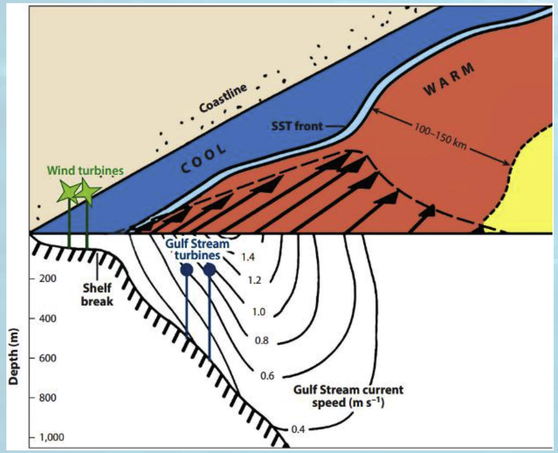
A COMPUTER VISION APPROACH TO CAPTURE THE WORLD COORDINATES OF A TETHER IN A TURBINE SYSTEM

Kaibin WEN (kwen@ncsu.edu), Zunyao MAO (zmao6@ncsu.edu), Gengshuo LIU (gliu22@ncsu.edu)
Department of Mechanical and Aerospace Engineering, NC State University, Campus Box 7910, Raleigh NC 27695-7910

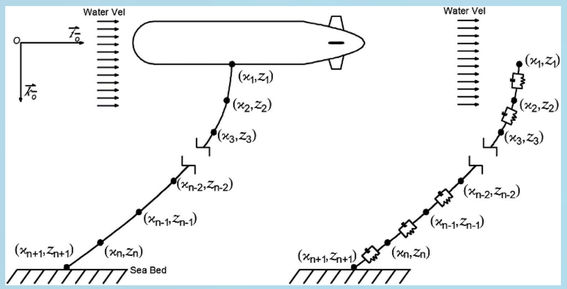
➢ Introduction

The North Carolina coast has a large source of hydrokinetic energy (energy in water flow) contained in the Gulf Stream. A mobile underwater turbine system is developed to harvest the energy. The system is connected by a tether to the sea floor and the motion of the tether is to be determined.



➢ Objective

Our study aims to build an experiment to test the motion of the tether. Use the experimental results to verify the math model developed by former researchers.



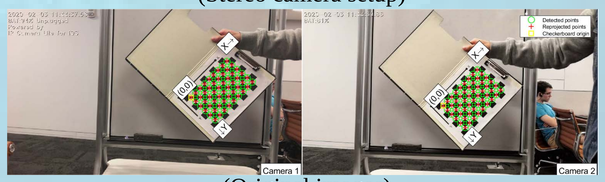
➢ Methods

- Build a tank to move the tether in it using a motor. The motion of the tether will be rather complex.
- Mark the tether on separate points with different colors.
- Set up 2 cameras around the tank to take videos.
- Process the videos and reconstruct the real world coordinates of the markers using stereo vision technology.

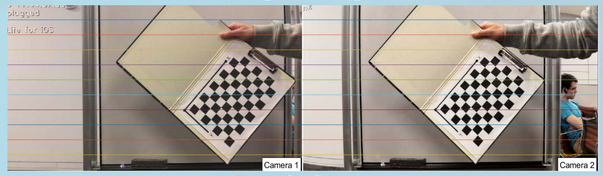
➢ Camera Calibration

The camera is a projection of the 3D world to a 2D plane, and it has distortion from the real world (Skew and tangential distortions). Using a number of chessboard images we can calibrate the cameras and rectify the images. (There are 12 image pairs in this example)

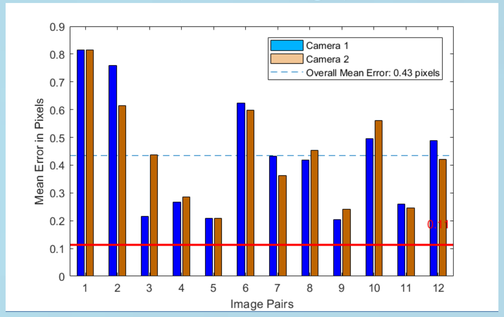
(Stereo camera setup)



