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Editorial

New Challenges in Fractional Systems 2014

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In many fields, theoretical and applied researches have strengthened the belief that fractional calculus is not only a branch of the mathematical analysis, but also a useful and powerful tool for engineers. Namely, fractional calculus allows both a better modeling of a wide class of systems with anomalous dynamic behavior and a better understanding of the facets of both physical phenomena and artificial processes. Hence the mathematical models derived from differential equations with noninteger/fractional order derivatives or integrals are becoming a fundamental research issue for scientists and engineers. In particular, fractional models are successful when describing power-law long-term memory or hereditary properties. They are also successful when anomalous diffusion, transport phenomena, and waves propagation in complex media require nonlocal operators, or when fractal-like properties are evident in some processes. These potentialities and the related benefits have attracted many experts and practitioners of different fields to reconsider mathematical models and engineering methods both for linear and for nonlinear systems.

To synthesize, many different areas of science and engineering invest on fractional order modeling and systems by now [1–7]. Moreover, in the last years, many researchers are becoming aware of the interdisciplinary aspects of complex engineering problems that require knowledge from different fields. At the same time, inspiration is often taken from theories or applications of different areas and sometimes it is necessary to combine scientific methodologies that are developed for different problems. To cite a recent example, achieving good results in delivering a high-quality multimedia service through wireless networks not only is a matter of advanced communication technologies and protocols, but also requires to build a proper transmission scheduler that employs classical or innovative control systems. Namely, a feedback control technique may schedule the transmission in advance [8, 9], but can also consider the fractional nature of the data traffic [10] and the fractional modeling of the streams [11].

The above remarks justify the interest in fractional modeling and fractional order systems that may represent a communication language to integrate expertise, results, and new ideas of researchers coming from different areas. The consequences could have a great impact on everyday life, services, technology, industrial processes, and environmental issues. However, fractional calculus and fractional order systems are not a panacea. Namely, many potentialities of fractional order systems are still unexplored or under investigation so that there are many challenges. The contributions gathered in this special issue offer a snapshot of different interesting researches, problems, and solutions.

In detail, the papers of this special issue cover topics in the fields of control systems, electric circuits, and image and signal processing, concern some aspects of mathematical modeling for biological and physical phenomena, and consider some applications of numerical and computational methods to engineering and finance. In the following, we briefly highlight these topics and synthesize the content of each paper.

The paper "*Fractional dynamics of computer virus propagation*," by C. M. A. Pinto and J. A. Tenreiro Machado, introduces a fractional order model to describe the propagation and spread of computer viruses due to dynamical interactions between computing and removable devices. The fractional order system is inspired by mathematical models for biological epidemics and extends an integer order model taken from the literature by using fractional order differentiation. Numerical results show that fractional modeling can serve to describe and capture very fast dynamics or long-term memory effects that cannot be represented by classical integer order models. The investigation is therefore interesting for antivirus development and for studying effective protective measures for applications based on internet connections that are exposed to computer viruses.

The paper "*On fractional order dengue epidemic model*," by H. Al-Sulamia et al., applies fractional calculus to model the spread of the tropical fever and considers memory effects. The model is very sensitive to the fractional order of differentiation. Moreover, the authors study the stability of the equilibrium points of the fractional order system describing the epidemic model. Numerical simulation of the fractional order system is based on the generalized Adams-Bashforth-Moulton method that provides an approximate solution, which converges to the fixed point after a longer time than with an integer order model.

The paper "*Algorithms of finite difference for pricing american options under fractional diffusion models*," by J. Xi et al., regards the application of fractional calculus tools to a financial topic, namely, developing accurate and effective algorithms for the price of American options. The authors start from fractional order partial differential equations used under fractional diffusion models to develop a first-order approximation. This is obtained by an iterative algorithm that avoids singularities in the integral part of partial integrodifferential equations and computes the numerical estimates by combining a fractional difference approach and a penalty method. Then the authors employ a spatial extrapolation for a second-order accurate estimate. The numerical results in the paper are intended to show the effectiveness and feasibility of the approach.

The paper "*Adaptive sliding control for a class of fractional commensurate order chaotic systems*," by J. Yuan and B. Shi, is in the framework of control methodologies developed for nonlinear fractional dynamic systems. The authors take advantage of fractional calculus tools and nonlinear control theory. They propose adaptive sliding mode control design for a class of commensurate fractional order chaotic systems. The authors first introduce a fractional integral sliding manifold for the nominal systems. Next, they prove the stability of the corresponding fractional sliding dynamics. Then, they obtain the desired sliding control law by using a Lyapunov candidate function and the Mittag-Leffler stability theory. The proposed sliding manifold is also adapted by a fractional adaptation law for perturbed systems because of uncertainties and external disturbances. Simulation tests are provided to show the performance of the designed controllers.

The paper "*Approximated fractional-order chebyshev lowpass filters*," by T. Freeborn et al., is in the field of research studies devoted to design of fractional order filters for analog signal processing. The authors use a nonlinear least squares optimization method to determine the coefficients of the fractional order transfer function that approximates the passband ripple characteristics of traditional Chebyshev lowpass filters. Matlab and SPICE simulation tests are used to verify the implementation of the fractional order filters.

The paper "*Computational challenge of fractional differential equations and the potential solutions: a survey*," by C. Gong et al., surveys computational costs of numerical methods to solve fractional differential equations. The authors analyze the computational complexity to solve time fractional, space fractional, and space-time fractional equations, with respect to the case of integer order partial differential equations solved by finite difference methods. The investigation aims at giving a useful guide for solving problems that are mathematically represented by complex fractional differential equations, also with variable fractional orders, and then requires numerical techniques with many time steps and many space grid points.

The paper "*On a time-fractional integrodifferential equation via three-point boundary value conditions*," by D. Baleanu et al., considers fractional differential equations useful to model physical processes that exhibit a fractional order behavior that varies with time and space. The complex, nonlinear fractional differential equations can be solved numerically but it is important to prove existence and uniqueness of the solution. To this aim, the authors investigate and prove the existence of solutions for a time-fractional integrodifferential equation via three-point boundary value conditions.

The paper "*Hybrid prediction and fractal hyperspectral image compression*," by S. Zhu et al., presents a method for hyperspectral image compression based on the combination of a prediction and a modified fractal coding technique. Hyperspectral images are important in remote sensing applications. The key point is to take advantage of the local self-similarity that exist between adjacent bands in the considered images to obtain a high compression ratio at low bitrate, resolution independence, and a fast decoding speed. The authors implement a hybrid algorithm that first carries out an intraband prediction and then applies an interband fractal encoding. The authors show the reduced encoding complexity, enhanced decoding quality, and higher peak signal-to-noise performance.

The paper "*A novel high efficiency fractal multiview video codec*," by S. Zhu et al., proposes a fractal multiview video codec for compressing three-dimensional video signals. The contribution can be considered in the context of research efforts devoted to improving transmission and reproduction of high-quality multimedia over broadband communication channels, for example, wireless networks of last generation. These processes are very important in streaming, videoconferencing, interactive videos, and other similar applications in delivery of multimedia digital services. In particular, the authors propose a compression algorithm that exploits temporal and spatial correlations and a disparity estimation to increase the codec efficiency for encoding and/or decoding a digital data stream or signal. Improvements are shown

in encoding performance (lower time and bitrate, higher compression ratio) and in quality of decoding.

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