DOPPLER_TOOLBOX

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1. PROBLEM DESCRIPTION

The Doppler Shift is defined as a change in pitch as a result of relative motion between a sound source and a receiver. As the source and receiver become closer together the sound waves arrive at closer intervals, and thus the receiver perceives a higher pitch than the original emitted frequency. As the source moves further away the receiver hears a lower frequency than what was emitted. The relative velocity also produces a change in magnitude (Nave 2012).

The Doppler Shift occurs between ANY sound source and receiver when there is relative motion. It is most noticeable when a plane flies overhead or an ambulance drives passed, however the Doppler Shift is always occurring, giving important auditory cues that allow us to so accurately and usually subconsciously, localize sound.

This principle forms the basis of many spatial related technologies, such as sonar, radar and acoustic mapping. Thus, it is of the utmost importance for anyone studying engineering, science, audio or acoustics to be aware of, and understand the Doppler Shift.

The computer program Matlab is used extensively by university students and professionals in these fields for coding purposes. The software includes many in-built functions for performing calculations, but none of the in-built functions address the doppler shift.

I believe the addition of a "Doppler Toolbox" would be a very effective and usable addition to the software for future releases.

2. SPECIFICATION

In general terms, the doppler shift can be mathematically calculated by determining the speed of a sound source and the frequency it emits. It is also possible to determine the speed of an object by finding the difference between an emitted sound wave and a received sound wave or by finding the difference between a transmitted electro-magnetic wave and a reflected electro-magnetic wave.

I have developed four basic prototype functions that make use of the doppler shift and could be easily implemented into the Matlab library. They include:

- POLICE_RADAR
- DOPPLER_SHIFT_APPROACHING
- DOPPLER_SHIFT_RECEDING
- DOPPLER_SHIFT_PASSING

3. IMPLEMENTATION

3.1 How will the functions be implemented?

1. POLICE_RADAR

This function simply shows how police radar works by calculating the speed of a moving object. An electro-magnetic signal at 10GHz is transmitted (ft) from a stationary policeman's radar gun. The wave is reflected off the moving vehicle and the reflected signal (fr) is received by the radar gun. The difference between the transmitted signal and the reflected signal is known as the 'beat frequency' (fb). The velocity of the target (vt) is equal to the beat frequency (fb) multiplied by the speed of the electro-magnetic wave (c) which is then ALL divided by the transmitted frequency (ft) multiplied by the value 2 (because the signal travels 2 distances, to the target and then back to the receiver). In this case c is equal to the speed of light $3*10^8$m/s.

$$vt = (fb*c)/(2*ft) \text{ m/s (Nave 2012)}$$

Figure 1 equation for calculating the speed of an object using the doppler shift

2. DOPPLER_SHIFT_APPROACHING

This function calculates the perceived frequency of a sound emitted from a source travelling directly towards a stationary receiver. The pitch does not fluctuate because the object is travelling directly towards the stationary receiver at a constant speed. The approaching frequency (fa) will be higher than the true frequency (fo). In this equation c is equals to the speed of sound 344m/s and vs is equal to the source velocity in m/s.

$$fa = [c/(c-vs)]*fo \text{ (Nave 2012)}$$

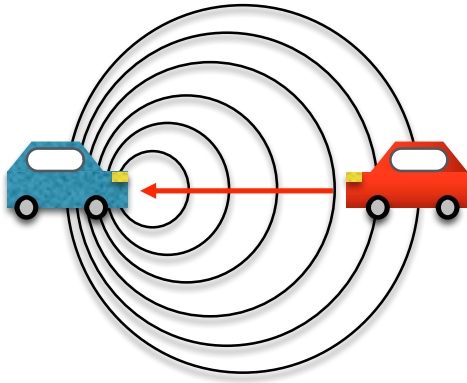*Figure 2 Equation for calculating the speed of an object using the doppler shift*

Figure 3. Increase in pitch from a directly approaching sound source traveling at a constant velocity towards a stationary receiver (Leer, 2016).

3. DOPPLER_SHIFT_RECEDING

This function calculates the perceived frequency of a sound emitted from a source travelling directly away from a stationary receiver. The approaching frequency will be lower than the true frequency.
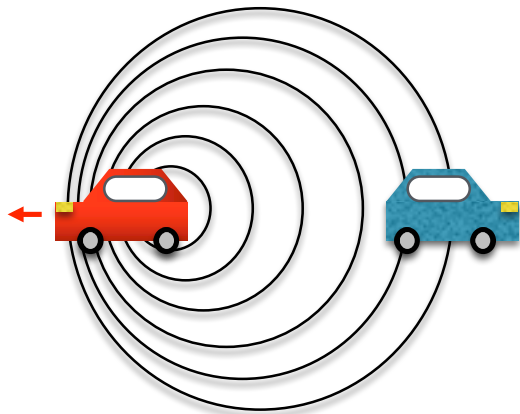

Figure 4. Decrease in pitch from a directly receding sound source traveling at a constant velocity away from a stationary receiver (Leer 2016).

