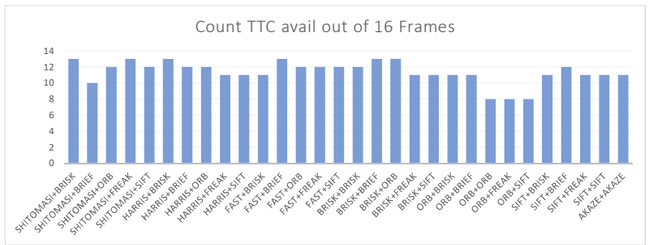
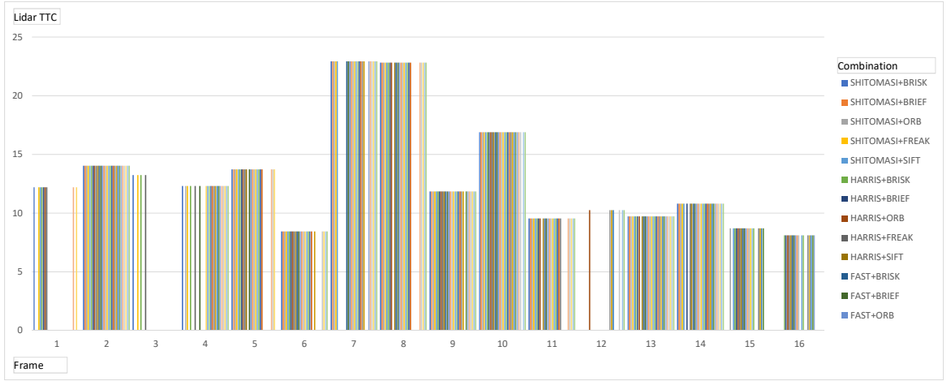
Rubric Point	Solution Description	Further Reference/Code
FP.1 Match 3D Objects	For both frames, Keypoints are tested for being contained in each BoundingBox Then, potential matches are found using keypoints that belong to a bounding box in the new frame are used to find matching keypoints in the previous frame, if they belong to more than one bounding box score for each potential match is increased Finally, for each bounding box in new frame, we choose the bounding box in previous frame with highest score as a match.	matchBoundingBoxes
FP.2 Compute Lidar-based TTC	TTC is calculated based on distance ratio Distance is estimated using nearest LiDAR point on X dimension (vehicle coordinates) To enhance noise rejection, we divide the space in Y dimension into 10cm slots, find nearest point in X dimension in each slot, modelling a rough rear surface for the car Then, we take a point closer to ego vehicle than the mean over this rear surface	computeTTCLidar
FP.3 Associate Keypoint Correspondences with Bounding Boxes	Similar to first step in FP.1, using a check for each keypoint if it's contained by ROI rectangle	clusterKptMatchesWithROI
FP.4 Compute Camera-based TTC	Same as exercise	computeTTCCamera
FP.5 Performance Evaluation 1	Logging for LiDAR TTC and Cam TTC to text file for each frame Also for each frame a Visualization showing top view and resulting TTCs isproduced and saved to jpg file	Excel file sheets: Raw Data, LiDAR TTC Overview and FP.5 Performance Evaluation 1
FP.6 Performance Evaluation 2		Excel file sheets: Raw Data, FP.6 Performance Evaluation 2

