Cours de traitement des signaux biomédicaux
6^{th} Matlab session

Commandes utiles

resample	resampling.

Routines pré-écrites

EQM	estimation MSE in a specific case
pred_RLS	adaptive signal prediction using RLS
pred_LMS	adaptive signal prediction using LMS
pred_NLMS	adaptive signal prediction using normalized LMS

Experiment 1 : analysis of vaso-vagal syncope onset

Due to the non-stationarity of syncope, it should be interesting to use adaptive techniques. Take the data in **heart_5.dat**, remove the mean values, subsample all three signals at 1 Hz (initial sampling frequency 4 Hz) with resample.

1. Perform adaptive prediction on respiration using LMS for a prediction order 4. Start first from the upper bound on μ (the one obtained with the signal variance), and check by how much you must decrease this value to avoid algorithm divergence. Note that an important feature of this problem is the steep non-stationarity at the end of the signal.
2. Perform adaptive prediction on respiration using NLMS for a prediction order 4. (coefficient γ between 0.1 and 0.2) and RLS (parameter λ between 0.99 and 0.95). Assess the influence of these parameters. Check that, in this case at least, RLS is better (visually and with respect to prediction error variance). Note also (λ = 0.99), that RLS prediction makes anomalities detection possible and allows one to determine the various dynamics.

Experiment 2 : classification of transcranial Doppler signals

Those signals are obtained from an ultrasound Doppler sensor placed at the level of the middle cerbral artery (sampling frequency 3000 Hz). They correspond to the migration of a solid (blood clot, blood plaque..., file **solides.mat**), gaseous (bubble, file **gazeux.mat**) corpuscle. These signals being non-stationary, an adaptive approach may be appropriate.

Apply normalized LMS (prediction order 3, $\gamma = 0.2$) to the various signals and infer what feature of coefficient time evolution can be used to discriminate the two signal classes.

Experiment 3 : detection of processing errors

The electrocardiogram (ECG) during an atrial fibrillation is characterized by a quasiperiodic atrial activity (AA) with a spectral peak around 5-10 Hz. But of course the component with by far the largest amplitude is the ventricular activity (VA), which considerably perturbs AA analysis.

File **AA_extraite.dat** contains an AA extracted from an ECG signal (sampling frequency 100 Hz) and theoretically devoid of VA interference. Alas, for some of the QRS complexes the cancellation did not perform well. Localization of these instants with imperfect.QRST cancellation is possible using event detection by model disruption.

1. Perform adaptive prediction on AA using RLS (facteur $\lambda = 0.995$, prediction order 6). You will have to re-run the adaptive prediction on the data to minimize the transient..
2. Then you obtain the changes in the coefficients using :

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>> D = hfil(2 :end, :) – hfil(1 :end-1, :);
>> evolution = sum(D.^2,2);
```

Experiment 4: adaptive prediction – case of a non-invertible correlation matrix
Generate a sinusoidal signal, frequency $f = 0.1$ length 200.
1. perform adaptive prediction using LMS, prediction order 2, $\mu = 0.2$ (what is the practical upper bound for μ?). Check that at convergence you get indeed the right prediction coefficients. Let us recall that for a sinusoid:

$$x(k) = [2\cos(2\pi f)]\, x(k\text{-}1) - x(k\text{-}2)$$

You can also check that you get the same coefficients at convergence, whether you take a null inital vector or an initial vector with all coefficents equal to one.
2. Perform the same experiment (null initial vector), but with a prediction order 3. what is counter-intuitive? Then try with an initial vector with all coefficents equal to one. Remarks ?

Experiment 5 : MSE as a function of μ
In this experiment we verify the experession of the MSE for the LMS algorithm with respect to the adaptation parameter μ, that is :

$$\Phi = [1 + \mu \mathrm{trace}(\mathbf{R})]\Phi_{\min}$$

We do that on a toy experiment in which white noise is predicted.
1. For a white noise with unit variance, what are the correlation matrix **R**, the optimal coefficient vector $\boldsymbol{w}^*$ and the minimum MSE$\Phi_{\min}$ for a prediction order p?
2. The routine EQM performs 250 realisations of a unitary variance white noise and 250 predictions of this white noise for a given prediction order and a given adaptation parameter μ, and outputs the mean prediction error variance. Check the validity of the formula above for μ from 0.01 à 0.05 with 0.01 increments (prediction order 1). You can verify that the concordance decreases when μ increases.
3. For $\mu = 0.01$ increase the prediction order from 1 to 5.

Note that in this experiment the prediction error variance is larger than the variance of the signal to be predicted! This is due to the fact that LMS uses a gradient estimate, and updates the weight vector even if it is hopeless.