Automation final exam practice sheet

Dr. Szymon Krupiński and Prof. Dr. Francesco Maurelli
Jacobs University Bremen

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General remarks

- The final exam is a closed book exam, but you are allowed a A4 double-sided hand-written cheat sheet with your notes and a digital calculator (with no pre-programmed instructions).
- This practice sheet contains more problems than a real exam.
- You have 2 hours to write your exam.
- Remember to show your work and reasoning, as it might save you some points even if your end result is not correct.

1 True or False?

[X Points]

Mark the following statements as True (T) or False (F)

Universal Motors can work both with AC and DC	T	F
A coriolis vibratory gyroscope attached to a steadily rotating object will not switch the indicated rotation sign if the object crosses the equator	T	F
At a unstable equilibrium point x_e of a system defined by $\dot{x} = g(x)$, we know that $g(x_e) = 0$	T	F
Automation communication protocols can specify the physical layer of communication in the OSI model	T	F
A Hall effect sensor can measure static magnetic field	T	F
Complementary filtering requires two dissimilar sensors measuring the same quantity	T	F
Gaussian noise with mean $\mu = 0$ present in the sensor measurement is a systematic error	T	F
An arch among two circles in a state machine represents a transition state among two actions at times t and $t-1$	T	F
A strain rosette measuring strain in 2 dimensions often has three components for redundancy purposes	T	F
A failure of the controllers or computers at the top of a SCADA system hierarchy is more likely to result in an injury than at the bottom	T	F

2 General sensor properties

[X Points]

Give example of three real life situations where you would expect to find...

1. a sensor which is accurate but not precise
2. a sensor which is precise but not accurate
3. a sensor which has resolution higher than its precision

Give an example and a short explanation for each of the points.

3 State machines

[X Points]
Build a finite state machine that will ring only when the user inputs the following sequence: x = 1, 0, 1, 0, 1 using two buttons labeled "1" and "0". Formally identify all the components of this state machine, and write both the state transition table and the graph.

4 Discretisation and filtering

[X Points]

Imagine the situation discussed in the class where we wanted to obtain an estimation of orientation $\hat{\theta}$ using a noisy values coming from an accelerometer (θ_a) and much less noisy but biased angular velocity data from a gyroscope (ω_g).

Consider a sensor fusion scheme with the following state-space representation:

$$\dot{\hat{\theta}}(t) = \omega_g(t) + k_p(\theta_a(t) - \hat{\theta}(t))$$

Write down the simplest possible discretisation over a fixed time step Δt which will allow the state estimation $\hat{\theta}$ to be computed in a loop. Using the coefficient $k_p = 0.2$ and $\Delta t = 0.1s$ and the values already present in the table, complete the two time step iterations. Fill in the calculated output estimation $\hat{\theta}_{t_0+\Delta t}$ and $\hat{\theta}_{t_0+2\Delta t}$.
Hint: use this common definition of the derivative ("forward Laplace scheme"): $\dot{y}(t_0+\Delta t) = \lim_{\Delta t \to 0} \frac{y(t_0+\Delta t)-y(t_0)}{\Delta t}$

Step	θ_a $[rad]$	ω $[\frac{rad}{s}]$	$\hat{\theta}$ $[rad]$
t_0	0.996	0.021	0.996
$t_0 + \Delta t$	1.010	0.021	
$t_0 + 2\Delta t$	0.980	0.021	

5 Strain gauge

[X Points]

A simple thin-film 1-dimensional strain gauge of initial resistance R_G of gauge factor 2 is attached to a metal beam. The gauge is incorporated into a Wheatstone bridge circuit as illustrated in Fig. 1. The fixed values of the resistors R_1 and R_2 are 2Ω and 5Ω respectively. A 9 Volts battery (V_S) powers the circuit. The adjustable resistance R_P is set to 3Ω and the bridge is balanced (i.e. the voltage meter between V_L and V_P shows zero).

1. Look at the upper part of Fig. 1. In which position, (A), (B) or (C) should the gauge be fixed to the beam?

2. What is the initial resistance of the strain gauge? What is the ratio η of the bridge?

3. The beam is stretched along the gauge's sensing direction by 20% of its length. Calculate what voltage that will be measured by the voltage meter between V_L and V_R.

