MIT 6.1820/MAS.453 – Mobile & Sensor Computing
Midterm Exam 2025

There are 20 questions and 10 pages in this quiz booklet. To receive credit for a question, answer it according to the instructions given. *You can receive partial credit on questions.* You have **60 minutes** to answer the questions.

Don't forget to write your name on this cover sheet NOW!

If you find a question ambiguous, be sure to write down any assumptions you make. Be neat. If we can't understand your answer, we can't give you credit!

THIS IS AN OPEN BOOK, OPEN NOTES, OPEN LAPTOP QUIZ.
YOU SHOULD NOT COMMUNICATE WITH ANYONE OTHER THAN THE INSTRUCTORS REGARDING THE MIDTERM DURING THE EXAM TIME AND YOU SHOULD NOT USE AI OR SEARCH

Do not write in the boxes below

1-6 (22)	7-9 (13)	10-11 (7)	12-13 (10)	14-17 (14)	18 (6)	19-20 (2)	Total (72+2)

Name: Answer Key

Please rewrite the pledge statment below then sign your name again:

I pledge not to communicate with anyone about this midterm and not to send or receive any aid for the duration of the exam from other people or from any form of AI.

Rewrite here:

Signature or Name:

Starters

1. *(3 points)* Circle True or False for each of these questions about **LEO satellites**:
   (a) True / False LEO mega-constellations have higher latency than satellites that are further in the sky (e.g., medium Earth orbit satellites) because the former need to route their packets through many satellites.
   (b) True / False LEO constellations need more satellites than mid-orbit satellites.
   (c) True / False medium Earth orbit satellite networks have higher throughput than LEO mega-constellations.

2. *(4 points)* Circle True or False for each of these questions about the **ETX** lecture:
   (a) True / False The ETX metric does not account for spatial reuse.
   (b) True / False The ETX metric accounts for rate adaptation.
   (c) True / False If ETX is computed just one-way (i.e., without taking the reverse path into account), then the ETX of a path A-B-C is the same as the ETX of the reverse path, ie., C-B-A.
   (d) True / False When estimating the link ETX, the reverse delivery ratio is important because it accounts for ACKs.

3. *(4 points)* Circle True or False for each of these questions about **inertial sensing**:
   (a) True / False Gyroscopes are used to infer orientation.
   (b) True / False In a Strapdown Inertial Navigation System, if the moving object does not rotate (i.e., does not change its orientation), then accelerometers are enough to estimate its x/y location.
   (c) True / False Dead-reckoning with IMUs would result in overestimating the distance traveled for a decelerating object.
   (d) True / False Hook's law is irrelevant to the operation of MEMS accelerometers.

4. *(3 points)* Circle True or False for each of these questions about **millimeter-wave (mmWave) networking:**
   (a) True / False mmWave signals attenuate faster than signals with lower frequencies like WiFi.
   (b) True / False mmWave networks have smaller bandwidth than WiFi.
   (c) True / False In mmWave networks where each access point and user device use antenna arrays, the transmitter and receiver need to align their beams to establish a high-throughput communication link.

5. *(4 points)* Circle True or False for each of these questions about using **sub-THz signals for sensing fruit ripeness**:
   (a) True / False sub-THz signals can typically penetrate the fruit all the way to the seed and use the reflections of the seeds to sense ripeness.

(b) True / False sub-THz signals have a smaller wavelength than mmWave signals.

(c) True / False mmWave signals have higher attenuation than sub-THz signals.

(d) True / False According to the project on sub-THz sensing discussed in class, cameras are better than sub-THz in sensing fruit ripeness.

6. *(4 points)* Circle True or False for each of these questions about the **augmented reality systems** we discussed in class:

(a) True / False Consider the virtual line that connects an RFID to the antenna on the headset. The Dilution of Precision (DOP) is influenced by the relative angles between these lines (as the user moves).

(b) True / False A higher DOP value would lead to better accuracy in position estimation.

(c) True / False During localization, moving the antenna on a straight line directly toward the RFID is the optimum trajectory to achieve high localization accuracy.

(d) True / False The XaiR platform uses a split architecture, where MLLM inference is handled by the XR headset, while 3D world processing is offloaded to a server.

mmWave Imaging

7. *(4 points)* Circle True or False for each of these questions about the **Hawkeye system** we discussed in class:

(a) True / False mmWave signals are mostly diffuse when reflecting off the surface of a car.

(b) True / False The mmWave radar used in Hawkeye has the same spatial resolution as a LiDAR.

(c) True / False In C-GAN, the generator and discriminator are trained separately and do not interact with each other during training.

(d) True / False The condition in the C-GAN in Hawkeye is based on the camera inputs.

