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大西 研究室	氏　　名	Fausto Lucena de Oliveira
博士論文題目	HRV Estimation from BP and Coding Strategy Analysis of the Cardiovascular Regulation	

Much has been discussed about how the cardiovascular system is under the influence of the autonomous nervous system. Yet, even with the recent advances in medicine and psychology, the mechanisms behind the cardiac dynamics remain largely unknown. Providing novel approaches to analyze autonomic cardiac regulation is essential to this issue. This thesis intends to cope with this issue by focusing on signal processing of cardiovascular data.

Herein, we explore two distinct but complementary problems in the field of biomedical engineering, whose subjects could shed some lights on the computational aspects of the cardiac processing. The first problem is to extract a signal from blood pressure that could mimic the modulatory behavior of the cardiac variability. Although this problem is not new, it remains the subject of considerable debate and interest among cardiologists. The second problem focuses directly on what kind of guiding principles are used by the heart to translate neuroregulatory messages into cardiac rhythm – a problem that has not been yet addressed.

The basic idea behind the first problem is to provide a way to analyze the autonomic regulation using blood pressure (BP) instead of electrocardiogram (ECG) waveforms. This measure is of special interest in clinical cardiology in which simple, noninvasive, and low cost measures are highly desirable. The objective of the second problem is to build a bridge between the variations of the autonomous nervous system and the responses of the heart. Specifically, we propose to study the coding strategy analysis of the cardiovascular regulation based on the statistics of cardiac-derived signals. Within this analysis, we test whether or not the cardiac rhythm could process information in a manner consistent with principles described by information theory.

In the first half of this thesis, we present a novel methodology to estimate heart rate variability from BP waveforms based on the hypotheses that both ECG and BP share similar harmonic behavior. Indeed, we model an alternative heart rate variability signal using a nonlinear algorithm, called heart instantaneous frequency (HIF). This algorithm tracks the instantaneous frequency through a rough fundamental frequency using power spectral density. Remarkably, our results show no significant statistical differences between HRV obtained from HIF using BP waveforms and HRV by the conventional QRS detectors.

In the second half, we present a generative model of the heartbeat intervals that captures the variations underlying the cardiac rhythm under the assumption of statistical independence. This model yields a population code that fairly matches with the proprieties of autonomic cardiovascular regulation. Strikingly, the structures composing the population resemble Gabor-like filters in shape. We conduct our theoretical analysis by comparing the response of these filters with the heart rate derived from controlled experiments of rabbits. In summary, our results strongly suggest that the pacemaker cells at the sinoatrial node in the heart have been adapted (through evolutionary processes) to maximize information, performing an independent component analysis of the incoming neuroregulatotry messages.