MIT 6.808 2021 – Mobile and Sensor Computing
Midterm Exam
SOLUTIONS

There are 23 questions and 9 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 **50 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 INTERNET QUIZ.
YOU SHOULD NOT COMMUNICATE WITH ANYONE OTHER THAN THE INSTRUCTORS REGARDING THE MIDTERM DURING THE EXAM TIME

Do not write in the boxes below

1-5 (18)	6-9 (6)	10-12 (6)	13-15 (6)	16-17 (6)	18-21 (9)	22-23 (2)	Total (50+2)

Name:

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.

Rewrite here:

Signature or Name:

Starters

1. *(4 points)* Circle True or False for each of these questions about **GPS**:

   (a) True / False GPS localization is performed using angle-of-arrival

   (b) True / False Correlation is necessary to discern the GPS signal

   (c) True / False Without assisted-GPS, getting a first GPS fix takes about 12 minutes

   (d) True / False GPS can localize you in a tunnel

2. *(3 points)* Select the best answer for the following questions about **localization**:

   (a) Which technology is susceptible to localization failures when the physical environment changes? (WiTrack / Fingerprinting)

   (b) Cricket localizes using (Time of Flight / Angle of Arrival)

   (c) To recognize someone walking in WiTrack without seeing a "ghost", which window size is appropriate? (50ms / 3 sec)

3. *(3 points)* Which of the following would you likely find in a **MEMS accelerometer** (select all that apply):

   (a) Compass

   (b) Capacitance

   (c) Gyroscope

4. *(3 points)* Circle True or False for each of the following questions about the **Glimpse paper**:

   (a) True / False It reduces the end-to-end latency of object recognition

   (b) True / False It considers the object to be correctly detected if the intersection between the bounding box of the detected and the bounding box of the original object is $>$50% of the bounding box of the original object

   (c) True / False It uses an active cache in order to predict where the object will move in the future.

5. *(4 points)* Circle True or False for each of the following questions about the 6.808 Labs:

   (a) True / False In lab 1 (location), GPS generally provided more data points than WiFi for location tracking.

   (b) True / False In lab 2 (anthills), the centrals broadcast advertising packets for the peripherals.

   (c) True / False In lab 3 (drawing letters), the sole source of error was the machine learning model.

   (d) True / False In lab 4 (maps from waypoints), we used the k-means algorithm to cluster similar waypoints from simulated traces.

Backscatter

6. *(1 points)* How do passive RFIDs power up?

   Passive RFIDs harvest energy from the reader's signal (using inductive coupling or radiative power).

7. *(1 points)* In 1 sentence, explain how RFIDs transmit bits of zeros and ones.

   By switching between different reflective states. Or by modulating their (antenna/matching/electrical) impedance.

8. *(2 points)* Why can't RFIDs work underwater?

   Because they rely on RF signals (1pt) which do not work well in water or die exponentially fast in water (1pt).

9. *(2 points)* What type of material does underwater backscatter use? Briefly explain what is the key property/properties of the material that makes it usable for backscatter?

   Underwater backscatter uses piezoelectric material (1pt). Its key property is to convert mechanical energy to electrical energy (1pt).

Health & Security

10. *(2 points)* In the VitalRadio system on wireless sensing of human vitals, which property of an RF signal does the system use to measure changes in the chest movement? Explain using 1 sentence and the corresponding equation.

    It uses the phase (1pt).

    $$\phi = 2\pi \frac{d}{\lambda}$$

    When the distance changes, so does the phase (1pt for both equation and explanation).

11. *(2 points)* In the Backdoor paper on inaudible voice commands, why does the attacker need two ultrasonic speakers? Explain in 2 sentences.

    If it uses just 1 speaker, then the sound becomes audible (1pt). This is because of non-linearities in the speaker's amplifier/diaphram (1pt).

12. *(2 points)* In the SonicPACT paper on contact tracing, how does the system deal with Doppler shift?

    It transmits a constant tone at the same time (1pt). It measures the Doppler shift of that tone, and uses it to shift back the wider band signal too (1pt).

Localization

13. *(2 points)* Alice wants to reproduce the Cricket system for localization, but she doesn't need the level of accuracy of Cricket. She only needs to track items with an accuracy of 1 meter. How fast does the receiver in Alice's design need to sample the received ultrasonic signals? Explain your answer.

    Resolution = v_{sound}/Sampling rate $\implies$ Sampling rate = v_{sound}/ Resolution (1pt).

    v_{sound} = 345 m/s $\implies$ Sampling rate = 345 Hz (or 345 Samples/sec) (1pt)

14. *(2 points)* Alice's system works really well when the beacon and listener are in the same room, but it starts giving many errors when Alice moves to another room. List 2 reasons why that might be happening.

    1. Sound does not go well (or gets distorted) through walls.
    2. Multipath - a non-line-of-sight path might confuse the receiver.

15. *(2 points)* Alice now wants to track a person on the other side of the wall and decides to reproduce a WiTrack-like device and without Cricket altogether. Again, she wants to achieve a 1-meter accuracy. What is the required bandwidth for Alice's new system?

    r = c/2B $\implies$ B = c/2r = 3e8/(2*1) = 1.5e8 Hz = 150MHz

    1 pt for recognizing it needs to be 1/2; 1 pt for c=3e8.

