

UID: _____

Due Date: 04/04/2024

Read carefully before start:

- You shall input your University ID (UID).
- Answer the questions in the corresponding box. Answers out of the box will not be graded.
- You have the option to either use an electronic device or print out the questions for answering. Either way, you must submit the electronic version of your answers through **Moodle**.

Question:	1	2	3	Total
Points:	15	25	60	100
Score:				

1. (15 points) IoT and mobile sensing

Score

- (1.1) (5 points) Although there is no universal definition, what are the two key components of an IoT system that we discussed in this course?

- (1.2) (5 points) List five sensors on your mobile phones and their functionality.

- (1.3) (5 points) GPS has become a staple in our daily lives, yet its accuracy in Hong Kong is sometimes questioned. What are the possible reasons for this? Please list your answers using bullet points.

2. (25 points) FMCW Acoustic Sensing

Score

Ethan is currently working on the development of a gesture tracking system that utilizes Frequency-Modulated Continuous-Wave (FMCW) signals, commonly known as chirp signals. Suppose we use acoustic devices to transmit and receive the signals. The in-air sound speed is $c = 343\text{m/s}$. At this stage, he is facing some challenges with specific details that require your help.

- (2.1) (5 points) The frequency range is $[f_0, f_1]$ Hz, and the period is T_s . Ethan wants to use linear up-chirp. Can you give the formula of frequency $f(t)$ as a function of time t ?

- (2.2) (5 points) Given the above FMCW signal, we can capture the frequency change in the IF signal. What is the range resolution?

- (2.3) (5 points) When using commodity acoustic devices, the starting frequency f_0 is usually set to 18kHz and the max frequency f_1 to 24kHz, with a chirp duration of $T_s = 5\text{ms}$. Please calculate the range resolution given this configuration.

- (2.4) (5 points) Following (2.3), consider a 1D scenario, and the speaker (Tx) and microphone (Rx) are colocated. There are three objects, with a distance of 0.4m, 0.8m and 1.5m from Tx/Rx respectively. f_1 is given by 22kHz. Suppose we only send one chirp (with period $T_s = 5\text{ms}$), please sketch the received signal and transmitted signal in one time-frequency graph.



Figure 1: Problem 2.4

- (2.5) (5 points) Please list the factors that bottleneck the range resolution in this system.

3. (60 points) WiFi Sensing

Score	
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Ethan now wants to capture his breathing rate using Wi-Fi signals. He has some problems during the development process. Suppose the breathing rate for normal adult is 12-20 BPM. The goal is to recover the breathing rate over time $b(t)$.

- (3.1) (15 points) We know that breathing is a periodic event. Using FFT on CSI can capture this periodicity.

Answer the following questions for (3.1.1) to (3.1.5).

Can we detect the breathing rate? If so, what is the frequency resolution of $b(t)$? If not, specify the reasons.

- 3.1.1. (3 points) Suppose we record a series of CSI for 1 minute, and CSI is sampled at 100Hz.

- 3.1.2. (3 points) Following Question 3.1.1, now we perform STFT on the CSI, with a window width of 5 seconds.

- 3.1.3. (3 points) Following Question 3.1.2, we reduce the window length to 2 seconds and then perform STFT on the CSI.

- 3.1.4. (3 points) Now we consider using a larger sampling rate. We use a window of 2s and boosting the sampling rate to 200Hz.

- 3.1.5. (3 points) Now we consider using a smaller sampling rate. We use a window of 10s and reducing the sampling rate to 20Hz.

- (3.2) (5 points) Ethan wants to deploy the Wi-Fi based breathing system on his home router. Note that Wi-Fi can work either on 2.4GHz or 5GHz. To achieve robust breathing rate estimation, which band is more recommended? Justify your answer.



