Chapter 5  PROGRAMMING EXERCISE

Experimenting with Quantization Error in C++

Imagine this scenario: You record something at 16 bits, and you don’t set your microphone level high enough before recording. Consequently, your maximum recorded amplitude is only about 25% of the maximum possible. You then try to fix the problem by normalizing the audio clip so that it takes 100% of the dynamic range.

What is the average quantization error on the scale of the bit depth when you quantize at 16 bits (apart from the normalization)?

How is this error magnified by the normalization process?

To verify your conclusions, write a C++ program that simulates the above scenario. The program should operate as follows:

- By evaluating and summing sine waves, generate a one second chord of the notes A, C, E, starting at the A below middle C.
- Reduce the amplitude of the sine wave to 25% of the maximum possible.
- Quantize the chord to 16 bits.
- Get the error for each sample on the scale of 16 bits (in an array the same length as the array of sample values). Call this `errQuant16`.
- Compute and display the average and maximum absolute values for `errQuant16`.
- Normalize the amplitude of `errQuant16` to 100%.
- Compute the error array again. Call this `errQuant16Norm`.
- Compute and display the average and maximum absolute values for `errQuant16Norm`.
- Requantize the original chord at 24 bits.
- Get the error for each sample on the scale of 24 bits and store them in a new array. Call this array `errQuant24`.
- Compute and display the average and maximum absolute values for `errQuant24`.
- Normalize the 24 bit sound wave to 100%.
- Compute the error array again. Call this `errQuant24Norm`.
- Compute and display the average and maximum absolute values for `errQuant24Norm`.
- Reduce the bit depth from 24 bits to 16 bits.
- Compute the error array again. Call this `err24to16`.
- Compute and display the average and maximum values for `err24to16`. 
• Get the sum of \( err\text{Quant24}^{\text{Norm}} \) and \( err\text{24to16} \). Call this \( total\text{Error24Downsampled} \).
• Compute and display the average and maximum absolute values for \( total\text{Error24Downsampled} \).
• Compare the averages of \( err\text{Quant16}^{\text{Norm}} \) and \( total\text{Error24Downsampled} \) and draw conclusions.