Mobile Robotics

Assignment 1

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Monsoon Semester 2019

INTRODUCTION

This report contains both our approach of solving questions posed in Mobile Robotics, Assignment-1, Spring 2019, as well as the observed outputs of our solutions and inferred results.

Question 1 : LiDAR-Camera Fusion

We have aligned the camera axis to the world axis(i.e. which is also the lidar axis). We've done this by the following transformations,

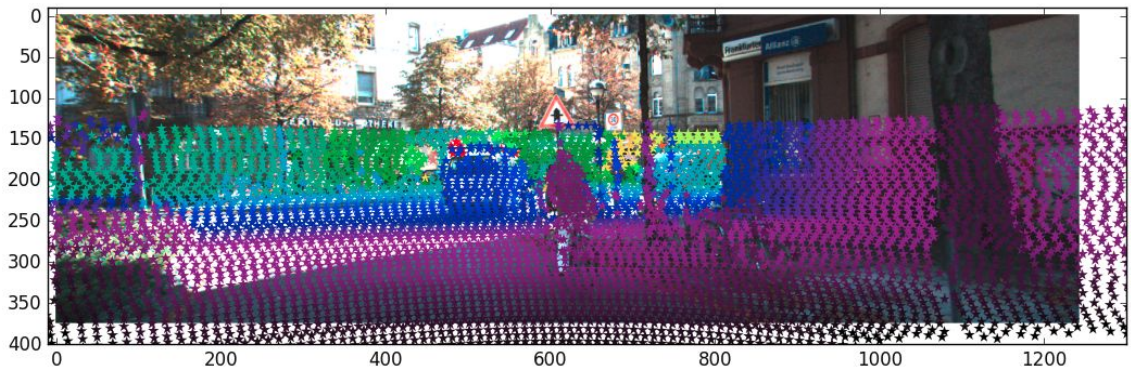
T = [[1, 0, 0, -0.27],
[0, 1, 0, -0.06],
[0, 0, 1, 0.08]]

$R = R_x(-90^*)*R_z(-90^*)$

The transformation R*T when applied on all points in the world-frame, maintain relative geometry w.r.t camera. The final transformation required to get the points from world frame to image plane is

K*R*T

The image with LiDAR points:



Question 2 : Drawing 3D Bounding Box

Following hint given we fix our world origin to be 1.65 meters below the height of the camera taking the image provided.

We start out by taking image coordinates of certain points at which we assume nearest and furthest edge of bounding box would be placed (Front Left Bottom and Rear Right Top). We chose these two diagonal vertices because there was no self-occlusion here. We then calculated car centre (with height added later), and then used below equation to find the translation of the car centre from world origin,

$B = -camera\_height * (K^{-1} * b) / (n * K^{-1} * b)$

Where,

$n = [0,-1,0]$

$b = [(x1+x2)/2, y2 , 1]$

And B is required translation to reach car. We get other coordinates of the required bounding box by adding/subtracting the car's dimensions. Following this, we turn all the 8 obtained vertices of the bounding box by 5^{o} anticlockwise. We then project it back onto the image using the given K matrix.

Below are the results obtained,

Result obtained is quite good and the bounding box fits around the car, in the direction of the car quite well.

Question 3 : How do AprilTags work

We load given image and world coordinates, with world centre being located at the bottom left corner of the first April Tag. We initialize our world and image coordinate lists in homogeneous form. We create the M matrix where M*h = 0 (under an ideal circumstance). Each point co-responds to 2 rows in the M matrix. Dimensions of this matrix are 16 * 9, with each row

$M_{2*i} = [-X_i , Y_i , -1, 0, 0, 0, x_i* X_i, x_i* Y_i , x_i]$

and

$M_{2*i+1} = [0, 0, 0, -X_i , Y_i , -1\ y_i* X_i, y_i* Y_i , y_i]$

for i = 0 ... 7

where $[X_i, Y_i]$ is the world coordinate amd $[x_i, y_i]$ is the corresponding pixel value

But in the real world this is not the case(due to noise), so we try to minimize this. To do this, we take SVD of the M matrix and take the last column of V obtained which corresponds with the lowest eigenvalue.

This column vector corresponding to the minimum eigenvalue contains the elements of the required homography matrix, H. It's reshaped column wise.

Below are the results obtained upon reprojecting world coordinates back onto the image using H.

The red squares mark the points using the computed homography matrix. The ‘*’ in blue are the given pixel values.

Our H matrix:

```
[ 6.82683938e-01,  3.92158646e-01,  2.63315386e-01]
[-2.01127940e-01, -4.67989114e-01,  2.26606230e-01]
[-1.79684666e-04,  1.30160209e-03,  9.35327158e-04]
```

BONUS :

We obtain R and t from H as per the following steps

1. Take the inverse of K. Let's call it K_inv
2. Multiply this with the homography matrix we computed. We call the column vectors of this matrix K_inv*H as h1, h2 and h3
3. We define a matrix M as [h1, h2, h1xh2] where x = cross product.
4. We take an svd of this matrix such that $M = USV^T$
5. The rotation matrix is just $U*V^T$ and t = h3/|h1|

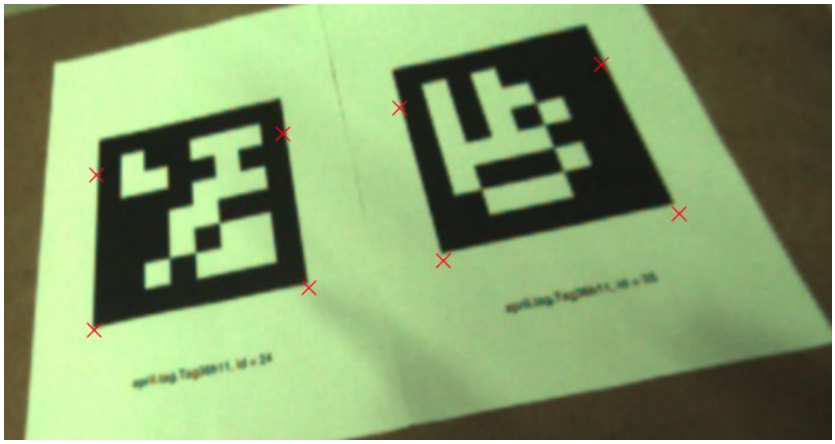
R matrix:

```
[ 0.97595487, -0.10186958,  0.19270361]
[-0.19122705, -0.82445352,  0.53264305]
[-0.10461504,  0.55668572,  0.82410964]
```

T vector:

```
[-0.1030549 ]
[-0.00296763]
[ 0.49536398]
```

We replaced third column of R with t. $K*[R_{3*2}|t]$ * world_co_ords gives us the following plot:



Team member contribution:

- LiDAR-Camera Fusion
  This question was done by Aryan
- Drawing 3-D bounding box
  This question was done by Anirudha
- How do AprilTags work:
  This question was a collaborative effort by both team members