Proposed Graduate Course at ANU: *Statistical Communication Theory*

Mark Reed
mark.reed@nicta.com.au

Title of the course: Statistical Communication Theory

Course Director: Dr. Mark Reed (ANU Adjunct Fellow)

Formal Description of course: This course provides a detailed study of fundamental statistical principles that underpin this subject. Emphasis will be on a modern treatment of detection and estimation theory. Elements of modulation theory and channel coding will be introduced at specific points in the course to link up with practical realities of digital communications.

Informal Description of course: The outcome of the course for interested students is a fundamental understanding of detection and estimation theory. The course will examine the underlying statistical tools to perform detection and estimation, including probability theory, detection theory, maximum likelihood detection with memory, MAP detection with memory, turbo processing, parameter estimation theory, synchronisation, channel state estimation and multiuser detection.

This course is based on a book being developed in conjunction with Prof. Simon Haykin, McMasters University, Canada.

Curriculum:

The proposed course outline is: -

- Introduction
  - Historical Evolution of Digital Communications: How and Why
  - The Challenge in Designing High-performance Receivers
  - Detection and Estimation using Statistics
- Probability Theory and Statistics
  - The Inference Problem
  - Bayesian Theory
  - Hypothesis Testing
  - Hypothesis-Testing (M-ary)
  - Parameter Estimation
  - Channel Models
  - Markov Models and Chains
- - Detection Theory
  - Gram-Schmidt Orthoganalization
  - Matched Filtering
  - Sufficient Statistics
  - Detection Criteria
  - The Receiver in its most Basic Form
  - Receiver-operating Characteristic (ROC) and its Properties
  - Bounds on Receiver Performance
- ML Detection with Memory
  - Channel Memory
  - The ML Criterion extended to deal with memory
  - State and Trellis Diagram
  - Dynamic Programming

  - The Viterbi Algorithm
  - Computational Limitations
  - The SOVA Algorithm
  - Theme Example - Viterbi Equalization for a Wireless Channel

- MAP Detection with Memory
  - The MAP Criteria Extended to Deal with Memory
  - Two Basic Notions of Estimation
  - Markov Chain Revisited
  - The (BCJR) APP Algorithm
  - Variants of the APP Algorithm
  - Forward-backward Interpretation of the APP Algorithm
  - Need for pre-processing
  - Theme Example - MAP Equalization for a Wireless Channel

- Turbo Processing
  - The Turbo Principle
  - Concatenated Transmitter configurations
  - Likelihood-ratio Calculations
  - Turbo Decoding
  - Turbo Equalization
  - Analysis Schemes
  - Complexity Reduction Strategies
  - Theme Example: Turbo Equalization for a Wireless Channel

- Parameter Estimation Theory
  - Parameter Estimation in Digital Communication Receivers
  - MSE, ML and MAP Estimation Procedures, and Their Statistical Properties
  - Amplitude Estimation in Noise

  - Phase/Frequency Estimation
  - Timing Estimation
  - Performance Bounds

- Synchronization
  - The Receiver Synchronization Problem
  - Signal Acquisition
  - Signal Tracking
  - Turbo Synchronization
  - Theme Example: Turbo Phase Synchronization for a Wireless Channel

- Channel State Estimation
  - Pilot Assisted (Supervised) Training Approach
  - Semi-blind State Estimation
  - State-space Model of the Channel
  - Kalman Filtering Strategy
  - Particle Filtering Strategy
  - Particle Filtering as a Feed-forward Method for Signal Tracking
  - Theme Example: Turbo Phase Synchronization for a Wireless Channel Revisited

- Multi-user Detection
  - The Multi-user Detection Problem
  - Maximum Likelihood Detector (Optimum Detector)
  - The Conventional Detector (Matched Filter)
  - Successive Interference Cancellation Strategy
  - Parallel Interference Cancellation
  - Turbo Multi-user Detection
  - Reduced Complexity Turbo Multi-user Receivers

- Analysis Schemes
- Theme Example: Reduced Complexity Turbo MUD Receiver

Presenters: Mark Reed

Dates and Locations: Nominally, `start date`, weekly, 10am-12pm in lecture room for 10 weeks

Completion date of course: `start date`+ 10 weeks

Notification date of course: `start date`+ 12 weeks

Workload: 20 hours of lectures, 40 hours of assignments reading and preparation for lectures. No formal examination.

Assumed knowledge of course: Basic probability theory (expectation, variance), undergraduate linear algebra (bases, matrix theory)

Prerequisites, entry requirements: It will assume working knowledge of Fourier Theory, Probability Theory, and Stochastic Processes at undergraduate level, communication systems at undergraduate level, undergraduate engineering degree.

Assessment procedures: Ten assignments, one each week.

Assignment options for the course: Four assignments handed out during the course. A pass will be dependent on satisfactory performance in the assignments

Examiners: Prof. Rodney Kennedy (RSISE,ANU) and Dr Mark Reed (ANU Adjunct)

Fees: Nil