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DSP - Project 1

Sound is the result of back and forth **vibration** of the particles of the medium through which the sound wave is moving. In the case of the air as the medium, the air particles are set in longitudinal motion, creating **compressions** and **rarefactions**.

In the project at hand, the sound waves[1] of four greek phonemes are plotted, individually examined, analyzed and compared. The '**x**' axis represents the **time** and the '**y**' represents the attribute of **amplitude**.
The **intensity** of a sound at each time step (x-axis), in our case the phoneme's, can be expressed via the **amplitude** value of the sound wave in db (decibel) at this particular time fragment (x-axis). The **pitch** depends on the **frequency** in which the vocal cords are vibrating, which is also depicted on the plot - the higher the frequency, the denser the signal (the more peaks and troughs in a time period / full cycle). A single frequency, constant in time, is called **pure** tone, while a sound consisting of multiple frequencies, is called **complex** tone. The vocal sounds are complex tones due to the nature of the production, in which multiple articulators contribute to the aforementioned procedure. Some phonemes' audio signals are characterised as **periodic** (/ a /[2]) and others' as **aperiodic** (/ s /).

1. Phoneme / a /

Max Amplitude value throughout the wave: 5518
Min Amplitude value throughout the wave: -6809

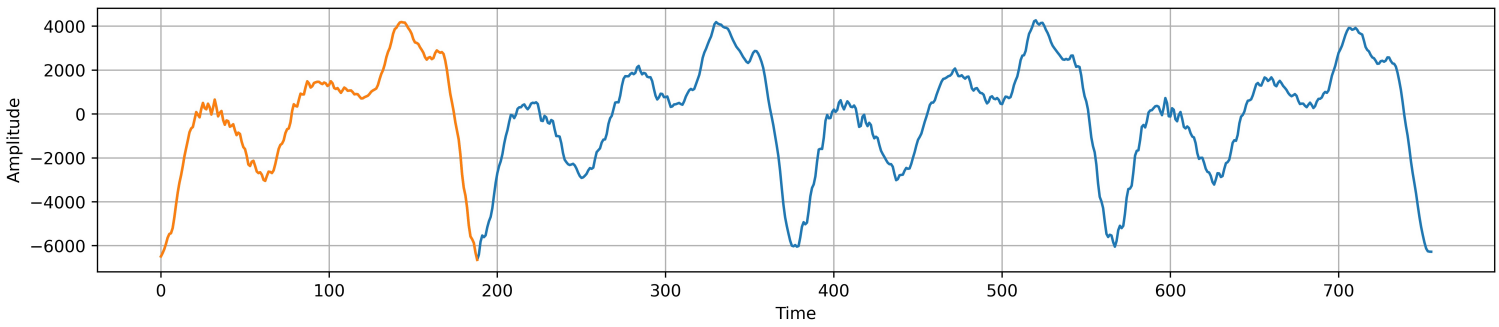

Figure 1: Plot of the sound wave of phoneme /a/

As **Figure 1** indicates, some kind of **periodicity** (visible pattern) is detected in the sound wave, with a time period of about 189 time steps, where approximately 3 peaks and 3 troughs emerge in each. The vowel / a / is a central low and unrounded **sonorous** phoneme , suggesting that the vocal cords are semi-open while letting the air flow from the lungs towards the exit of the vocal tract. All the articulators are positioned in such a way to allow the unhindered air flow in the oral cavity.

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[1] The **sample rate** of the audio signals is **44.1**kHz

[2] The phoneme symbols are following the **IPA** (International Phonetic Alphabet)

2. Phoneme / o /

Max Amplitude value throughout the wave: 2039
Min Amplitude value throughout the wave: -4121