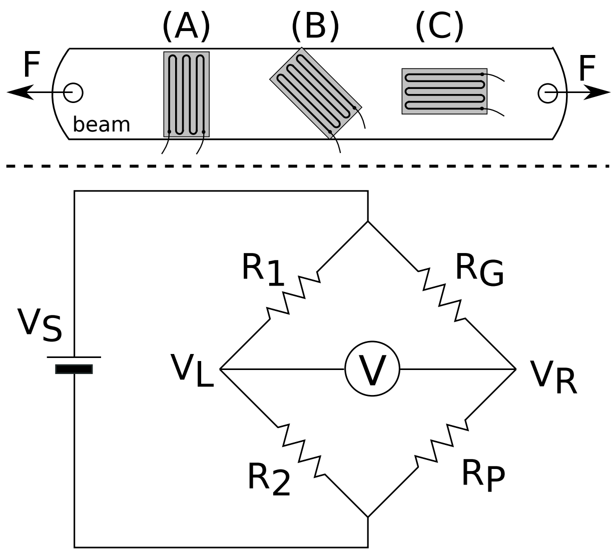

Figure 1: Strain gauge and Wheatstone bridge

4. To what new resistance value will the adjustable resistance R_P have to be set in order to re-balance the bridge?

6 Motors

[X Points]

Describe a three phase AC induction motor:

1. What components does it have?
2. What is the method of functioning?
3. Give a couple of examples where such motors can be found.
4. What is the reason for using a delta-star configuration change during the start-up?

7 Probability

[X Points]

Show that for some continuous random variables $x \in X$ and $y \in Y$

$$\rho(x|y) = \frac{\rho(y|x)\rho(x)}{\int_x \rho(y|x)\rho(x)dx}$$

Label each identity and rule that you apply in demonstrating this relationship step-by-step.

8 Industrial problem

[X Points]

A scrap laddle for loading scrap metal into an electric arc furnace is suspended on a travelling lift with two chains. The chains can be lowered or hoisted up in order to tilt the laddle (=individual chain vertical position is how the system is controlled). You can assume that you know what each chain's current height is. For moving the scrap metal, it stays horizontal ($\alpha = 0°$). For loading the furnace, it must be tipped by $\alpha = 45°$ around the y axis (=the tilt of the laddle is the state of the system). It should not be tipped in the other direction (negative alpha values). Propose a sensor to instrument the laddle so that the tipping and righting operation can be automatised.

1. Identify the right sensor technology to use in this case
2. Sketch where and how the sensor should be mounted (position, orientation)
3. Describe the operating principle of this technology, name the physical quantities involved and the basic hypotheses (if any)
4. Write the mathematical formula corelating the identified measurable quantity with the tipping angle of the laddle.

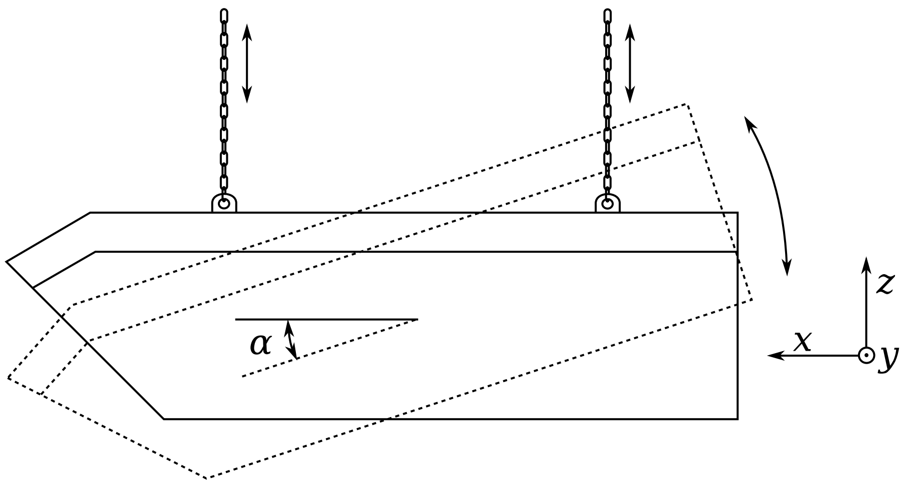

Figure 2: Scrap laddle schema for problem 2