ROBT502 – ROBOT PERCEPTION AND VISION

Laboratory Report 6

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1. Introduction

This report presents the processes and results of camera calibration, image stitching, and the subsequent use of a stitched map for robot navigation.

2. Camera Calibration

The camera calibration was initiated by capturing multiple photos (41 samples) of a chess board from various angles with the provided camera (In our case *Camera - 1*). The calibration was carried out using OpenCV, supported by code sourced from GitHub repository (Python version). After running the code we could obtain the camera matrix (see formula below), which included the focal length and further used to calculate the camera's angle of view. The intrinsic camera matrix typically has the form:

$$\text{cameraMatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}$$

where,

- f_x : The focal length of the camera in terms of pixels along the x-axis.
- f_y : The focal length of the camera in terms of pixels along the y-axis.
- c_x : The x-coordinate of the optical center of the camera.
- c_y : The y-coordinate of the optical center of the camera.

The camera matrix and undistorted image we have obtained from 41 samples are shown below.

Fig. 1. Undistorted image

```
In [36]: cameraMatrix

Out[36]: array([[1.03350085e+03, 0.00000000e+00, 3.13826153e+02],
                [0.00000000e+00, 4.87478413e+03, 2.41659048e+02],
                [0.00000000e+00, 0.00000000e+00, 1.00000000e+00]])
```

Fig. 2. Camera matrix

3. Image Stitching

Following calibration, the undistorted images of the labyrinth were stitched together to create a panoramic map. We have used another piece of code from a recommended GitHub repository, designed specifically for image stitching purposes. Let's delve into various methods commonly used for image stitching.

Feature-Based Stitching: This is the most common technique where distinctive points (features) are identified in each image using algorithms like SIFT or SURF. These features are matched across images, and a transformation matrix is calculated to align and blend the images seamlessly.

Direct Stitching: This method uses the pixel values directly rather than relying on feature detection, making it suitable for images with little texture. It includes aligning images based on pixel intensities and often employs techniques like optical flow.

Frequency Domain Stitching: Here, images are transformed into the frequency domain using a Fourier Transform. Alignment is determined using phase correlation, which finds the shift needed to align the images. The stitched image is obtained by applying the inverse transform.

Projection-Based Stitching: This involves projecting images onto a common surface such as a cylinder or sphere, which is especially useful for 360-degree panoramas. The projection aligns the images before they are stitched together.

For this lab, we attempted to apply *Panorama stitching* and the *Brute-Force matcher*, both of which yielded poor results as illustrated below.

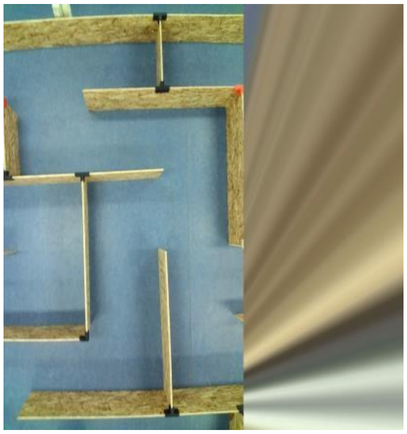

Fig. 3. Camera 1 and 2 image stitching

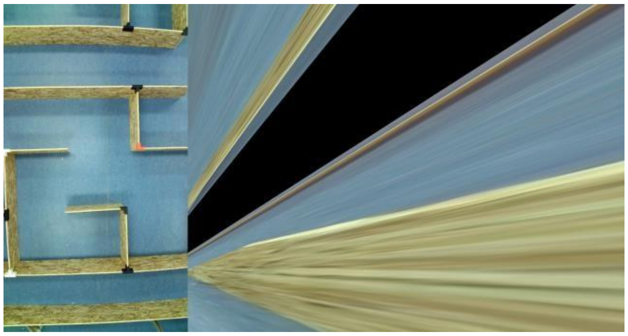

Fig. 4. Camera 5 and 6 image stitching

We suspect the poor results stem from the following issues:

- *Misalignment* (images don't align correctly) – We have noticed that cameras are moved significantly between shots and there were changes in perspective that the stitching algorithm couldn't compensate for.
- *Parallax Error* – Images are taken from different viewpoints, and nearby objects shift position relative to distant objects across the frames. Stitching algorithms often assume a single viewpoint and can struggle to reconcile these shifts.

Given these challenges, we attempted to stitch the images using Photoshop, as shown in the figures below.

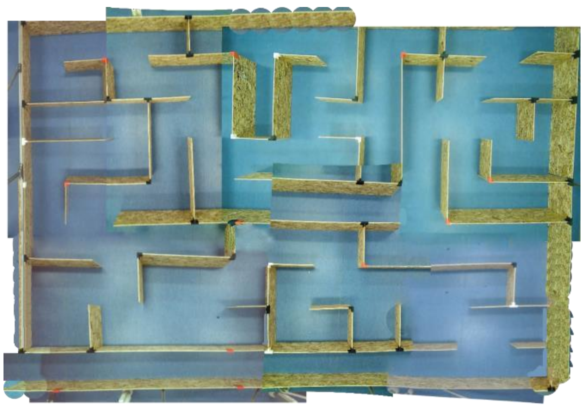

Fig. 5. Manual Stitching

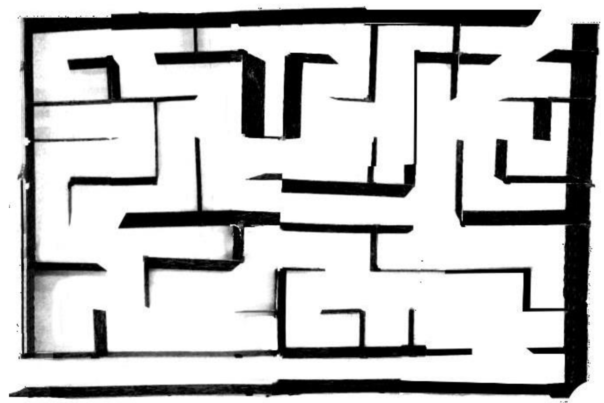

Fig. 6. Contrasted and Gray Scaled Map

4. Testing Navigation on Obtained Map

With the stitched map ready, the subsequent task was to navigate a robot through the labyrinth, utilizing the map as a real-time guide. The simulation of navigation using the stitched map are shown in the attached video. The navigation hyperparameters are the same as in "Lab - 5", but with slight adjustments (*Inflation radius – 0.01*, *Cost scaling factor – 5*).

Video: link