The Chinese University of Hong Kong
Shun Hing Institute of Advanced Engineering
Distinguished Lecture Series 2010

Sampling Theory and Practice: 50 Ways to Sample your Signal

by

Professor Martin Vetterli

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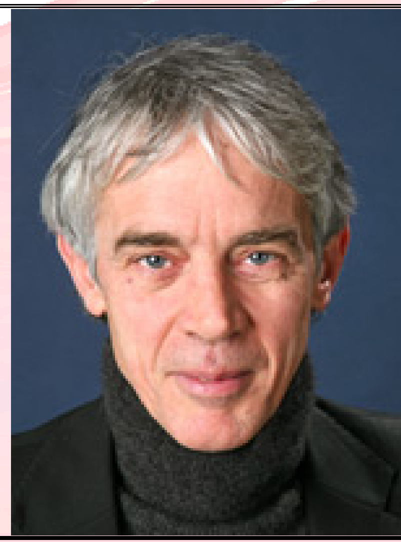

Date: 22 November 2010 (Monday)
Time: 11:00 am – 12:30 pm
Venue: TY Wong Hall, 5/F, Ho Sin-Hang Engineering Building, CUHK

Abstract

Sampling is a central topic not just in signal processing and communications, but in all fields where the world is analog, but computation is digital. This includes sensing, simulating, and rendering the real world. The question of sampling is very simple: when is there a one-to-one relationship between a continuous-time function and adequately acquired samples of this function? Sampling has a rich history, dating back to Whittaker, Kotel'nikov, Shannon and others, and is a active area of contemporary research with fascinating new results.

The classic result of sampling is the one on bandlimited functions, where taking measurements at the Nyquist rate (or twice the maximum bandwidth) is sufficient for perfect reconstruction. These results were extended to shift-invariant subspaces and multiscale spaces during the development of wavelets, as well as in the context of splines. All these methods are based on subspace structures, and on linear approximation.

Recently, non-linear methods have appeared. Non-linear approximation in wavelet spaces has been shown to be a powerful approximation and compression method. This points to the idea that functions that are sparse in a basis (but not necessarily on a fixed subspace) can be represented efficiently.

The idea is even more general than sparsity in a basis, as pointed out in the framework of signals with finite rate of innovation. Such signals are non-bandlimited continuous-time signals, but with a parametric representation having a finite number of degrees of freedom per unit of time. This leads to sharp results on sampling and reconstruction of such sparse continuous-time signals, namely that 2K measurements are necessary and sufficient to perfectly reconstruct a K-sparse continuous-time signal. In accordance with the principle of parsimony, we call this sampling at Occam's rate. We indicate an order K^3 algorithm for reconstruction, and describe the solution when noise is present, or the model is only approximately true.

Next, we consider the connection to compressed sensing and compressive sampling, a recent approach involving random measurement matrices. This is a discrete time, finite dimensional set up, with strong results on possible recovery by relaxing the l_0 into l_1 optimization, or using greedy algorithms. These methods have the advantage of unstructured measurement matrices (actually, typically random ones) and therefore a certain universality, at the cost of some redundancy. We compare the two approaches, highlighting differences, similarities, and respective advantages.

Finally, we move to applications of these results, which cover wideband communications, noise removal, distributed sampling, and super-resolution imaging, to name a few. In particular, we describe a recent result on multichannel sampling with unknown shifts, which leads to an efficient super-resolution imaging method.

Biography of the Speaker

Martin Vetterli got his Engineering degree from Eidgenoessische Technische Hochschule Zuerich (ETHZ), his MS from Stanford University and his Doctorate from Ecole Polytechnique Federale de Lausanne (EPFL).

He was an Associate Professor in EE at Columbia University in New York, and a Full Professor in EECS at the University of California at Berkeley before joining the Communication Systems Division of EPFL. He held several positions at EPFL, including Chair of Communication Systems, and founding director of the National Center on Mobile Information and Communication systems. He is currently a Vice-President of EPFL, in charge of institutional affairs.

He works on signal processing and communications, in particular, wavelet theory and applications, image and video compression, joint source-channel coding, self-organized communication systems and sensor networks, and has published about 140 journal papers on the subjects. His work won him numerous prizes, like best paper awards from EURASIP in 1984 and of the IEEE Signal Processing Society in 1991, 1996 and 2006, the Swiss National Latsis Prize in 1996, the SPIE Presidential award in 1999, and the IEEE Signal Processing Technical Achievement Award in 2001. He is a Fellow of IEEE, of ACM and EURASIP, and was a member of the Swiss Council on Science and Technology (2000-2004). He is an ISI highly cited researcher in engineering.

He is the co-author of three textbooks, with J. Kovacevic, "Wavelets and Subband Coding" (Prentice-Hall, 1995), with P. Prandoni, "Signal Processing for Communications", (PPUR, 2008) and with J. Kovacevic and V. Goyal, of the forthcoming book "Fourier and Wavelet Signal Processing" (2010).

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** Light refreshment will be served at 10:45 am before the lecture **