Horizontal visibility graphs: exact results for random time series

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The visibility algorithm has been recently introduced as a mapping between time series and complex networks. This procedure allows to apply methods of complex network theory for characterizing time series. In this work we present the horizontal visibility algorithm, a geometrically simpler and analytically solvable version of our former algorithm, focusing on the mapping of random series (series of independent identically distributed random variables). After presenting some properties of the algorithm, we present exact results on the topological properties of graphs associated to random series, namely the degree distribution, clustering coefficient, and mean path length. We show that the horizontal visibility algorithm stands as a simple method to discriminate randomness in time series, since any random series maps to a graph with an exponential degree distribution of the shape P(k) = (1/3)(2/3)**(k-2), independently of the probability distribution from which the series was generated. Accordingly, visibility graphs with other P(k) are related to non-random series. Numerical simulations confirm the accuracy of the theorems for finite series. In a second part, we show that the method is able to distinguish chaotic series from i.i.d. theory, studying the following situations: (i) noise-free low-dimensional chaotic series, (ii) low-dimensional noisy chaotic series, even in the presence of large amounts of noise, and (iii) high-dimensional chaotic series (coupled map lattice), without needs for additional techniques such as surrogate data or noise reduction methods. Finally, heuristic arguments are given to explain the topological properties of chaotic series and several sequences which are conjectured to be random are analyzed.

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