WRITE UP 2D Camera Tracking

MP.0 Mid-Term Report: PDF submitted

MP.1 Data Buffer Optimization: Data buffer is a 1-D vector whose size is limited to 2 elements by using an "if" condition on vector size. This is essentially a ring buffer of capacity 2. The images in the buffer follow the rule of FIFO with each new entry, the oldest one is removed to make room for a new image. The image is removed from the beginning of the vector using the erase() function.

MP.2 Key point Detection: Key point detectors are implemented in functions in the matching2d_student.cpp. ShiTomasi was already implement in the file. Harris was implemented as a separate function and rest of the functions were implemented in a 3rd detector function. In the main() function detector strings can be selected which are arguments for the detector functions called. The detector string is used by the 3rd detector function to select the appropriate detector and it creates a detector object and uses it to process and detect key points from an image. The function then returns the key points to the main() function.

MP.3 Key point Removal: In the main() function a "for" loop is used to loop through all key points detected and check if they are present in the ROI. Key points present are added to a new vector for key points to get a vector of key points which are only in the ROI.

MP.4 Key point Descriptors: Key point descriptors are implemented in a function in the matching2d_student.cpp. The function is called in the main() function with descriptor name in string type as one of the arguments. All the descriptors have associated string in the main() function which can be selected manually, followed by recompilation of the source code. The

MP.5 Descriptor Matching: The FLANN matching and KNN selector are implemented in the matching2D_student.cpp in the function matchDescriptors(). The function takes as arguments strings for matcher type and selector type. Depending on the matcher type (BF or FLANN) and selector type (NN or KNN) selected in the main() function the appropriate matcher object is created and selector function match() or knnMatch() is used to match the descriptors between images. The descriptors for each image are also arguments of the matchDescriptors() function.

MP.6 Descriptor Distance Ratio: The descriptor matches found in the KNN selector section of the code in the matchDescriptors() function implements the distance ratio logic. For each knnmatch element in the knnmatch vector the first 2 matches in the element are checked for the distance ratio requirement and if the first match meets the requirement of distance ratio it is added to the matches vector which is returned to the main() function.

MP.7 Performance Evaluation 1: Number of preceding vehicle key points tabulated in table 1. For all detectors the number of key points are roughly the same except for Harris which did tend to find more than average key points in a couple of images.

Distribution of key points:

Shi-Tomasi detector key points are spread out in clusters in the ROI window. Based on the sample image, the key points detected are corners and along edges with large contrasts.

Harris detector key points are far and few and from the sample image. Upon parameter tuning it was realized that the key points are being detected very close together in tight cluster and seem to be overlap when marked in the adjacent image.

FAST detector key points are spread out all over the ROI window. The features detected are primarily corners. As can be seen in the sample image, areas with high density of corner features like license plate have key points detected.

BRISK detector key points are primarily distributed in the upper portion of the preceding vehicle in the ROI window but are spread out.

ORB detector key points are spread out similarly to the FAST detector which makes sense as ORB does implement a modified version of FAST detector algorithm.

AKAZE detector key points are mainly distributed on the outer edge regions of the preceding vehicle. The key points were detected with default settings. The license plate area is devoid of any key points.

SIFT detector key points have been detected in all decently laminated areas of the preceding vehicle. Since SIFT is a blob detector and not a corner detector per se, the feature detected are not just corners. The key points are distributed all over.

Table 1 Preceding Vehicle Keypoints

	ShiTomasi	Harris	FAST	BRISK	ORB	AKAZE	SIFT
Image 1	122	49	407	254	822	162	137
Image 2	117	39	415	274	803	157	131
Image 3	122	62	389	276	787	159	121
Image 4	117	56	413	275	814	154	135
Image 5	115	83	371	293	780	162	134
Image 6	112	312	396	275	806	163	139
Image 7	112	36	407	289	805	173	136
Image 8	120	130	393	268	801	175	147
Image 9	111	93	386	258	759	175	156
Image 10	108	186	389	249	750	175	135

MP.8 Performane Evaluation 2:
For each detector # of matched key points for the different descriptors are in tables 2 - 8. ShiTomasi, Harris, FAST, BRISK, ORB, and SIFT detectors do not work with KAZE feature descriptor. The SIFT detector and ORB descriptor do not work together.

