riemann-Liouville type, Math. Probl. Eng., 2020, 1-8 (2020) · Zbl 1459.39014 · doi:10.1155/2020/6598682

[26] P. O. Mohammed and T. Abdeljawad, Discrete generalized fractional operators defined using h-discrete Mittag-Leffler kernels and applications to AB fractional difference systems, "Math. Meth. Appl. Sci.", (2020), 1-26.

[27] J. Shi; M. Han; N. Zhang, Uncertainty principles for discrete signals associated with the fractional Fourier and linear canonical transforms, SIViP, 10, 1519-1525 (2016)

[28] H. M. Srivastava, Fractional-order derivatives and integrals: Introductory overview and recent developments, Kyungpook Math. J., 60, 73-116 (2020) · Zbl 1453.26008 · doi:10.5666/KMJ.2020.60.1.73

[29] H. M. Srivastava and P. O. Mohammed, A correlation between solutions of uncertain fractional forward difference equations and their paths, "Front. Phys.", 8 (2020).

[30] H. M. Srivastava, P. O. Mohammed, C. Ryoo and Y. S. Hamed, Existence and uniqueness of a class of uncertain Liouville-Caputo fractional difference equations, "J. King Saud Univ. Sci.", 33 (2021), 101497.

[31] Z. Wang; B. Shini; D. Baleanu, Discrete fractional watermark technique, Front. Inform. Technol. Electron. Eng., 21, 880-883 (2020)

[32] G. Wu; D. Baleanu; Y. Bai, Discrete fractional masks and their applications to image enhancement, De Gruyter, Berlin, 8, 261-270 (2019)

[33] B. Zhang and P. Shang, Uncertainty of financial time series based on discrete fractional cumulative residual entropy, "Chaos", 29 (2019). · Zbl 1433.62272

This reference list is based on information provided by the publisher or from digital mathematics libraries. Its items are heuristically matched to zbMATH identifiers and may contain data conversion errors. It attempts to reflect the references listed in the original paper as accurately as possible without claiming the completeness or perfect precision of the matching.