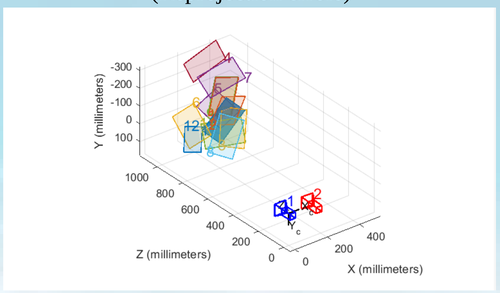
(Original images)



(Rectified images)



(Reprojection errors)



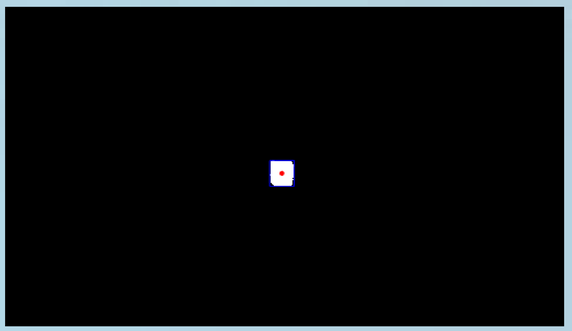
（A calibration example of the camera on iphone8 (left) and Huawei honor10 (right) using MATLAB stereoCameraCalibrator App)

➢ Camera synchronization

Two cameras start at different time. We use audio matching to synchronize them. The microphones on both cameras are turned on, so we can use some video editing software to match the audio taken from the environment. The software we used is Adobe Premiere Pro CC.

➢ Image Coordinates Tracking

The tether is marked with different colors on separate points. By using the computer vision algorithm we can filter out the background colors and only track one color point at a time. By changing parameters, we can get the pixel coordinates of every point.

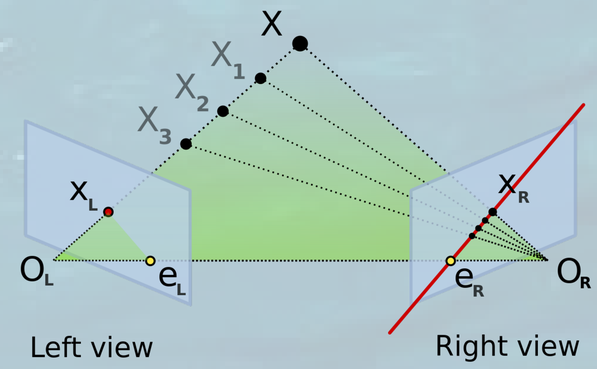


(We do not have a tether model to run the experiment, so we use a metal rod instead.)

➢ 3D coordinates reconstruction

Now we need to combine the videos of the cameras together to get real world coordinates. The function of multi-camera is similar to our eyes. So we use two cameras which can establish a stereo vision. The way to find the real world coordinates is called epipolar geometry.

When a photo is taken, 3D points are projected onto a 2D plane, so the depth information is lost. By combining two cameras from different angles, the depth can be restored.



(A demonstration of epipolar geometry)

➢ Results

Using the algorithms in MATLAB and OpenCV, we can find out the 3D coordinates of a color point with respect to the one camera's position. Simply processing each frame of the videos, we can get the coordinates of a marker in a certain time period.

➢ Conclusion

- 3D reconstruction is a popular topic nowadays in computer vision technology. In this experiment, we tracked separate markers on the tether to build up the motion and shape of the actual tether.
- Using two cameras as a stereo pair can give us the 3D coordinates. If more accuracy is required, we can set more stereo camera pairs in different angles and compare the results to reduce errors.

➢ References

- Tandon, S., Divi, S., Muglia, M., Vermillion, C., & Mazzoleni, A. (2019). Modeling and dynamic analysis of a mobile underwater turbine system for harvesting marine hydrokinetic energy. *Ocean Engineering*, *187*, 106069. doi:10.1016/j.oceaneng.2019.05.051
- Camera Calibrator. (n.d.). Retrieved from https://www.mathworks.com/help/vision/ug/stereo-camera-calibrator-app.html
- Scratchapixel. (2014, November 22). Computing the Pixel Coordinates of a 3D Point. Retrieved from https://www.scratchapixel.com/lessons/3d-basic-rendering/computing-pixel-coordinates-of-3d-point/mathematics-computing-2d-coordinates-of-3d-points
- Epipolar Geometry. (n.d.). Retrieved from https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_calib3d/py_epipolar_geometry/py_epipolar_geometry.html
- matlab-双目标定及场景重建. (n.d.). Retrieved from https://blog.csdn.net/osunbo/article/details/53698618