Consider classes of signals which have a finite number of degrees of freedom per unit of time, and call this number the rate of innovation of a signal. Examples of signals with finite rate of innovation include stream of Diracs (e.g. the Poisson process), non-uniform splines and piecewise polynomials.

Eventhough these signals are not bandlimited, we show that they can be sampled uniformly at (or above) the rate of innovation using an appropriate kernel, and then be perfectly reconstructed. Thus, we prove sampling theorems for classes of signals and kernels that generalize the classic “bandlimited and sinc kernel” case. In particular, we show how to sample and reconstruct periodic and finite length streams of Diracs, non-uniform splines and piecewise polynomials, and this using sinc and gaussian kernels. For infinite length signals with finite local rate of innovation, we show local sampling and reconstruction based on spline kernels.

The key in all constructions is to identify the innovative part of a signal (e.g. time instants and weights of Diracs) using an annihilating or locator filter, a device well known in spectral analysis and error correction coding. This leads to standard computational procedures for solving the sampling problem, which we show through experimental results.

Applications of these new sampling results can be found in signal processing, communications systems and biological systems.

Keywords: Sampling, generalized sampling, poisson processes, non-uniform splines, piecewise polynomials, non-bandlimited signals, analog-to-digital conversion, annihilating filters.