From raw nonstationary time series to actionable biorhythm insights with manifold learning techniques for clinical use

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In clinical health monitoring, we are no longer limited to isolated snapshots of patient data. The widespread use of wearable devices and other technologies now enables the continuous collection of rich, multimodal physiological waveforms over extended periods. However, the nonstationarity nature of these datasets can pose a serious challenge for healthcare providers and medical researchers, particularly when they require clinically useful and actionable information at the point of care. In this talk, I will present recent advances in applying manifold learning to address key signal processing and time series analysis problems in this setting. I will first describe methods for estimating various forms of heat kernels and their associated infinitesimal generators using manifold learning algorithms, along with the theoretical foundations that support them. Building on this framework, I will introduce algorithms for Gaussian process regression and dynamical system analysis. Finally, I will illustrate these approaches through clinical applications in sleep monitoring and hemodynamic analysis. I will also highlight open statistical problems that arise in this framework. If time permits, I will report additional results on how to apply random matrix theory to achieve manifold denoising, with an application to fetal electrocardiogram analysis.