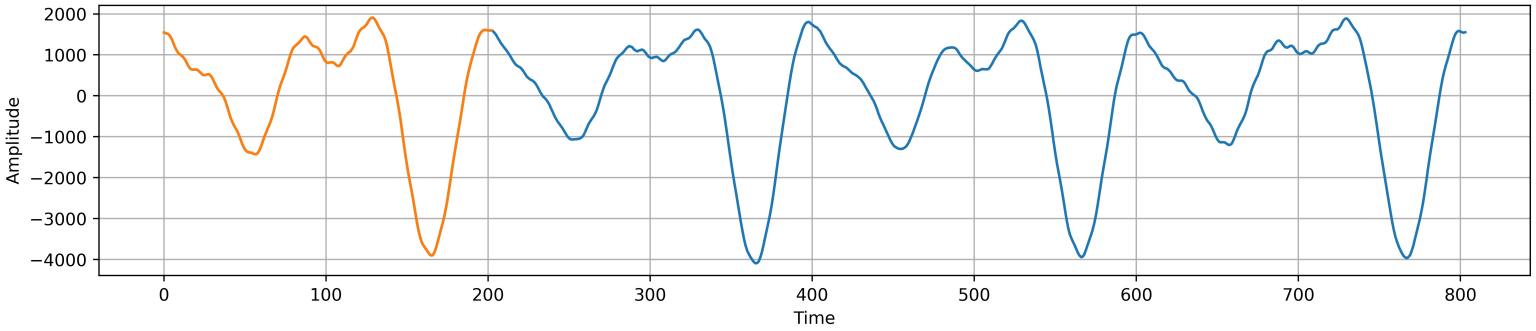

Figure 2.1: Plot of the sound wave of phoneme /o/

The pattern here, has a time period of about 203 time steps. Three peaks and three troughs were distinguished in the pattern. The / o / vowel also resides in the category of the voiced phonemes, so the same apply to it (concerning the voicing). It is a mid-back rounded **resonant** vowel.

Both phonemes are vowels (/ a /, / o /), the sound waves of which exhibit patterns that are characterised by periodicity. Generally, in the case of the vowels, the vocal cords are adducted and vibrating, finally producing an output sound that is a combination (sum) of the **fundamental** frequency and the **harmonics** of the vocal cords as well as the resonated sound waves (in the oral cavity) with characteristics depending on the rest of the articulators' position and movements. The nature of the vocal sound wave as a **complex tone** is indicated by **Figure 1 and Figure 2**, where each wave form seems to be the sum of multiple waves (e.g. harmonics), resulting in reduced smoothness and clarity of the pure fundamental tone[3]. Phoneme /a/ is more sonorous than phoneme /o/, a remark made soon after a casual comparison between the amplitude attribute of two audio signals (**Figure 2.2**), which is reasonable, considering the higher constriction level of the sound from the articulators (e.g. rounded lips).

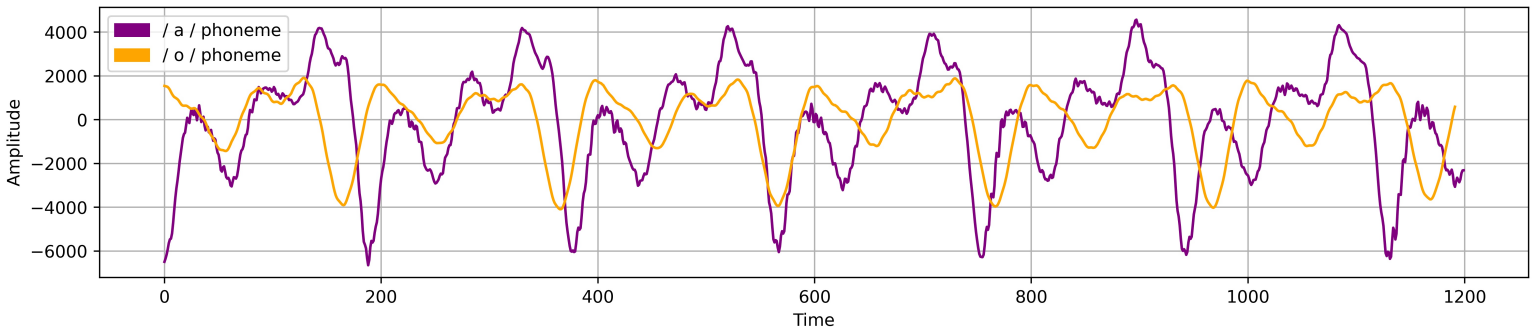

Figure 2.2: Plot of /a/ and /o/ phoneme's respective sound waves

[3] Harmonics, whose frequencies are close to a resonance frequency of the vocal tract, pass freely through the vocal tract, producing a formant. Harmonics, whose frequencies are not close to resonance frequencies, do not pass freely through the vocal tract; they become weakened and form troughs between the formant peaks.

