CALIFORNIA STATE SCIENCE FAIR
2002 PROJECT SUMMARY

Name(s)
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Project Number
J1212

Project Title
Harmonic Analysis: Using the Least Squares Method to Analyze Sound Waves

Abstract

Objectives/Goals
My goal was to use a sum of sine functions to accurately estimate sound waves from various musical instruments.

Methods/Materials
I used a Minidisc digital recording device, microphone, computer (with Audioview 32 sound analysis software, Maple computer program, and Matlab computer program), and musical instruments (piano, acoustic guitar, tuning fork, and recorder). I used the Minidisc to record the sounds from various musical instruments. After downloading the sounds onto my computer as WAV files, I used Audioview to extract just a few hundredths of a second of each sound to analyze. Then I rewrote the WAV files as TXT files using Matlab. These TXT files would contain the data amplitude values Maple could read and analyze.

I wrote procedures in Maple using a combination of the least squares method and a loop function to estimate the phase and amplitude of a simple sine function that best fits the data. My hypothesis was that the different frequencies would be integer multiples of a given fundamental frequency. My final equation is a sum of sine functions with different frequencies, amplitudes, and phases. I used the values from these theory equations to produce amplitude values for a TXT file. I converted this TXT file into a WAV file and played back the theory sound.

Results
Using 10 to 20 frequencies, I was able to approximate the data for single tones from a musical instrument quite well (the average root mean squared error was about 1/10th the size of the amplitude of the original wave). For more complex sounds, however, I require a more sophisticated method, as the RMSE of my approximation of a complex sound (such as a human voice LAH) is quite high.

Conclusions/Discussion
Using a combination of loop and least squares methods, sums of sines can approximate tones for musical instruments fairly accurately. However it takes a large amount of computer time (20-30 minutes for one tone) and does not work accurately for sounds from the human voice.

Summary Statement
I analyzed sound and tried to approximate it using a sum of simple sine functions.

Help Received
Dad introduced concept and corrected my programming syntax. Mom helped put board together.