ADAPTIVE IDENTIFICATION, FILTERING AND CONTROL

PROBLEM ADA1 (1 person, 6 points)
Compare RLS with and without forgetting factor and LMS in case of bursts or jump discontinuities. Design and study three different examples, to emphasize the algorithms' behavior and performance.

PROBLEM ADA2 (1 person, 10 points – 2 persons, 6 points)
Consider a disturbance $d(t) = \sin(2\pi f(t)t)$, where $f(t) = f_0 + n(t)$, f_0 being a costant and $n(t)$ a noise term, *e.g.* $n(t) = N \sin(2\pi f_n t)$, with $f_n << f_0$, and $N \in \{0, 0.001f_0, 0.01f_0, 0.1f_0\}$. Study the problem of attenuating the disturbance with an adaptive filter scheme (use plain LMS with FIR filters and adaptive notch filters), assuming that $f(t)$ is known. Study, in particular, how f_n affects the overall noise attenuation performance.

PROBLEM ADA3 (1 person, 6 points)
RLS can also be defined to operate on a sliding window (see T. Soderstrom and P. Stoica, "System identification", Problem 9.10). Implement it in Matlab and compare it on simple examples (ARX systems with time varying parameters) with the version using the forgetting factor for different values of the window length and forgetting factor.

ACTIVE NOISE CONTROL

PROBLEM ANC1 (3 persons, 10 points)
Compare the methods proposed in the listed references for the rejection of a multi-harmonic signal. Study the problem for varying initializations of the frequency estimates, and for varying amplitudes and distances (in frequency) of the harmonic components of the disturbance.

References:

- P.A. Regalia, "An improved lattice-based adaptive IIR notch filter", *IEEE Trans. on Signal Processing*, vol. 39, n. 9, pp. 2124–2128, 1991.
- J.E. Cousseau, S. Werner, and P.D. Donáte, "Factorized All-Pass Based IIR Adaptive Notch Filters", *IEEE Trans. on Signal Processing*, vol. 55, n. 11, pp. 5225–5236, 2007.
- R. Marino and P. Tomei, "Global Estimation of Unknown Frequencies", *IEEE Transactions on Automatic Control*, vol. 47, n. 8, pp. 1324–1328, 2002.

PROBLEM ANC2 (2 persons, 10 points)
Analize with the aid of simple examples the relevance of the so-called commutation error (as defined in the cited papers) in active noise control problems.

References:

- C.-W. Liao and J.-Y. Lin, "New FIR filter-based adaptive algorithms incorporating with commutation error to improve active noise control performance", *Automatica*, vol. 43, pp. 325–331, 2007.
- J.-Y. Lin and C.-W. Liao, "New IIR filter-based adaptive algorithm in active noise control applications:Commutation error-introduced LMS algorithm and associated convergence assessment by a deterministic approach", *Automatica*, vol. 44, pp. 2916–2922, 2008.

PROBLEM ANC3 (2 persons, 10 points)
Disturbances that are uncorrelated with the reference signal cannot attenuated by the standard FXLMS algorithm. Study the method proposed in the reference to address this problem. Code the proposed algorithm in Matlab and repeat the simulations illustrated in the paper to verify their correctness.

References:

- M.T. Akhtar and W. Mitsuhashi, "Improving Performance of Hybrid Active Noise Control Systems for Uncorrelated Narrowband Disturbances," *IEEE Transactions on Audio, Speech, and Language Processing*, vol.19, n.7, pp. 2058–2066, Sept. 2011.

PROBLEM ANC4 (2 persons, 10 points)
The listed reference studies the attenuation of sinusoidal disturbances in the presence of errors in the estimation of the disturbance frequency. Study the proposed method, implement the algorithm in Matlab and repeat the simulations documented in the paper.

References:

- H.-J. Jeon, T.-G. Chang, S. Yu, and S.M. Kuo, "A Narrowband Active Noise Control System With Frequency Corrector," *IEEE Transactions on Audio, Speech, and Language Processing*, vol. 19, n. 4, pp. 990–1002, May 2011.

PROBLEM ANC5 (2 persons, 10 points)

The listed reference proposes an active control that does not require the use of error gradients, thus avoiding altogether the use of a model of the secondary path. Implement such algorithm in Matlab and compare it with FXLMS on the same simulations presented in the paper.

References:

- N.K. Rout, D.P. Das, and G. Panda, "Particle Swarm Optimization Based Active Noise Control Algorithm Without Secondary Path Identification," *IEEE Transactions on Instrumentation and Measurement*, vol. 61, n. 2, pp. 554–563, February 2012.

