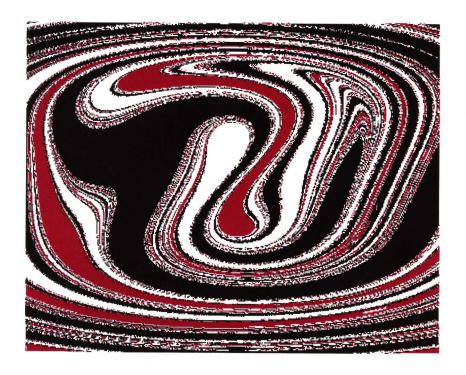# Nonlinear Dynamics

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Special Issue of Fractional Order
Calculus and Its Applications
Edited by Prof. J.A.Tenreiro Machado

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Preface

The Fractional Calculus (FC) is, simultaneously, a new and old research issue. This contradiction comes from the fact that most scientists are not aware of its existence and, often, discover that this 'new' tool provides fruitful perspectives in their studies. Nevertheless, FC emerged with classical integral and differential calculus. In fact, in 1695 L'Hôpital wrote a letter to Leibniz asking for the meaning of $D^n y$ if $n = 1/2$. Leibniz replied 'It seems that useful consequences shall be drawn from these paradoxes one day, as there are no paradoxes that do not prove useful'. The term 'fractional calculus' was adopted at that time and, although many researchers find more adequate the terminology 'integration and differentiation of arbitrary order', is used even nowadays.

Since the first ideas of Leibniz many mathematicians have joined efforts to develop this area and we can mention the studies of Euler (1730), Laplace (1812), Abel (1823), Liouville (1832) and Riemann (1847), just to name a few. In spite of the work that was done, many aspects are still far from being totally clear and this gives to the field a kind of exotic reputation that, somehow, precludes FC to be openly adopted in scientific and engineering applications. For example, we can refer that, unlike in the integer-order case, we have several alternative definitions for a fractional derivative. The different expressions lead to complementary points of view, a final and comprehensive geometrical interpretation for a fractional derivative is not well established yet.

The present day multiplicity of interpretations extends to the applications of FC. A typical case is the relationship between FC and chaos/fractals. While some authors simply deny it, others think that a deeper knowledge will come from merging knowledge from both fields. Whatever be the conclusion, the unquestionable fact is that fractional derivatives reveal properties not supported by their integer-order counterpart. For example, the time (or fading) memory characteristic of a fractional-order model seems to be related with irreversibility in physic processes while integer-order models just provide bidirectional time descriptions.

Bearing these ideas in mind, we found important to publish a special issue on FC covering a wide spectrum of aspects, namely mathematics, physics and engineering applications.

A brief chronological list of the most relevant publications and events in the area shows a 'convergence' to the establishment of FC as a new paradigm in modeling and analysis. In the timeline of FC last century events we may point out:

- A. Gemant (1936) adopts FC for studying elastoviscous bodies.
- B. Ross (1974) organizes the first conference on fractional calculus and its applications.
- K. Oldham and J. Spanier (1974), K. Miller and B. Ross (1993), S. Samko, A. Kilbas and O. Marichev (1993), K. Nishimoto (1984, 1987, 1989, 1991) and V. Kiryakova (1994) publish monographs on FC.

- A. Le Méhauté (1990), A. Carpinteri and F. Mainardi (1997) and R. Hilfer (2000) edit books on the application of FC in physics.
- V. Kiryakova (1998) starts editing the journal fractional calculus and applied analysis.
- A. Oustaloup (1991 and 1995) and I. Podlubny (1999), publish books about control systems theory using FC concepts.

In this line of thought, we posed a challenge to the research community and developed the project of publishing studies integrating different points of view. The group of papers published in the sequel, including many well-known researchers in the area, constitutes the result of this common effort. We hope that this special issue, starting with articles focusing fundamental aspects and moving up to application oriented studies, will constitute a new milestone motivating scientists and engineers to include FC as a tool for extending human knowledge.

At this point I would like to thank the reviewers for their precious suggestions and comments and to the authors for their willingness in participating in the event. I am also grateful to Professors Raouf A. Ibrahim and Ali H. Nayfeh for their kind support and patience during this two-year project.

J. A. Tenreiro Machado
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