CENG4480 Homework 2

Due: Nov. 17, 2017

Q1 A simple Infra-Red Sensor system to detect passing human is presented as in Fig. 1. A and B are IR Sensors which will generate different output voltages for different infra-red intensity, and higher voltage level corresponds to high light intensity.

(1) Explain how this system works for counting passing pedestrians.

(2) To increase counting accuracy, usually B is covered with materials that can reflect infra-red light. Explain why.

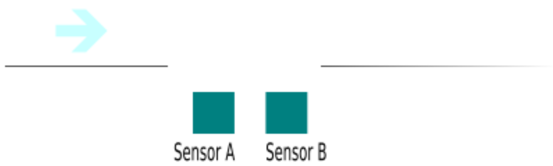

Figure 1: IR-System

Q2 Exemplify the working principles of sensors that measure:

1. Flow
2. Temperature
3. Pressure
4. Motion
5. Liquid Level

Q3 Consider a capacitive displacement transducer as shown in Figure 2. Determine the change in voltage (Δv_0) where the air gap changes from 0.01 in to 0.015 in. (Note: R, v_i and v_o are given.)

Q4 Briefly describe how PID affects motor control.

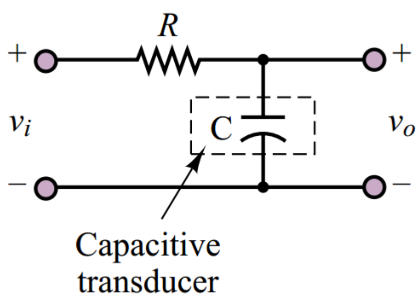

Figure 2: Capacitive displacement transducer.

Q5 Please try to give the discrete incremental PID formulations. Some notations are given:

- $u(t)$ is the output of a controller in the tth measurement interval.

- $e(t)$ is the error between the target value and measurement value in the tth measurement interval. And the error is measured every T time interval (T is small enough).

- The PID parameters, K_p, K_i and K_d, are all set.
  (Hint: incremental means $\Delta u(t) = u(t) - u(t-1)$.)

Q6 In a wireless sensor network, because of imperfect manufacturing techniques, sensor drift emerges. Therefore, the trustworthy sensor data cannot be obtained. Kalman filter can be used to estimate ground-truth data by calibrating the drift.

Assume that the drift d_t in the tth time slot satisfies $d_t = d_{t-1} + \Delta_{t-1}$, where Δ_t is a random variable that obeys a Gaussian distribution with zero-mean and δ_t-variance. In the initial time, the sensor has no drift (i.e. $d_0 = 0$), while the estimated drift equals to zero (i.e. $\hat{d}_0 = 0$). We use a method to get a set of measurement values of the drift in one sensor at time t, i.e. $\mathbf{y}_t = d_t \cdot \mathbf{b} + \mathbf{n}_t$ where $\mathbf{n}_t$ with zero-mean and $\mathbf{R}_t$-covariance is a noise vector of n Gaussian random variables. And $\mathbf{b}$ is a known vector. Try to give the formulation of optimal estimated value of $\hat{d}_t$ via using Kalman filter model.

Q7 Given a linear system

$$\begin{cases} \mathbf{x}_t = \mathbf{A}_{t-1}\mathbf{x}_{t-1} + \omega_{t-1}, \\ \mathbf{z}_t = \mathbf{B}_t\mathbf{x}_t + \mathbf{v}_t, \\ \mathbf{v}_t = \mathbf{C}_{t-1}\mathbf{v}_{t-1} + \mathbf{n}_{t-1}, \end{cases} \tag{1}$$

where ω_t and $\mathbf{n}_t$ are independent and obey Gaussian distribution zero-mean and covariance $\mathbf{Q}_t$ and $\mathbf{R}_t$, respectively. Please give the estimate equation and measurement equation of the system.

Q8 Given two Gaussian distributions $N(x_0; \mu_0, \sigma_0)$ and $N(x_1; \mu_1, \sigma_1)$, try to give the expectation and variance of a new distribution which is the product of these two Gaussian distributions.