TITLE: A Use of Echocardiography in the Study of Heart Diseases

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GENERAL LEVEL: Senior

CONTEXT: Medicine

MATHEMATICS NEEDED: Finite Fourier series

OTHER MATHEMATICAL SCIENCES NEEDED: Use of computer optional

COMMENTS: The context of the problem is interesting to the student, since it illustrates how mathematics and the computer can be used to diagnose heart disease. A video tape of the presentation is available.

SUMMARY: The student is given a facsimile of an echocardiogram. The student must find a method of digitizing the curve and from this obtain a mathematical representation of the curve.

SUGGESTED USES:

Part of a case study course in applied mathematics 3 weeks
Independent study 3 weeks
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TO THE STUDENT

1. Introduction:

Echocardiography has become a valuable tool for the noninvasive examination of the heart. In this technique a short burst of ultrasound is transmitted through the chest wall and 'echoes' are received from underlying tissue interfaces which separate regions of differing acoustic impedance. By measuring the time which elapses between transmission of the ultrasound and reception of an echo, and assuming a particular value for the speed of sound in tissue, it is possible to locate the structures within the heart and, by many repetitions of the transmission-reception sequence, to quantify their temporal behavior. An echocardiogram is the graphical presentation of such data.

A portion of a typical normal echocardiogram is shown in Figure 1. Several waveforms appear in it, each of which is associated with the motion of a particular cardiac structure. By careful examination of these waveforms physicians are able to diagnose abnormalities in cardiac function or in cardiac structure. The particular structure which is the subject of the present study is called the anterior mitral leaflet. Figure 2 is a tracing of a typical normal anterior mitral leaflet waveform.

Present-day clinical practices involve the application of different analysis techniques in order to diagnose various possible cardiac conditions. A study has been conducted in which echocardiography is used to develop and analyze a method which can be applied to discriminate between the various possible abnormalities or diseases which can affect cardiac behavior so that a common technique can be used for all these diagnostic problems.

In this study, echocardiograms were run on 194 subjects and an anterior mitral leaflet waveform was extracted for each subject. In order to analyze and compare these waveforms it is necessary to represent them in some way. Since each is in the form of a curve it is natural to consider the curve as the graph of a function and to attempt to find a suitable representation for this function.

2. The Problem:

The problem with which we shall deal is a part of the overall study described in Section 1. It can be stated as follows. Given an echocardiogram showing the anterior mitral leaflet waveform, obtain a functional representation for this curve.

Notice that to proceed on this problem one must first obtain an echocardiogram for the subject then trace off the anterior mitral leaflet waveform. You are provided with an enlarged copy of an echocardiogram in Figure 3.
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Figure 1: A portion of a normal echocardiogram.

Figure 2: A tracing of a typical normal anterior mitral leaflet waveform.
To facilitate your study, and to provide some uniformity so that you may compare results with your colleagues, you are also provided with a tracing of the desired curve in Figure 4. Specifically, the problem is to obtain a functional representation for the anterior mitral leaflet waveform which is given in Figure 4.

3. Further Information On the Overall Problem:

Although you are dealing in this problem with only one part of the overall study, the use to which your treatment will be put is explained here for your information. You have found a function which represents your given waveform. This method is now applied to all 194 anterior mitral leaflet waveforms. This involves obtaining the data points for each one and then calculating the functional representation. Since obtaining the data points by hand is time consuming and inaccurate it is clearly desirable to find a way to automate this procedure. Research efforts are being conducted on this problem.

The next step in the study is to determine how many of the terms in the functional representation of each curve are actually necessary in order to distinguish a particular curve from other curves which are significantly different, that is exhibit a certain disease or malformation. Groups of similar waveforms constitute disease classes. When this is done it will be possible to take the anterior mitral leaflet waveform for a new subject, find the functional representation for this waveform, and use the coefficients of the representation to determine the disease class to which this waveform belongs.

Each of these last two phases of the study is a non-trivial problem in its own right, and is described as a separate problem.