Technical University of Ilmenau

Department of Automation Engineering

AT.425.EN

Advanced System Identification

Examination Question Booklet

Date: *INSERT DATE*

Time: *INSERT TIME*

Location: *INSERT LOCATION*

Duration: 2 hours

Version: AT.425.EN.2021.SAMPLE.a

Instructor: Prof. Yuri A.W. Shardt

General Instructions

1) All cheating leads to failing the examination.
2) A regular calculator without any external communication capabilities is permitted. All other electronic devices (including cell phones, smart watches, and computers) are strictly forbidden.
3) The examination is open book, that means that you are permitted to use your own copy of the course notes, your own dictionary, and your own copy of the textbook.
4) The date and time when you can review your examination will be posted on the departmental website: http://tu-ilmenau.de/en/dept-automation/.

Total Points: 192 Points

Total Pages: 6 (including this cover page)

Department of Automation Engineering

AT.425.EN Advanced System Identification

Question 1(45 marks): True or False

Please write for each of the following statements "true" or "false" with justifications. Please only use the words "true" or "false". (One point for true/false and 2 points for the justification.)

a) There are 10 provinces and 3 territories in Canada.

b) Regression analysis seeks to minimise the sum of the absolute value of difference between the predicted and measured values, that is, $min\ |y - \hat{y}|$.

c) If the autocorrelation function is given as $\rho(\tau) = 0.5^{\tau}$ for all $\tau \geq 0$, then it can be concluded that the process is a moving average process.

d) If the roots of the B-polynomial of an ARMA process are -0.45, 0.15, $0.75\pm0.5i$, then the process is invertible.

e) The presence of an integrator can be detected by a slowly decaying term in the partial autocorrelation plot.

f) Differencing a time series removes any integrating components present.

g) The maximum likelihood parameter estimates for an ARMA process are asymptotically normally distributed.

h) If a peak at $f = 0.25$ cycles/sample is observed on the periodogram, then it can be concluded that the process has a seasonal component, such that $s = 0.25$.

i) The Kalman filter is used to determine the parameter estimates for state-space models.

j) Grey-box modelling combines the advantages of first-principle and data-driven models.

k) The controller, process, and disturbance models together create the plant model.

l) Only the one-step ahead predictor has a variance equal to the white noise variance.

m) Many nonzero autocorrelation and cross-correlation values implies that the fit of the model is poor.

n) Indirect identification of closed-loop processes requires that only the input and output signals be available.

o) A polynomial basis function can fit any nonlinear function arbitrarily well.

Question 2 (50 marks): Time Series Analysis

a) For a causal AR(2) process, derive the autocorrelation.

b) Explain how you would identify a seasonal component.

c) Given the data in Table 1, determine an appropriate ARIMA model for the time series. It should be noted that 1,000 data points were used to compute the samples.

Table 1: Autocovariance and partial autocorrelation data (for Question 2.c)

Lag	Autocovariance $\gamma(\tau)$	Partial Autocorrelation $\rho_{X\mid X_{t+1},\ldots,X_{t+\tau-1}}(\tau)$
0	5.212	—
1	3.832	0.735
2	2.919	0.045
3	2.183	0.064
4	1.645	0.022
5	1.234	0.028
6	0.923	0.013

d) Once the orders of the different components had been determined, you obtained the following parameter estimates for the ARMA model:

$$a_1 = 0.25 \pm 0.75,\ a_2 = 0.51 \pm 0.85$$

$$b_1 = 0.552 \pm 0.005,\ b_2 = 0.352 \pm 0.005$$

All confidence intervals are 95% confidence intervals. Which parameters are significant? What do the parameter estimates suggest about the model? What type of model would you fit?

e) Consider an ARMA(1,0,1) process of the form $u_t = \frac{C\left(z^{-1}\right)}{D\left(z^{-1}\right)} = \frac{A - Bz^{-1}}{C - Dz^{-1}} e_t$. Derive the spectral density function for u_t in terms of the transfer function parameters and the white noise spectral density.

Question 3 (50 marks): Process Identification

a) What is the one-step ahead linear predictor for the model given as

$$G_p = \frac{z^{-3}}{z^{-2} + 0.25z^{-1} + 1}, G_d = \frac{1}{1 - 0.25z^{-1}}$$

What is the variance of this predictor?

b) What is the time delay for the figures provided in Figure 1? Assume open-loop conditions.

