Distribute: October 27, 2026 Due: November 3, 2026, 3:00 PM via email to David McDonagh

Problem Set 2 – Cancer Engineering – Foundations – Fall 2026

Do not use AI in preparing your answers (e.g., ChatGPT or any similar LLM).

1. Dr. Anthony Santella:

Based on your completed version of the in class project, run some tests on different combinations of training data, model and hyperparameters, recording results and noting possible explanations.

The original starting notebook for reference:

https://colab.research.google.com/drive/10ptDoyZpyzcTBri4Dxhfkkc7Uv1vV9Ad?usp=sharing

Share the link here to your final notebook used to perform experiments:

1. (4pt) Note the overall accuracy of the original model on both noisy and clean images, and the performance of the model trained with noise augmentation.

Performance on Test Data

	Train Data Noise Augmented p=1	Train Data No Noise
Test Data Noise		
Test Data No Noise		

Has augmentation of the training data caused performance to converge on the two test sets?

Where has it converged to and why might this be?

Why might training on noise make performance worse on non noisy images?

2. (3pt) What happens to noise augmented performance over the two test data sets if you reduce the probability of noise augmentation in the training data set?

Performance on Test Data

	Train Data Noise Augmented p=.?
Test Data Noise	
Test Data No Noise	

Why might you see this pattern of results

3. (3pt) Now Repeat this process initializing the densenet121 to use pretrained weights, (a flag in constructor controls this). This will initialize feature extractors to values highly trained on the general ImageNet classification dataset. How does classification perform?

Performance on Test Data

	Train Data Noise Augmented p=?	Train Data No Noise
Test Data Noise		
Test Data No Noise		

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Why might performance on unexpected noisy results be poor even with pretrained feature extractors?

How does this initialization with weights from another task (transfer learning) change the appearance of the feature vectors for noisy and clean images compared to a model trained from scratch?

4. (3pt) Test the behavior of the noise augmented model when initialized with pretrained weights *and* allowed to continue training for two epochs instead of stopping at 1
   Performance on Test Data

	Train Data Noise Augmented p=?
Test Data Noise	
Test Data No Noise	

5. (3pt) Now quadruple the noise in both the noisy train and test data set, what happens?

	Train Data Noise Augmented std=.8 p=?
Test Data Noise	
Test Data No Noise	

   Why is the performance not as good, even when you train on noisy data?

   Speculate on how you could try to get performance back up on these more noisy images? Optionally, tweak some parameters (more epochs, worse noise in training, etc) and see how close this gets you.

6. (4pt) With your final model (or any earlier one you prefer), now adjust your script to compute classifications on the test data with several noise levels in the loader (changing the sigma while keeping the noise probability constant), also record the signal to noise ratio with the method you developed during class. Now plot performance vs signal to noise and separately plot performance vs the standard deviation of the noise augmentation. How well does your signal to noise ratio capture the difficulty of classification at each noise level? Include plots here or in the final notebook.

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2. From Dr. Jason Lewis

Problem 1: Basic Principles [2.5 pts]

Question: Describe the basic principles of PET imaging. Include the role of positrons, annihilation events, and the detection of gamma rays.

Problem 2: Clinical Applications [2.5 pts]

Question: List three clinical applications of PET imaging and briefly describe how PET contributes to each.

Problem 3: Radiochemistry of non-metals [2.5 pts]

Questions:

3a. What type of chemical bond is used for incorporate non-metals to the molecules?

3b. Briefly discuss the need for incorporating non-metallic radioisotopes into radiopharmaceuticals.

3c. State 2 advantages and disadvantages of radioiodinated antibodies over radiometallated antibodies

Problem 4: Radionuclide Considerations [2.5 pts]

Question: Which of the following factors significantly impact the successful application of a particular radionuclide in radiopharmaceutical production.

a) Radioactive half-life
b) Cost of the precursor material
c) Availability of the precursor material
d) Appropriate type of decay
e) All of the above

In class presentation will count for 10 points.

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3. From: Dr. Kayvan Keshari:

You are interested in the role of androgen signaling in the setting of prostate cancer. Recent work has shown that inhibition at the level of the androgen receptor (AR) demonstrates dramatic responses in primary prostate cancer but leads to the emergence of resistance. With this in mind, your aim is to characterize this process and the result of modulating AR signaling.

1. [10 pts] Using magnetic resonance based molecular imaging, how would you visualize both the expression of your target (AR) and how would you pharmacologically modulate AR to demonstrate that you have "hit the target"? Describe what model system you would use both *in vitro* and *in vivo*, what the limitations of this approach would be and reference relevant literature.

