MIT 6.808 2019 – Mobile and Sensor Computing
Midterm Exam

There are 22 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 **90 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 A CLOSED BOOK QUIZ.
YOU MAY USE TWO DOUBLE-SIDED PAGE OF NOTES.

Do not write in the boxes below

1-8 (33)	9 (7)	10-12 (8)	13-14 (12)	15-17 (6)	18-20 (14)	21-22 (10)	Total (90)

Name: SOLUTIONS

Starters

For each of the questions below, select True or False. There may be more than one True answer for every statement.

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

   (a) True / False Correlation is needed to boost received GPS signal above noise floor

   (b) True / False Correlation is needed to estimate the delay between the satellite and the GPS receiver

   (c) True / False GPS localization is based on trilateration

   (d) True / False Even though 3 anchors are typically enough for computing a location, GPS requires signals from at least 4 satellites

2. *(4 points)* Circle True or False for each of these statements about different localization/imaging systems we discussed in class.

   (a) True / False The RADAR paper relies on RSSI fingerprinting

   (b) True / False The Cricket system needs radio signals for sending messages but not for localization.

   (c) True / False The WiCapture system (for virtual reality) can recover the shape of the trajectory of a WiFi device but cannot get the location.

   (d) True / False The RF-Pose system can generate a skeleton from reflections obtained from a single point in time.

3. *(4 points)* Circle True or False for each of these statements about the WiTrack system.

   (a) True / False In the WiTrack system, even after performing background subtraction, there is some multipath left that needs to be dealt with.

   (b) True / False The original WiTrack system (in the paper we read in class) can operate correctly with 2 people in the environment

   (c) True / False The WiTrack system is based on measuring the time-difference-of-arrival (TDoA)

   (d) True / False The WiTrack system can estimate 3D positions by ellipsoid intersection.

4. *(5 points)* Which of these is true about the E-ZPass (e-Toll Transponder)? (Circle True or False for each choice.)

   (a) True / False The E-ZPass transponder is a kind of RFID.

   (b) True / False It has a battery.

   (c) True / False The transponder harvests energy from the reader's signal

   (d) True / False The Caraoke project we discussed in class can separate between different E-ZPass transponders using their phase offset.

   (e) True / False The Caraoke project reduces the number of antennas/readers needed by using the fact that the car is always on the road plane.

5. *(4 points)* Circle True or False for each of these statements about the Gnome system for GPS Localization.

   (a) True / False Multipath leads to path deflation (i.e., shortening the path length)

   (b) True / False The system uses GPS signal to infer the building heights.

   (c) True / False The system considers different candidate locations, and identifies the correct one as that which requires the minimum adjustment after accounting for reflections.

   (d) True / False The system achieves higher accuracy by increasing the number of satellites visible to a GPS receiver.

6. *(4 points)* Circle True or False for each of these statements about the Farmbeats project.

   (a) True / False It sends all the data to the cloud to minimize any computation at the farm or in the farmer's home.

   (b) True / False It uses lower frequencies than standard WiFi in order to operate over longer distances.

   (c) True / False It leverages weather prediction in order to properly time the irrigation.

   (d) True / False It uses UAVs (drones) in order to generate panoramas, which in turn help in the learning model.

7. *(4 points)* Circle True or False for each of these statements about the Vital-Radio project.

   (a) True / False It uses FMCW as a filter which allows it to work for multiple users.

   (b) True / False It uses a low-pass filter in order to remove the breathing signal and obtain the heart rate.

   (c) True / False It can get the vital signs (breathing and heart rate) even if the person is facing away from the device, but not if the person is facing sideways.

   (d) True / False It cannot get the vitals if the person is walking.

8. *(4 points)* Circle True or False for each of these statements about the Backdoor system.

   (a) True / False It needs at least two *acoustic* speakers.

   (b) True / False If we flip the pre-amplifier and low-pass filter in the receiver microphone design, we would solve the problem of smartphones hearing inaudible sounds.

