UNIVERSITÀ DI PAVIA

Anno Accademico 2016/2017

IDENTIFICATION OF MODELS AND DATA ANALYSIS

Enrollment year	2016/2017
Academic year	2016/2017
Regulations	DM270
Department	DEPARTMENT OF ELECTRICAL,COMPUTER AND BIOMEDICAL ENGINEERING
Course	INDUSTRIAL AUTOMATION ENGINEERING
Curriculum	PERCORSO COMUNE
Year of study	1°
Period	Annual (26/09/2016 - 09/06/2017)
ECTS	12
Language	Italian
Prerequisites	Basic notions of set theory, logic, calculus, function maximization.
Learning outcomes	Knowledge of basic notions of: estimation theory (maximum likelihood estimation, a-posteriori estimation); neural-based model identification; stochastic processes (mean, autocovariance, spectral density, optimal prediction); identification of ARMAX models. Ability to solve identification and prediction problems ranging from model formulation to the use of computer tools (Matlab) for parameter estimation and model simulation.
Course contents	System Identification deals with methodologies that enable the construction of mathematical models of systems and signals based on experimental data. In presence of complex systems whose behavior can be hardly reduced to known "laws of nature", the use of identification techniques is often the only way to obtain models to be used in the context of forecasting, simulation, and control. The methods presented in the course are widely used in heterogeneous fields such as automation, biomedical engineering, econometry, hydrology, geophysics and telecommunications. Some basic notions of probability, estimation theory and stochastic processes are recalled. The main properties (stability, input-output description in the time and frequent domains) of linear discrete-time systems are introduced. In the context of parametric estimation, the issues of model validation and model

complexity are extensively discussed. Neural based identification is also illustrated and discussed, pointing out pros and cons with respect to standard approaches. The study of dynamic systems addresses three main topics: the optimal prediction of stationary stochastic processes (Wiener filtering), the identification of linear discrete-time systems, and spectral estimation (both nonparametric and maximum-entropy).

Probability: basic notions

probability notion;
independence, conditional probability, total probability and Bayes theorems;
Bernoulli trials, Poisson events;
the notion of random variable (R.V.), cumulative distribution function, probability density function, functions on one R.V.;
mode, median, moments of a R.V.;
joint random variables: distribution, density, moments, independence, incorrelation, functions of random variables;
Law of Lrge Numbers, Gaussian R.V., Central Limit Theorem.

Statistics: basic notions

notion of estimator; properties of estimators;
sample moments and their main properties;
confidence interval for the sample mean, Student's t.

Identification of linear-in-parameter models:

the least squares method, normal equations, identifiability;
Best Linear Unbiased Estimator: estimator, variance of parameters;
validation and choice of complexity: chi-square test, F-test, FPE, AIC, and MDL criteria.

Estimation theory:

maximum likelihood estimation: properties and examples;
a-posteriori estimation, Bayes estimator;
cross-validation, model complexity and the bias-variance dilemma;
identification of nonlinear-in-parameter models.

Neural identification:

Radial basis function neural networks;
Multi-layer perceptron networks;
generalization, overfitting, selection of network size.

Stochastic processes and optimal prediction:

mean, autocorrelation, autocovariance, independence, incorrelation;
white noise, random walk, MA, AR, and ARMA processes, Yule-Walker equations;
stationarity, power spectral density, nonparametric spectral estimatiom;
spectral factorization, optimal prediction.

	Identification of dynamic systems: classes of dynamic models: output error, ARX, ARMAX; prediction-error methods for system identification; least-squares identification of ARX models: probabilistic analysis and persistent excitation.
Teaching methods	Lectures, Practical class
Reccomended or required readings	Lecture notes (http://sisdin.unipv.it/labsisdin/teaching/teaching.php). M. Bramanti. Calcolo delle probabilità e statistica. Esculapio. A. Papoulis. Probability, Random Variables, and Stochastic Processes. McGraw-Hill. L. Ljung. System Identification: Theory for the User. Prentice-Hall.
Assessment methods	Written examination
Further information	Written examination

The activity is split

502522 - **IDENTIFICATION OF MODELS AND DATA ANALYSIS A**

502594 - **IDENTIFICATION OF MODELS AND DATA ANALYSIS B**

UNIVERSITÀ DI PAVIA

Anno Accademico 2016/2017

IDENTIFICATION OF MODELS AND DATA ANALYSIS A	
Enrollment year	2016/2017
Academic year	2016/2017
Regulations	DM270
Academic discipline	ING-INF/04 (AUTOMATICS)
Department	DEPARTMENT OF ELECTRICAL,COMPUTER AND BIOMEDICAL ENGINEERING
Course	INDUSTRIAL AUTOMATION ENGINEERING
Curriculum	PERCORSO COMUNE
Year of study	1°
Period	1st semester (26/09/2016 - 13/01/2017)
ECTS	6
Lesson hours	45 lesson hours
Language	ITALIAN
Activity type	WRITTEN AND ORAL TEST
Teacher	DE NICOLAO GIUSEPPE (titolare) - 6 ECTS
Prerequisites	Basic notions of set theory, logic, calculus, function maximization.
Learning outcomes	Knowledge of basic notions of probability and statistics. Ability to solve data analysis and estimation problems ranging from model formulation to the use of computer tools (Matlab) for parameter estimation and model simulation.
Course contents	System Identification deals with methodologies that enable the construction of mathematical models of systems and signals based on experimental data. In presence of complex systems whose behavior can be hardly reduced to known "laws of nature", the use of identification techniques is often the only way to obtain models to be used in the context of forecasting, simulation, and control. The methods presented in the course are widely used in heterogeneous fields such as automation, biomedical engineering, econometry, hydrology,