2. [10 pts] Assuming modulation of AR has a metabolic effect, what would you expect to observe and how would you image changes in AR driven metabolism using MR based strategies? Be sure to describe which molecules and approaches you would use both to non-invasively monitor changes and also any methods to verify your results.

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4. From Dr. Ross Boltyanskiy (Optics):

Low grade gliomas (cancerous cells in the brain) can be difficult to distinguish from healthy glial cells. Glioma cell morphology is subtly different. Glioma proliferation and glycolysis are modestly enhanced compared to healthy cells. In the exercise below you are tasked with designing different optical imaging approaches to distinguish between the two cell populations. In thinking through this exercise, you are welcome to look into / research glioma signaling and morphology deviations as far as it would help you answer the questions below.

1. Suppose you have a mixed in-vitro (in a dish) population of low grade gliomas and astrocytes (a type of healthy glial cells). Provide 3 distinct possible optical imaging approaches that would allow you to distinguish between the two cell types. With each approach you should be able to label cells as healthy or malignant.
    a. Please list the 3 techniques and in a few sentences describe how each works [3.5pts].
    b. Discuss the benefits and drawbacks of each technique [3.5pts]
    c. Explain if each technique will give you a qualitative or a quantitative metric [1.5pts]
    d. Explain if each technique provides contrast based on a material property or a biological function. [1.5pts]

2. Now you would like to work on eventually translating your work to the clinic. You start with a mouse model with brain cancer and are now interested in developing in-vivo optical imaging approaches to detect gliomas. The tumor can either be an orthotopic xenograft or a flank tumor.
    a. Please list 2 optical imaging approaches that would allow you to differentiate low grade gliomas from the surrounding healthy cells in vivo in the mouse model. In a few sentences, please describe how each technique works [3.5 pts]
    b. Discuss the benefits and drawbacks of each technique [3.5 pts]
    c. Explain if each technique will give you a qualitative or a quantitative metric [1 pt]
    d. Explain if each technique provides contrast based on a material property or a biological function. [1 pt]
    e. How can you measure the accuracy of your identification? In other words, what is one way you can verify that your in-vivo identification of cancer and healthy cells is working properly. [1 pt]

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5. From Dr. Ross Boltyanskiy (MRI):

Objective: Write a brief lab report describing and explaining your experiments with the table-top MRI's. The report should include a summary of your procedure as well as relevant graphs. In the report, please make sure to address the following questions:

1. [1] Did you perform shimming and tuning / matching? What is the purpose of those adjustments?
2. [2] Discuss T_1 measurements:
    a. How did you measure T_1?
    b. What did you get for the T_1 of the inner and outer samples?
    c. Please include labeled graphs
    d. Please show which regions in the samples you used for analysis
3. [2] Discuss T_2 measurements:
    a. How did you measure T_2?
    b. What did you get for the T_2 of the inner and outer samples?
    c. Please include labeled graphs
4. [1] Please show a T_1-weighted image that demonstrates good T_1 contrast between the two samples. What parameters did you use?
5. [1] Please show a T_2-weighted image that demonstrates good T_2 contrast between the two samples. What parameters did you use?
6. [1] Please explain why the inner and outer samples are light or dark in each of the above images (T_1-weighted and T_2-weighted)
7. [2] Create a T_1-map and display one or two images where the T_1's of the outer and inner samples are clearly visible
8. [2] Create a T_2-map and display one or two images where the T_1's of the outer and inner samples are clearly visible
9. [2] How did you perform a test of SNR vs. number of scans?
    a. What did you plot?
    b. How did you fit it?
    c. Is the signal changing as a function of the number of scans?
    d. Is the background changing as a function of the number of scans?
    e. Based on (d) and (e) is the software adding signal or averaging it when multiple scans are combined?
10. [1] How is the number of pixels in your image affected by the number of frequency encodes and the number of phase encodes?
11. [3] For one of the images you acquired (with good signal and good contrast), let's explore k-space.
    a. Please show an absolute value of the k-space image

b. How does the reconstructed image (in regular coordinates) change when you cut off a significant fraction of k-space outside of the center? Cut off at least 30%
c. How does the reconstructed image (in regular coordinates) change when you cut off the center of k-space?

12. [1] Please reflect on the sources of error.

13. [1] Please reflect on what you liked and didn't like about this exercise. How would you adjust it for next year?