Computer Vision:
Image formation and analysis

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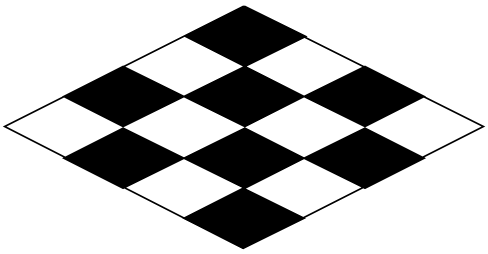
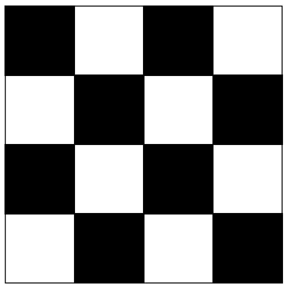
Working Conditions: This is an open-book exam. You have the right to use your course notes and any reference material. You may answer in English or French. You must write legibly. Unreadable text will not be graded.

Duration : 3 hours.



Calibration pattern as seen by the camera (Questions 1 and 2)



Overhead view of calibration pattern (Question 2).

1) (4 points) A chess board may be used as a calibration pattern to estimate a homography. Explain how to use an edge detector and a Hough transform to determine the position of the corners of the squares in an image of a chess board.

2) (4 points) Explain how to calculate a homography H_S^i from the chess board to the image. Explain how to use the homograpy H_S^i to estimate an overhead view of the chessboard.

3) (4 points) A scene is illuminated with a lamp with programmable color filters. The lamp has 4 such filters giving four illumination spectrums {white, red, green, blue}. Certain objects in the scene give specular reflections. Your problem is to detect the pixels that correspond to specular reflections.

To calibrate your system, you observe white sheet of paper illuminated the lamp with each filter. Explain how to estimate a Normal (Gaussian) density function of the chrominance (C_1, C_2) for the illumination under each filter.

You need to determine the pixels that correspond to specular reflections. How can you determine the probability of a chrominance vector at a pixel given a specular reflection? How can you estimate the probability of a specular reflection given a chrominance vector of a pixel?

4) (4 points) You have a camera that may be steered in pan, tilt and zoom. Your camera produces images that are 512 x 512 pixels. Each pixel is coded as RGB with 8 bits per color.

a) How can you transform your image into orthogonal components for luminance (L) and chrominance (C_1, C_2) (Note there are several possible answers. Any of them are acceptable).

b) $P^L_{xx}(i, j; \sigma)$ represents the second derivative of the image, L, at pixel (i, j), along the row direction. This derivative is calculated using a Gaussian receptive field of scale parameter σ. What mathematical formula must you program to obtain $P^L_{xx}(i, j; \sigma)$?

c) How can you determine the parameters for σ at pixel (i, j) such that the derivatives remain invariant to changes in zoom?

d) How can you use $P^{C_1}_x(i,j;\sigma)$ and $P^{C_1}_y(i,j;\sigma)$ in order to determine a first derivative oriented in the direction θ.

5) (4 points) How many convolutions of the filter [1, 2, 1] must be made in order to obtain a response that is equivalent to convolution with a Gaussian of size $\sigma = 4$?