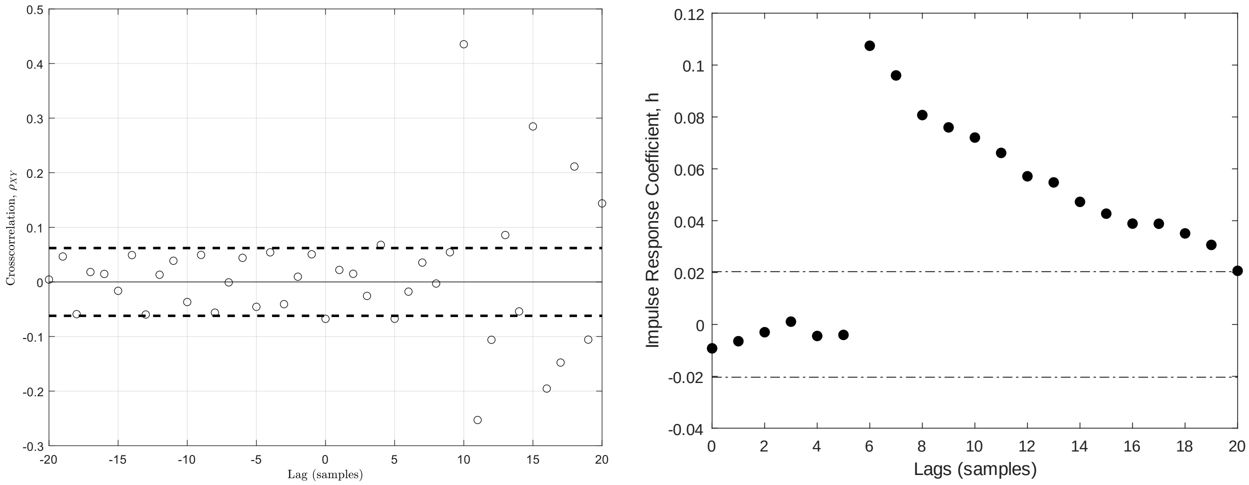

Figure 1: Estimating time delay: (left) Cross-correlation plot and (right) Impulse response coefficients

c) A step test was performed at t = 0 s with a magnitude of 1 kg/min. It is expected to run the system identification experiment for 3 hr. Given the information in Figure 2, design a PRBS signal for the process. Clearly state and justify any assumptions you make and provide explanations for all values selected.

