# *Introduction to two articles on the computational and mathematical developments of the phase vocoder*

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Almost half a century ago, when Cooley and Tukey (re-)invented and popularized an efficient algorithm for the computation of the Discrete Fourier Transform, they could not imagine the impact that such an arrangement of multiplications and sums would have had on the development of science, technology and . . . music. Indeed, in music the FFT (Fast Fourier Transform) has become a synonymous of spectral analysis by Fourier transformation, and most of the people using the acronym have only a vague idea of the computational and mathematical achievements that are being hidden behind those three letters. The phase vocoder is one of the many sons of the FFT, and it is also a popular tool among computer musicians. The time-frequency plane is the space where the objecthood of sounds expresses itself in human-understandable form and, since the early works at Bell Labs in the nineteen-thirties, different kinds of vocoder have been proposed as tools that allow humans and machines to manipulate sound objects in this space. Still, the effectiveness of the phase vocoder as a tool derives from solid computational and mathematical roots that have not ceased from growing.

In this special issue dedicated to the phase vocoder, two articles present a broad view on the latest developments in the mathematics and computation of the phase vocoder and its extensions. Marco Liuni and Axel Röbel present an overview of the relevant literature on time-frequency representation and manipulation of sound, with special attention to some classic problems, such as the decomposition of sounds into their noisy, sinusoidal, and transient components, or the alignment and synchronization of phases after transformations in the frequency domain. Then, they describe some recent adaptive methods, where the resolutions in time and frequency can be adaptively and locally traded according to the sound morphology, or where the features in the time-frequency space have statistical nature. Finally, through a conversation with Marco Stroppa, Liuni and Röbel give a glimpse of how a musician can develop a mastery and a compositional praxis around a powerful tool such as the phase vocoder. In recent years, Gianpaolo Evangelista, Monika Dörfler, and

Ewa Matusiak have been introducing some of the most promising mathematical and computational innovations in the area of time-frequency analysis and transformation of sound. In this issue, they give a self-contained and detailed overview of the theory of Gabor frames as well as some relevant musical application examples. They start from the backbone of the phase vocoder, which is the Short-Time Fourier Transform, and describe its three souls: As a sequence of Fourier transforms, as convolution, or as scalar product. Then, they move from accessible linear algebra to describe Gabor frames and warping operators in the frequency domain. Their mathematical machinery makes it possible to introduce arbitrary deformations of the time and frequency axes without losing the possibility to reconstruct the original signal from the analysis data. The warping of time-frequency cells allows arbitrary, non-uniform time or frequency resolution, thus introducing new degrees of flexibility and an effective extension of the phase-vocoder family of techniques.