Signal Processing: Arrhythmia Detection Algorithms for Implantable Cardioverter Defibrillators

Introduction and Impact: The heart is controlled by electrical impulses that signal the heart's four chambers to contract, each at the proper time. The heart works in an endless contract-relax/contract-relax cycle. An average heart beats 100,000 times a day, pumping some 2,000 gallons of blood through its chambers to the rest of the body and then back to the heart. Over a 70-year life span, that adds up to more than 2.5 billion heartbeats. The normal heartbeat cycle is described by the "PQRSTU" wave shown in Figure 1 (below, left). An arrhythmia is an irregular heartbeat caused by disordered electrical activity that disrupts the normal contract-relax cycle and results in rapid, unsynchronized, uncoordinated contractions, see Figure 1 (below, right). When this occurs, little or no blood is pumped from the heart; the person can faint, suffer chest pains, and even sudden death may occur. The heart can be converted back to a normal rhythm with a small electrical shock (called a "therapy"). An electronic device called an implantable cardioverter defibrillator (ICD) administers an electric shock to the heart; it is an effective treatment for people at high-risk. The ICD constantly monitors heart rhythm; it must accurately and quickly detect when the rhythm becomes abnormal and determine whether a therapy is required—the ICD's built-in capacitors administer the therapy when needed.

Hands-on Project: The students will use Matlab to program two arrhythmia detection algorithms employed in ICDs. They will evaluate their algorithms using real electrocardiograms (ECGs) and learn about the statistical performance measure called sensitivity. The first, simpler algorithm is rate-based and relies on a first derivative of the ECG; it is limited in its ability to properly distinguish arrhythmias that require therapy (VT) from those that don't (SVT). The second, more complicated algorithm uses additional information to better discriminate VTs and SVTs. The comparison of the two algorithms will illustrate the tradeoff between algorithm complexity (more complex = better detection) and time (more complex = slower detection). *Through their comparisons, the students will discover the impact of algorithm computational complexity on the real-time constraint that is critical to the ICD's ability to save lives.*

An example of further reading for this project is the recent article that describes the ethical issues surrounding a manufacturer's unwillingness to recall defective ICDs.

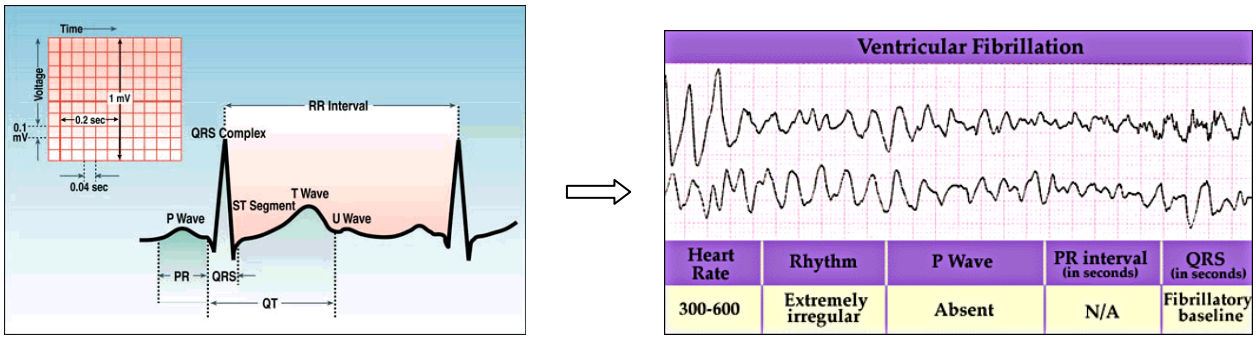

Figure 1. A normal heart rhythm (left) is described by the "PQRSTU" wave. A ventricular fibrillation arrhythmia occurs (right) when abnormal electrical activity upsets the heart's normal contract-relax cycle.