Characterizing Atrial Fibrillation Dynamics using Multiplex Visibility Graphs

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Atrial fibrillation is the most common arrhythmia world-wide. Despite technological advances, the current therapeutic options have only modest long-term success rates[1]. This partially reflects the incomplete understanding of the dynamics underlying atrial fibrillation. In this work we characterize healthy (normal sinus rhythm) and fibrillatory cardiac dynamics by using visibility graphs[2] on multivariate time series[3], derived from simulations and clinical data.

We performed simulations of normal rhythm and fibrillatory dynamics using the mono-domain formulation of the Rogers and McCulloch model. Clinical data were recorded from 4 patients with atrial fibrillation before and after successful catheter ablation procedure using a multi-electrode basket catheter. From multivariate times series of simulated and clinical data, we constructed multiplex visibility graphs. We then compared the structural properties of multiplex visibility graphs between time series from healthy and fibrillatory rhythms. For both simulations and clinical data, the giant component of the multiplex visibility graph was higher in time series of normal rhythm compared to time series of fibrillatory rhythms. The structural efficiency of the multiplex graphs was higher in normal rhythm compared to fibrillatory rhythms.

Multiplex visibility graphs provide novel insights in cardiac dynamics, paving the way for a more in-depth characterization of fibrillatory rhythms. In particular, normal sinus rhythm is associated with multiplex visibility graphs that have greater connectivity and structural efficiency compared to fibrillatory dynamics. Our long-term goal is to develop a network-based method that could be used to define procedural end-points and identify alternative therapeutic targets.

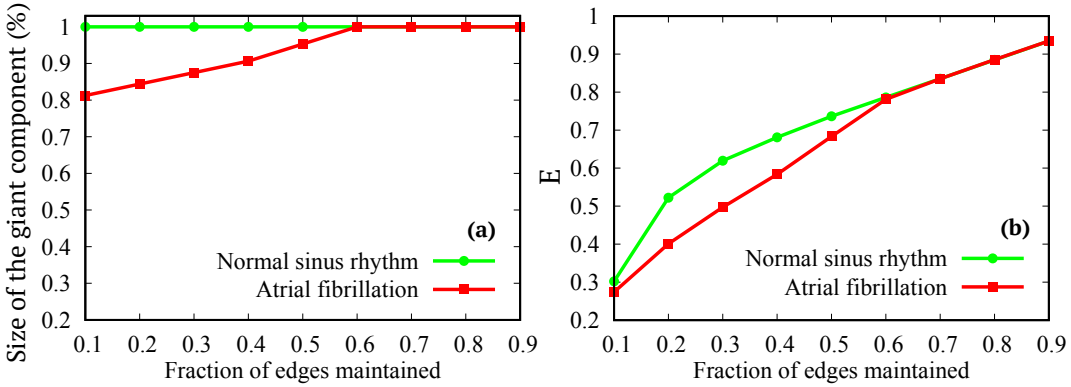

FIG. 1: Size of the giant component (a) and structural efficiency (b) of the network as a function of the fraction of the strongest edges maintained in the clinical data. The two rhythms are successfully distinguished when considering particular weight thresholding regimes (i.e. below 40% of edges maintained).

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