Fractional Dynamics Identification via Intelligent Unpacking of the Sample Autocovariance Function by Neural Networks

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Many single-particle tracking data related to the motion in crowded environments exhibit anomalous diffusion behavior. This phenomenon can be described by different theoretical models. One of them is fractional Brownian motion (FBM) which was examined as the exemplary Gaussian process with fractional dynamics. The autocovariance function (ACVF) is a function that determines completely the Gaussian process. In the case of experimental data with anomalous dynamics, the main problem is first to recognize the type of anomaly and then to reconstruct properly the physical rules governing such a phenomenon. The challenge is to identify the process from short trajectory inputs. Various approaches to address this problem can be found in the literature, e.g., theoretical properties of the sample ACVF for a given process. This method is effective; however, it does not utilize all of the information contained in the sample ACVF for a given trajectory, i.e., only values of statistics for selected lags are used for identification. An evolution of this approach is proposed, where the process is determined based on the knowledge extracted from the ACVF. The designed method is intuitive and it uses information directly available in a new fashion. Moreover, the knowledge retrieval from the sample ACVF vector is enhanced with a learning-based scheme operating on the most informative subset of available lags, which is proven to be an effective encoder of the properties inherited in complex data. Finally, the robustness of the proposed algorithm for FBM is demonstrated with the use of Monte Carlo simulations.