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Title: Udacity 3D-Camera Final Project

FP.1 : Match 3D Objects

The *matchBoundingBoxes* function iterates through extracted image points found in the passed by reference with the matches vector. It compares matched points in the previous and current frames for continuity. If consistent existence of points is found by the *matchPointToBoundingBox* using a ROI of the bounding box, then the points are stored in a local vector *listOfmatches*. If number of the occurrence is updated within a local vector named *listOfMatches*. Otherwise, the loop continues on to the next point in the matches vector. Once all points in the matches vector have been compared, another for loop is used to iterate through all points in the local vector, and store the best points in the bbMatches map.

```
void matchBoundingBoxes(std::vector<cv::DMatch> &matches,std::map<int,int>
              &bbBestMatches, DataFrame &prevFrame, DataFrame &currFrame)
```

FP.2 : Compute LiDAR-based TTC

The time to collision (TTC) was calculated using the following formula:

- *TTC = (minXCurr * dT) / (averageXPrev - averageXCurr)*

The standard deviation of the mean of the distance calculated from the Lidar measurements were not considered in the analysis of the data. Only a simple mean point in the x direction with not removing obvious outliers. With that consideration, the explanation of the above formula, the minXCurr is distance of the closest lidar point from the preceding vehicle. The averageXCurr and averageXPrev are the average distances of lidar points in the current and preceding frames. Improvements could be made to how data is filtered in the with Lidar data by including deviation of the mean to reduce the spread of the data to further improve the results; however, the cost in processing time may determine the level of attention given to the point data, which is better determined with knowing the sensor specifications and typical variances expected from any dataset by that sensor to recommend a best approach.

FP.3 : Associate Keypoint Correspondences with Bounding Boxes

The key point matches are clustered and associated with bounding boxes in the *clusterKptMatchesWithROI* function. A for loop iterates through all points in the *kptMatches* vector checks if the point exists in the given bounding box, and if so, stores it in a vector. Next, the average distance of all points found in the bounding box is calculated. Finally, another for loop again iterates through all the points in the *kptMatches* vector, checks if it's again within the bounding box, and if the current point falls within a distance threshold. If so, the point is stored in that bounding box's key point matches.

FP.4 : Compute Camera-based TTC

The formula used in the *computeTTCCamera* function was adapted from the previous lessons. The TTC was calculated by iterating through all points in the *kptMatches* vector, and each of those points to all other points in the same vector using an inner for loop.

The formula used to calculate the TTC is as follows:

- *TTC = -dT / (1 - medDistRatio)*

The median distance was used to remove any outlier influence.

Performance Evaluation

TTC Lidar estimation varied from 0.2% -12% to the outliers resulting above 35% tended to be with the Harris Corner Detector. The trend showed the number of points above 1000 helped to achieve a good TTC result. It is worth noting our primary concern at this point is a vehicle bumper and structure that may be normal to the xz plane and therefore, edges on a modern vehicle bumper may not be as pronounced as a vehicle turning in front where the side and rear of the vehicle is obtained in the measurement. This would help the Harris detector with edge and corner results than this test case. Having a small number of points to base measurements would explain less than effective detector and descriptor selection for the task. Therefore, would directly affect the accuracy in timing. This can be viewed in the report when the Harris (corner, edge) detector was used in combination with other descriptors types.

A spreadsheet containing the final results can be found in the subfolder:

Dbanks_Final_3D_Camera_Project.csv.