Using Fuzzy Measure Entropy to Improve the Stability of Traditional Entropy Measures

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Traditional entropy measures, such as Approximate Entropy (ApEn) and Sample Entropy (SampEn), are widely used for analyzing heart rate variability (HRV) signals in clinical cardiovascular disease studies. The popularity of them stems from their capability in providing quantitative information about the complexity of both short- and long-term signals that are often corrupted with noise. Nevertheless, traditional entropy measures have a poor statistical stability due to the 0-1 judgment of Heaviside function. The objective of this study is to introduce a new entropy measure Fuzzy Measure Entropy (FuzzyMEn) in order to improve the stability of traditional entropy measures through introducing the concept of fuzzy sets theory. By drawing on Chen et als research in fuzzy entropy (FuzzyEn), FuzzyMEn uses the membership degree of fuzzy function instead of the 0-1 judgment of Heaviside function as used in the ApEn and SampEn. Simultaneity, FuzzyMEn utilizes the fuzzy local and fuzzy global measure entropy to reflect the whole complexity implied in HRV signals and improves the limitation of FuzzyEn, which only focus on the local complexity. Detailed comparisons of ApEn, SampEn, FuzzyEn and FuzzyMEn were given in this study. The simulation results showed that FuzzyMEn and FuzzyEn had better algorithm consistency than ApEn and SampEn. And FuzzyMEn had a better sensitivity than FuzzyEn. To verify the validity of FuzzyMEn for clinical application, a total of 120 subjects (two groups: heart failure group, 22 females and 38 males, median age 62.4 ± 12.6, and healthy control group, 33 females and 27 males, median age 51.5 ± 16.9) were enrolled. The results showed that FuzzyMEn exhibited best performance for distinguishing two groups. Therefore, FuzzyMEn is an appropriate method to evaluate the complexity of HRV signals. It would be of interest to apply this method to the study of other clinical physiological signals.