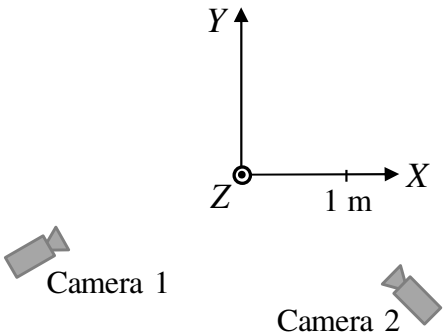
KIN 523 Winter 18
Homework 2 – Motion Capture Pavol

Due: 1/30/18

Answer the following problems.
You must show all work, including formulas used, numbers substituted, and answers with units.
If Excel was used, e-mail a copy of the workbook to me.
If a computer program was used, either attach or e-mail me a copy of the program.
Your written portion must indicate what equations were used in Excel and/or your program.

You are performing motion capture with 2 cameras, positioned as shown in the figure to the right, at heights (Z) of 1 m and 0.7 m, respectively. During motion capture, a point within a camera's field of view will appear at a location (u,v) in the camera's image, where u and v are the horizontal and vertical locations within the image, respectively. The relationship between the (X,Y,Z) position of a point in 3-D space and its position u in the camera's image is given by the Direct Linear Transformation (DLT):



$$u - \Delta u = \frac{L_1X + L_2Y + L_3Z + L_4}{L_9X + L_{10}Y + L_{11}Z + 1} \qquad \text{(eq. 1)}$$

where Δu is the lens distortion. Each camera has a sensor that is 1024 x 1024 pixels, such that u and v can both range in value from 1-1024.

1. *(2.8 pts)* To calibrate Camera 1, you film 7 control points with known (X,Y,Z) locations and record the corresponding horizontal positions, u, of these points in the camera image. You find the following:

Control Pt.	X (m)	Y (m)	Z (m)	u (px)
1	0	0	0	367.6
2	0.3	0	0	323.8
3	0.8	0	0	268.1
4	0	0.4	0	518.4
5	0	1.0	0	703.4
6	0	0	0.3	357.9
7	0.8	1.0	0.3	552.4

px = pixel

Assume that $\Delta u = 0$ for Camera 1. What are the *values* and *units* of L_1, L_2, L_3, L_4, L_9, L_{10}, and L_{11} in equation (1) for Camera 1?

Hint: With the 7 control points, you have 7 equations and 7 unknowns.

You perform a similar calibration for Camera 2 and find the following values for the L_i constants for Camera 2, relating pixels to meters (i.e. in the same units as for Camera 1):

L_1	L_2	L_3	L_4	L_9	L_{10}	L_{11}
-551.0	-160.5	-89.7	689.9	-0.381	0.381	-0.175

During the calibration, you also find the following lens distortion function for Camera 2:

$$\Delta u = L_{12}(u - u_0) r^2 \qquad \text{(eq. 2)}$$

where:

$$r^2 = (u - u_0)^2 + (v - v_0)^2 \qquad \text{(eq. 3)}$$

with the constants:

u_0 (px)	v_0 (px)	L_{12} (px^{-2})
512	512	-4.0×10^{-7}

2. After calibrating the cameras, you film the motion of a marker located on the top of small robotic vehicle as the vehicle moves about the room. You film the marker at 30 frames/s. You know that the Z position of the marker is 0.15 m throughout the movement. A comma-delimited text file "Marker.csv" has been posted to Canvas with the resulting camera data. The first row of the file contains header information. Each subsequent row comprises a frame of data:

Column	Contents	Units
1	Frame number	
2	u position of the marker in the image of Camera 1	px
3	u position of the marker in the image of Camera 2	px
4	v position of the marker in the image of Camera 2	px

   a. *(0.3 pts)* Compute the time that corresponds to each frame. The first frame of data corresponds to a time of zero.

   b. *(0.5 pts)* Use equations (2) and (3) to compute the value of Δu for Camera 2 as a function of time for the marker data recorded.

   c. *(3.1 pts)* Using the results of problems 1 and 2(b) with the other information given, find the (X,Y) position of the marker as a function of time.

      Hint: Because the Z position of the marker is known, you will only have 2 unknowns in each DLT equation.

   d. *(0.4 pts)* Create a table containing the results of problems 2(a), 2(b), and 2(c), with appropriate formatting.

e. *(0.4 pts)* Graph the marker *Y* vs. *X* position from problem 2(c). The graph must show the individual data points, connected by lines. Axes must be labeled with a descriptor and units.

f. *(1.2 pts)* For the marker motion that was filmed in this problem:

   i) Were the camera placements appropriate?

   ii) Were the locations of the control points used to calibrate Camera 1 in problem 1 appropriate?

   iii) Was 30 frames/s an appropriate frame rate at which to film the marker?

   Give a *brief* justification for your answers for each part. Also, if your answer is that the camera placements, control points, and/or frame rate were inappropriate, state how you would change them to make them more appropriate.

g. *(0.4 pts)* Could we have used just 1 camera to accurately capture the motion of the marker in this problem?

   If *yes*, explain and justify what changes to the set-up and/or additional calibration information would be needed to accurately capture the motion using 1 camera.

   If *no*, explain and justify why more than 1 camera is needed.

3. *(0.3 pts) Briefly* explain why it would be of benefit to use more than 7 control points in the calibration procedure of problem 1.

   Note: In problem 1, we did not use the *v* position of the control point in the camera image to calibrate the camera. If we had, we would only have had to film 6 control points, but the equations would have been harder for you to solve.

4. *(0.6 pts)* In general, what would be ***two*** potential benefits of using 3 cameras instead of 2 to capture the 3-D motion of a marker? *Briefly* explain how/why each benefit results.