HOMEWORK ASSIGNMENT #1

DUE: 2:00 PM, Thursday, September 17, 2020

CSCI 677: Advanced Computer Vision, Prof. Nevatia
Fall Semester, 2020

Submit solutions on the DEN class page.

You may choose to write solutions by hand; in that case, please submit a scanned copy.

1. For this problem, assume that the image coordinates are specified in the normalized coordinate system and 3-D points are specified in the camera coordinate system. Consider a line, *l*, in the image, given by parameters (a, b, c). We know that the corresponding 3-D line casting this image lies in a plane. Derive the equation of this plane (in the camera coordinate system).

2. Suppose that we have a right-handed camera coordinate system (X_c, Y_c, Z_c) associated with origin at the lens center (or the pin hole), as in the examples discussed in class. Suppose that the imaging plane is at a distance of 50 millimeters from the lens center, the imaging surface (a planar patch) is 900 x 900 pixels, each pixel is .05 millimeters in each dimension and that the principal ray intersects the imaging surface in the center.

   Let the image (or retinal) coordinate system have its origin at the upper left corner of the imaging sensor, the *x*-axis along the top-row and the *y*-axis points downward (at an acute angle of 88 degrees to the *x*-axis). Assume that the x-axis in the image plane is parallel to the $\hat{x}$-axis in the normalized image plane.

   Now suppose that the camera is placed in a world coordinate system (O_w, X_w, Y_w, Z_w) such that O_c is at location (2, 3,-5) in the world coordinate system (all distances expressed in meters); X_c is parallel to X_w and then the camera is rotated by 10 degrees about the X_c axis in a clockwise direction (visualize as a person taking a picture with camera pointing down slightly). All questions below correspond to this configuration.

   a) Compute the final projection matrix, M (as used in equation 1.16 of the FP book, or slide 22 of Lecture 4 notes). Note that M will transform a given point $(X, Y, Z,1)^T$ in the world coordinates (expressed in meters) to the image coordinates, $(x, y, 1)^T$, expressed in pixel units (ignore the issue of rounding off pixel coordinates to integers).

   b) Compute the vanishing point of vertical lines in the world (i.e. lines parallel to the Y_w axis) in the image coordinates.

c) Consider a set of parallel lines in the horizontal plane (i.e. the X_w, Z_w plane). Find the vanishing point, in the image coordinates, of this set of lines in terms of the direction of the lines. Again, you may use any equations given in the book or in class but derive any other equations that you make use of (if any). You are encouraged, but not required, to use projective geometry formulation.

d) Show that the vanishing points of the horizontal lines lie on a line in the image plane. Derive the equation of this line, also called the horizon line. Again, you may use any equations given in the book or in class but derive any other equations, if any, that you make use of. You are encouraged, but not required, to use projective geometry formulation.

Note: For parts (b), (c) and (d) above, you may use any equations given in the book or in class but derive any other equations that you make use of. You are encouraged, but not required, to use projective geometry formulation.