MIT 6.808 2020 – Mobile and Sensor Computing
Midterm Exam

There are 28 questions and 11 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 **80 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

1-6 (23)	7-12 (6)	13-16 (8)	17-20 (11)	21-22 (7)	23-26 (18)	27-28 (7)	Total (80)

Name:

Please sign or write your name again below pledging the below statement.

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

Signature or Name:

Starters

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

1. *(3 points)* Circle True or False for each of these statements about RFID technologies:
   (a) True / False The Caraoke system discussed in class can decode and localize transponders despite collisions.
   (b) True / False HF and LF RFIDs need to be tapped on the reader because they harvest energy ~~from vibrations.~~
   (c) True / False Passive RFIDs communicate by alternating between reflective and absorptive states.

2. *(4 points)* Circle True or False for each of these statements about the Pothole Patrol system discussed in class:
   (a) True / False Placing the sensor on the windshield would give the best performance (least noise), but the paper avoided placing it there because it was difficult to mount at the time.
   (b) True / False The Pothole Patrol paper performs feature engineering.
   (c) True / False The xz ratio allows eliminating non-pothole events where the left and right sides of the car experience similar vertical accelerations and similar tangential accelerations (tangential refers to the direction perpendicular to the road but in the road plane).
   (d) True / False The Pothole Patrol system uses loosely labeled data to avoid over-training on rough (i.e., non-smooth) roads.

3. *(4 points)* Circle True or False for each of these statements about the Vital-Radio system.
   (a) True / False If there is only one person in the environment, FMCW is not needed.
   (b) True / False If the FMCW bandwidth is larger, the system would be able to extract the individual heart rate of users even if they are only 20 cm apart. **Vital-Radio was not limited by FMCW resolution (~15cm already)**
   (c) True / False The system works correctly when the user is facing away from the device because it uses the wall's reflection of the user's chest. **chest expands in all directions**
   (d) True / False The average heart rate is enough for emotion recognition. **need length of individual heartbeat**

4. *(4 points)* Circle True or False for each of these statements about the CTrack system.
   (a) True / False It uses 2 HMMs.
   (b) True / False The system sequences GSM fingerprints on a spatial grid by combining both tower ID and RSSI information.
   (c) True / False The system uses wardriving in order to generate training data.
   (d) True / False The system uses ~~both WiFi and~~ GSM data.

5. *(4 points)* Circle True or False for each of these statements about the Farmbeats project.
   (a) True / False It combines three technologies: WiFi, Whitespace connectivity, and LTE.
   (b) True / False By performing spatial smoothing and temporal smoothing, it can reduce the number of deployed sensors while maintaining good accuracy.
   (c) True / False The paper uses LoRa to achieve low latency and low power.
   (d) True / False Each of the deployed sensors has its own solar panel for energy harvesting.
   There's a combined solar panel

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

   (a) True / False The active cache component of the system reduces the end-to-end latency for object recognition. **it hides but not reduces it (tricks user into thinking it is lower)**

   (b) True / False The trigger frame component of the system reduces the bandwidth required for object recognition.

   (c) True / False Both the active cache and the trigger frame components measure scene changes to optimize overall performance.

   (d) True / False The system does not have any benefits if the end-device is already equipped with object detection hardware.

Connectivity Technologies

Select the best technology for each of the application domains listed below. Choose just **one** answer for each application domain.

7. *(1 point)* Which of the below connectivity technologies would you use for city-scale, high-bandwidth applications?

   (a) LoRa
   (b) RFID
   (c) LTE
   (d) WiFi

8. *(1 point)* Which of the below technologies would you use for ultra-low-power, long-lasting, access control applications?

   (a) LoRa
   (b) RFID
   (c) LTE
   (d) WiFi

9. *(1 point)* Which of the below technologies would you use for city-scale, low-power, low-bandwidth communication?

   (a) LoRa
   (b) RFID
   (c) LTE
   (d) WiFi

10. *(1 point)* Which of the below connectivity technologies would you choose for EToll transponders?

    (a) HF RFID
    (b) LF RFID
    (c) UHF RFID
    (d) Battery-free RFID

11. *(1 point)* Which of the below technologies would you choose for tagging all items in a warehouse for inventory control?

    (a) LTE
    (b) WiFi
    (c) RFID
    (d) BLE

12. *(1 point)* Which of the below technologies would you choose for smartphone-compatible, low-power, room-scale connectivity?

