System Identification, Lecture 12

Kristiaan Pelckmans (IT/UU, 2338)

Course code: 1RT880, Report code: 61800 - Spring 2012
F, FRI Uppsala University, Information Technology

16 Mai 2012
Overview Part II


2. Subspace Identification.

3. Further Topics.


5. Wider View.
1. SI = Recovery/Approximation of Systems from Experiments.


3. Interdisciplinary.
Adaptive Filtering

1. What: "Track optimal filter $h_t$ which purifies the signals."
   Ex.:
   
   (a) Initialize $f_0 = 0_d$, $t = 0$
   (b) Predict $f_{t-1}(x_t)$ and measure feedback $e_t = (y_t - f_{t-1}(x_t))$
   (c) Update $f_t = f_{t-1} + g(e_t)$
   (d) Repeat for $t = 1, 2, \ldots$

2. Why:
   • Communication.
   • Acoustics.
   • Filters.

3. Results:
   • Differential Equation.
   • Algorithmic.
   • Equalization.
   • Efficiency.
• Time-varying.

4. Relevance 2 SI:
  • D/A and anti-aliasing filters.
  • Equalization and communication.
  • Block-adaptive filters and networks.

5. Text:
1. What: "Numerical analysis is the study of algorithms that use numerical computation (as opposed to general symbolic manipulations) for the problems of mathematical analysis (as distinguished from discrete mathematics)."

2. Why: continuous $\rightarrow$ finite.

3. Results:
   - Matrix manipulations.
   - Characterizations.
   - Decompositions.

4. Relevance 2 SI:
   - Subspace ID.
   - LAPACK/NUMPACK.
   - Distributed Computation.
5. Text:
Numerical Optimization

1. What:
\[
\min_{\theta \in \mathcal{D}} J(\theta) \quad \text{s. t.} \quad \theta \in \Theta
\]

2. Why: Local/Global?

3. Results:
   - LS versus non-LS.
   - Linear versus nonlinear.
   - Convex versus Non-convex.
   - Heuristics.
   - Speed of convergence & Comp. demand.

4. Relevance 2 SI:
   - Toolbox and Embedded Systems.
   - Practical and theoretical efficient algorithms.
   - Differential vs. non-differential.
   - Recursive Identification.
• Motor.
• How to interpret numerical/asymptotic result?

5. Text:
Theoretical Computer Science

1. What: "The design and study of algorithms."

2. Why:
   • Efficient algorithms.
   • Computational and Memory Complexity.

3. Results:
   • Sorting, ..., bin-packing.
   • P versus NP.
   • Randomization.
   • Heuristics.
   • Reduction to numerical analysis.
   • Beyond matrices.

4. Relevance 2 SI:
   • Sequential and Online.
• Nonlinear ID.
• Greedy strategies.

5. Text:
1. What: "Operations research is an interdisciplinary mathematical science that focuses on the effective use of technology by organizations."

2. Why:
   - WWII.
   - Optimal Strategies.
   - DP.
   - Abstractions (models).

3. Results:
   - MINCUT - MAXFLOW - linear Programming.
   - Combinatorial Optimization.
   - Matching, Allocation, Scheduling, Paths and Routing.
   - Sequential Testing and Quality Control.

4. Relevance 2 SI:
• Combinatorial Models.
• Networked Systems.
• Optimization.

5. Text:
1. What: "A computer program is said to learn from experience $E$ with respect to some class of tasks $T$ and performance measure $P$, if its performance at tasks in $T$, as measured by $P$, improves with experience $E$.”

$$y \approx f(X)$$

2. Why:
   - Nonlinear models and predictors.
   - How to characterize and relate many different tools?

3. Results:
   - Toolboxes (SVM, splines, Decision trees).
   - ML matured $\rightarrow$ parameters 2 functions.
   - Algorithms.
   - Complexity Control and Generalization.
• Theoretical ML vs. Applications (DARPA).

4. Relevance 2 SI:
   • Off-the-shelf tools.
   • Generalization Analysis.
   • MATLAB, WEKA, Python, ...

5. Text:
Statistical Inference


\[ X \sim \mathcal{N}(0_n, \Sigma) \]

ML:

\[ \hat{\Sigma} = \arg\max_{\Sigma} L(X_n; \Sigma) \]

2. Why:

- Stochastics as an abstraction of irrelevant, individual effects.
- Optimal model \( \rightarrow \) Optimal predictor?
- Averaging behavior.

3. Results:

- Stochastic Processes, IID.
• Statistical Models.
• ML.
• CLT and Cramer-Rao.
• Hypothesis Testing.
• Finite sample results.
• Beyond ML: Penalized ML, U-, L-, M-, V-, R-statistics.

4. Relevance 2 SI:

• Timeseries.
• Often nonlinear in parameters.
• Often Newton-Raphson.
• Inference and covariance.
• R, SAS, Python, stata, SPSS, Matlab, Excel.
• Data visualization tools.

5. Text:
Information Theory

1. What: "Modeling as communication - a model as summary of the data."

2. Why:
   - Choice of model subjective.
   - Objective guidelines?
   - Fundamental limits.

3. Results:
   - Shannon’s source coding theorem $|\text{com}(X)| \geq h(X)$
   - Shannon’s noisy source coding theorem $|\text{com}(X)|/|X| \geq \frac{C}{1-h(X)}$
   - Entropy, KL, MI.
   - MDL.
   - rate Distortion theory.

4. Relevance 2 SI:
• Compression.
• Foundation to Stochastic.
• Gambling, Investment and Universal rules.

5. Text:
1. What: "Econometrics studies statistical properties of econometric procedures"

2. Why:

3. Results:
   - Noise and correlations.
   - Jumps and outliers.
   - Variance Stabilizing transformations.
   - Gambling and Maximal profit strategies.
   - Stochastic Calculus (\(\hat{I}_to\))

4. Relevance SI:
   - Timeseries modeling.
   - Preprocessing.
   - Continuous time.
estimation and inference in econometrics

Russell Davidson
James G. MacKinnon
Nonlinear Systems

1. What: "Study of the dynamics arising from nonlinear systems."

2. Why:
   • Models → I/O Behavior.
   • I/O Behavior ? models?

3. Results:
   • Oscillators.
   • Bifurcation Diagrams.
   • Long range prediction.
   • Stability and Limit Cycles.

4. Relevance SI:
   • Diagnostics to Identified Nonlinear model.
   • Observed behavior → Model structure?
• Phase

5. Text:
Conclusions

To remember

- Least Squares.
- Extensions.
- Toolbox.
- Tuning.