PROBLEM ANC6 (2 persons, 10 points)

The following paper proposes a method for the simultaneous control of narrowband and broadband disturbances. Implement the proposed method in Matlab, repeat the simulations documented in the paper and discuss advantages and drawbacks of this approach.

References:

- Y. Xiao and J. Wang, "A New Feedforward Hybrid Active Noise Control System," IEEE Signal Processing Letters, vol. 18, n. 10, pp. 591–594, October 2011.

KALMAN FILTERING

PROBLEM KF1 (1 person, 8 points)
Consider the cannon ball example (http://greg.czerniak.info/guides/kalman1/). Build a simulator of the cannon ball flight dynamics. Assume that noisy measurements of the ball position and velocity are available and build a Kalman filter to estimate the ball position. Test different initializations and different initial guesses of the state and output noise covariances (keep diagonal matrices). What happens if only ball position measurements are available? What if only the ball *x* position is available? What if there is an unmodeled wind effect with a costant speed in the *x* direction?

PROBLEM KF2 (2 persons, 10 points)
Implement and compare the Kalman filter-based frequency tracking methods discussed in the listed references. Reproduce the same experimental results shown there.

References:

- S. Corbetta, A. Dardanelli, I. Boniolo, S.M. Savaresi, and S. Bittanti, "Frequency estimation of narrow band signals in Gaussian noise via Unscented Kalman Filter", *49th IEEE Conference on Decision and Control* (*CDC*), Atlanta (GA), USA, pp. 2869–2874, Dec. 15-17, 2010.
- S. Bittanti and S.M. Savaresi, "On the parametrization and design of an extended Kalman filter frequency tracker", *IEEE Transactions on Automatic Control*, vol. 45, n. 9, pp. 1718–1724, 2000.

PROBLEM KF3 (1 person, 8 points)
In Kalman filtering applications the covariance matrices of the disturbances are a critical design parameter. Implement the covariance parametrization method described in the cited reference and repeat the two numerical simulations reported there.

References:

- S. Formentin and S. Bittanti, "An insight into noise covariance estimation for Kalman filter design", 19th IFAC World Congress, Cape Town, South Africa, 2014.

PROBLEM KF4 (1 person, 6 points)
The SUAS Code is a set of Matlab routines for state estimation of a fixed-wing Unmanned Aircraft System (UAS) using different combinations of sensors. Read the companion article and run the code on the available data comparing the different performances obtainable with the different sensors.

References:

- J.D. Barton, "Fundamentals of Small Unmanned Aircraft Flight," *Johns Hopkins APL Technical Digest*, Vol. 31, n. 2, 2012.
- http://www.jhuapl.edu/ott/Technologies/Copyright/SuasCode.asp

PARTICLE FILTERING

PROBLEM PF1 (1 person, 10 points)
Solve the localization problem descripted at https://www.youtube.com/watch?v=sz7cJuMgKFg with a particle filtering approach. Compare the results with a classical Kalman filtering method.

PROBLEM PF2 (1 person, 8 points)
Consider the cannon ball example (http://greg.czerniak.info/guides/kalman1/). Build a simulator of the cannon ball flight dynamics. Assume that noisy measurements of the ball position and velocity are available and build a particle filter to estimate the ball position. Test different initializations and different initial guesses on the prior probability. What happens if only ball position measurements are available? What if only the ball x position is available? What if there is an unmodeled wind effect with a costant speed in the x direction?

MULTIVARIABLE IDENTIFICATION

PROBLEM MIMO1 (1 person, 10 points)
With reference to the dryer data:

- ftp://ftp.esat.kuleuven.be/pub/SISTA/data/process_industry/dryer2.dat.gz
- ftp://ftp.esat.kuleuven.be/pub/SISTA/data/process_industry/dryer2.txt
- (see also the process description at p. 967, Sec. VII.C of the cited paper)

perform a multivariable model identification using both an ARX input-output representation in the matrix polynomial format and LS, and a subspace method (use the `n4sid.m` Matlab routine). Compare the results on the validation data, both in terms of prediction and simulation accuracy, for different model orders.

References:

- C.T. Chou and J.M. Maciejowski, "System Identification Using Balanced Parameterizations", *IEEE Transactions on Automatic Control*, vol. 42, n. 7, pp. 956–974, July 1997.

PROBLEM MIMO2 (1 person, 10 points)
With reference to the glass furnace data:

- ftp://ftp.esat.kuleuven.be/pub/SISTA/data/process_industry/glassfurnace.dat.gz
- ftp://ftp.esat.kuleuven.be/pub/SISTA/data/process_industry/glassfurnace.txt
- (see also the example description in Sec. 9.2 of the cited paper)

perform a multivariable model identification using both an ARX input-output representation in the matrix polynomial format and LS, and a subspace method (use the `n4sid.m` Matlab routine). Use the first 700 data as identification data and the following 300 as validation data. Compare the results on the validation data, both in terms of prediction and simulation accuracy, for different model orders. Compare also with results documented in the given reference paper.

