Visual Navigation of Airboat to Recharge Station

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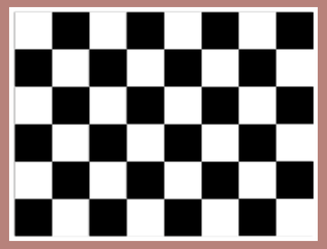
INTRODUCTION

Airboat is designed for small bodies of water. It helps monitor the water quality parameters such as dissolved oxygen and pH .

Airboat used to be guided by GPS. However, because of the inaccuracy of GPS, this method cannot satisfy the requirement that the boat need to reach a specific point accurately. For example, when the boat is out of charge, it needs to go back to the recharge station. In this case, the boat has to use other guidance method. Visual guidance is one of the most common methods.

Platypus Airboat



Checkerboard

A checkerboard is put on the recharge station as a marker to be recognized by camera. By analyzing the corners of checkerboard, the position relation between camera and marker can be acquired. In this way, camera help finish the guidance task even when GPS does not work.

Method

We use Raspberry Pi 3 Model B and Pi Camera to acquire all the image data and process the images with OpenCV.

Raspberry Pi 3

Raspberry Pi Camera

- Get the intrinsic parameters of camera

- Fix the intrinsic parameter and acquire the extrinsic parameters like rotation matrices and translation vectors every 0.25 meters forward from 5 meters

```
rvecs:
  - !!opencv-matrix
    rows: 3
    cols: 3
    dt: d
    data: [ -3.5624646044696284e-03, 7.5523197212496529e-01,
        6.5544792098699789e-01, 9.9892306155285893e-01,
        -2.7634053494423716e-02, 3.7270312385742910e-02,
        4.6260414436161745e-02, 6.5487481808945991e-01,
        -7.5432018844022153e-01 ]
```

Rotation Matrices

```
tvecs:
  - !!opencv-matrix
    rows: 3
    cols: 1
    dt: d
    data: [ -5.5232572565973931e+02, -1.7195133164996869e+02,
        4.3139687874719721e+03 ]
```

Translation Vectors

- According to image-forming principle, the distance between two projective points changes with the distance between camera and checkerboard

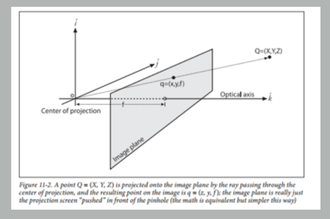


Figure 11-2. A point Q = (X, Y, Z) is projected onto the image plane by the ray passing through the center of projection, and the resulting point on the image is q = (x, y, f); the image plane is really just the projection screen "pushed" in front of the pinhole (the math is equivalent but simpler this way)

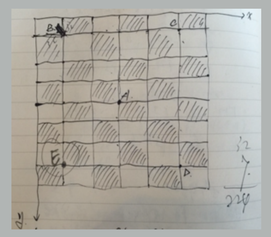
The Relation Between image and camera coordination

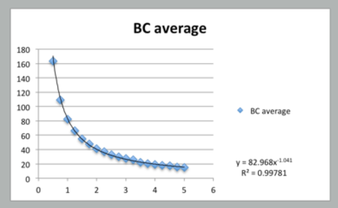
$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = R \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + t$$

$$x' = x/z$$
$$y' = y/z$$
$$u = f_x * x' + c_x$$
$$v = f_y * y' + c_y$$

Translation Formulas

- (X,Y,Z) are the coordinates of a 3D point in the world coordinate space. [R|t] is a matrix of extrinsic parameters. Coordinates of a point (X,Y,Z) can be translated to a coordinate system, fixed with respect to the camera, with the formulas above (f_x, f_y, c_x, c_y are intrinsic parameters)





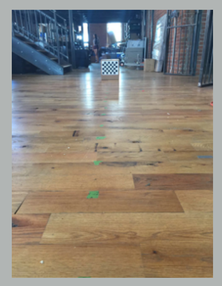
The Relation Between BC and Real distance

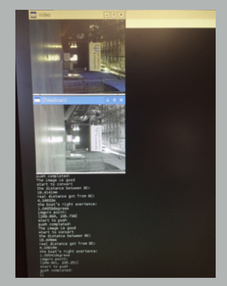
- The distance between projective points of point B and C could better reveal the real distance. The relation can be seen in the following chart and the formula can be fitted as $y=82.968x^{-1.041}$

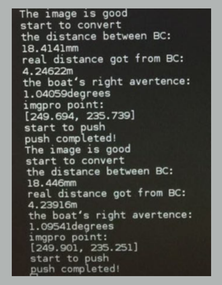
- When the camera sways from side to side, the vertical coordinate of a specific projective point is fixed, but the horizontal coordinate will change. This change can be used to measure the deflection.

RESULT

- The position information can be revealed in the screen in real time. However, since time is limited, the raspberry pi has not been connected to the main control E-board. The rest future work will be done in the following 2 months





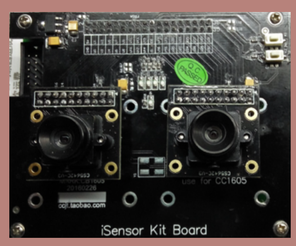


- *Upper Left is the actual testing scene*
- *Upper Right is the result on the screen*
- *Below is the position information we got*

Future Work

- ☞Connect the raspberry pi to the odroid and complete the PID control algorithm with the data from camera
- ☞Test the program on the boat in real lake
- ☞Use binocular vision to increase the accuracy

Testing in Real Lake



Binocular Camera Module

Binocular Vision

PLATYPUS

Carnegie Mellon University