Lidar TTC	Det+Desc																														
Frame#	SHITOMASI+BRISK	SHITOMASI+BRIEF	SHITOMASI+ORB	SHITOMASI+FREAK	SHITOMASI+SIFT	HARRIS+BRISK	HARRIS+BRIEF	HARRIS+ORB	HARRIS+FREAK	HARRIS+SIFT	FAST+BRISK	FAST+BRIEF	FAST+ORB	FAST+FREAK	FAST+SIFT	BRISK+BRISK	BRISK+BRIEF	BRISK+ORB	BRISK+FREAK	BRISK+SIFT	ORB+BRISK	ORB+BRIEF	ORB+ORB	ORB+FREAK	ORB+SIFT	SIFT+BRISK	SIFT+BRIEF	SIFT+FREAK	SIFT+SIFT	AKAZE+AKAZE
1	12,1924			12,1924	12,1924	12,1924	12,1924	12,1924	12,1924																	12,1924		12,1924		
2	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517	14,0517
3	13,2373			13,2373		13,2373			13,2373																						
4	12,2969		12,2969	12,2969		12,2969			12,2969			12,2969				12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969	12,2969
5	13,7339	13,7339	13,7339	13,7339	13,7339	13,7339	13,7339	13,7339	13,7339	13,7339		13,7339	13,7339	13,7339	13,7339	13,7339	13,7339	13,7339	13,7339	13,7339								13,7339	13,7339	13,7339	
6	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554	8,44554		8,44554						8,44554	8,44554	8,44554	8,44554
7	22,9333	22,9333	22,9333	22,9333	22,9333						22,9333	22,9333	22,9333	22,9333	22,9333	22,9333	22,9333	22,9333	22,9333	22,9333	22,9333	22,9333			22,9333			22,9333	22,9333	22,9333	22,9333
8	22,8333	22,8333	22,8333	22,8333	22,8333	22,8333	22,8333	22,8333		22,8333	22,8333	22,8333	22,8333	22,8333	22,8333	22,8333	22,8333	22,8333	22,8333	22,8333								22,8333	22,8333	22,8333	22,8333
9	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604		11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604	11,8604
10	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818	16,8818		16,8818	16,8818	16,8818	16,8818
11	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674		9,54674	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674	9,54674							9,54674	9,54674	9,54674	9,54674
12								10,2536													10,2536	10,2536	10,2536					10,2536		10,2536	10,2536
13	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779		9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779	9,73779
14	10,8182	10,8182	10,8182	10,8182	10,8182		10,8182		10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182	10,8182
15			8,71483		8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483	8,71483						
16						8,10814	8,10814	8,10814	8,10814	8,10814	8,10814	8,10814	8,10814	8,10814	8,10814		8,10814	8,10814				8,10814	8,10814	8,10814	8,10814	8,10814						
Out of 16	13	10	12	13	12	13	12	12	11	11	11	13	12	12	12	12	13	13	11	11	11	11	8	8	8	11	12	11	11	11	



TTC availablitiy for reach combination over 16 frames

LiDAR TTC (sec)	
0	N/A
1	12,1924
2	14,0517
3	13,2373
4	12,2969
5	13,7339
6	8,44554
7	22,9333
8	22,8333
9	11,8604
10	16,8818
11	9,54674
12	10,2536
13	9,73779
14	10,8182
15	8,71483
16	8,10814



LiDAR TTC value is not affected by matching technique, except when matching fails

Examples where the TTC estimate of the Lidar sensor does not seem plausible

Frame	Detector	Descriptor	LidarTTC	CamTTC	Visual	TTC DIF
9	SHITOMAS	BRISK	11,8604	18,3625	_0009.jpg	6,5021
9	SHITOMAS	BRIEF	11,8604	12,6708	_0009.jpg	0,8104
9	SHITOMAS	ORB	11,8604	12,4803	_0009.jpg	0,6199
9	SHITOMAS	FREAK	11,8604	#NAME?	_0009.jpg	#NAME?
9	SHITOMAS	SIFT	11,8604	13,451	_0009.jpg	1,5906
9	HARRIS	BRISK	11,8604	11,554	_0009.jpg	0,3064
9	HARRIS	BRIEF	11,8604	12,0485	_0009.jpg	0,1881
9	HARRIS	ORB	11,8604	13,0386	_0009.jpg	1,1782
9	HARRIS	FREAK	11,8604	-0,37828	_0009.jpg	12,23868
9	HARRIS	SIFT	11,8604	10,8632	_0009.jpg	0,9972
9	FAST	BRISK	11,8604	-1,20359	_0009.jpg	13,06399
9	FAST	BRIEF	11,8604	13,9848	_0009.jpg	2,1244
9	FAST	ORB	11,8604	14,7897	_0009.jpg	2,9293
9	FAST	FREAK	11,8604	#NAME?	_0009.jpg	#NAME?
9	FAST	SIFT	11,8604	12,3686	_0009.jpg	0,5082
9	BRISK	BRISK	11,8604	20,056	_0009.jpg	8,1956
9	BRISK	BRIEF	11,8604	17,1026	_0009.jpg	5,2422
9	BRISK	ORB	11,8604	15,5809	_0009.jpg	3,7205
9	BRISK	FREAK	11,8604	20,63	_0009.jpg	8,7696
9	BRISK	SIFT	11,8604	16,9792	_0009.jpg	5,1188
9	ORB	BRISK	11,8604	12,2284	_0009.jpg	0,368
9	ORB	BRIEF	11,8604	13,2757	_0009.jpg	1,4153
9	ORB	FREAK	11,8604	15,0839	_0009.jpg	3,2235
9	ORB	SIFT	11,8604	12,8918	_0009.jpg	1,0314
9	SIFT	BRISK	11,8604	39,1126	_0009.jpg	27,2522
9	SIFT	BRIEF	11,8604	14,6838	_0009.jpg	2,8234
9	SIFT	FREAK	11,8604	-3,88353	_0009.jpg	15,74393
9	SIFT	SIFT	11,8604	-0,80739	_0009.jpg	12,66779
9	AKAZE	AKAZE	11,8604	15,2002	_0009.jpg	3,3398

