ECEn 631 3D Reconstruction and Trajectory Estimation

Objectives:

- Learn to obtain 3D information of points of interest.
- Learn to track the baseball location in the image accurately.
- Learn to obtain 3D information of the baseball.
- Use the detected x, y, and z coordinates of the baseball to estimate ball trajectory

Instructions:

- Use the **Baseball Catcher system in Room 408 EB** to complete this assignment.
- This assignment will help prepare you for your baseball catcher team project. Save your code and reuse it later.
- Write your own code to read in the images to perform the tasks for this assignment.
- All team members can use the same image sequence for this assignment.
- Generate a PDF file that includes (with proper headings) a pair of stereo images and X, Y, and Z coordinates for all selected points (Task 1), five stereo image pairs with ball location highlighted (Task 2), and data points and trajectories in two graphs (Task 3).
- Submit your PDF file and source code file(s) in one zip file without the folder or directory.
- Use your first name and last name (e.g., justinsmith.zip) as the file name.
- Login to myBYU and submit your work through BYU Learning Suite online submission.

Image Acquisition:

- Read the Baseball Catcher User Guide carefully before you operate the baseball catcher.
- Create a team folder for your team in the Baseball Catcher system in 408EB.
- Check the "Use Camera" box and set the maximum number of frames to acquire.
- Uncheck the "Display" button so the system can capture images as fast as the camera framerate allows.
- Select "Sequence" and the "Capture Frames" button to capture stereo image sequences of the baseball.
- Have one of your team members feed the baseball into the pitching machine.
- Click "Capture Frames" button immediately after the baseball leave the pitching machine.
- You may/should implement a ball detection function to trigger the acquisition so you can capture the sequence from the very first frame. You need it for the Baseball Catcher project anyway.
- Click "Replay Sequence" to examine the stereo image sequences. Repeat until you are satisfied with the image quality.
- Select "Stereo" and click the "Save Sequence" button to save both the left and right image sequences. A folder (yyyymmddhhmmss) and two subfolders (/L and /R) will be created to save the captured left and right image sequences.
- Copy these images to your thumb drive or cloud drive and remove them from the computer hard drive (**empty the recycle bin**).

Task 1: 3D Measurement 30 points

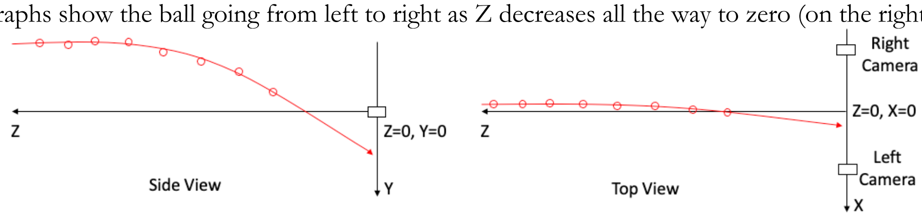
- Select one pair of chessboard images from your stereo calibration image sequence from the Stereo Calibration and Rectification assignment for this task.
- Use OpenCV function findChessboardCorners() to find chessboard internal corners.
- Use OpenCV function cornerSubPix() to refine corner locations.
- Use undistortPoints() and your calibration parameters to undistort AND rectify the 4 outermost corner points.
- Use perspectiveTransform() and your calibration parameters to calculate the 3D information of the 4 outermost corner points.
- List these four corner points in the order of upper left, upper right, lower left, and lower right.
- This is a good exercise for you to check if your 3D measurement code works correctly.
- Repeat the above steps for both left and right images.
- You need to calculate X, Y, and Z measurements w.r.t. BOTH left and right cameras and obtain two sets of measurements.
- Include the stereo image pair with the four outermost corner points circled and their 3D (X, Y, and Z) information measured w.r.t. the left camera and right camera in your PDF file. Prove your result is correct by comparing the X, Y, and Z measurements from the left and right cameras using $P_l = RP_r + T$ if you use triangulation for general configuration (Lecture 14 Slide 29) or $P_l = P_r + [\|T\| \quad 0 \quad 0]^T$ if you use the reprojection matrix Q from rectification (Lecture 14 Slide 17). You should also compute the actual distance between two points on the chessboard.
- Submit your code for this task.

Task 2: Baseball Tracking 20 points

- Use the baseball stereo image sequence you have captured for this task.
- Estimate and process the region of interest of each image frame to reduce processing time.
- Detect and track the baseball in your left and right image sequences.
- Include the 5th, 10th, 15th, 20th, 25th, and 30th frames (starting when the baseball is detected) from both sequences with the region of interest and ball location highlighted in your PDF file.
- Submit your code for this task.

Task 3: Baseball Trajectory Estimation 50 points

- Calculate 3D baseball location from every pair of the entire stereo sequences in inches w.r.t. the left camera.
- Transfer 3D points to the catcher's coordinate system (midpoint of between the left and right cameras)
- Plot one graph of the ball location with the Y and Z coordinates and one graph of the ball location with the X and Z coordinates. Keep the coordinates the SAME SCALE when you plot the graphs to avoid visually distorting the trajectory.
- Make sure your graphs show the ball going from left to right as Z decreases all the way to zero (on the right).



- Mark all data points in both graphs and plot the entire estimated trajectories and calculate the final X and Z when Z is zero.
- Explain how you estimate the ball trajectory and calculate and report the final X and Y measurements when Z=0.
- Include these graphs in your PDF file.
- Submit your code for this task.

Congratulations! You are ready to start your baseball catcher project. It is suggested that you integrate the code you have developed for this and the previous assignments into your team's baseball project so that your team can calibrate the stereo system easily and whenever it is needed. It is important that you can write your calibration parameters into a file after you calibrate the system and read them back into your program every time you start your program.