8. *(3 points)* The three main challenge of mmWave radar perception in comparison to a camera:

(a) multi-path

(b) no color

(c) specularity

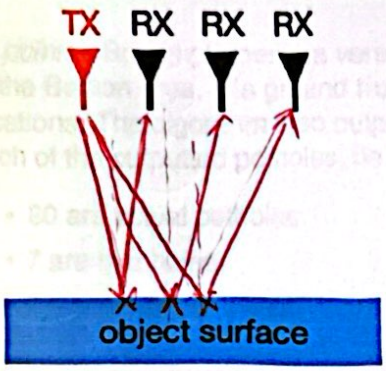
resolution

9. *(6 points)* In each of the scenarios below, we use radars to image the surface of the objects. The objects' surfaces are very smooth. In each scenario, there is one or more Tx and one or more Rx. For each scenario:

1 • Add an "x" to the point(s) of the surface that will reflect the transmitted signal back to each of the Rx receivers.

1 • Draw the rays of the transmitted and the received signal(s)

1 • Explain your reasoning



- diagonal / $\theta_{incident} = \theta_{reflected}$ or specular

Figure 1: Scenario A

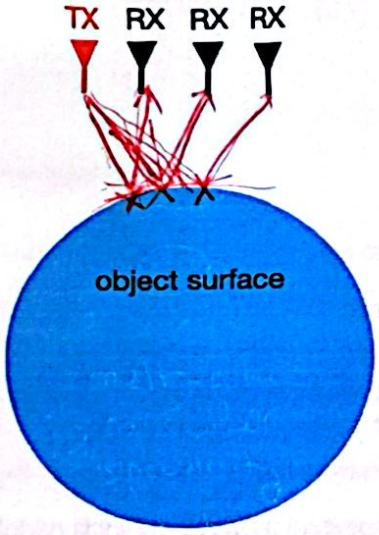


Figure 2: Scenario B

Pothole Patrol

10. *(3 points)* Circle True or False for each of the statements below on the **Pothole Patrol** Paper:

    (a) True / False The xz ratio helps distinguish between potholes and expansion joints.

    (b) True / False A speeding car experiences a smaller change in the z acceleration than a slower car if both cross over the same pothole.

    (c) True / False Attaching the IMU to the windshield or dashboard would give the same accuracy as attaching it to a laptop in the back seat.

11. *(4 points)* Bob implements a version of the Pothole Patrol system and runs an evaluation in the Boston area. His ground truth measurements indicate that there are 89 real pothole locations. The algorithm also outputs 89 estimated pothole locations. But, upon examining each of the outputted potholes, he finds the following:

    - 80 are actual potholes
    - 7 are manholes
    - 2 are expansion joints

    What is the precision and recall of Bob's implementation? Explain your work in detail.

    TP = 80

    $\text{Recall} = \frac{TP}{\text{rel potholes}} = \frac{80}{89}$

    $\text{Precision} = \frac{TP}{\text{total output}} = \frac{80}{89}$

Backscatter

12. *(2 points)* Circle True or False for each of the statements below on **backscatter**.

    (a) True / False The MIT card harvests energy from shaking.

    (b) True / False iPhone's near-field communication uses inductive coupling.

    (c) True / False To read RFIDs that are attached to clothes, an RFID reader need to be placed in close proximity (1cm)

    (d) True / False E-Toll transponders like EZpass leverage RFID technology.

13. Rohan likes the acoustic backscatter paper and figures that he wants to implement a version that is similar to underwater backscatter but one that works in the air. He builds a backscatter node that operates at 20kHz (i.e., near-ultrasound) and has its own battery, so it doesn't need to harvest energy. To enable backscatter communication, he transmits a 20kHz signal from his phone's microphone and receives the backscatter response on his laptop's microphone.

(a) *(2 points)* The laptop's mic will receive both the direct signal from the phone and the backscatter modulated reflection from the backscatter node. If everything is static (including speaker, microphone, backscatter node, and no motion in the environment), how can the laptop eliminate the interference caused by the 20kHz tone transmitted from the phone's speaker so that it can obtain only the backscatter response? Briefly explain your answer.

by subtract
or code
or HPF

(b) *(2 points)* The backscatter node has a bitrate of 100bps. Each packet is 50 bits long. How much time does it take to transmit each packet?

$\frac{50}{100} = 0.5s$

(c) *(4 points)* Rohan now wants to communicate from one side of a wall to another side of the same wall. He wants to know whether he should use RF or acoustic signals to build a backscatter system. Note that he would use the appropriate hardware in either case (i.e., if he performs acoustic backscatter, he would use a speaker, microphone, and acoustic backscatter node for acoustics. If he performs RF backscatter, he would use Tx/Rx antennas and RF backscatter nodes). For each of the following two scenarios, answer whether it is better to use acoustic backscatter or RF backscatter due to their propagation properties. Explain your reasoning (no points will be given without reasoning)

- Scenario A: the backscatter node is on one side of the wall touching it, and the transmitter and receiver on the other side of the wall, also touching it.

-acoustic-
- through solid

- Scenario B: the backscatter node is on one side of the wall but 1 meter away from it, and the transmitter and receiver are on the other side of the wall, also 1 meter away from it.