Table 2 Preceding Vehicle Matched Keypoints

SHITOMASI	BRISK	BRIEF	ORB	FREAK	AKAZE	SIFT
Image 1 - 2	94	112	104	86	NA	110
Image 2 - 3	88	111	102	90	NA	108
Image 3 - 4	78	102	96	83	NA	102
Image 4 - 5	87	100	100	87	NA	101
Image 5 - 6	83	99	102	85	NA	98
Image 6 - 7	78	99	94	79	NA	98
Image 7 - 8	83	98	96	80	NA	93
Image 8 - 9	86	108	103	86	NA	105
Image 9 - 10	79	99	94	82	NA	95

Table 3 Preceding Vehicle Matched Keypoints

HARRIS	BRISK	BRIEF	ORB	FREAK	AKAZE	SIFT
Image 1 - 2	29	25	26	28	NA	28
Image 2 - 3	21	19	20	25	NA	25
Image 3 - 4	33	45	36	35	NA	36
Image 4 - 5	28	28	27	31	NA	28
Image 5 - 6	30	26	26	33	NA	24
Image 6 - 7	77	114	104	96	NA	100
Image 7 - 8	21	17	18	21	NA	23
Image 8 - 9	66	70	75	84	NA	74
Image 9 - 10	55	50	60	55	NA	47

Table 4 Preceding Vehicle Matched Keypoints

FAST	BRISK	BRIEF	ORB	FREAK	AKAZE	SIFT
Image 1 - 2	251	310	297	243	NA	306
Image 2 - 3	234	323	300	240	NA	316
Image 3 - 4	238	290	291	225	NA	290
Image 4 - 5	235	326	312	249	NA	302
Image 5 - 6	207	265	272	223	NA	277
Image 6 - 7	243	314	301	256	NA	314
Image 7 - 8	242	312	313	242	NA	306
Image 8 - 9	239	309	293	249	NA	295
Image 9 - 10	241	299	299	241	NA	297

Table 5 Preceding Vehicle Matched Keypoints

BRISK	BRISK	BRIEF	ORB	FREAK	AKAZE	SIFT
Image 1 - 2	168	174	155	154	NA	177
Image 2 - 3	169	195	167	173	NA	187
Image 3 - 4	157	182	155	153	NA	171
Image 4 - 5	170	177	161	168	NA	177
Image 5 - 6	171	182	156	158	NA	168
Image 6 - 7	186	193	181	181	NA	190
Image 7 - 8	174	208	165	169	NA	193
Image 8 - 9	167	186	170	173	NA	173
Image 9 - 10	184	179	170	165	NA	181

Table 6 Preceding Vehicle Matched Keypoints

ORB	BRISK	BRIEF	ORB	FREAK	AKAZE	SIFT
Image 1 - 2	595	397	536	360	NA	582
Image 2 - 3	587	402	565	350	NA	577
Image 3 - 4	564	345	505	333	NA	568
Image 4 - 5	600	362	557	350	NA	580
Image 5 - 6	576	345	536	344	NA	558
Image 6 - 7	608	437	598	339	NA	584
Image 7 - 8	523	412	551	323	NA	556
Image 8 - 9	538	411	554	332	NA	564
Image 9 - 10	528	410	551	332	NA	566

Table 7 Preceding Vehicle Matched Keypoints

AKAZE	BRISK	BRIEF	ORB	FREAK	AKAZE	SIFT
Image 1 - 2	128	137	134	123	135	132
Image 2 - 3	128	133	124	128	138	134
Image 3 - 4	126	130	129	128	132	129
Image 4 - 5	118	130	128	121	126	136
Image 5 - 6	129	134	130	122	128	136
Image 6 - 7	131	146	132	133	146	147
Image 7 - 8	136	150	142	144	147	147
Image 8 - 9	136	147	144	145	149	153
Image 9 - 10	143	150	141	135	148	149

Table 8 Preceding Vehicle Matched Keypoints

SIFT	BRISK	BRIEF	ORB	FREAK	AKAZE	SIFT
Image 1 - 2	63	86	oom	64	NA	81
Image 2 - 3	64	76	oom	70	NA	79
Image 3 - 4	60	72	oom	62	NA	83
Image 4 - 5	65	83	oom	65	NA	92
Image 5 - 6	59	69	oom	59	NA	90
Image 6 - 7	65	75	oom	60	NA	82
Image 7 - 8	64	76	oom	64	NA	82
Image 8 - 9	67	69	oom	65	NA	100
Image 9 - 10	79	87	oom	79	NA	101

MP.9: Performance Evaluation 3:
The top 3 detector/descriptor combinations based on the data are:
FAST + ORB
ORB + BRIEF
FAST + BRIEF

Table 9 Mean Time (ms) per Keypoint Detection

Detector	Mean Time/Keypoint
ShiTomasi	0.01312
Harris	0.04134
FAST	0.00053
BRISK	0.13741
ORB	0.0020
AKAZE	0.07609
SIFT	0.11298

Table 10 Time (ms) per descriptor

Detector/ Descriptor	Brief	BRISK	ORB	FREAK	AKAZE	SIFT
ShiTomasi	0.01440	0.01908	0.00840	0.42255	NA	0.15101
Harris	0.01336	0.02486	0.01429	0.71988	NA	0.35627
FAST	0.00512	0.01086	0.00454	0.11513	NA	0.14126
BRISK	0.00453	0.01143	0.01943	0.16771	NA	0.24643
ORB	0.00359	0.01022	0.00860	0.05979	NA	0.51454
AKAZE	0.00795	0.01441	0.02259	0.27680	0.59161	0.20236
SIFT	0.00587	0.01306	NA	0.35459	NA	0.69759