ECEn 631 Stereo Calibration and Rectification

Objectives:

- Learn stereo camera geometry.
- Learn to calibrate stereo system using OpenCV functions.
- Learn to rectify stereo images.

Instructions:

- Use the **stereo system in Room 250 B34** to complete this assignment.
- This assignment will help prepare you for your baseball catcher team project. Save your code and reuse it later.
- Learn to use the baseball project code to capture images for this assignment.
- You should ask your team members to help you capture the images (one holds the chessboard and one clicks the button)
- Write your own code (like previous assignments) to read in the images you have saved to calibrate the system.
- Team members can use the same images for this assignment.
- You can download the practice images and data online from BYU Learning Suite to confirm that your code works before using your own images.
- You will lose 20 points if any of the following requirements is not met:
  - Generate a PDF file that includes (with proper headings) two sets of intrinsic and distortion parameters (Task 1), extrinsic parameters and essential and fundamental matrices (Task 2), two images with epipolar lines (Task 3), two original, rectified, and absolute difference images (Task 4), and your explanations.
  - 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:

- Create a copy of the baseball project code for your team in the system.
- The baseball project code allows you to capture one set of 32 stereo images in bitmap format at a time.
- Set delay time between frames (the Delay (mSec) Edit Box). 200 ~ 300 mSec is a good selection.
- Click "Grab" to show the live video on the image display screens.
- Have one of your team members hold the chessboard in front of the camera(s) and move the chessboard around.
- Make sure the chessboard stays in the view of both cameras. You may have to experiment a little to determine the view boundary.
  - Make sure you step back and forth until the images are in focus, especially around the edges.
  - Make sure the lighting isn't too bright above the calibration board, if the squares get washed out, the calibration parameters will not be very good. Tilting the board slightly forward helps remove glare a little.
  - Make sure the entire frame is visible. Move bookshelves and other obstructions if needed to make sure the calibration grid is visible in as much of the frame as possible.
  - You can capture and use as many images as you want. In general, using more images gives you better calibration result.
- Click "Capture Images" button. The frame number will be shown in green in the upper left corner of the left screen.
- Change the delay time back to 30 mSec and click "Replay Images" to examine the images. Repeat the entire procedure until you are satisfied with the image quality.
- Click "Save Images" to save the images. Type in the file name in the "File Name" box. You need to select the folder and type in the file name (e.g., C:\Projects\BaseballCatcher - team#\Images).
- The program will automatically add the letter "L" or "R" and a sequential number to each file. You will get 32 images for the left camera (ImgL0.bmp ... ImgL31.bmp) and 32 images for the right camera ((ImgR0.bmp ... ImgR31.bmp) in the folder you select.
- You should calibrate two cameras separately in order to get good intrinsic and distortion parameters for each camera (Task 1).
- You can then use the two sets of intrinsic and distortion parameters (one set for each camera) to calibrate the stereo system (Task 2).
- You will capture total three sets of image pairs for this assignment. The first set is for calibrating the left camera. The second set is for calibrating the right camera. The third set is for calibrating the stereo system.
- The Baseball program will automatically capture 32 pairs at a time. You only need the left images for the left camera (the first set) and the right images for the right camera (the second set). You will need both left and right images for stereo calibration.
- When capturing 32 good images for **single camera calibration**, you want to move the chessboard around so that the entire camera view is covered. Don't worry about what is seen by the other camera (you won't need them and will delete them anyway).
- When capturing the stereo pairs, you need to make sure that the entire chessboard is seen by both cameras.
- Copy these images to your thumb drive and remove them from the computer hard drive (**empty the recycle bin**).

The chessboard made for this assignment and the baseball project has 3.88-inch black and white squares. The x and y coordinates of the chessboard 3-D points entered to the calibration function should be multiplied by 3.88. The z coordinates stay the same (0).

Task 1: Camera Calibration 25 points

- You can download practice images and the resulting calibration parameters from Learning Suit to confirm that your code works. Please note that the stereo system used to capture these images is different (lens focal length, baseline, and chessboard size) from the system for the baseball catcher. Read the instruction carefully.
- Capture 32 or more good chessboard images for each camera at approximately 25 feet away.
- Find chessboard corners (subpixel) and do cameraCalibrate() for each camera.
- This task is the same as Task 2 in Assignment 2. You can reuse the code and don't have to submit the code again.
- Include one set of the intrinsic (3×3) and distortion (1×5) parameters for each camera in your PDF File.

Task 2: Stereo Calibration 25 points

- Capture one set of stereo images (32 pairs).
- Use the two sets of intrinsic and distortion parameters calculated in Task 1 and the OpenCV stereoCalibrate() function to obtain a unique set of extrinsic parameters between the two cameras, an essential matrix and a fundamental matrix.
- Include the extrinsic parameters (3×3 R and 3×1 T), essential matrix (3×3), and fundamental matrix (3×3) in your PDF file.
- Submit your code for this task.

Task 3: Epipolar Lines 25 points

- Select one pair of images from your stereo image pairs for this task.
- Use undistort () to undistort lens distortion for both images. Selected 3 points of interest from the left image and 3 **different** points from the right image and draw a circle around them on their respective image.
- Use the fundamental matrix from Task 2 and computeCorrespondEpilines() to find and draw 3 epipolar lines of the selected 3 points for each image. The epipolar lines found for the three points in the left image should be drawn in the right image and vice versa. Confirm that the corresponding points lie on their epipolar lines in the other image.
- Include both images with the superimposed colored epipolar lines in your PDF file.
- Submit your code for this task.

Task 4: Rectification 25 points

- Select one pair of images from your stereo image pairs for this task.
- Use stereoRectify( ), initUndistortRectifyMap( ), and remap( ) functions to rectify both left and right images.
- Confirm that the image rows are aligned by drawing a few horizontal lines in both rectified images.
- Include the two original images and the two rectified images in your PDF file.
- Include the two absolute difference images (between the rectified and original images) in your PDF File.
- Submit your code for this task.