Probabilistic Models of the Visual Cortex

Fall 2025 Homework 1

Prof. Alan Yuille

Instructions

1. **Deadline**: Sep 26, 2025 at 11:59 PM.

2. **Penalty for late submission**: 20% score deduction per day (or part thereof)

3. **Submission format**: PDF file named *<your_jhed>*-hw1.pdf.

4. **Warning**: Start the coding part (Question 4) early!

5. **Collaboration**: Feel free to discuss the questions with friends, but be sure to write your answers entirely independently!

6. **Questions?** Start a Canvas Discussion, attend office hours, or send an email!

Question 1: NI and AI vision (14 points)

Please give brief and clear answers to the questions below.

1. Vision is extremely hard due to the complexity and ambiguity of natural images. Name *three* complexities **(3 points)** and *two* ambiguities in vision **(2 points)**.

2. Understanding NI vision can help with AI vision problems. Briefly describe *three* perceptual phenomena known to NI that could help AI **(3 points)** and another *two* that are unlikely to help AI **(2 points)**.

3. The ventral visual stream is most well-known for its ability to perform object recognition (though it also contributes to other aspects of visual processing!) Name *three* theories of object recognition in the ventral stream **(3 points)** and *one* metaphor for it **(1 point)**.

Question 2: Visual Illusions (12 points)

Visual illusions teach us about the assumptions that the brain makes when interpreting images. These assumptions are often correct but occasionally wrong, as shown by the illusions. Write a two- to three- sentence explanation for each of the illusions below (**1 point each**). Does each illusion involve low-, mid-, or high-level vision? (**1 point each**) Note that all these illusions are discussed in the Early Vision chapter by Yuille and Kersten.

1. Neon color spreading

2. Motion binding

3. Hollow face illusion

4. Dalmatian dog

5. Ball in a box

6. Checker-shadow illusion

Question 3: Linear Filters (12 points)

1. In class, we discussed models of simple and complex cells in region V1 of the visual cortex. Briefly describe some differences between them (e.g. with respect to their input, types of information that they are sensitive to, etc.) **(4 points)** Is a complex cell considered to be a linear filter of its input? Why or why not? **(2 points)**

2. What kind of information in an image does the first-order derivative of Gaussian filter capture? **(1 point)** What about the second-order derivative of Gaussian filter? **(1 point)**

3. Suppose you smooth an image by applying a Gaussian filter followed by a first-order derivative of Gaussian filter. Does the order of applying these filters matter? Why or why not? **(4 points)**

Question 4: Experimental Section (16 points)

In this section, you will probe standard receptive field models of neurons such as Gabor functions and Laplacians of Gaussians using sinusoidal inputs. Here's a link to the Jupyter notebook with all the code you'll need: `https://github.com/Tiezheng11/ProbabilisticModelsOfVisualCognition2025FA/blob/main/homework_1/image_filters.ipynb`!

For this homework, you do NOT need to submit any code to us. We only expect to see generated plots and answers to the questions in the notebook.