(3.3) (40 points) We can also compute the ACF of the CSI for breathing estimation, and furthermore, motion and speed estimation. Below are several figures illustrating the calculated ACFs. Please answer 1) what is the most likely cause for the result, motion, speed, breathing, or empty (static environment with no human presence)? 2) what is the corresponding estimation value (motion statistic, speed in m/s, and/or breathing rate in BPM)? Write N/A in case of empty.

3.3.1. (10 points) Case: motion / breathing / speed / empty; Value: _____

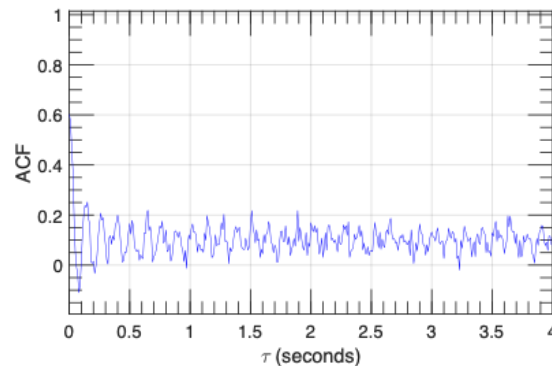


Figure 2: Problem 3.3.1

3.3.2. (10 points) Case: motion / breathing / speed / empty; Value: _____

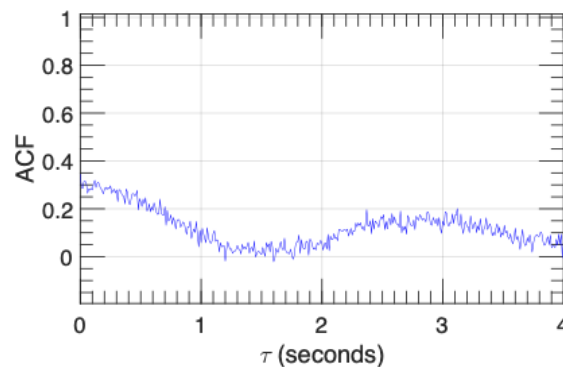


Figure 3: Problem 3.3.2

3.3.3. (10 points) Case: motion / breathing / speed / empty; Value: _____

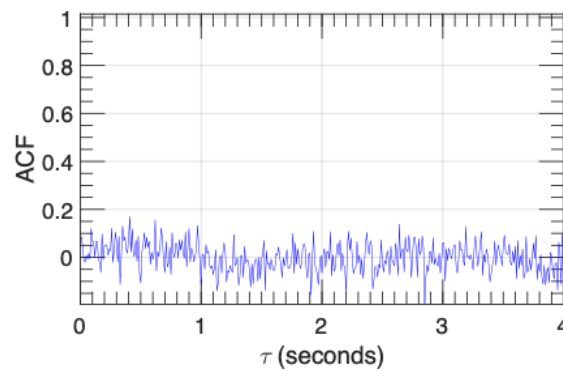


Figure 4: Problem 3.3.3

3.3.4. (10 points) Case: motion / breathing / speed / empty; Value: _____

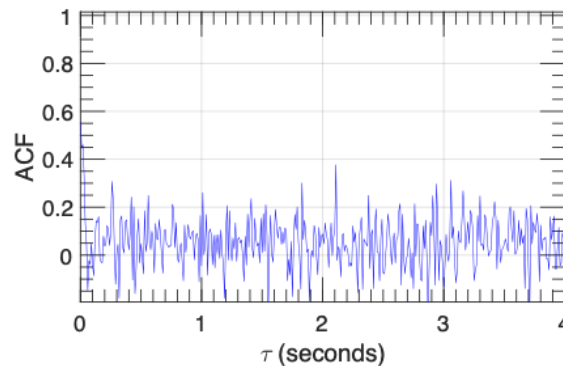


Figure 5: Problem 3.3.4

Bonus Question (3 points)

This assignment takes me _____ hours to complete.

I think the difficulty of this assignment is _____ (from 1-10; 1: easy; 10: difficult).

I have used GenAI tools (e.g., ChatGPT) for this assignment (yes / no): _____

*******End of Assignment*******