3. Phoneme / s /

Max Amplitude value throughout the wave: 2003
Min Amplitude value throughout the wave: -2304

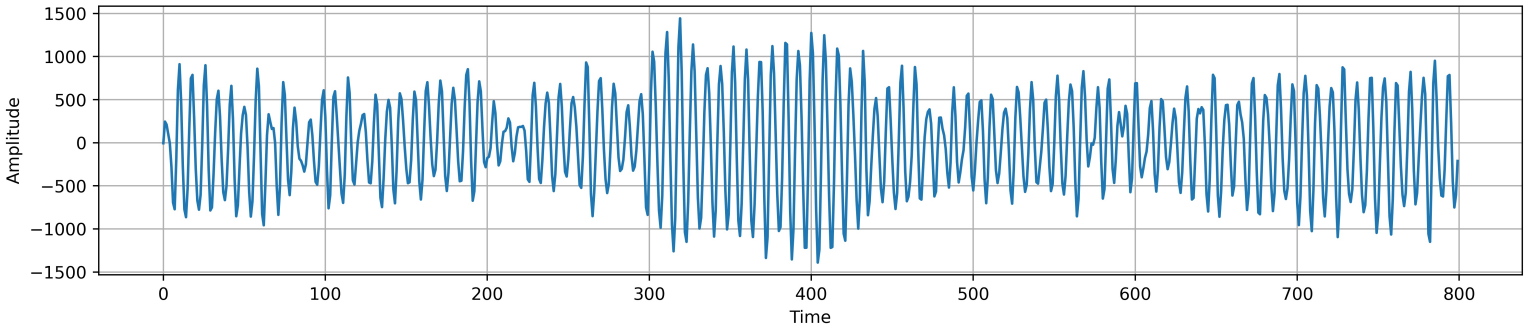

Figure 3: Plot of the sound wave of phoneme /o/

The sound of fricative alveoral phoneme /s/ is more like an **aperiodic** hissing (**white noise**) with a possible random pattern in some parts of the signal, as observed from **Figure 3**. This sound is produced by air flowing through constricted articulators, producing audible frictional turbulence. The vocal cords are abducted, an articulator position deployed for the production of all the **voiceless** phonemes.

4. Phoneme / k /

Max Amplitude value throughout the wave: 5907
Min Amplitude value throughout the wave: -9117

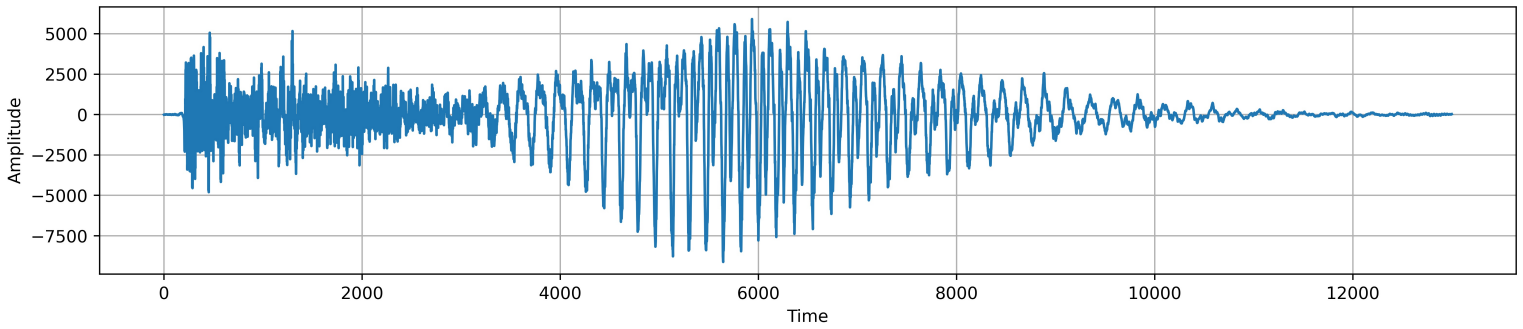

Figure 4: Plot of the sound wave of phoneme /k/

Here, the plot indicates an **aperiodic** sound without any patterns, commencing abruptly with a burst, followed by a stronger burst, where the maximum amplitude valude of the signal occurs, some time fragments afterwards. That signal suggests a **stop** phoneme, such as the **voiceless** velar plosive / k /. During the production of this consonant, the outgoing airstream is obstructed, then intraoral pressure is being built up and finally, as **Figure 4** shows, the air is released, producing the noise burst which is the sound of / k /.

Both phonemes concern voiceless consonants (/ s /, / k /) with no consistent patterns in the produced sound waves. In the case of the purely **voiceless** sounds (/ s /), there is no fundamental frequency (no vibration of the vocal cords), so the sound is considered **white noise**.