   (c) True / False The non-linearities lead to frequencies that are the sum and the differences of the transmitted frequencies. Both the sum and differences are important for the Backdoor system to work.

   (d) True / False The system can work with hearing aids, smartphones, and laptops.

BLE Energy Consumption

9. *(7 points)* Alyssa P. Hacker has developed a BLE-equipped sensor node to use on a bicycle. It advertises data when the bicycle is moving, consuming on average 0.25 milliAmp in the advertisement state; at all other times, the node is on standby consuming 0.5 microAmp. She estimates that the average use of her bicycle (i.e., advertisement state) is 1 hour per day. Ignore the energy consumed in switching between standby and advertisement states. The node uses a coin-cell battery with capacity 500 milliAmp-hours. For how long will the node function before running out of energy?

(4) average consumption: $\frac{0.25\,mA \times 1 + 0.5\,\mu A \times 23}{24} = 0.011\,mA$ on average.

(2) (1) (1)

(3) # years $= \frac{500\,mA\text{-}h}{0.011\,mA\text{-}h} = 45889 \approx 125$ years $= 5.1$ years

(2) (1) 8.33 days

Networking

Consider the simple wireless network in the figure below where the number on each link refers to the packet delivery probability on the forward path. (Assume the delivery probability on all reverse links is 1). All nodes are half duplex. Also for this problem assume **no acks**.

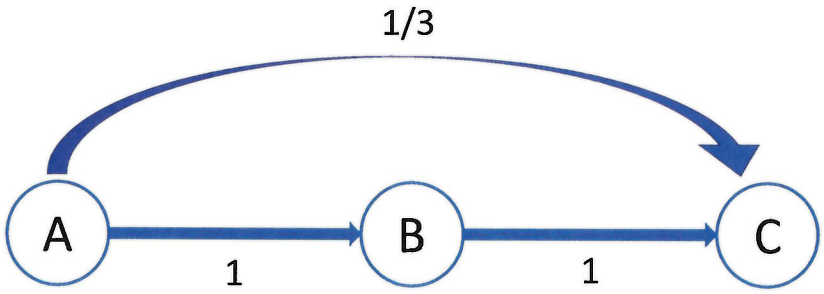


Figure 1: Multi-hop Network

10. *(2 points)* What is the ETX of each of the following links?

    $A \rightarrow B$ ___1___

    $A \rightarrow C$ ___3___

11. *(2 points)* Consider a sender at A and a receiver at C. If the shortest-path routing protocol uses ETX as the link metric, which of the two paths it will pick: $A \rightarrow C$, or $A \rightarrow B \rightarrow C$?

    And, what is the shortest-path ETX? ___2___

12. *(4 points)* Alyssa Hacker notes that shortest-path routing does not leverage the broadcast nature of the wireless medium. Specifically, when node A transmits a packet on the wireless medium, both B and C receive this packet but with different probabilities (B receives the packet with probability 1, and C receives the packet with probability 0.333). What is the expected number of transmissions to deliver a packet from A to C if a routing protocol can leverage the broadcast nature of the medium? Show your calculations. (You can assume no other packets in the network. You don't need to describe the routing protocol.)