4. DOPPLER_SHIFT_PASSING

This function calculates the perceived pitch change for a sound source traveling at a constant velocity past a stationary receiver.
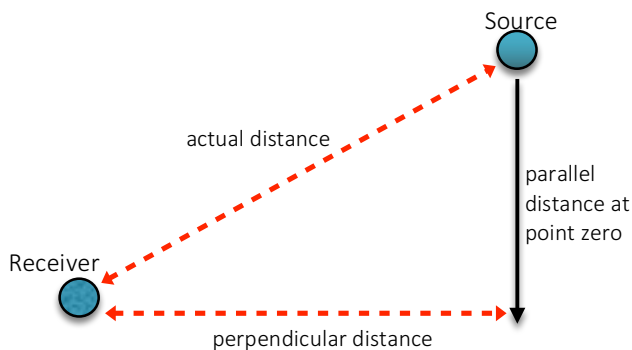

Figure 5. Shows the different distances associated with a passing object traveling at a constant velocity.

The first step in this calculation is the determine the actual distance between the source and receiver, by assigning values to the parallel distance at point zero and the perpendicular distance, as shown in Figure 3.
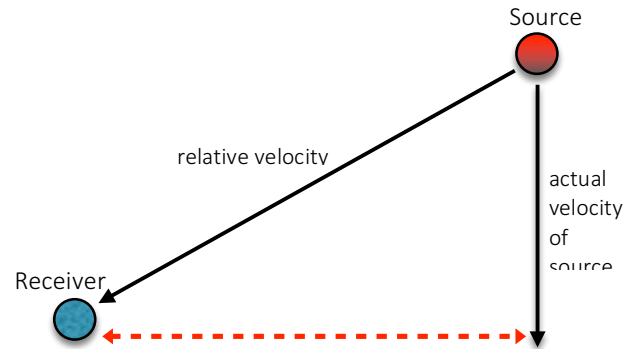

Figure 6. Shows the different velocities associated with a passing object (Leer 2016).

The next step in the function is to calculate the velocity of the source relative to the receiver. After the relative velocity is known, the perceived frequency can be calculated. Refer to Figure 6.
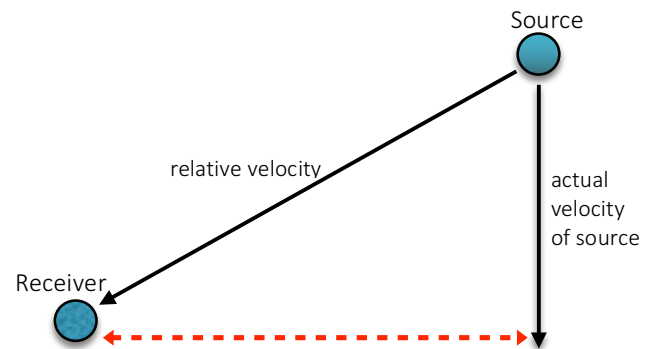

Figure 7. Shows the different relative velocities (Leer 2016).

The different relative velocities are calculated for each increment of time. See Figure 7. This method assumes that for each time increment the relative velocity stays the same. Therefore, the smaller the time increment, the more accurate the change in pitch.

4.   EVALUATION

The Doppler Toolbox will be aimed at helping students and professionals understand and calculate the phenomena known as the doppler shift in a variety of different applicable situations. It will include the four functions outlined above.

Sound files in the form of .wav have been outputted from the working prototypes for doppler shift approaching, doppler shift

receding and doppler shift passing. These files can be played for immediate evaluation. These files include:

- approaching_pitch_shift.wav
- receding_pitch_shift.wav
- perceived_doppler_shift.wav

The four working Matlab functions as well as a script called 'Doppler_Toolbox_script' have also been included for evaluation.

In order to test the final product, a number of assessments should be performed with intended users. These should include a listening assessment, a usability assessment and an aesthetic assessment. These will help determine how much a Toolbox like this will be used.

4.1 Future Research

Unfortunately, these prototypes do not include any magnitude changes which are likely to be as important as pitch changes for sound localization. The functions would be more effective if this aspect was also implemented.

Other considerations for future development include the addition of:

- HRTF's
- stereo panning
- a moving receiver
- multiple sources and receivers

5. ACKNOWLEDGMENTS

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6. REFERENCES

1. Nave, R. 2012, *Police Radar*, HyperPhysics, Georgia, viewed 26th May 2016, <http://hyperphysics.phy-astr.gsu.edu/hbase/sound/dopp.html>

2. Nave, R. 2012, *Doppler Effect*, HyperPhysics, Georgia, viewed 26th May 2016, <http://hyperphysics.phy-astr.gsu.edu/hbase/sound/dopp.html>

3. All diagrams were created by Rachael Leer