Visual servo-ing for passing through unknown free spaces

1st Venkateshkrishna
Masters in Robotics
Worcester Polytechnic Institute
Worcester, MA 01609
vparsuram@wpi.edu

2nd Athithya, Lalith
Masters in Robotics
Worcester Polytechnic Institute
Worcester, MA 01609
lnavaneethakrishnan@wpi.edu
(using 2 late days)

3rd Gampa, Varun
Masters in Robotics
Worcester Polytechnic Institute
Worcester, MA 01609
vgampa@wpi.edu

***Abstract*—This project focuses on estimating the center of an unknown free space, and making the drone fly though them. For this project, using optical flow, we were able to estimate the contour of the free space in the wall infront of the drone. Post which using visual servo-ing, the drone hovers around parallely to the wall, till the center of contour of free space aligns with the center of camera, that is, the center of fre space is infornt of the drone. Then the drone is given the command to fly straight, which would pass through the free space in the wall.**

I. Introduction

In this project, we describe the pipeline developed to detect the free space and align the quadrotor, allowing it to pass through the obstacle without crashing in. We have used, Spynet for generating the optical flow. Spynet takes in two images, generally the position of camera for both the images, is very slightly different. In these images, it can be seen, in the images, the objects which are far away move very less, whereas objects which are closer, would shift much more. The deep learning model developed, is trained on such pairs of images and generates the optical flow. Hence objects which are closer can be segmented, as the optical flow would show that the wall. And the wall which is behind would have a different optical flow model. Hence, we can find the portion in the image, where the optical flow on the wall is different. The contour of the hole in the wall is then extracted using threshold and contouring techniques. Then the center of the hole is found as the center of contour. Next, based on the position of the center of the contour, velocity control is used to move the drone. A simple PI controller is used for this purpose. After the center of the contour, is in the center of the image (within an error bound), then drone is made to fly straight to pass through the wall.

II. Using Spynet for optical flow generation

Spynet is a lightweight network for generating optical flow. It works significantly well if the poses of the camera between two images is very less. This is done, as we need to evaluate the deep CNN on the Nvidia Jetson Orin Nano during runtime. The network evaluation time for this network is about 0.35 seconds.

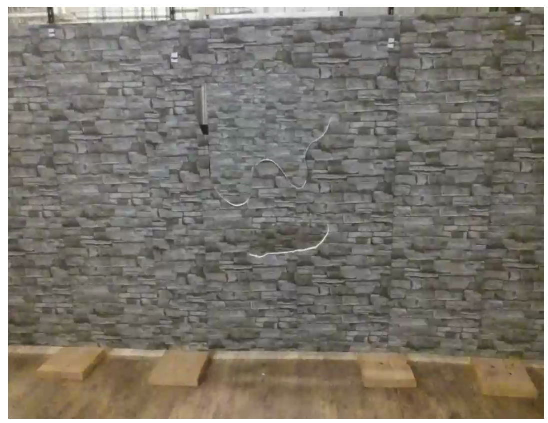

Fig. 1. Front and back wall, with hole in the front wall

III. Contour generation

After optical flow is generated, then it is converted to an rgb image, where each pixel would show, how much that corresponding pixel moved. As the majority of the image is the wall and the wall behind front wall, the pixel intensity of the wall behind, which can be observed through the wall would be different. We then converted the image to a gray scale image, and using adaptive thresholding the hole in the wall is segmented. Then using opencv's contour function, we find the contour of the hole and it's center.

IV. Visual servoing

Once, the center of the contour is found in the image. Depending on it's position, the velocity control is applied to the drone, to move the drone such that the center of the contour lies in the center of the image. A PI controller is used for velocity control. This cycle is repeated till the center of the contour lies in the center of the image. The time for each cycle is about 0.4 seconds.

V. Results

We see that the drone is able to navigate through the free space in the wall. Optical flow generated in blender is shown. Using the ground truth, intersection over union (iou) is calculated. It is seen that the iou is above 80%.