    Expected = $\frac{1}{3} \times 1 + \frac{2}{3} \times 2 = \frac{5}{3} < 2$

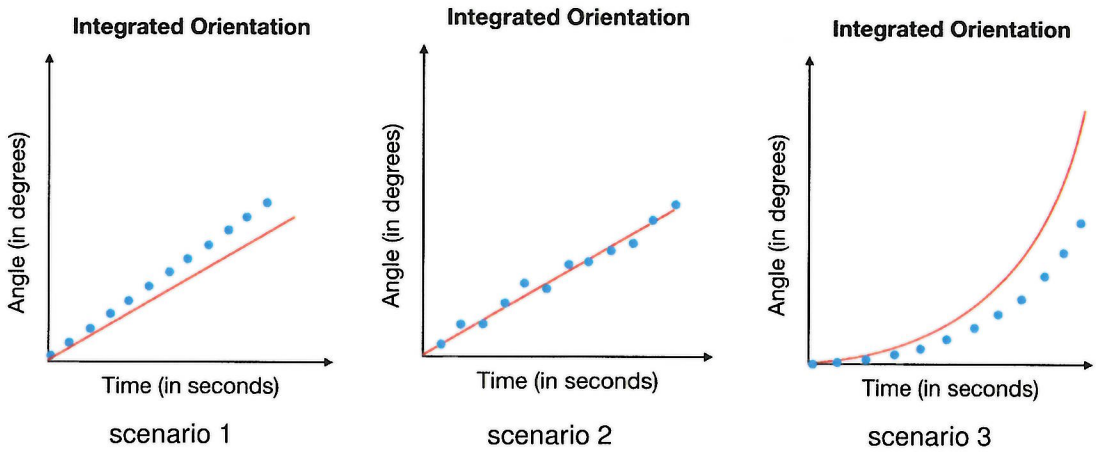
    1 1

    Some reasoning that it might go directly in 1 path → 2

Inertial Sensing

13. *(6 points)* Recall that a gyroscope measures angular velocity and uses it to estimate orientation. However, the estimated and ground truth orientations may deviate from each other due to a number of factors which we discussed in class.

    The below three figures provide the ground truth (red) and estimated (blue) orientation in three different scenarios. State the cause of deviation in each of the three scenarios.



scenario 1 scenario 2 scenario 3

Figure 2: Orientation vs time in three different scenarios

(a) The cause of deviation for scenario 1 is: bias

(b) The cause of deviation for scenario 2 is: gaussin noise

(c) The cause of deviation for scenario 3 is: non-liner motion

14. *(6 points)* The below figure shows a 2D strapdown navigation system. At $t = 0$, the system is at rest location (2m, 4m) with respect to the origin, and at an angle ψ of 30 degrees. The system starts moving with a constant acceleration $a_x = 0.2m/s^2$ and $a_y = 0.4m/s^2$. What is its location with respect to the origin after 3 seconds? Show your calculations and explain your answer.

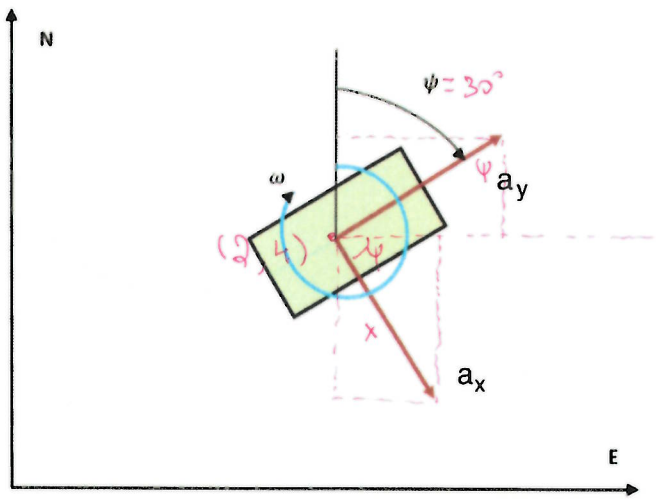


Figure 3: 2D Strapdown navigation system

(2)

$x = \frac{1}{2} a_x t^2 = \frac{1}{2} \times 0.2 \times 3^2 = 0.9\,m$

$y = \frac{1}{2} a_y t^2 = \frac{1}{2} \times 0.4 \times 3^2 = 1.8\,m$

$\sin 30 = 0.5$

$\cos 30 = 0.866$

(2) (1)

$\Delta E = x \cos\psi + y \sin\psi = 0.9 \times 0.866 + 1.8 \times 0.5 = 1.6794$

$\Delta N = -x \sin\psi + y \cos\psi = -0.9 \times 0.5 + 1.8 \times 0.866 = 1.1088$

$\Rightarrow \quad E = 2 + 1.6794 \approx 3.68\,m$

$N = 4 + 1.1088 \approx 5.11\,m$

(1)

Pothole Patrol

The pothole patrol system uses different thresholds and filters to eliminate unwanted events. In one or two sentences, briefly answer the following questions and explain your reasoning.

