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Comments on the description and initialization of fractional partial differential equations using Riemann-Liouville's and Caputo's definitions

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Abstract

In this paper, it is shown that neither Riemann-Liouville's nor Caputo's definitions can be used to properly take into account initial conditions in the description of a fractional partial differential equation. This demonstration is done on a counterexample. Some suggestions are made to address this problem.

Keywords: Fractional partial differential equations, Caputo's fractional differentiation, Riemann-Liouville's fractional differentiation, initialization.

1. Introduction

In the field of fractional systems, many results have been obtained through straightforward extensions of existing results dedicated to integer systems. Sometimes these generalizations were proposed a little hastily and led to incorrect interpretations. While the various definitions of fractional differentiation that now coexist are all mathematically exact, their physical meaning remains obscure [1], [2], [3], [4], [5]. The way in which some take initial conditions into account remains debatable. For the first time, the non-equivalence of Riemann-Liouville's and Caputo's definitions in the presence of initial conditions or more accurately *history* was revealed in [6]. The question that immediately followed was: what happens when these definitions are used in a pseudo state space description of the form:

$$D^\alpha x(t) = Ax(t) + Bu(t), \quad y(t) = Cx(t) + Du(t) \quad (1)$$

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