Experimental challenge*: **Unhuman voice**

Introduction to digital signals — Deadline: End of the course

Experimental part

The proposal is to reproduce digitally three effects that come from the analog times. In every case use Octave or Matlab to load an audio file as a sample $\{y_k\}_{k=1}^{L}$ and to store or play the result.

The first effect consists in multiplying the sample by a pure tone (sine or cosine) of certain frequency ν. Adjusting ν one gets a fairly good robot voice effect (professional results are obtained with *vocoders*, relying heavily on Fourier analysis). It depends on your taste and your sample but I have got decent results with $\nu = 800\ Hz$ (real time frequency, not counting ν_s).

The second effect is called *distortion* and it appeared as a defect of the first electric guitars that was exaggerated intentionally later. By the low quality of the early amplifiers, loud sounds produced noise. To reproduce the effect one applies to the signal a function that is close to a multiple of the identity near the origin and introduces a severe clipping to large values. I have tried $f_1(x) = \frac{2}{\pi}\arctan(ax)$ and $f_2(x) = \operatorname{sgn}(x)\big(1 - e^{-a|x|}\big)$ with a large.

The third effect is the *vibrato*, well-known in music. As the name suggests, it introduces a kind of vibration in the sound. You can produce it, creating a new sample with $z_{m(k)} = y_k$ where $m(k) = k + H(k)$ with H a discrete harmonic oscillator. I have tried $H(t) = Q\big(W + W\cos(\omega t)\big)$ with Q the uniform quantizer. For $W = 10$ (under $\nu_s = 44100$) and ω corresponding to $\nu = 5000\ Hz$ the effect with music is not very bad. For voice I have found $W = 20$ more convenient. In both cases it would be improved using interpolation of nearby values instead of quantization but I have no tried it.

Mathematical part

This challenge is mainly experimental, to play with the many variations and parameters to get good results so the mathematical part is rather meager.

In connection with the first effect, write the relation between the discrete Fourier transform of the signal and that of the robotized signal. For the second effect, be sure that you see that f_2 is close to a multiple of the identity near the origin. If you want to try the third effect a must is to find the relation between ν and ω.

*Some experiments are classical, some are my idea and others come from specific sources. In the latter case I have omitted the reference here on purpose to force the students to work on their own. If you are the author, please do not get angry. I intend to incorporate the references to the final version of the notes.