15. *(2 points)* How does it discard scenarios when the car is accelerating, braking, or making turns? Specifically, does it use a high-pass filter or a low-pass filter on the accelerometer data and why?

HPF b/c slow changes in acc. vs high/unexpected changes.

16. *(2 points)* How does it discard expansion joints and rail crossing (i.e., distinguish them from potholes)?

$\frac{a_x}{a_z} >$ threshold

17. *(2 points)* Why does it cluster the pothole events?

improve robustness as may not occur in exactly same GPS location + eliminate noise.

Wireless Sensing and subsea IoT

The underwater to air communication system discussed in class (TARF) uses an acoustic transmitter and a radar receiver. The radar captures vibrations on the surface of the ocean caused by the underwater speaker. For the below questions, assume that the vibrations have a peak-to-peak amplitude of 10 μm. Answer the following questions about the system.

18. *(4 points)* If the system used FMCW radar to measure the surface vibrations. What should the bandwidth of the radar be in order to have a resolution of 10 μm? Show your calculations.

$r = \frac{c}{2B} \Rightarrow$ ~~3x1~~ $B = \frac{c}{2r} = \frac{3\times10^8}{10\times10^{-6}} = 3\times10^8\times10^5 = 3\times10^{13}$ 2

3 THz or 1.5 THz

↳ both 2 & not 2

1

19. *(6 points)* Instead of simply using the bandwidth, the TARF system relies on the phase of the wireless reflection. If the frequency of the transmitted signal is 60 GHz, what will the peak-to-peak phase variation be?

2

back & forth

$\phi = \frac{2\pi d}{\lambda} = 2\pi \times \frac{2d}{\lambda} = \frac{2\pi \times 2\times10\mu m}{\lambda} = \frac{4\pi \times 10\times10^{-6}}{5\times10^{-3}} = 0.025$ rad or $1.44°$ 1

$10^{-2}\ 10^{-3}$

$\lambda = \frac{c}{F} = \frac{3\times10^8}{60\times10^9} = \frac{3}{6}\times10^{-2} = 0.5\times10^{-2} = 5mm$

1 1

20. *(4 points)* Ocean ripples cause waves whose height is 10 cm peak-to-peak, i.e., $10,000\times$ larger than the vibrations caused by the underwater speaker. What are the two steps that the radar needs to perform in order to obtain the surface vibrations from the underwater speaker despite the ocean surface ripples.

1) phase unwrap 2

2) HPF 2

Potpurri

21. *(4 points)* The Glimpse paper uses two main components in order achieve continuous object recognition. What are these two components? Describe the need for each of them in 1-2 sentences.

① ①

- active Cache : track through frames w/o need to go to cloud.
- trigger frame : ≠ ces ⇒ reduce bandwidth

① ①

22. *(6 points)* In several papers we studied, *precision* and *recall* were used to evaluate the performance of various inference, learning, or detection methods (e.g., CTrack, Glimpse). Consider a sensor-based system set up to detect the malfunction of industrial equipment in a factory. You observe the following sequence of malfunction events detected by the system:

Time slot	1	2	3	4	5	6	7	8	9	10	11	12	13
Event detection by system		X		X		X	X	X	X			X	X
Actual event (truth)	X	X	X				X	X		X		X	

For this sequence of events, what are the precision and recall metrics? Explain your answer in the space below and write the numbers in the blanks.

correct = 4 ①

actual = 7 ①

decision = 8 ①

① $\frac{\text{correct}}{\text{decision}} = \frac{4}{8} = \frac{1}{2}$

Precision: _____.

Recall: _____.

① $\frac{\text{correct}}{\text{actual}} = \frac{4}{7}$. ①

End of quiz!