ETX and Mesh Networking

16. *(3 points)* Consider the wireless network shown below. The delivery probabilities are shown above each edge. If no delivery probabilities are specified, the nodes are out of range. Node A is sending messages to node D. What is the bottleneck throughput of each of the two paths? Which path would be chosen if the choice were based on the bottleneck throughput? (Decimal or percentage is fine)

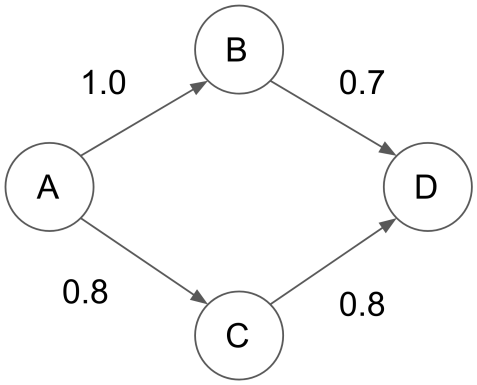

Figure 1: Simple wireless topology. The labels on the links are the delivery probabilities

ABD: 0.7 (1pt)
ACD: 0.8 (1pt)
Chosen Path: ACD (1pt)

17. *(3 points)* What is the ETX for each of the two routes? (e.g. throughput for $A->B->D$ and $A->C->D$)? What path would be chosen based on ETX?

ETX Calculation:
ABD: 1/1+1/0.7 = 2.42 (1pt)
ACD: 1/0.8 + 1/0.8 = 2.5 (1pt)
Chooses: ABD (1pt)

Inertial Navigation

Ben Bitdiddle is building an autonomous vehicle and has (dangerously) decided to use an IMU as his only sensor. He's having trouble with his system and needs you to help! The software is having issues accurately identifying the velocity of the vehicle.

For each of the following issues, diagnose (circle) the most likely source of error:

18. *(1 points)* Ben tries driving his vehicle at a constant acceleration. The inferred velocity is consistently above the ground truth velocity.

    Circle one: Non-Linear Motion, Bias, Gaussian Noise

19. *(1 points)* Ben tries driving his vehicle at a constant acceleration. The inferred velocity is always around the ground truth velocity, but never exactly correct.

    Circle one: Non-Linear Motion, Bias, Gaussian Noise

20. *(1 points)* Given the autonomous driving context here, which of the following technologies would help Ben improve his AV's location accuracy (select the best answer)?

    (a) LoRa
    (b) WiFi
    (c) GPS
    (d) Cricket

21. *(6 points)* Ben's car can be considered a 2D strapdown navigation system. At t=0, the system is at rest location (E=2m, N=4m) with respect to the origin, and at an angle ψ of 45 degrees. The system starts moving with a non-constant velocity v_x(t) = $1m/s$ and v_y(t) = $2t - 4m/s$ (where t is time). What is the car's location with respect to the origin (E=0,N=0) after 4 seconds? Show your calculations and explain your answer.

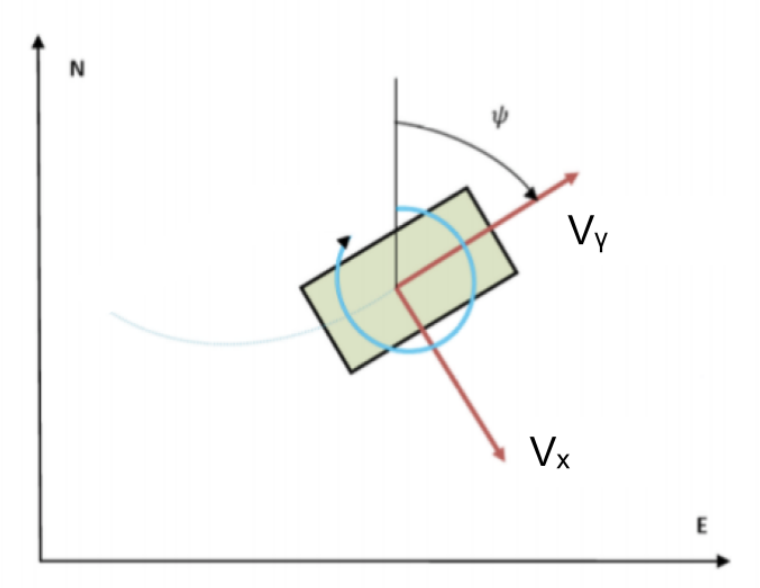

Figure 2: Ben's 2D strapdown navigation system.

We are given the velocity in the car's x and y directions as a function of time, and told that the car starts at rest. To calculate the displacement from the car's starting location (in the car's coordinate frame) over the 4 seconds, we integrate the velocity: $d_x(4) = \int_{t=0}^{t=4} 1dt = [t]_0^4 = 4 - 0 = 4$ and $d_y(4) = \int_{t=0}^{t=4} 2t - 4dt = [t^2 - 4t]_0^4 = ((16 - 16) - 0) = 0$. So we have that $d_x(4) = 4$ and $d_y(4) = 0$.

What remains is converting from the car coordinate frame to the world coordinate frame. The car experiences 0 displacement in the y direction, so we don't have to worry about that. In the x direction, we notice that the car starts at an angle $\psi = 45\,\text{deg}$. Breaking out the components, this yields a net displacement in the E direction of $+2\sqrt{2}$ and in the N direction of $-2\sqrt{2}$. We add this to the car's original starting location in the world frame $(E = 2m, N = 4m)$, which yields the final answer $(E = 2 + 2\sqrt{2}m, N = 4 - 2\sqrt{2}m)$.

1pt for realizing the need to integrated; 1pt for each of the correct answers of x/y; 2pts for coordinate transformation; 1 for adding the base of E/N

Class Feedback (Bonus)

22. *(1 points)* What was/were your favorite lecture(s)/topic(s) in this class?

23. *(1 points)* What was/were your least favorite lecture(s)/topic(s) in this class?

End of quiz!