Spectral Mutation in Soundback: A Brief Description

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Abstract: Soundback is a widely used Macintosh program that performs a wide variety of soundfile manipulations. With versions 0.8 and above of Soundback, the authors have implemented a system of spectral mutation functions, which allow for a wide variety of transformations between soundfiles in the spectral domain. This article briefly describes the program’s spectral mutation features, more fully described in Erbe (1994) and Polansky and Erbe (1995).

Introduction
Soundback (Erbe, 1994) is a widely used program for soundfile manipulation on the Macintosh. Most of Soundback’s functions are based on a flexible FFT/IFFT process, with user control over the size, shape and resolution of the FFT and windowing. The program offers high quality soundfile transformations such as convolution, phase vocoder (allowing time stretching and pitch shifting), binaural filters, spectral dynamics processing, and other functions.

Polansky’s mutation functions (Polansky and McKinney, 1991; Polansky, 1992) are generalized morphological transformations which create mutations “between” morphologies (ordered sets). The mutation functions were originally designed for higher-level morphologies such as melodies, duration series or statistical profiles of a parametric interval over time. The functions compute intervals between elements of a morphology, and separate those intervals into magnitude and sign (direction).

Each of the mutation functions "pastes" or interpolates, in a different way, the sign or magnitude of one morphology into the sign or magnitude of the other, creating a third morphology which is a measurable combination of the two sources. In Soundback Version 0.8 and above, the mutation functions are implemented in the spectral domain, where the individual FFT frames of soundfiles are considered to be the morphologies.

Introduction to the Mutation Functions
Each spectral mutation function produces a different type of timbral “cross-fade.” Each function takes two soundfiles (source and target) and returns a third soundfile (mutant). The functions operate on the phase/amplitude pair for each frequency band in the mutation soundfile. For a mathematical description of the functions, see Polansky and Erbe (1995).

The degree of mutation is called \( \Omega \) specified as a single value between 0 (completely the source) to 1 (completely the target) or as a function over the duration of the resultant soundfile. Intermediary values for \( \Omega \) create spectra which are interpolations (not necessarily linear) between the two input spectra. The mutation is thus a soundfile spectrally “between” the source and the target in some way (specified by the mutation type) and to some degree (specified by \( \Omega \)).

Each of the different mutations operates in its own way on a different combination of the magnitude or the direction of FFT-frame intervals. Five different mutation functions are used in Soundback, along with two concatenations of them. They are called: Uniform Signed Interval Mutation (USIM), Irregular Signed Interval Mutation (ISIM), Uniform Unsigned Interval Mutation (UUM), Irregular Unsigned Interval Mutation (UUM), and the Linear Contour Mutation (LCM). These functions are described in detail in Polansky and Erbe (1995), Polansky (1997) and Polansky and McKinney (1991).
Figure 1 shows interval computation for three successive FFT-frames of three spectral bands of one source. This computation uses adjacency intervals (absolute intervals are also possible).

The Different Mutation Functions:
The USIM and the ISIM are the simplest mutations, a spectral cross-fade and spectral band-replacement, respectively. The USIM ("uniform") operates on each spectral band interval for every FFT-frame, cross-fading amplitude differences between corresponding spectral bands. The ISIM replaces the amplitude interval of the source by that of the target for each frame to create that of the mutation (simply adding the signed interval to the amplitude of the previous spectral frame).

In irregular mutations, the decision of whether or not to mutate (replace the source amplitude by the target) is determined by \( \Omega \), treated as a probabilistic value. In other words, the ISIM (and IUIM and LCM) is a stochastic spectral band replacement based on \( \Omega \).

The IUIM and the IUIM are two different ways of "pasting" or interpolating the amplitude differences of the target spectra onto the sign of the source, resulting in mutations which, when complete, are still some combination of the source and target. The IUIM interpolates between the source and target interval, but retains the sign, or direction of the source interval. A completely mutated spectra by the IUIM has the magnitude intervals of the target but the signs of the source intervals. The IUIM is the irregular version of the IUIM, pasting magnitude intervals stochastically, while retaining sign.

The LCM, perhaps the most unusual sounding and unpredictable mutation, does the opposite of the IUIM, pasting the signs of the target onto the magnitudes of the source, generally resulting in an unrecognizable but often sonically interesting spectral transformation.

The mutation functions can be classified as follows:

<table>
<thead>
<tr>
<th>Function</th>
<th>Uniform</th>
<th>Sign</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>USIM</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>ISIM</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>IUIM</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>IUIM</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>LCM</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

Note that the opposite of "irregular" is "uniform." Uniform mutations do something to every frequency band. How much they do depends on \( \Omega \). Irregular mutations change a given frequency band completely from source to target (sign, magnitude or both), but the number of frequency bands they operate on depends
on $\Omega$ in irregular mutations, $\Omega$ may be thought of as the "probability of replacement" for a given band (the percentage of bands replaced). In uniform mutations, $\Omega$ functions as an interpolation value (degree of "between-ness"). Note that there is no UCM since it wouldn't make sense; contour is defined in the context of these mutations as being up, down, or equal.

**A visual example of a concatenated mutation**

Certain mutations are "incomplete", with $\Omega = 1$ they produce some "image" of the target which is the same in terms of either intervallic magnitude or direction. By concatenating incomplete mutations, complete mutations are formed which produce interesting spectral transformations. Figure 2 is a visualization of a concatenated mutation (the output of the $LC4F$ is applied to the $RUIM$). In this "waterfall" plot, the $z$-axis is time (assuming the mutations are performed over time to effect the transformation of one FFT into another). The $x$-axis is FFT-band, and the $y$-axis is amplitude. This figure shows the result of ten intermediary mutations between the source and target. The source is a kind of sawtooth (monotonically decreasing spectra), the target a slightly randomized triangular spectral configuration.
Visual Examples of the Mutations

The four examples below show the effects of several of the mutations on two simple functions, plotted over up to ten gradually increasing values for $\Omega$ from 0 to 1. In the case of the incomplete mutations ($ICM_{ULM}$), no final triangular function is not shown (not allowed). For the sake of visual clarity in the more complex mutations, fewer intermediary functions are shown.

![Graphs showing visual examples of four mutation trajectories](image)

Figure 3: Visual examples of four mutation trajectories

In Soundbath, several features are added to tailor these mutation functions to spectral processing of data, including: band persist, delta emphasis, absolute and relative interval computation, and dynamic control of mutation index. For a complete description of these concepts see Polansky and Erbe (1995), Erbe (1994).

References


