Deterministic and Stochastic Analysis in Biomedical Engineering: Chaotic Dynamics vs. Brownian Motion

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The goal of this research project is to analyze and to classify the Electrocardiograms (EKGs) of healthy and unhealthy patients through two novel methods. The first method consists of viewing the EKG as a stochastic process. The EKG was broken down into four main parts, namely, P-Wave, QRS-Complex, T-Wave, and RR-Interval. Each of these parts was modeled through a Diffusion Process characterized by a starting point, drift, and volatility. Using the logistics of Brownian Motion, it was possible to predict the exact probability for the EKG-curve to stay within a certain healthy range for each interval. The results for each interval were combined to identify a probability for the whole EKG to stay within the healthy range. It was observed that all healthy EKGs consistently scored above 92%. Inconclusive EKGs scored between 90%-92%. Unhealthy EKGs scored below 90%. Knowing only this, unknown EKGs were accurately classified by their healthiness. The second method was based on viewing the EKG as a trajectory of a deterministic dynamical system. EKGs were classified by their respective Lyapunov Exponents. It was observed that healthy EKGs all had positive Lyapunov Exponents, indicating chaotic behavior; while, unhealthy EKGs had no positive Lyapunov Exponent present, indicating non-chaotic behavior. This result showed that the healthier a patient was, the more chaotic behavior would be present in their EKG. Both methods were able to accurately classify and analyze EKGs. The result of this project can be applied to medical diagnoses, and serve to identify and treat heart diseases in earlier stages of development.