Nonlinear Manifold Learning for Financial Markets Integration

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The design of efficient market portfolios is highly dependent on the identification of uncorrelated assets, since they yield better opportunities for diversification. Typical portfolio construction techniques first transform the series of prices to returns, and then solve an optimization problem to maximize returns while minimizing the inherent risk of the portfolio. In this work, the assets are treated from a differential geometric perspective, towards extracting their underlying structure in the form of a *low-dimensional smooth manifold*. Doing so, we expect to achieve increased robustness against market fluctuations.

Nevertheless, the intrinsic complexity and nonlinearity of financial markets make it hard to construct an integral mathematical model to characterize the financial system, and thus early warning models are difficult to be constructed. To this end, our proposed method first maps the series of prices into a higher-dimensional domain via *time-delay embedding*, in order to reconstruct the underlying phase space. Then, a smoother low-dimensional representation of the prices series is obtained by learning the inherent manifold structure of the reconstructed phase space, which is then used to provide early warnings about critical market transitions.

Conventional manifold learning methods construct the attractor manifold by preserving geodesic distances between points in the phase space. On the other hand, in the financial practice investors use to represent data via probability distributions. Because of that, considering only the geometric structure of a data space hides essential characteristics of the data and destroys their proximity relations (topology). To address this issue, our method measures the *information change* between data points in the phase space. Finally, having obtained the learned manifold, a hidden Markov model (HMM) is applied to classify the low-dimensional projections, and subsequently the corresponding time series points, in terms of their criticality.

Experimental evaluation with real market indexes reveals the robustness of the proposed information-based manifold learning method coupled with a HMM for accurate identification of critical market transitions, providing reliable early warnings for investors.



Figure 1: Flow diagram of the proposed method for information-based manifold learning towards detecting critical financial periods.

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