Conclusions

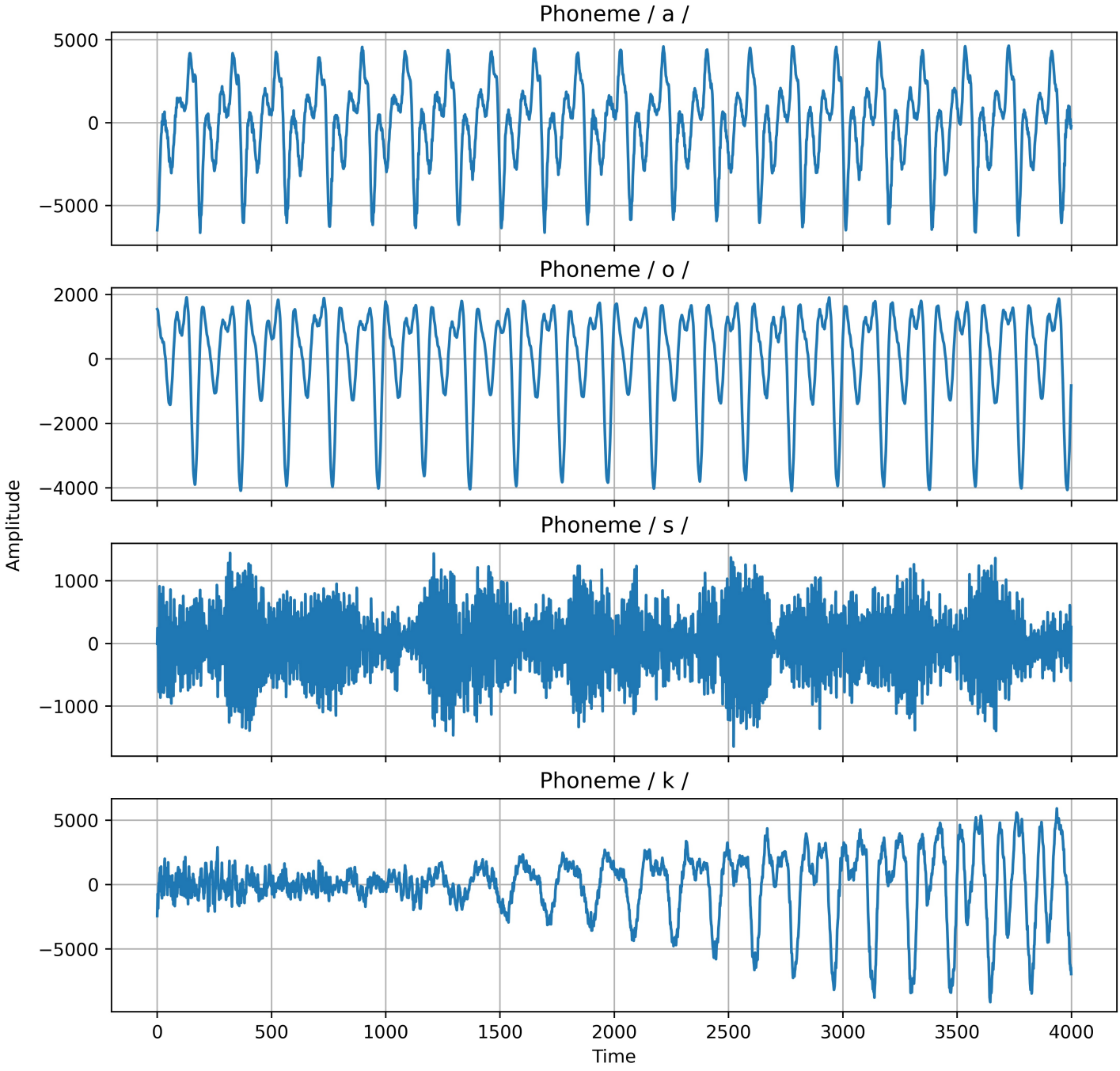

Figure 5: Plot of the sound waves of phonemes /a/, /o/, /s/ and /k/

All the plots above are in the same zoom scale (time). After comparison and examination of the four sound waves (**Figure 5**), we can make some interesting conclusions about the respective phonemes (/ a /, / o /, / s / and / k /):

- The vowels' sound waves have concrete or almost **clear patterns** that repeat themselves throughout the signal in (almost) the same way (**periodic** sound). On the contrary, the consonants' waves usually have random patterns without repetition consistency or even no patterns at all (**aperiodic** sound).
- The consonants' waveforms are more **dense** than the vowels'. They carry more information within the same time frame (4000 time steps), especially phoneme / s /.
- The above, might be a result of the different **articulation** of each phoneme, as well as the nature of the sound produced by the specific movements of the vocal tract.
- The **sample rate** of the four audio signals above is 44100Hz, which means if they were to be sampled with a bigger rate, such as 88.2kHz or even greater, we might have spotted more characteristics and differences, as the wave form would have been closer to the analogue (actual) signal.