    (a) LTE
    (b) WiFi
    (c) RFID
    (d) BLE

Device-based Localization

In the Cricket paper discussed in class, each cricket transmits a radio signal and an ultrasonic pulse. Let us assume that there is a single beacon and a listener, and the distance between them is 8m.

If the beacon transmits a packet at t=0s:

13. *(2 points)* At what time is the ultrasonic chirp received by the listener? Show your calculation.

    8/343=23ms

14. *(2 points)* At what time is the radio transmission received by the listener? Show your calculation.

    8/c = 26ns

15. *(2 points)* How does the listener estimate the distance to the beacon? Explain in 1-2 sentences.

    Starts timer when RF received, till time when ultrasound received
    multiplies time difference by speed of sound

16. *(2 points)* What is the error in distance estimation between the exact and estimated distance? Show your calculation.

    Error is 0.26ns*343 = 9.15 um
    Can't account for RF propagation time

Device-Free Localization

In the WiTrack lecture, we discussed that it is possible to locate both static and moving users by using different subtraction windows. We perform background subtraction using two different windows: 3second and 30ms windows. After background subtraction, assume we are able to eliminate all multipath reflections and are only left with reflections off humans in the environment.

Below, we show the 2D output (representing a 2D plane) from each of the two subtraction windows. The "X" correspond to the location of peaks in the 2D output (i.e., user locations).

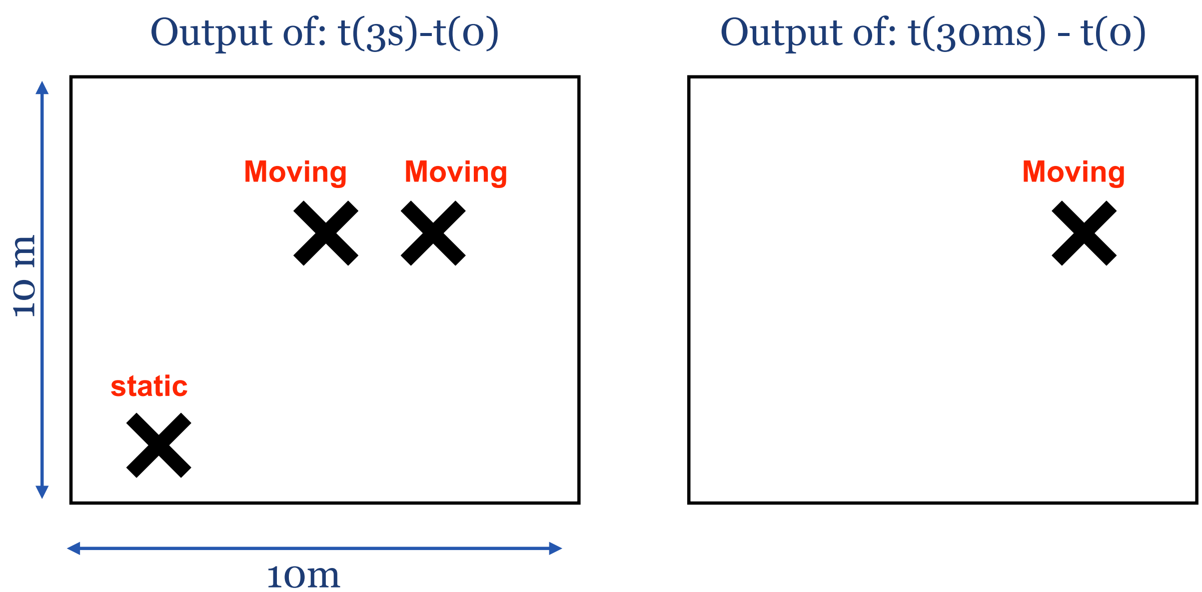


Figure 1: Two Subtraction Windows

17. *(3 points)* Based on the above outputs, what is the minimum possible number of users in the environment? Briefly explain your reasoning.

    2 — see below

18. *(4 points)* Assuming all users are either sitting or walking. Label each "X" in the above output as a static or a moving user. Explain your reasoning for each label.

    static user appears only in 3s due to breathing (slow motion)
    moving user appears as ghost (initial+final position) in 3s

    (Note: reasoning should be correct to get the mark)

19. *(2 points)* How fast is/are the moving user(s) walking? Briefly explain your reasoning.

    Distance between two moving locations /3seconds ~2/3 m/s

20. *(2 points)* Using the same data from the above experiment, we used a 5second instead of a 3second subtraction window. This time, we only got 2 peaks (i.e., two X's in the 2D output of the long subtraction window instead of 3 peaks).

