Session Number: 1609

Development and Evaluation of a Course Module on Cardiac Signal Procesing

Alan V. Sahakian, Eric Y. Yang
Biomedical Engineering Department, Northwestern University

Abstract

We report our experiences with a new course module covering cardiac signal processing in an instrumentation course intended for advanced undergraduates. The module covers the state of the art in analog, digital and mixed signal processing methods with a focus on the latest design approaches. This includes low-power Digital Signal Processing (DSP) and switch/capacitor methods in cardiac pacemakers and advanced DSP methods in external electrocardiographic instruments. Adaptive signal processing is introduced as a method to extract a desired signal component in the presence of others.

The evaluation is based on a challenge. Students are presented with the methods and a set of example applications in classroom lectures. They are then given a new cardiac signal processing problem and asked to work collaboratively in a "think, pair, share" exercise. They report their results to the class for discussion. The basis of the evaluation is the students' ability to identify an effective signal processing strategy.

Acknowledgement

This work was supported in part by the Engineering Research Centers Program of the National Science Foundation under Award Number EEC-9876363.

Introduction

Many modern medical instruments rely heavily on signal processing. Electrocardiographic monitors and implantable cardiac pacemakers and defibrillators all need to perform signal processing but each has a very different set of constraints, e.g. energy. Very different methods are employed, for example subthreshold analog or switch/capacitor implementations with only very limited DSP in a cardiac pacemaker, and nearly full DSP implementations in an external device. Within the category of DSP there are many different possible approaches.

We developed a course module, partly web-based, which presents several relevant signal processing methods and shows their application.

Organization of module

The module is organized into three one-hour lectures meant to come near the end of an instrumentation course. The first lecture introduces the topic and describes the first two signal processing approaches: passive analog, active analog. The advantages and limitations of each are discussed, for example the use of passive analog filters in interference suppression (RF feedthroughs) in pacemakers and implantable defibrillators, where active circuitry can not meet bandwidth requirements. As an example of an active analog signal processing application, the analog R-wave detector is described.

In the second lecture two discrete-time methods are described: switch/capacitor, and DSP. Examples of switch/capacitor and flying capacitor approaches are presented in the context of their use in cardiac pacemakers. The switch/capacitor analog of a resistor is presented as an intuitive example which is straightforward to analyze. DSP is presented as a very general method with growing importance. The canonical form of a digital filter is presented and some simple digital filters are (such as the notch filter) and a DSP-based QRS detector are described.

The third and final lecture describes an advanced application of DSP. The problem of extracting the fetal electrocardiogram from the abdomen of its mother is presented and the classical solution using adaptive signal processing[1] is shown.

The challenge comes at the end of the final lecture. Students are asked to break into groups of two and discuss a new signal processing challenge given to them by the instructor. For example, the problem of extracting the atrial activity from the high-voltage leads of an implanted defibrillator is given. The groups are asked to outline a method which would could solve the problem, and how it could be implemented. Students are instructed to think alone for five minutes, then to discuss their ideas with their partner for an additional five minutes. After this, groups are asked to report out to the rest of the class on their approaches. This “think, pair, share” exercise evaluates the students’ understanding and the effectiveness of the module.

Two web-based (Java) tools are included within the module. The first is a DSP-based QRS detector which allows the students to examine signals at various points in the signal flow and to adjust threshold and other parameters to see their effects. The second tool is a demonstration of an adaptive canceller which allows the students to adjust filter parameters (such as coefficient of adaptation) and to see the effects. Thus they gain an appreciation for how such performance parameters as misconvergence and convergence rate are affected by parameter choice in a design. Both tools include example signals with varying signal-to-noise ratios, interference and artifacts.

The module was tested as a pilot project in the Winter quarter of 2001 in BME 383, Cardiovascular Instrumentation, at Northwestern University. Development has continued based on that experience and it will be used again in the Winter quarter of 2002.

Conclusions

We have developed and evaluated a module on cardiac signal processing for use in a senior (or graduate) level course in instrumentation. It is accompanied by web-based tools which demonstrate some applications.

Bibliography

1) B. Widrow, et al., “Adaptive noise canceling: principles and applications,” Proc. IEEE, 63(12): 1692-1716, 1975.

Biographies

Alan V. Sahakian received the Ph.D. in Electrical Engineering in 1984 from the University of Wisconsin – Madison. Since then he has been on the faculty of Northwestern University where he is currently Professor of Biomedical Engineering and of Electrical and Computer Engineering and the Associate Chair of the ECE Department. He holds the Charles Deering McCormick Professorship in Teaching Excellence. He has also worked as a Senior Electrical Engineer at Medtronic, Inc., and is currently the Northwestern University ASEE Campus Representative.

Eric Y. Yang is a Biomedical Engineering Junior at Northwestern enrolled in the Honors Program in Medical Education (seven-year BS/MD). He contributed to this project as a summer Research Experience for Undergraduates student.