DSP Project: DTMF Scheme

Sangillo, George
Electrical Engineering
FAMU
Tallahasse, FL, USA
george1.sangillo@famu.edu

***Abstract*— Many telephones use a dual tone multi frequency (DTMF) scheme to encode key-presses as audio tones and vice versa for decoding. In the following report, the methods for decoding a sequence of key presses are investigated and implemented. This is done using Digital Signal Processing (DSP) concepts and MATLAB.**

Keywords—DTMF, DSP, MATLAB, filter bank, spectrum analysis

I. Introduction

DTMF are used worldwide mainly because of the high dialing speed compared to the previous standard of rotary telephones. They have also been used in applications such as voice mail, e-mail, and ATMs. They have many advantages such as a fast response, low cost, low power consumption, and they are easy to construct. Figure 1 shows the encoding scheme for key-presses to audio tones.

Frequencies (Hz)	1209	1336	1477	1633
697	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	*	0	#	D

Figure 1: Mapping of Key-Presses and Dual Audio Tones

Reference [2] and [3] were used to better understand the needed concepts. The two methods used in this report for decoding a sequence of key presses are a bank of band-pass filters and segmentation and spectrum analysis. The Encoder closely uses the method that was used in Program 1 that was included on the CD that goes in conjunction with [1]. Also, the decoding from dual audio tones to key-presses and how to use the power spectral density (PSD) to decode use the code from [1] as inspiration.

II. Solution

A. Assumptions

Throughout the design and testing of the algorithms there were several values that were set and some assumptions were made. The sampling frequency is 8 kHz. The number of samples is 205. The length of the FIR bandpass filters are 100. Also, it is assumed that only valid digits were pressed on the keypad. For both the Encoder and Decoder, they are done at one digit at a time.

B. Encoder

The Encoder algorithm encodes each digit one at a time given an array of characters that would appear on a keypad. The correct tone frequencies are looked up. The output is the sum of the two sinusoids using the two tones and noise is artificially added using the **randn** function.

C. Decoder

a) Bank of Band-Pass Filters: The algorithm for this method uses the convolution of the input sinusoidal and the impulse response of each bandpass filter to determine which tones are present. There should be two outputs of this convolution where the maximum amplitude are much higher than the others. By using a threshold value, the two tones that are present can be determined. In turn, the digit can be decoded from these two tones.

b) Segmentation and Spectrum Analysis: The algorithm for this method uses the power spectral density (PSD) to determine which tones are present. The two peaks of the PSD determine the two tones that are present, which are used to decode which digit was pressed.

D. Files Breakdown

- "TestMethods.m" - function used for comprehensive testing of both decoding methods.
- "encode.m" – function used for encoding the digits into the sum of the two sinusoids from the dual audio tones and embedded in noise.
- "FilterBank.m" – higher function for decoding key presses using filter bank.
- "filban.m" – function that creates filter bank and decodes each key press individually.
- "ImpRes.m" – function that creates the impulse response of the bandpass filter, given the center frequency
- "maxAmp.m" – function that looks at the maximum amplitude of each bandpass filter and checks if it's greater than the threshold value.
- "SpectrumAnalysis.m" – higher function for decoding key presses using spectrum analysis.
- "specanaly.m" – function that looks at the PSD and decodes each key press individually.
- "dec.m" – function used in "specanaly.m" to determine the row and column values for decoding as shown in Figure 1.

- “Method_Comparison.pdf” – Command window of an example using each method and then the results from using the “TestMethods.m” script for comprehensive testing.
- “Workspace.mat” – workspace file that contains all the data used and results shown in this report.
- The “Figures” folder contains the filter bank output and Periodogram results given the input shown at the first command line in the “Method_Comparison.pdf” file.

III. ANALYSIS

A. DTMF Tones

Each row is represented by a low frequency whereas the columns are represented by high frequencies. This is done so that none will have a harmonic relationship with the others and prevent misinterpretation of which tones where pressed.

B. Results of the Algorithms

The algorithms were tested using a MATLAB script file that would randomly assign one of the 16 possible characters representing the possible values of a keypad. The script file performs thorough testing by iterating 1000 times. However, the phone number being represented is kept static at 10 digits. This was because there were indexing issues that were not solved.

a) Bank of Band-Pass Filters: Figure 2 is an example of the output for the Filter Bank method when the input digit is ‘8’. The algorithm would correctly decode a digit 98.04% of the time. It would correctly decode the entire sequence 81.8% of the time.