    We have already ruled out all the following potential reasons:

    - All users are still within the 10m x 10m space.
    - The moving user(s) final position is different from their initial position.
    - All users remain at least 2m away from each other throughout the experiment.

    In 1-2 sentences, explain what might've caused this.

    Breathing cycle is periodic and chest returned (close) to original position after full cycle of 5s

Networking

21. *(2 points)* Consider the wireless network shown below in Figure 2. The delivery probabilities shown are the combined delivery probabilities (i.e., the product of the forward and reverse link delivery probabilities). If no delivery probability is specified, the nodes are out of range. Node S is sending packets to D using a shortest path routing protocol based on the ETX metric. What is the path S will choose? What is the ETX metric of this path?

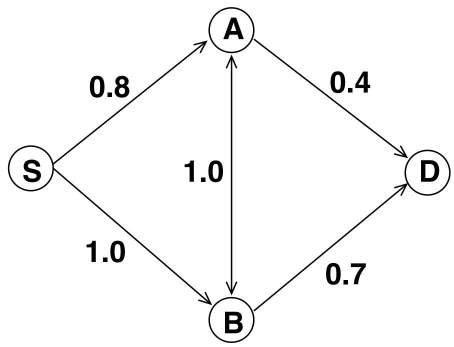


Figure 2: Simple wireless topology. The labels on the links are the delivery probabilities.

S-B-D

ETX = 1/1+1/0.7

22. *(5 points)* Consider the chain of 5 equally spaced nodes shown in Figure 3. The radio range is slightly larger than the inter-node distance, i.e., each node can sense his left and right neighbors only. Each link is perfect, i.e., the delivery probability is always 1.0 for any link. Node S is sending packets to D.

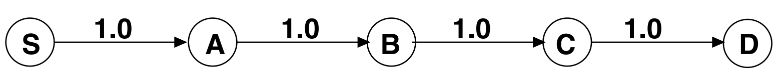


Figure 3: Simple wireless topology. The labels on the links are the delivery probabilities.

(a) What is the ETX metric of the 4-hop path in Figure 3?

4

(b) Assume that the capacity of the wireless medium is 1 packet/second and there is a protocol which schedules transmissions optimally. What is the maximum throughput of the flow from S to D in Figure 3? Briefly explain your answer.

S & C can tx at the same time without interfering

1/3

(c) Why can't the ETX metric accurately predict the throughput of the path in Figure 3 whereas it correctly predicts the throughput of the path in Figure 2?

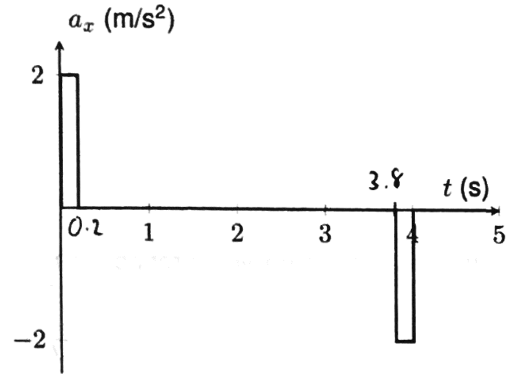
doesn't account for spatial re-use

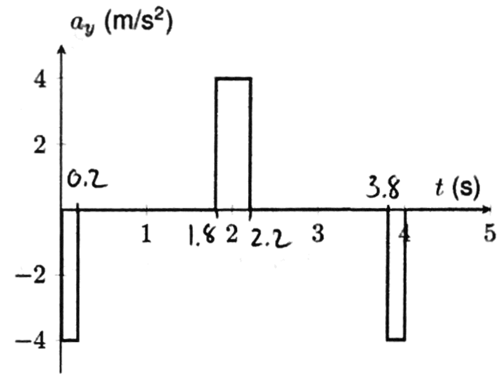
Inertial Sensing

23. *(10 points)* Alice moves a device to track her movement and perform gesture recognition using accelerometer data, similar to Lab 3. Suppose that the accelerometer is free of noise and bias, there is no movement in the *z* direction, the orientation of the phone is constant, and the starting velocity and position ~~is~~ are zero at $t = 0$ s. The accelerations in the *x* and *y* directions, in m/s^2, are given by

