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Horizontal Visibility Graphs as analysis tool for river runoff dynamics

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Horizontal Visibility Graphs (HVGs) are a recently developed method to construct networks based on time series. Values (the nodes of the network) of the time series are linked to each other if there is no value higher between them. The network properties reflect the nonlinear dynamics of the time series.
For some classes of stochastic processes and for periodic time series, analytic results can be obtained for the degree distribution, the local clustering coefficient distribution, the mean path length, and others. HVGs have the potential to discern between deterministic-chaotic and correlated-stochastic time series.
We investigate a set of around 150 river runoff time series at daily resolution from Brazil with an average length of 65 years. Most of the rivers are exploited for power generation and thus represent heavily managed basins. We investigate both long-term trends and human influence (e.g. the effect of dam construction) in the runoff regimes (disregarding direct upstream operations). HVGs are used to determine the degree and distance distributions. Statistical and information-theoretic properties of these distributions are calculated: robust estimators of skewness and kurtosis, the maximum degree occurring in the time series, the Shannon entropy, permutation complexity and Fisher Information. For the latter, we also compare the information measures obtained from the degree distributions to those using the original time series directly, to investigate the impact of graph construction on the dynamical properties as reflected in these measures.
We also show that a specific pretreatment of the time series conventional in hydrology, the elimination of seasonality by a separate z-transformation for each calendar day, changes long-term correlations and the overall dynamics substantially and towards more random behaviour. Moreover, hydrological time series are typically limited in length and may contain ties, and we present empirical consequences and extensive simulations to investigate these issues from a HVG methodological perspective.
Focus is on one hand on universal properties of the HVG, common to all runoff series, and on site-specific aspects on the other.