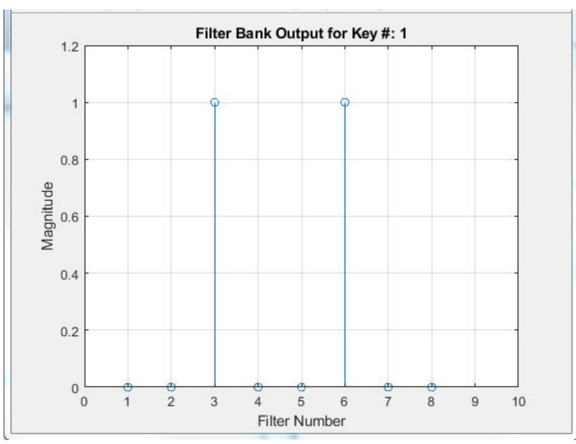

Figure 2: Filter Bank Output when digit is '8'

b) Segmentation and Spectrum Analysis: Figure 3 is an example of the output for the Spectrum Analysis method when the input digit is ‘8’. The algorithm would correctly decode a digit 89.87% of the time. However, it would only correctly decode the entire sequence 33.7% of the time.

Looking at both of the Both of these statistics support display that the Spectrum Analysis method is not as effective as the Filter Bank method.

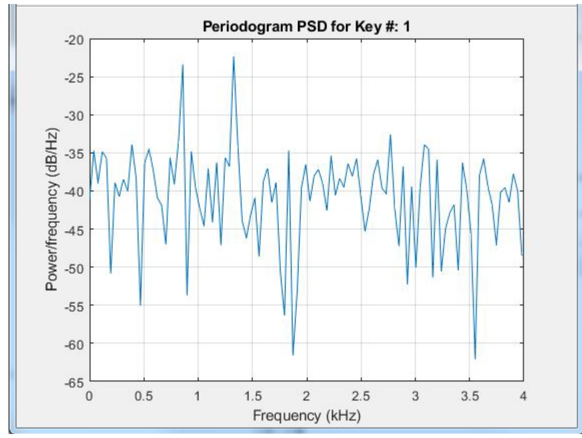

Figure 3: Periodogram Output when digit is '8'

There were not any particular digits that would be regularly confused with another; however, the digits would usually be confused with digits along the same lower frequency tones (i.e.’4’->’6’,’0’->’*’, etc.).

C. Key-Press Duration vs. Recognition Accuracy

Because of the manner in which the algorithms were designed, they are not able to exhibit the tradeoff between the duration of key-presses and the accuracy of its recognition. However, in general the duration of key-presses and the accuracy of its recognition have a mostly inverse relationship. As the duration of key-presses increases, then the harmonics of each key-press will begin to spill over into the next key-press. This will cause an increase in likelihood of misinterpretation of the key-press which decreases the accuracy of its recognition.

D. Noise

As in most cases, adding noise to a signal can significantly affect the frequency content of the signal. In the case of the DTMF scheme, it can cause the frequency of one or both of the tones to be misinterpreted. This can be combated by using error-checking mechanisms. For example, if the signal is decoded multiple times and the output is computed as different values each time then the values are obviously incorrect. However, if the same test is ran and the outputs are computed as the same value each time, then they are most likely accurate.

IV. SUMMARY

DTMF schemes are increasingly used across the world for its many advantages. The input of the encoder is a one dimensional array of characters found on a keypad, which then outputs a sum of the dual audio tones with noise. The two methods used in this report for decoding the sequence of key presses are a bank of band-pass filters and segmentation and spectrum analysis. Based on comprehensive testing, the filter bank method is proven to be the more accurate of the two with less digit errors and more complete sequences. This project has helped to further reinforce DSP concepts learned from lecture and I hope to use it in the future both in my Senior Design Project and possibly future career. If I was able to further work on this project, I would allow my decoding algorithms to take in real-world data as input.

REFERENCES

[1] Sanjit K. Mitra, “Digital Signal Processing: A Computer-Based Approach,” 4th ed, 2011.

[2] Mathworks, “Practical Introduction ot Time-Frequency Analysis” The MathWorks, 2018. [Online] Avalable: https://www.mathworks.com/help/signal/examples/practical-introduction-to-time-frequency-analysis.html#d120e6008. [Accessed Dec. 8, 2018].

[3] B. N. Getu and H. A. Attia, "Identification of dialed telephone numbers in touch tone telephone system based on frequency analysis," 2014 World Symposium on Computer Applications & Research (WSCAR), Sousse, 2014, pp. 1-5.