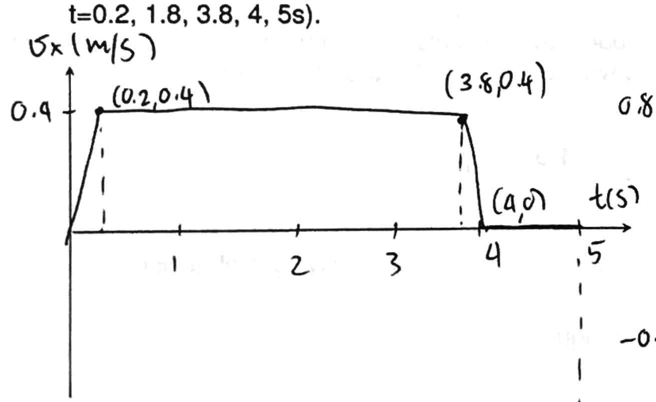
$$a_x(t) = \begin{cases} 2 & \text{if } 0 < t \leq 0.2 \\ -2 & \text{if } 3.8 < t \leq 4 \\ 0 & \text{otherwise} \end{cases} \quad \text{and} \quad a_y(t) = \begin{cases} -4 & \text{if } 0 < t \leq 0.2 \text{ or } 3.8 < t \leq 4 \\ 4 & \text{if } 1.8 < t \leq 2.2 \\ 0 & \text{otherwise} \end{cases}$$

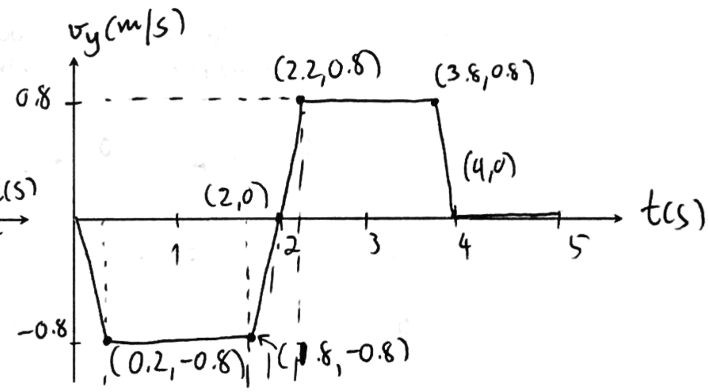
The plots of accelerations in the *x* and *y* directions, a_x and a_y, are shown below.

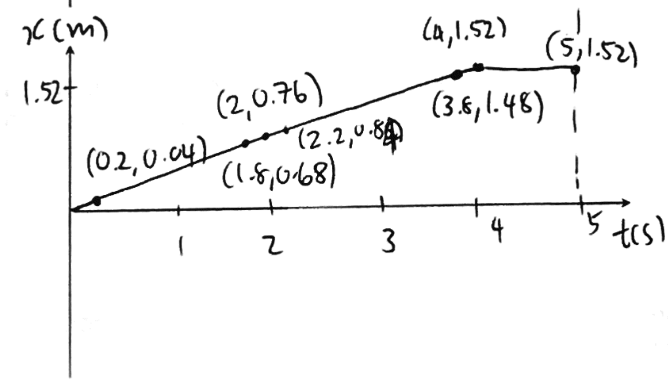


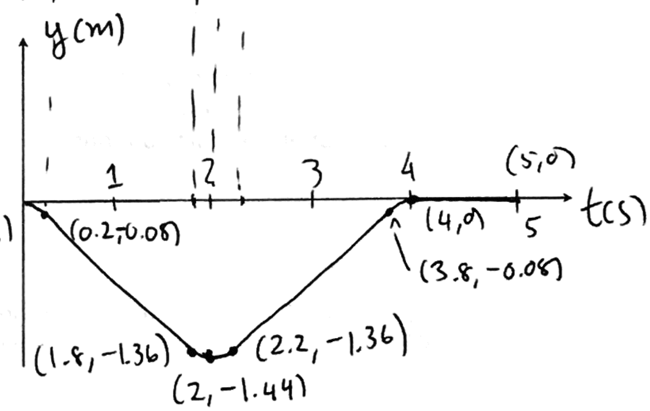


Sketch the **velocity** and **position** in the *x* and *y* directions from $t = 0$ s to $t = 5$ s. Label the **axes** with units and indicate the values at each of the **peaks**, **valleys**, and transition points in your plots (e.g., at t=0.2, 1.8, 3.8, 4, 5s).

