**Corso di Laurea Magistrale in Ingegneria Meccatronica (Mechatronic Engineering)**
**Corso di Laurea Magistrale in Ingegneria Informatica (Computer Engineering)**

# 01RKYQW / 01RKYOV – Estimation, Filtering and System Identification (was: 01PDDQW / 01PDDOV – Identification and Control Methodologies)

**A.A. 2023/24**

Teacher: prof. Michele Taragna

**Description**
The course lessons are taught in English.
The purpose of this course is to provide basic methodologies and software tools for building mathematical models of linear and nonlinear (static or dynamic) systems starting from experimental data.

**Credits:** 6

**Prerequisites**
The following notions are essential: knowledge of the representations of linear dynamic systems (input-state-output equations, transfer functions) and of their fundamental properties (stability, controllability, observability); essentials of probability theory and statistics; basic concepts of linear algebra and Zeta transform. The knowledge of the MATLAB software environment is required.

**Program**
1) Introduction to estimation and prediction problems. Main statistical estimation methods (least-squares, weighted least-squares, maximum likelihood estimators, Bayesian estimators) and their basic properties (correctness, efficiency, consistency), with evaluation of parametric estimation error.
2) Set-membership estimation theory for different norm assumptions on noise, with evaluation of Estimate Uncertainty Sets and Intervals. Optimal and Central estimates, with evaluation of Feasible Parameter Sets and Parameter Uncertainty Intervals.
3) Introduction to Kalman filtering problem: dynamic one-step and multi-step predictors, dynamic optimal filter, steady-state one-step predictor and filter, nonlinear predictors and filters.
4) Identification of linear dynamic systems from input-output measurements: FIR, ARX, ARMAX and OE models. Predictive approach and models in predictor form. Asymptotic analysis of prediction-error identification methods. Least-squares method: probabilistic analysis, persistence of excitation, practical procedure. Recursive least-squares methods. Model structure selection and validation (whiteness test and residual analysis; FPE, AIC and MDL criteria).
5) Identification of nonlinear dynamic systems from input-output measurements: statistical and set-membership methods. Neural networks: approximation properties, learning.

**Practicals**
Classroom practicals are focused on the development of both academic and applicative examples.
Some other practicals are carried out in computer laboratories and are focused on modelling real-world static or dynamic systems (position transducer, hair dryer, water heater) and on Kalman predictor and filter design and simulation for a given linear dynamic system, using MATLAB toolboxes (Control System, System Identification, Neural Network based System Identification) running under MATLAB R2014a.

**References**

1. Sergio Bittanti, *Teoria della Predizione e del Filtraggio*, VII edition, Pitagora Editrice Bologna, 2004 (in Italian)
2. Sergio Bittanti, *Identificazione dei Modelli e Sistemi Adattativi*, VI edition, Pitagora Editrice Bologna, 2004 (in Italian)
3. Thomas Kailath, Ali H. Sayed, Babak Hassibi, *Linear Estimation*, II edition, Prentice Hall, Upper Saddle River, N.J. (U.S.A.), 2000

4. Lennart Ljung, *System Identification: Theory for the User*, II edition, Prentice Hall PTR, Upper Saddle River (U.S.A.), 1999
5. Lennart Ljung, *System Identification Toolbox User's Guide*, The MathWorks Inc., Natick, MA (U.S.A.), 1988-1997

The overall tutorial material used during the course (lecture slides, laboratory exercises with proposed solutions, official formulary) can be downloaded from the web page www.ladispe.polito.it/corsi/MIC/
During the current academic year, the course will be delivered in person only and will not be videotaped. This entire course was recorded in the academic years 2020/21 and 2019/20, laboratory activities included: the corresponding video recordings are already available as Virtual Classrooms on the Teaching Portal page called "Registrazioni altri corsi".

**Examination rules**

- The final assessment consists of a written test, about three hours long, to be performed in computer laboratories using the MATLAB software tools running under MATLAB R2014a. The examination is typically made of: a model building practice of an unknown system starting from given data; a second exercise on Kalman predictor and/or filter design and simulation for a given linear dynamic system; a closed-book theory question on any topic of the course (proofs included), lasting about 20 minutes and worth 4 points, being the score of the entire exam set to 32 points.
- To withdraw from the exam, it is necessary to send an e-mail to the teacher within 48 hours from the closing of the test. If the student withdraws, the examination rating is recorded as "withdrawn"; otherwise, the examination rating is recorded and therefore the student is considered as "graded".
- Only students who have never been graded in previous exam sessions (with any score, sufficient or insufficient) are exempt from the closed-book theory question; they will have the entire time available to carry out the other exercises, whose overall score in this case will be rescaled to 32 points.
- The exit from the laboratory before the end of the exam is allowed only in case of student withdrawing.
- During the exam, the student is allowed to have on its table only the test paper and writing material (pens, pencils, erasers). Any other item (notes, books, blank sheets of paper, mobile phones, backpacks, tablets, notebooks, etc.) is forbidden.
- During the exam, the student is not allowed to use textbooks or notes, except the official formulary of this course, directly provided by the teacher during the test as pdf file (and downloadable before the exam from the course web page). No other material is allowed, i.e., no personal notes, exercises, MATLAB code or solutions of specific exercises, in complete or partial form, coded in any way.
- Students found with forbidden items (e.g., notes, books, solved exercises, phones, tablets, etc.) or caught communicating or attempting to communicate with each other are automatically considered as flunked.

**Communications and announcements**

Communications and announcements are published on the Teaching Portal official course webpage and on

www.ladispe.polito.it/corsi/MIC/

**Office hours and how to contact the teacher**

The teacher can be contacted:

- by phone (011-090.7063) in the Dipartimento di Elettronica e delle Telecomunicazioni;
- by email (email address: michele.taragna@polito.it)

or alternatively at the beginning, during the breaks or at the end of lessons and laboratories.
The teacher is also available to provide a face-to-face or remote advice by arranging a meeting through one of the contact methods indicated above.