	geophysics and telecommunications. Some basic notions of probability, estimation theory and stochastic processes are recalled. The main properties (stability, input-output description in the time and frequenct domains) of linear discrete-time systems are introduced. In the context of parametric estimation, the issues of model validation and model complexity are extensively discussed. Neural based identification is also illustrated and discussed, pointing out pros and cons with respect to standard approaches. The study of dynamic systems addresses three main topics: the optimal prediction of stationary stochastic processes (Wiener filtering), the identification of linear discrete-time systems, and spectral estimation (both nonparametric and maximum-entropy). Probability: basic notions probability notion; independence, conditional probability, total probability and Bayes theorems; Bernoulli trials, Poisson events; the notion of random variable (R.V.), cumulative distribution function, probability density function, functions on one R.V.; mode, median, moments of a R.V.; joint random variables: distribution, density, moments, independence, incorrelation, functions of random variables; Law of Lrge Numbers, Gaussian R.V., Central Limit Theorem. Statistics: basic notions notion of estimator; properties of estimators; sample moments and their main properties; confidence interval for the sample mean, Student's t. Identification of linear-in-parameter models: the least squares method, normal equations, identifiability; Best Linear Unbiased Estimator: estimator, variance of parameters; validation and choice of complexity: chi-square test, F-test, FPE, AIC, and MDL criteria.
Teaching methods	Lectures, Practical class
Reccomended or required readings	Lecture notes (http://sisdin.unipv.it/labsisdin/teaching/teaching.php). M. Bramanti. Calcolo delle probabilità e statistica. Esculapio. A. Papoulis. Probability, Random Variables, and Stochastic Processes. McGraw-Hill. L. Ljung. System Identification: Theory for the User. Prentice-Hall.
Assessment methods	Written examination

Further information

	Written examination
Sustainable development	

goals - Agenda 2030	$lbl_legenda_sviluppo_sostenibile

Anno Accademico 2016/2017

IDENTIFICATION OF MODELS AND DATA ANALYSIS B

Enrollment year	2016/2017
Academic year	2016/2017
Regulations	DM270
Academic discipline	ING-INF/04 (AUTOMATICS)
Department	DEPARTMENT OF ELECTRICAL,COMPUTER AND BIOMEDICAL ENGINEERING
Course	INDUSTRIAL AUTOMATION ENGINEERING
Curriculum	PERCORSO COMUNE
Year of study	1°
Period	2nd semester (01/03/2017 - 09/06/2017)
ECTS	6
Lesson hours	50 lesson hours
Language	Italian
Activity type	WRITTEN AND ORAL TEST
Teacher	DE NICOLAO GIUSEPPE (titolare) - 5 ECTS MARSEGLIA GIUSEPPE ROBERTO - 1 ECTS
Prerequisites	Basic notions of set theory, logic, calculus, function maximization.
Learning outcomes	Knowledge of basic notions of: estimation theory (maximum likelihood estimation, a-posteriori estimation); neural-based model identification; stochastic processes (mean, autocovariance, spectral density, optimal prediction); identification of ARMAX models. Ability to solve identification and prediction problems ranging from model formulation to the use of computer tools (Matlab) for parameter estimation and model simulation.
Course contents	System Identification deals with methodologies that enable the construction of mathematical models of systems and signals based on experimental data. In presence of complex systems whose behavior can be hardly reduced to known "laws of nature", the use of identification

	techniques is often the only way to obtain models to be used in the context of forecasting, simulation, and control. The methods presented in the course are widely used in heterogeneous fields such as automation, biomedical engineering, econometry, hydrology, geophysics and telecommunications. The main properties (stability, input-output description in the time and frequenct domains) of linear discrete-time systems are introduced. In the context of parametric estimation, the issues of model validation and model complexity are extensively discussed. Neural based identification is also illustrated and discussed, pointing out pros and cons with respect to standard approaches. The study of dynamic systems addresses three main topics: the optimal prediction of stationary stochastic processes (Wiener filtering), the identification of linear discrete-time systems, and spectral estimation (both nonparametric and maximum-entropy). Estimation theory: maximum likelihood estimation: properties and examples; a-posteriori estimation, Bayes estimator; cross-validation, model complexity and the bias-variance dilemma; identification of nonlinear-in-parameter models. Neural identification: Radial basis function neural networks; Multi-layer perceptron networks; generalization, overfitting, selection of network size. Stochastic processes and optimal prediction: mean, autocorrelation, autocovariance, independence, incorrelation; white noise, random walk, MA, AR, and ARMA processes, Yule-Walker equations; stationarity, power spectral density, nonparametric spectral estimatiom; spectral factorization, optimal prediction. Identification of dynamic systems: classes of dynamic models: output error, ARX, ARMAX; prediction-error methods for system identification; least-squares identification of ARX models: probabilistic analysis and persistent excitation.
Teaching methods	Lectures, practical class, workshops
Reccomended or required readings	Lecture notes (http://sisdin.unipv.it/labsisdin/teaching/teaching.php). A. Papoulis. Probability, Random Variables, and Stochastic Processes. McGraw-Hill. L. Ljung. System Identification: Theory for the User. Prentice-Hall.
Assessment methods	Written examination

Further information	Written examination
Sustainable development goals - Agenda 2030	$lbl_legenda_sviluppo_sostenibile