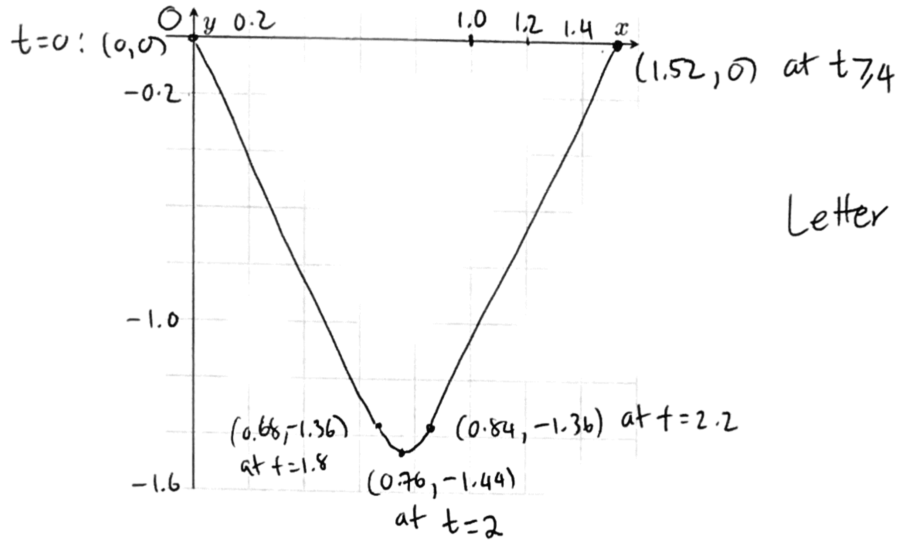






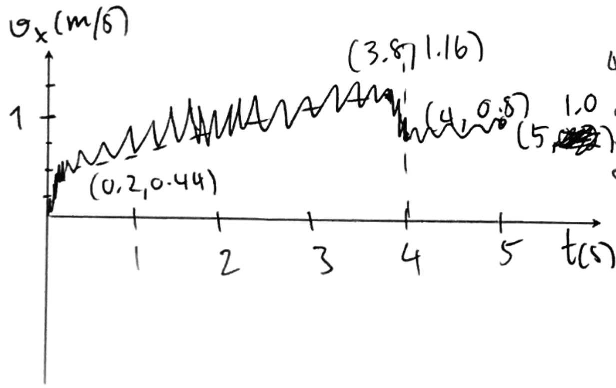


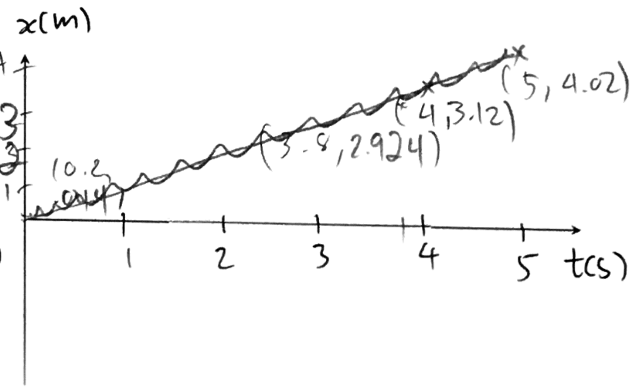
24. *(2 points)* Sketch the trajectory of the device in the *xy*-plane. What letter does the device trace?



Letter V

25. *(4 points)* Bob performs the exactly same movement. However, the x-axis accelerometer suffers from a constant bias of +0.2 m/s^2 and a small zero-mean Gaussian noise. Sketch the velocity and position in the x direction. Label the axes with units.





26. *(2 points)* List two ways to stabilize the noisy trajectory tracking.

- Exponential damping
- Non-linear damping
- Rest recognition
- Calibration, eg. to remove non-zero bias?

Evaluation Metrics & Object Recognition

27. *(2 points)* In the Glimpse (split computing) lecture, what criteria are used to determine that recognition is correct?

    1) IOU >50%
    2) label matches ground truth

28. *(5 points)* Below, we show 6 different images where we expect Glimpse to recognize all road signs in each image.

Figure 4: Precision & Recall

(a) Compute the overall precision. Explain your answer in details.

precision = #correct / # detected = 3/5

(b) Compute the overall recall. Explain your answer in details.

recall = #correct / # actual = 3/7 (there are two in the bottom right figure)

(c) Compute the overall F-measure.

2/(1/precision+1/recall)

End of quiz!