Frame 6 LiDAR perceives the distance to vehicle in front is decreasing rapidly, while top view shows no significant difference

Frame	Detector	Descriptor	LidarTTC	CamTTC	Visual	TTC DIF
6	SHITOMAS	BRISK	8,44554	-10,6638	_0006.jpg	19,10934
6	SHITOMAS	BRIEF	8,44554	13,2198	_0006.jpg	4,77426
6	SHITOMAS	ORB	8,44554	19,1734	_0006.jpg	10,72786
6	SHITOMAS	FREAK	8,44554	#NAME?	_0006.jpg	#NAME?
6	SHITOMAS	SIFT	8,44554	14,7141	_0006.jpg	6,26856
6	HARRIS	BRISK	8,44554	-0,17584	_0006.jpg	8,621378
6	HARRIS	BRIEF	8,44554	18,1741	_0006.jpg	9,72856
6	HARRIS	ORB	8,44554	-1559,68	_0006.jpg	1568,126
6	HARRIS	FREAK	8,44554	-0,19528	_0006.jpg	8,640822
6	HARRIS	SIFT	8,44554	16,7854	_0006.jpg	8,33986
6	FAST	BRISK	8,44554	-0,53623	_0006.jpg	8,981771
6	FAST	BRIEF	8,44554	14,5234	_0006.jpg	6,07786
6	FAST	ORB	8,44554	15,8335	_0006.jpg	7,38796
6	FAST	FREAK	8,44554	-9,03085	_0006.jpg	17,47639
6	FAST	SIFT	8,44554	13,2684	_0006.jpg	4,82286
6	BRISK	BRISK	8,44554	70,7064	_0006.jpg	62,26086
6	BRISK	BRIEF	8,44554	26,8787	_0006.jpg	18,43316
6	BRISK	ORB	8,44554	73,6525	_0006.jpg	65,20696
6	BRISK	FREAK	8,44554	16,3304	_0006.jpg	7,88486
6	BRISK	SIFT	8,44554	16,2984	_0006.jpg	7,85286
6	ORB	BRIEF	8,44554	21,1103	_0006.jpg	12,66476
6	SIFT	BRIEF	8,44554	16,6336	_0006.jpg	8,18806
6	SIFT	FREAK	8,44554	-0,29021	_0006.jpg	8,735749
6	SIFT	SIFT	8,44554	34,0825	_0006.jpg	25,63696
6	AKAZE	AKAZE	8,44554	13,6631	_0006.jpg	5,21756

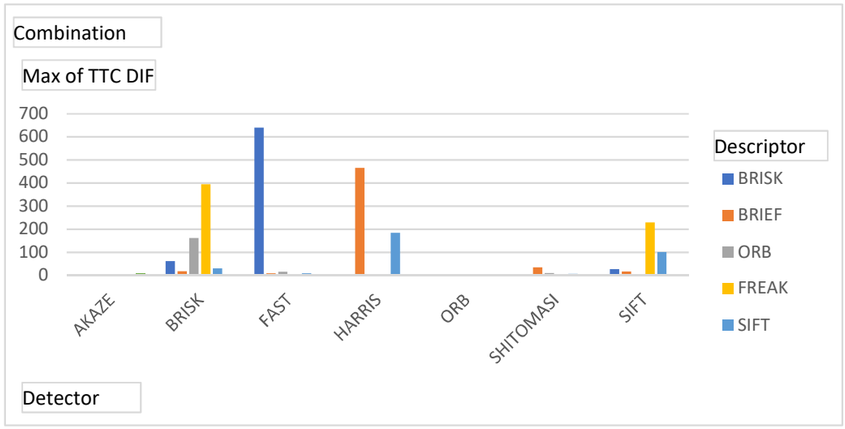
Frame 6 LiDAR perceives the distance to vehicle in front is decreasing rapidly, while top view shows no significant difference

Observation
It seems this issue is invariant across all detector/descriptor configurations, therefore it has to do with LiDAR data and TTC calculation method
LiDAR perceives the distance to vehicle in front is decreasing rapidly, while top view shows no significant difference
This is correlated with significant noise variation in the top view in either frame, I can only guess this could be resulting of vibrations on the car in the front which in turn affects laser beam reflections

Combination	(Multiple Items)

