Final project. Extraction of a useful signal from noisy data

The objectives of this assignment are to encourage you to think creatively and critically to extract a useful signal from noisy experimental data, find best estimation method of a dynamical process and make forecast of its future development.

This assignment is to be done in groups of 2-4 students, and only one document is submitted for the group. You may also freely talk with students in other groups, but the final documents that you submit must be done only by your group.

The assignment consists of two parts.

Part 1. Best approximation method
Chose best approximation method of given experimental data to reconstruct the dynamics of process in question. You may apply quasi-optimal estimation methods such as running mean, forward-backward exponential smoothing, and complex minimization of deviation and variability indicator.

1. Provide grounds why the chosen method is the best method of approximation.
   Criteria might be the following: visual analysis, quantitative criteria, simplicity of implementation, and any other arguments.
2. Which regularities are found from obtained approximation after reduction of noise?
3. Discuss what are the risks of obtained estimations and conclusions about the process.

Data for group 1. Mean-arterial pressure.
Matlab file: MAP.mat
Format of data: 1 column – mean arterial pressure of a man of 24 years old.

Data for group 2. Sunspot numbers.
Matlab file: Sunspot.mat
Format of data: 1 column – year, 2 column – month, 3 column – monthly sunspot number

Data for group 3. Solar radio flux at F10.7 cm.
Matlab file: Radio_Flux.mat
Format of data: 1 column – year, 2 column – month, 3 column – solar radio flux at F10.7 cm**.**

Part 2. Tracking and forecasting in conditions of measurement gaps
The trajectory of a moving object is disturbed by normally distributed unbiased random acceleration a_i with variance $\sigma_a^2 = 0.2^2$. In general measurements of coordinate x_i are performed every second with variance of measurement noise $\sigma_\eta^2 = 20^2$. Observation interval is 200 seconds. However, there are measurement gaps. Probability of measurement gaps is $P = 0.5$ (group 1), $P = 0.3$ (group 2), $P = 0.2$ (group 3).

Hint 1: Create measurements with gaps
To create the measurements with gaps, create the random value ξ that is **randomly** distributed at every step i. If $\xi_i \leq P$, then $z(i) = NaN$ (gap), if $\xi_i > P$, then $z_i = X_i + \eta_i$.

Hint 2: Kalman filter in condition of gaps
Kalamn filter is a recurrent algorithm consisting of two procedures, extrapolation and filtration.
We do filtration when we have the available measurements. When the measurements are absent, to not interrupt the recurrent process, at filtration step we should indicate that the filtered estimate is equal to extrapolated estimate $X_{i,i} = X_{i,i-1}$ and filtration error covariance matrix is equal to extrapolation error

covariance matrix $P_{i,i} = P_{i,i-1}$. We do this as we don't have any information to improve our estimates at filtration step (no measurements).

Task 1: Develop Kalman filter to track moving object under this conditions.
Task 2: Determine filtered and extrapolated errors of estimation (1 step and 7 steps ahead) over 500 runs of filter. Compare them with true estimation errors.
Task 3. Analyze the decrease of estimation accuracy in conditions of measurement gaps. Compare results when measurements are obtained without gaps.

Consult charts Final_project_discussion.pdf

Wednesday, May 24
Present your results with charts in 20 minutes.

Friday, May 26
Submit the final version of your project to canvas.