











perceptual dimensions that may be tracked by the human listener (e.g., the salience of a particular instrument), while preserving the most critical data channels in the spectral parameters for computational recovery.

## 5. DISCUSSION AND FUTURE WORK

To summarize, SPE encapsulates the data points, either from raw input or analyzed structures, to the abstract statistical shape or parameters (e.g., mean and variance) of a magnitude-spectrum frame. This facilitates a uniquely constrained yet flexible composition expanded from the target magnitude spectrum, and even allows additional mapping of data to such as the choice of chord or onset shape for perceptual decoding. As we include multiple data dimensions in the analysis, mapping, and encoding paths, the entire signal flow may grow into a quite complex system as Figure 4.

We did not, however, examine musical expressions that extend over several seconds (e.g., rhythms, melodic patterns) in this discussion. For future work, we plan on examining spectral encoding techniques over time utilizing symbolic parameterizations. Relevant work includes Smalley's spectromorphology [23], an analytical framework for electro-acoustic music in which the author lists qualitative distinctions in each morphing (moving) steps of spectral contents. The chosen parameters (e.g., "upbeat" + "transition" + "closure") combine and form a complex musical gesture over time. In addition, spectral modeling synthesis [18] also provides insights in creating time-varying timbral structure with the deterministic and random components.

The time-varying encoding poses a practical issue with the time resolution of the data stream. SPE analyzes the STFT frames of the output audio with a reasonable frequency resolution (e.g., 1024 samples at the sampling rate of 44100 for harmonic or granular approach), which limits the data rate to at least one datum per 20 milliseconds. This is quite slow compared to, for example, audification or even possibly PMS. The data rate is forced to decrease even more when using encoding techniques such as granular synthesis or mixed-timbre composition because of the susceptibility to voice phasing. Also, adding time-domain audio effects such as delay and reverberation also smears out the phase relationship, causing more errors in machine listening.

## 6. CONCLUSION

We presented spectral parameter encoding, a dual-layer framework for musically expressive yet functional design of sonification. It employs a simple structural analysis to facilitate a semi-automated organization of mapping, and data encoding to spectral features as well as computational feature extraction to ensure the minimized loss of information as a whole in the process of transformation and mapping. Although the use of spectral distribution imposes certain acoustic constraints, it allows a variety of musically-organized sonification from timbral to harmonic expressions with the possibility of a multi-timbral structure.

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