Problem Description

The wah effect is more commonly known to the general public as a guitar effect, it shapes tone of the guitar in such a way so that the guitar has a human vowel sound 'u' to 'ah' and thus the 'wah' sound. There are two main problems of most wah pedals on the market. The first one being unable to produce a more vocal like tone, in other words the sound of a wah pedal generally have a good vowel quality but never as good as the human voice. The second problem is that a lot of the guitar players, especially if they are really into the wah effect; spend a lot of time searching for the perfect wah pedal that produces the sound they want. Each pedal on the market has its own characteristics, different sweep ranges and frequency responses. It is both time consuming and costly to experiment and buying all the different pedals for the guitarists, especially recording guitarists if they want different type of wah sounds on songs or even different sections of the songs. The Dunlop Classic Cry Baby GCB95F model is famous for its creamy and smooth sounds that goes really well with funk riffs and lightly overdriven chord strumming. But when it is time for a screaming lead solo which most of the hard rock fans would take it to above the 12th fret of the guitar, there are hardly any difference between the effect turned on and the bypass mode. Some may suggest getting an Ibanez Weeping Demon since its sound is more suitable for high gain settings, but it won't produce the warm and bright tone in the clean settings as the GCB95F. The aim for this wah effect application is to solve these problems and allow users to customise their own settings so the effect sound can be flexible and with more options.
Specification

Of cause we won't be expecting the guitar signal to sound exactly like a human voice from a foot controlled device but there are ways to improve the vocal quality of the sounds. The idea of a wah effect is to have a bandpass filter with a peaking centre moving up and down the frequency spectrum, same the rocking the pedal back and forth.

A few basic attributes of the effect are:

**Minimum point** - The lowest value that the peaking centre can move to  
**Maximum point** - The highest value that the peaking centre can move to. 
**Damping factor** - Controls the shape of the filter, the lower the value the smaller the filter.

If we have our minimum point set to 500Hz and maximum point at 1500Hz, when the peaking centre is at 500 it is the same as toe up on the wah pedal and toe down at 1500. But if we take a closer look at how the human voice actually works we'll see why the pedals won't sound more like a human vowel.

From the above diagram, we can see that what makes up a human speech vowel. The formants regions makes up the u or the ah sounds, and there are two important formant regions to be considered in making a human speech vowel. As mentioned above, the wah pedals only have one peaking frequency centres, which acts as one of the formants in the frequency spectrum. To achieve an improved wah sound we can add a second filter in the frequency and act like a second formant of the human speech vowel. This will improve the output sound, as if two wah pedals are chained together next to each other and being used simultaneously.

As for the second problem, the effect application will have the minimum and the maximum value settings according to the users desires. The users can set one of the formants to be static, which the minimum and the maximum values are close to each other and controls the other one by foot to achieve a more vocal like sound. Another options is to have the uncontrolled formant to move up and down continuously with pre settings, this allows more experiments with the effect and hopefully the user can create a few settings that has its own characteristics.
Implementations

Using the difference equation:

\[ y_l(n) = F_1 y_b(n) + y_l(n-1) \]
\[ y_b(n) = F_1 y_h(n) + y_b(n-1) \]
\[ y_h(n) = x(n) - y_l(n-1) - Q_1 y_b(n-1) \]

with tuning coefficients \( F_1 \) and \( Q_1 \) related to the cut-off frequency, \( f_c \) and damping, \( d \):

\[ F_1 = 2 \times \sin(\pi \times f_c / f_s) \quad \text{and} \quad Q_1 = 2 \times d \]

We set the damping value to be 0.05, \( f_s \) to the sampling frequency of the input signal, \( f_c \) to be the minimum value in the beginning. \( f_c \) moves up and down and sweep range until it reaches the maximum value and comes back down again as the user controls the pedal.

For the uncontrolled formant, we use a triangle wave of centre frequency values to make the peaking frequency moves up and down the spectrum automatically.

\[ \Delta = F_w / F_s \]

change in centre frequency per sample, we set \( F_w \) to be 2000.

\[ F_c = \text{min}(\Delta) : \text{max}(\Delta); \]

while (length(\( F_c \)) < length)

\[ F_c = [ F_c (\text{max}(\Delta) : -\Delta : \text{min}(\Delta)) ]; \]
\[ F_c = [ F_c (\text{min}(\Delta) : \Delta : \text{max}(\Delta)) ]; \]

end

The length affects the speed of the uncontrolled formant movement. In this case the length of the input is used to set the effect.
Evaluation

The typical wah setting has the minimum value set to 500 and the maximum to be 3000, this wah effect application can do just that. As different brands of wah pedals have different pre settings, this application can emulate the sounds as the user specifies or set to the factory presents of the pedals in the market. The ideal situation for the application is for it to be digitally implemented in foot pedals but it will require the user to have knowledge of the wah effect concept. Suitable for advanced who wishes to have a unique tone or experimenting with the effect options. It has been tested that if one of the formants is set to static at a higher frequency domain; and the foot controlled formant is set at the lower area, the result will be far better than an ordinary wah pedal in getting closer to a vowel sound. Another interesting sounding setting is to have both formants at a distance the range of both peaking centres to be within 400 sweep range, preferably the higher one will always be smaller in range. The user will have to experiment with the effect a bit and be able to achieve some extreme results.