References:

- P. Van Overschee and B. De Moor, "N4SID: Subspace Algorithms for the Identification of Combined Deterministic-Stochastic Systems", *Automatica*, vol. 30, n. 1, pp. 75–93, 1994.

PROBLEM MIMO3 (2 persons, 10 points)
With reference to the Cascaded Tanks data:

- http://www.it.uu.se/research/publications/reports/2010-020/NonlinearData.zip (files Tank1.mat and Tank2.mat)
- (see also the description of the example and of the data in Sec.s 3 and 4 of the PDF file, respectively)

perform a multivariable nonlinear model identification using the FROE algorithm on two MISO (multiple-input-single-output) NARX models, one for each of the two outputs. Use one data-set for identification and the other for validation. Compare the obtained model with that resulting from the application of a subspace identification method (use the n4sid.m Matlab routine). Compare the results on the validation data, both in terms of prediction and simulation accuracy.

PROBLEM NL1 (2 persons, 10 points)

With reference to the pH neutralization process data:

- ftp://ftp.esat.kuleuven.be/pub/SISTA/data/process_industry/pHdata.dat.gz
- ftp://ftp.esat.kuleuven.be/pub/SISTA/data/process_industry/pHdata.txt
- (see also the process description in the cited paper)

perform a nonlinear model identification using both the FROE method with polynomial NARX models and feedforward neural networks. Divide the dataset in identification and validation data (take care of representing all possible conditions in both datasets). Use the former only for model estimation and the latter for model evaluation, both in terms of prediction and simulation accuracy. Compare the results with different model complexity assumptions.

References:

- T.J. Mc Avoy, E. Hsu and S. Lowenthal, "Dynamics of pH in controlled stirred tank reactor", *Ind. Eng. Chem. Process Des. Develop.*, vol. 11, pp. 68–70, 1972.

PROBLEM NL2 (2 persons, 10 points)

With reference to the heat exchanger data:

- ftp://ftp.esat.kuleuven.be/pub/SISTA/data/process_industry/exchanger.dat.gz
- ftp://ftp.esat.kuleuven.be/pub/SISTA/data/process_industry/exchanger.txt
- (see also the process description in the cited paper)

perform a nonlinear model identification using both the FROE method with polynomial NARX models and feedforward neural networks. Divide the dataset in identification (first 3000 data) and validation data (the remaining 1000 data). Use the former only for model estimation and the latter for model evaluation, both in terms of prediction and simulation accuracy. Compare the results with different model complexity assumptions.

References:

- S. Bittanti and L. Piroddi, "Nonlinear identification and control of a heat exchanger: a neural network approach", Journal of the Franklin Institute, vol. 334B, pp. 135–153, 1997.

PROBLEM NL3 (1 person, 10 points)

The listed reference compares different old and new nonlinearity tests. Implement the tests and try them on the documented examples.

References:

- T. Knudsen, "Test for Nonlinear Input Output Relations in SISO Systems by Preliminary Data Analysis".

PROBLEM NL4 (1 person, 10 points – 2 persons, 8 points)

The listed reference compares two different algorithms for the identification of Wiener-Hammerstein systems. Code the two algorithms in Matlab and test them on the given simulation example.

References:

- M. Schoukens, E.W. Bai, and Y. Rolain, "Identification of Hammerstein-Wiener Systems", *16th IFAC Symposium on System Identification*, pp. 274-279, Brussels, Belgium, July 11-13, 2012.

PROBLEM NL5 (2 persons, 10 points) – MILANI, URZINO

With reference to the Coupled Electric Drives data:

- http://www.it.uu.se/research/publications/reports/2010-020/NonlinearData.zip (files DATAPRBS.MAT and DATAUNIF.MAT)
- (see also the description of the example and of the data in Sec.s 2 and 4 of the PDF file, respectively)

perform a nonlinear model identification of the SISO system with the FROE algorithm, using NARX or NARMAX models. Use one data-set for identification and the other for validation. Compare the results on the validation data, both in terms of prediction and simulation accuracy.

PROBLEM NL6 (2 persons, 10 points)

The identification of hybrid systems, where the dynamics may switch from one model to another, is important in several applications. Implement the method described in the listed reference for the identification of piecewise affine (PWA) models and test it on the analytical examples documented there.

References:

- A. Bemporad, A. Garulli, S. Paoletti, and A. Vicino, "A Bounded-Error Approach to Piecewise Affine System Identification", *IEEE Transactions on Automatic Control*, Vol. 50, no. 10, pp. 1567-1580, October 2005.