- RF
- reflection from air/wall boundary

Health Sensing

14. *(1 points)* What is the minimum number of frequencies that an oximeter needs? 2

15. *(4 points)* An oximeter uses frequencies typically in the red/visible and/or NIR/IR regions to measure blood oxygen saturation by distinguishing between oxygenated and deoxygenated hemoglobin.

16. *(3 points)* Circle True or False for each of these questions about PPG-based health sensing:

    (a) True / False The PPG signal is unaffected by changes in ambient light, such as sunlight or artificial lighting.

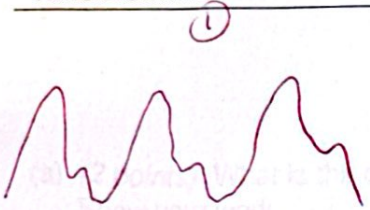
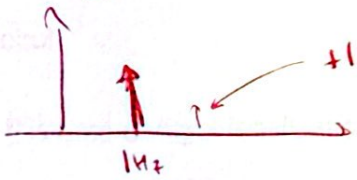
    (b) True / False PPG sensors detect changes in light absorption caused by variations in blood vessel volume within each heartbeat.

    (c) True / False Sensor placement does not impact the accuracy of PPG readings.

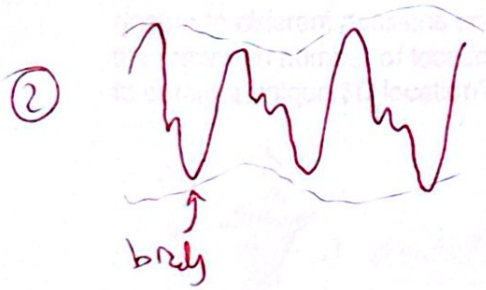
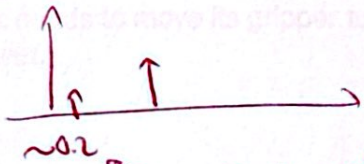
17. Weitung is wearing a smartwatch that is equipped with a ppg sensor for cardiac monitoring. He is holding his hand and body steady by lying down on the ground in a dark room.

    Draw a sketch of the output of the PPG signal in **time-domain** and in the **frequency domain** (i.e., after taking an FFT for each of the scenarios). Explain your answer in both.

    - *(2 points)* When Weitung holds his breath:

Time Domain	Frequency Domain
	

    - *(4 points)* When Weitung is breathing:

Time Domain	Frequency Domain
	

RF Localization

18. Laura wants to design a robotic system that picks RFID-tagged items from inside a pile. The overall problem has the following components:

(a) The robotic system consists of a robotic arm, similar to the figure shown to the left, and the arm has an antenna on it. The antenna can transmit and receive FMCW signals.

(b) The pile consists of a number of RFID-tagged items, similar to that shown in the figure. These are special kinds of RFIDs, each of which can uniquely reflect back the FMCW signal while adding an ID.

To perform localization, the robot transmits FMCW signals with 1 GHz bandwidth which are backscattered by the RFID (these RFIDs can operate with the full 1GHz bandwidth). The robot can use time of flight in localization.

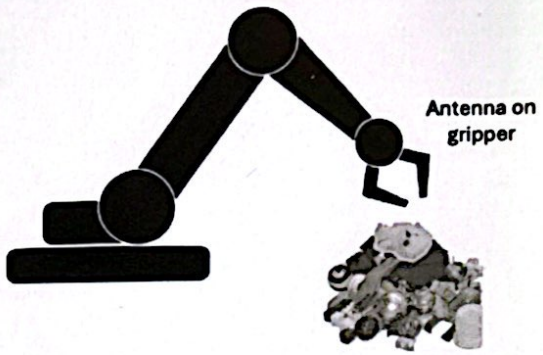


Figure 3: Laura's Robot

(a) *(2 points)* What is the distance resolution of this time-of-flight localization approach? Show your work. (1) (1)

$$\frac{c}{2B} = \frac{3\times10^8}{2\times10^9} = 15\text{cm}$$

(b) *(2 points)* The robot knows that all the items are below (rather than above) its gripper. It can move its antenna to different locations and collect time-of-flight measurements from each of these locations. Note that in this problem the antenna cannot continuously collect measurements as the robot moves. This means that the robot needs to move its gripper to different positions and collect time-of-flight measurements from them. What is the minimum number of locations N that the robot needs to move its gripper to in order to obtain a unique 3D location? Explain your answer.

(1) 3

(2) why?

(c) *(2 points)* Laura notices that if the location of the N points is too close, she gets much larger 3D location errors than if the locations are chosen to be further away. Explain why.

- DOF

or - noise

or - resolution

Class Feedback (Bonus)

19. *(1 points)* What was/were your favorite lecture(s)/topic(s) in this class?

20. *(1 points)* What was/were your least favorite lecture(s)/topic(s) in this class?

End of quiz!