ABSTRACT

The contractions of the heart are triggered by electrical excitations which originate from a region in the right atrium, called the sino-atrial node (SAN). However, the heart may suddenly lose its ability to pump blood effectively due to SAN malfunction or, an occurrence of electrical turbulence in the ventricles, leading to sudden cardiac death (SCD). SCD is not only a problem of biology and medicine but, also a problem of physics and mathematics. This is because the heart is not only a biological organ but also an electrical conductor and a mechanical pump.

The first-hand information used in the diagnosis of cardiac arrhythmias and other cardiac diseases is an electrocardiogram (ECG). In this work, ECG has been successfully reproduced for both normal as well as diseased cases. Since ECG measures the electrical activity in the heart, different ECG patterns indicate different electrical states of the heart.

In this paper, a mathematical model based on modified Van der Pol oscillators has been used to describe heart rhythms. Hence, a system of differential equations is used to realize the heart dynamics. Numerical simulations are carried out in MATLAB simulator that shows good agreement with real heart rhythm behaviour. The paper further investigates the control design for the pathological or chaotic behaviour of heart. The problem of chaos control has been the area of intensive study for the last decade. Theoretic and practical components of this problem are conditioned by the fact that oscillatory and chaotic processes are often found in nature and technics.

This paper employs chaos control technique by means of parameter variation. The idea is to change the system parameters in such a way as to produce the desired kind of behaviour. The influence of parameter variations on the asymptotic behaviour of the system is studied using a standard tools used in analysis of chaotic systems: Bifurcation diagram and the Lyapunov exponent plot.

Keywords: electrocardiogram (ECG), heart, chaos, control, stability, bifurcation, Lyapunov exponent, modified Van der Pol oscillator.