Max of TTC DIF	Column Labels					
Row Labels	**BRISK**	**BRIEF**	**ORB**	**FREAK**	**SIFT**	**AKAZE**
AKAZE						8,6167
BRISK	62,26086	18,43316	161,5439	394,9957	30,3789	
FAST	639,3617	9,1743	16,4118	#NAME?	9,2157	
HARRIS	#NAME?	465,90326	#NAME?	#NAME?	184,04126	
ORB		#NAME?	#NAME?	#NAME?	#NAME?	
SHITOMASI	#NAME?	34,753	10,72786	#NAME?	6,4436	
SIFT	27,2522	16,5222		229,0341	100,93621	

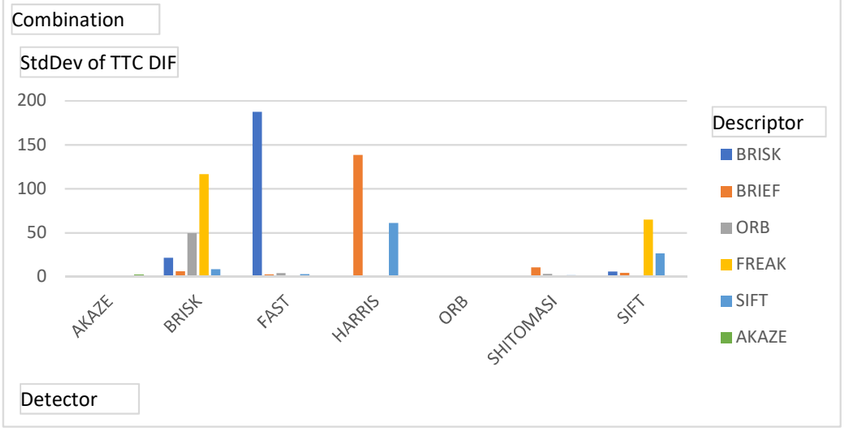
Smaller Max deviation is better



Combination	(Multiple Items)

StdDev of TTC DI	Column Labels					
Row Labels	**BRISK**	**BRIEF**	**ORB**	**FREAK**	**SIFT**	**AKAZE**
AKAZE						2,478
BRISK	21,71157798	6,2794986	49,64175	116,6173	8,6216414	
FAST	187,499459	2,6201952	4,296568	#NAME?	2,8985742	
HARRIS	#NAME?	138,37888	#NAME?	#NAME?	61,132026	
ORB		#NAME?	#NAME?	#NAME?	#NAME?	
SHITOMASI	#NAME?	10,539771	3,3342	#NAME?	1,9232798	
SIFT	5,804754186	4,5791425		65,05182	26,630205	

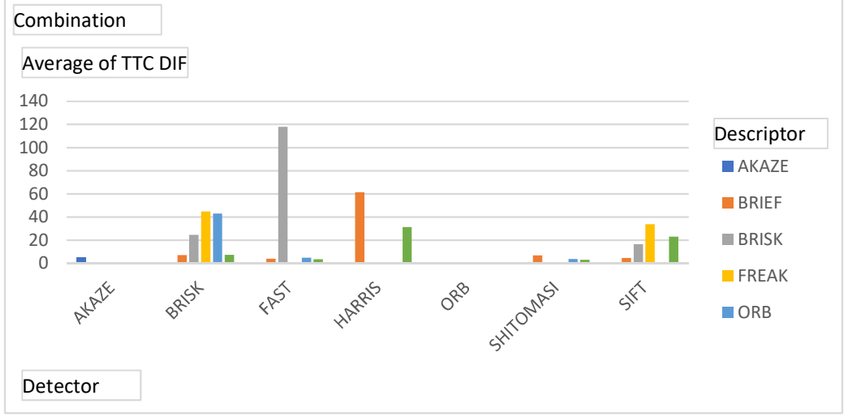
More stable deviation means we can compensate for it easier



Combination	(Multiple Items)

Average of TTC D	Column Labels					
Row Labels	**AKAZE**	**BRIEF**	**BRISK**	**FREAK**	**ORB**	**SIFT**
AKAZE	5,235602727					
BRISK		6,9394046	24,50591	44,6944	42,978235	7,2108
FAST		3,89172	117,9375	#NAME?	4,7231967	3,4205
HARRIS		61,303582	#NAME?	#NAME?	#NAME?	31,187
ORB		#NAME?		#NAME?	#NAME?	######
SHITOMASI		6,786083	#NAME?	#NAME?	3,5733333	3,0227
SIFT		4,5581	16,51033	33,72002		22,868

Smaller deviation mean is better



Note: ORB+BRISK is excluded due to high variance