2006-150: LEARNING APPLICATIONS OF THE SAMPLING THEOREM THROUGH PHARMACOKINETICS OF BLOOD SUGAR

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Learning Applications of the Sampling Theorem through Pharmacokinetics of Blood Sugar

Purpose:

The purpose of this problem-based in-class exercise was to use Student – Centered Instruction (SCI) principals to allow senior biomedical engineering students to apply their knowledge of the sampling theorem and quantization to a pharmacokinetics problem. This paper gives one example of many problem-based exercises used in a senior level Digital Signal Processing class.

Introduction:

Student-Centered Instruction (SCI) is an approach to learning that has been gaining ground in the education literature for the past ten years. Using this technique, teachers provide students with opportunities (usually in the form of exercises) to learn independently or in small groups. SCI techniques include substituting active learning experiences for lectures, holding students responsible for material that has not been explicitly discussed in class, assigning open-ended problems or problems requiring critical or creative thinking, and using self-paced and/or cooperative (team-based) learning.[2] The literature suggests that SCI leads to increased motivation to learn, greater retention of knowledge, deeper understanding, and more positive attitudes toward the subject being taught.[1,3-6] Although SCI techniques are readily applied in the education fields, they have only a small, but growing, following in the engineering education fields.

SCI techniques were implemented into a senior level Biomedical Digital Signal Processing Course at the Milwaukee School of Engineering during the Fall Quarter in 2005. Although the entire class was presented using SCI techniques, only one example of a 50-minute in-class problem is presented here. This problem is based on the absorption of sugar into the blood and was used to further enhance the student's understanding of the applications of the sampling theorem and quantization to real world Biomedical Engineering problems.

The Exercise

At the beginning of class, students were given a one page handout on the pharmacokinetics of oral administration of drugs as well as the absorption rate for sugar. The topic of pharmacokinetics was not covered directly in this class, but had been introduced in several previous classes including physiology, statistics, and biofluid and mass transport. Students had to rely on their previous knowledge and the information in the handout to incorporate material not explicitly covered in class. This incorporation of knowledge from other classes or not explicitly covered in class is one aspect of SCI learning.

Part 1: Students were required to do the following:

1. Using their knowledge of pharmacokinetic principles and regression analysis, determine a predictive model of sugar absorption in the blood.
2. Using the predictive model, their knowledge of time constants, and the sampling theorem, determine the sampling rate needed to properly sample the sugar absorption.

Students worked on this portion of the exercise for approximately 25 minutes. Using their laptop computers, predictive differential equations were derived, solved, and graphed. Using the curve, data sampling rates were then determined.

Part 2: Students are then prompted to determine how to sample the data. Directions to the students were to give specifications for analog to digital hardware necessary to correctly sample the data. They are instructed to outline a procedure that includes the number of bits needed, the range of the signal acquisition, and the allowable RMS error in the measurements as well as a justification for their choices. This portion of the exercise took approximately 20 minutes, but this time varied widely between groups. Groups that were able to justify their choices from a quick literature search in their book or on the internet were much more likely to complete this section more quickly than those students who argued over how to choose signal ranges and allowable RMS errors.

Part 3: Students were given actual blood sugar data. This data was taken from an experiment preformed by the instructor prior to class. After 8 hours of fasting, a baseline blood sugar measurement was taken using a standard diabetic blood sugar meter. Two large sodas (with a total of 20g of sugars) were then ingested by the subject as quickly as possible. Blood sugar measurements were then taken every five minutes for an hour and a half after completion of ingestion. The data was collected prior to class to facilitate time constraints.

Students were instructed to sample the data given to them using their defined sample rate (determined in Part 1), plot the data, and determine if it fit their predictive model (derived in Part 1). Differences between the model and measured data were then explored by the students. The instructions on what differences to investigate or how to look at the data were left vague so that groups had freedom to choose what aspect of blood sugar absorption they wanted to look at. Students used the remaining 10 minutes of class to work on this section, but the time was not enough to complete an adequate investigation. The remaining work was completed as a homework assignment.

Analysis of SCI Exercise

This SCI exercise was undertaken on a class of 15 senior Biomedical Engineering students. Group sizes varied from two to three students, although groups of two tended to make more progress than groups of three in the allotted time.

Part 1 of this exercise was not very open-ended as there is a standard differential equation that can be solved for and graphed. Additionally, because the curve each group determined was the same, the minimum sampling rate needed to correctly sample the data was not unique to each group.

Part 2 of this exercise was very open ended. Students had to specify and justify what the allowable RMS error would be in their measurement, do some research as to the range of values for blood sugar (both normal and abnormal) and then use this information to calculate the number of bits needed for their acquisition. Solutions varied widely between groups, depending on the specifications set forth by the group.

Part 3 of the exercise was left intentionally vague so that groups had the freedom to look at differences between the theoretical and actual data. Some groups chose to calculate differences in individual points on the curve; others compared the theoretical and actual absorption rates; while others determined the effect of increasing the sampling rate on the error. The wide diversity in the way groups looked at this portion of the exercise was interesting in so far as it allowed the instructor to gauge how deep an understanding a group had on the topic of sampling and quantization error. The downside was that most of this portion of the assignment had to be completed outside of class time, especially by groups that had more than two members.

Additionally, the in-class activity was designed to incorporate knowledge students had from previous classes. Information learned in differential equations, statistics (regression analysis), physiology, and biofluids were weaved together to deter students from compartmentalizing their knowledge. Integration of topics from previous classes also reinforces the student's perception that topics previously learned were actually important and useful.

Evaluation of Student Work

To evaluate the group work performed by the students, a rubric was created. On a scale of 5 points (0 being poor and 5 being excellent), each part of the in class assignment was graded. Groups that received a "5" on Part 1 had correct derivation of the pharmacokinetic model using the given blood sugar absorption coefficient, a plot of the equation, and a correctly chosen sampling rate. Groups that received a "5" on Part 2 had properly justified and referenced values for allowable RMS error and ranges for blood sugar values. Using these justified values, groups then correctly calculated the number of bits needed for their analog – to – digital converter. Groups that received a "5" on Part 3 performed a fairly complicated comparison of actual to theoretical data. Groups just calculating point by point comparisons scored a "3", while groups looking at effects of changing sampling rates scored a "5". The class average on the assignment was 12 out of 15 points.

Conclusion

This in-class assignment uses SCI principals to allow students to use their knowledge of sampling and quantization error and apply it to a real world biomedical engineering problem. It has portions that are close ended, in so much as the sampling rate is the same for each group, yet it allows enough freedom for each group to determine its own limitations for the acquisition and investigate comparisons between theoretical and actual data. It also incorporates a previous base of knowledge (statistics, physiology and systems) into the problem in order to dissuade students from compartmentalizing their knowledge. The one major drawback of this assignment was that all groups were unable to complete the assignment due to its length. This led the instructor to assign the remaining work to be completed outside of class time.

References

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