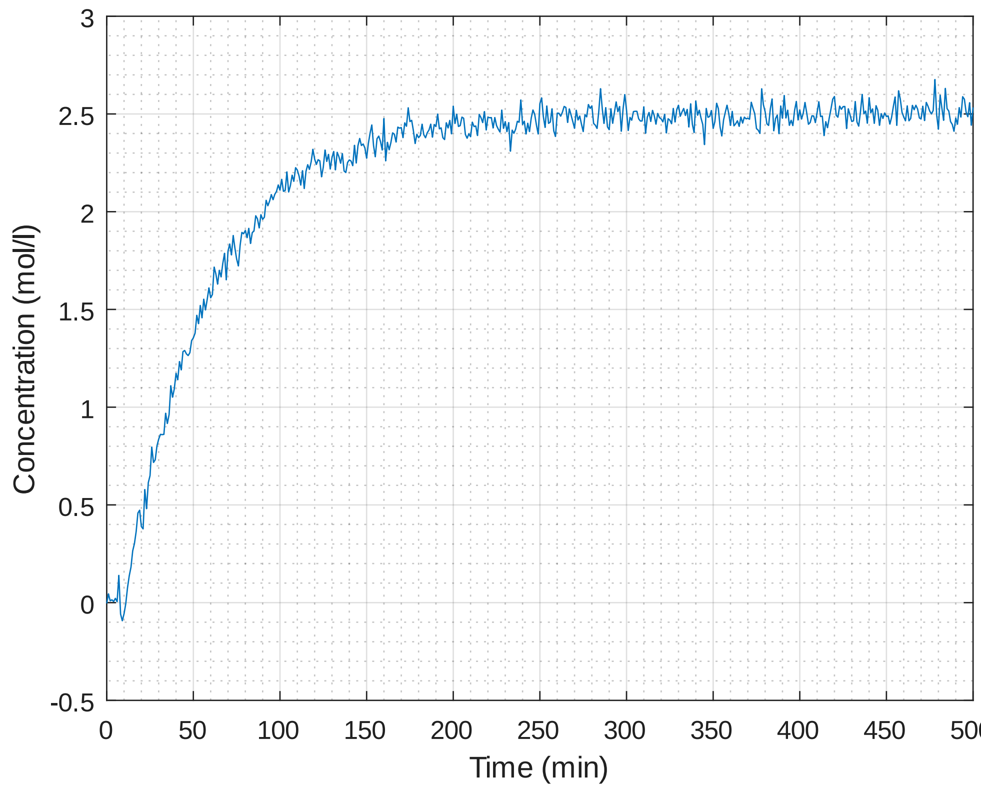

Figure 2: Step Test Data for Question 3.c

d) Fitting a model to the data you had obtained from an open-loop experiment, you obtained the results shown in Figure 3. Please evaluate the model and determine if it is sufficient? If not, what would you change?

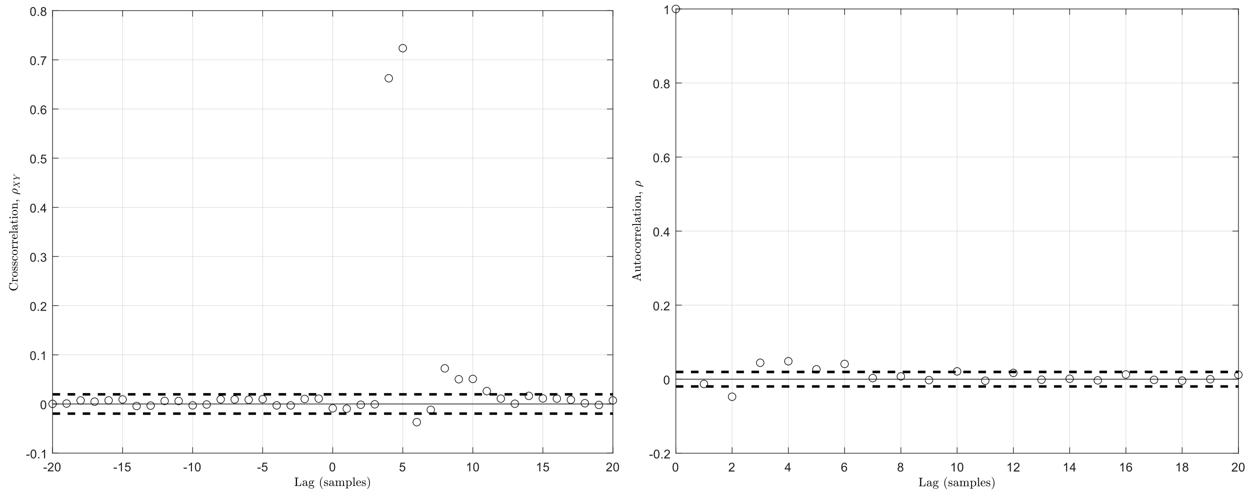

Figure 3: Model validation for the open-loop case: (left) Cross-correlation between the input and the residuals and (right) Autocorrelation of the residuals

e) Consider the process shown in Figure 4. If only the r_t and y_t signals were available and the process were running in closed loop, what methods could be used to identify the model? What other information would you need?

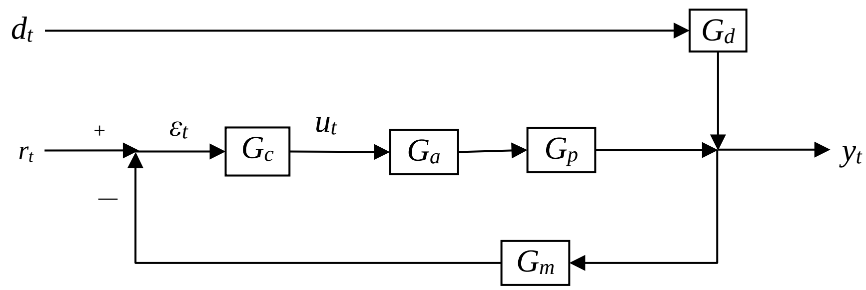

Figure 4: Block Diagram for Q3.e