Fig. 2. Picture from the live demo

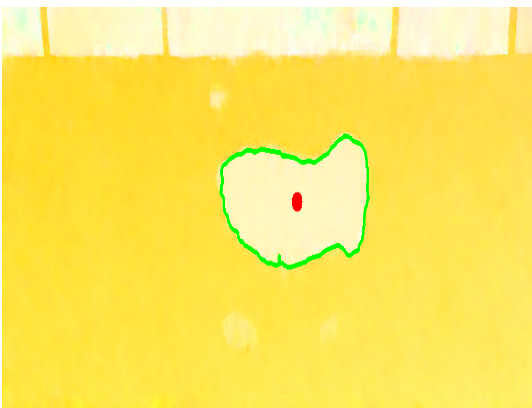

Fig. 3. The detected gap

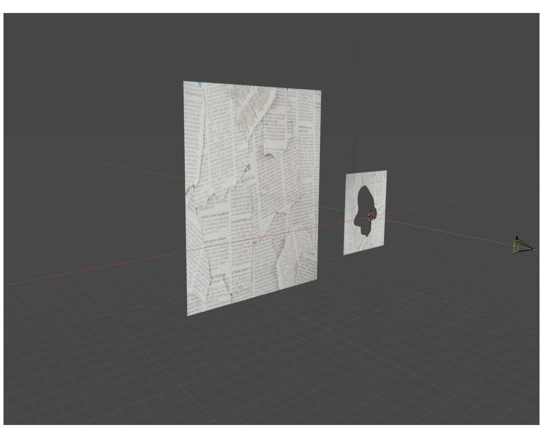

Fig. 4. Blender visualization

Fig. 5. Thresholded image of blender simulation

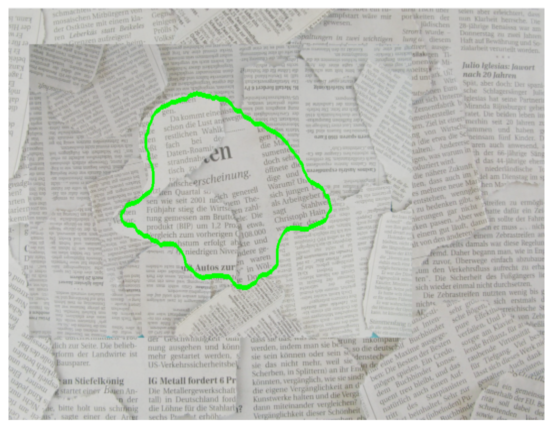

Fig. 6. Contour on blender rendering

Fig. 7. Ground truth

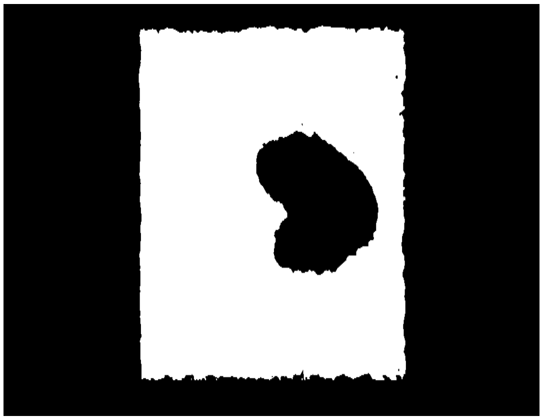

Fig. 8. Thresholded image 2 of blender simulation

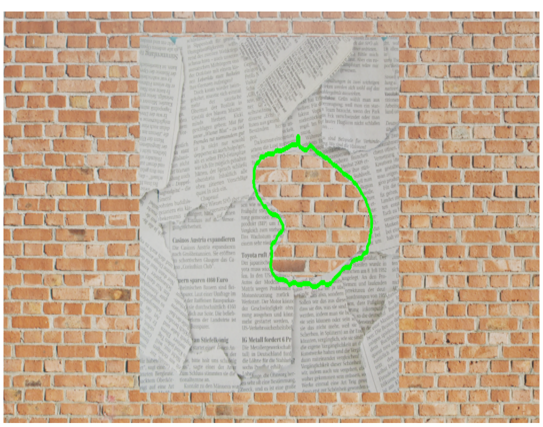

Fig. 9. Contour on second blender rendering

VI. Videos

A video of the footage of the drone navigating the obstacle course is shared in the folder under the name runVideo.mp4

VII. Conclusion

In this project, we built the pipeline for navigating through unknown gaps. This is done using the video from DJI Tello's onboard camera which has a resolution of 720x960. The detection and navigation is done in real time.

References

[1] Spynet: link