# Zaborszky Distinguished Lecture Series
# 2007 Lectures


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## Sampling and Quantization in System Modeling, Control and Signal Processing

**Overview**

This series of three lectures will outline ideas related to efficient data representation in system modeling, control and signal processing. A central theme in the lecturers will be the role of spatial and temporal sampling. Each lecture will cover background theory together with a number of real world applications. Brief details of the topics to be covered in each lecture are given below.

## Lecture 1: Sampling and Quantization in System Modeling
## Monday December 3, 2007


**Abstract**

High performance signal processing and control depends, inter-alia, on the availability of accurate models. Typically such models are obtained by a combination of physical modeling and analysis of experimental data. Moreover modern data recording equipment inevitable uses some form of sampling and quantization. This raises the question of the relationship between the sampled and quantized data and the underlying continuous time system. In this lecture, we will study this question for both linear and nonlinear dynamical systems. The ideas will be illustrated by the problem of identification of continuous time autoregressive systems and nonlinear systems from sampled data.


**Outline**

1. The Elements of Sampling – Input Holds, Anti-aliasing Filters and Samples
2. Sampled Data Models for Linear Systems – a First Look
3. Delta versus Shift Operator Models
4. Sampling Zeros for Deterministic Linear Systems
5. Sampling Zeros for Stochastic Linear Systems
6. Application to Identification of Continuous Time Autoregressive Models from Sampled Data
7. Robustness Issues using Sampled Data
8. Frequency Domain Identification from Sampled Data
9. Sampled Data Models for Nonlinear Systems

10. Characterization of “Sampling Zero Dynamics” for Deterministic Nonlinear Systems
11. “Sampling Zero Dynamics” for Stochastic Nonlinear Systems
12. Applications to Nonlinear System Identification from Sampled Data

## Lecture 2: Sampling and Quantization in Signal Processing
## Tuesday December 4, 2007

**Abstract**
Most signals of interest in signal processing are analogue in nature. However, to store, transmit or manipulate data from systems it is necessary that the data first be converted to sampled format. This raises a number of questions regarding the relationship between the sampled data and the underlying continuous signals. A core question is that of perfect reconstruction i.e., given the sampled data, under what conditions can one perfectly reconstruct the continuous data? Many examples of these ideas exist, e.g., in medical imaging, audio compression and video recording.

**Outline**

1. Brief review of Shannon/Nyquist Sampling Theorem
2. Generalized Sampling Expansion
3. Periodic Sampling
4. Sampling of Multivariable Signals
5. Sampling and Reciprocal Lattices
6. Design and Analysis of Synthesis filters for Perfect Reconstruction
7. Filter Banks
8. Applications to Audio Compression and Video Camcorders

## Lecture 3: Sampling and Quantization in Digital Control
## Wednesday December 5, 2007

**Abstract**
Sampling and Quantization are central to the topic of digital control. In particular sampling and quantization are an inescapable consequence of the use of A/D and D/A converters. Moreover, there is a growing trend to implement control systems over communication networks. In this context, sampling and quantization become of particular importance. In this lecture we will outline a number of ideas related to digital and networked control. The ideas will be illustrated by practical results related to control over communication networks.

**Outline**

1. Brief Review of non-networked Control
2. Communication Links and Models

3. Optimal Coder/Decoder Design for Networked Control
4. The Role of Architectures in Networked Control – beyond two degrees of freedom
5. Stability and Performance Limits
6. Channel Capacity Requirements for Closed Loop Stability in Networked Control
7. Filter Banks in Networked Control
8. Missing Packets
9. Design Case Studies and Experimental Results