2D Feature Tracking

MP.1
Initially I tried implementing ring buffer using a queue instead of vector. However, I realized that I will have to make changes to end() method at multiple places, requiring more code refactor than expected for this. So instead, I decided to keep the vector data structure and used erase() method to remove the first frame when more than 2 frames are present in the ring buffer. Although using erase() to remove first element is not efficient, it does not severely affect performance either in our case.

MP.2
I implemented Harris detector based on one of the previous exercise from the module. For rest of the modern detectors, I created a common FeatureDetector object to be used with all the other detector classes. I used the create method to initialize the object for the respective detector class while passing the default arguments I found from the opencv documentation. Finally, I used the detect method to populate keypoints vector.

MP.3
I used the contains method from cv::Rect to filter out the points that cover the preceding vehicle.

MP.4
Completed

MP.5
Completed

MP.7 / MP.8 / MP.9

See next page for the table which covers data for all three tasks.
Based on the totaltime (detector time + descriptor time) field in the table, the top three detector/descriptor combinations are:

Rank	Detector	Descriptor
1	FAST	ORB
2	FAST	BRISK
3	ORB	BRISK

NOTE:
1. (SIFT + ORB)* kept failing due to out of memory issues.
2. (AKAZE + AKAZE)* was the only combination possible. Seems like they cannot be combined with other detectors and descriptors.

* (Detector + Descriptor)

img #	Detector	time (ms)	keypoints	filtered kpts	Descriptor	time (ms)	# matches	total time (ms)
1	SHITOMASI	19.7525	1370	125	BRISK	1.66076		21.41326
2	SHITOMASI	17.3675	1301	118	BRISK	2.4892	30	19.8567
3	SHITOMASI	17.0494	1361	123	BRISK	2.39245	30	19.44185
4	SHITOMASI	16.5057	1358	120	BRISK	2.32289	43	18.82859
5	SHITOMASI	16.8917	1333	120	BRISK	2.26027	30	19.15197
6	SHITOMASI	16.8706	1284	113	BRISK	2.27759	38	19.14819
7	SHITOMASI	16.3444	1322	114	BRISK	2.24934	34	18.59374
8	SHITOMASI	17.0105	1366	123	BRISK	2.32059	29	19.33109
9	SHITOMASI	15.6651	1389	111	BRISK	2.26106	37	17.92616
10	SHITOMASI	16.0993	1339	112	BRISK	2.22081	29	18.32011
1	SHITOMASI	15.8985	1370	125	ORB	1.24591		17.14441
2	SHITOMASI	17.8517	1301	118	ORB	0.987417	19	18.839117
3	SHITOMASI	16.3346	1361	123	ORB	0.9717	16	17.3063
4	SHITOMASI	16.3463	1358	120	ORB	1.19417	24	17.54047
5	SHITOMASI	16.0606	1333	120	ORB	1.16069	18	17.22129
6	SHITOMASI	16.1836	1284	113	ORB	1.14576	17	17.32936
7	SHITOMASI	16.2168	1322	114	ORB	1.15454	16	17.37134
8	SHITOMASI	16.7098	1366	123	ORB	1.23471	16	17.94451
9	SHITOMASI	16.879	1389	111	ORB	0.979286	19	17.858286
10	SHITOMASI	15.9626	1339	112	ORB	1.02554	14	16.98814
1	SHITOMASI	15.6015	1370	125	FREAK	43.1649		58.7664
2	SHITOMASI	16.6608	1301	118	FREAK	38.914	39	55.5748
3	SHITOMASI	11.8174	1361	123	FREAK	39.3729	28	51.1903
4	SHITOMASI	11.9462	1358	120	FREAK	39.3402	37	51.2864
5	SHITOMASI	11.6121	1333	120	FREAK	39.3697	32	50.9818
6	SHITOMASI	11.6725	1284	113	FREAK	39.0598	34	50.7323
7	SHITOMASI	12.816	1322	114	FREAK	38.9231	33	51.7391
8	SHITOMASI	11.5371	1366	123	FREAK	39.1812	33	50.7183
9	SHITOMASI	11.4576	1389	111	FREAK	38.9729	37	50.4305
10	SHITOMASI	11.5805	1339	112	FREAK	38.7584	26	50.3389
1	HARRIS	12.4281	115	17	BRISK	0.529997		12.958097
2	HARRIS	12.4456	98	14	BRISK	0.45181	5	12.89741
3	HARRIS	12.6022	113	18	BRISK	0.501787	4	13.103987
4	HARRIS	12.7124	121	21	BRISK	0.565761	4	13.278161
5	HARRIS	13.4765	160	26	BRISK	0.592077	6	14.068577
6	HARRIS	26.8051	383	43	BRISK	0.739922	10	27.545022
7	HARRIS	12.2665	85	18	BRISK	0.504654	27	12.771154
8	HARRIS	14.1843	210	31	BRISK	0.624088	3	14.808388
9	HARRIS	13.3442	171	26	BRISK	0.568359	8	13.912559
10	HARRIS	18.0049	281	34	BRISK	0.661904	5	18.666804
1	HARRIS	12.2959	115	17	ORB	0.813038		13.108938

2	HARRIS	11.8529	98	14	ORB	0.825991	5	12.678891
3	HARRIS	12.3029	113	18	ORB	0.781007	2	13.083907
4	HARRIS	12.3634	121	21	ORB	0.840975	3	13.204375
5	HARRIS	12.9216	160	26	ORB	0.84742	3	13.76902
6	HARRIS	27.1369	383	43	ORB	0.918555	2	28.055455
7	HARRIS	11.7996	85	18	ORB	0.813122	23	12.612722
8	HARRIS	14.2953	210	31	ORB	0.865929	3	15.161229
9	HARRIS	13.0799	171	26	ORB	0.805118	7	13.885018
10	HARRIS	18.4887	281	34	ORB	0.918111	4	19.406811
1	HARRIS	12.3131	115	17	FREAK	38.2664		50.5795
2	HARRIS	12.1515	98	14	FREAK	37.9954	4	50.1469
3	HARRIS	12.4713	113	18	FREAK	37.6827	1	50.154
4	HARRIS	12.425	121	21	FREAK	38.2035	3	50.6285
5	HARRIS	14.1215	160	26	FREAK	38.6184	6	52.7399
6	HARRIS	26.8206	383	43	FREAK	38.7123	9	65.5329
7	HARRIS	11.6869	85	18	FREAK	38.5434	23	50.2303
8	HARRIS	14.7056	210	31	FREAK	38.7641	6	53.4697
9	HARRIS	13.4659	171	26	FREAK	38.22	10	51.6859
10	HARRIS	18.5439	281	34	FREAK	38.1312	8	56.6751
1	FAST	1.01852	1824	149	BRISK	1.74717		2.76569
2	FAST	0.951278	1832	152	BRISK	1.88948	52	2.840758
3	FAST	0.938179	1810	150	BRISK	1.74381	48	2.681989
4	FAST	0.985243	1817	155	BRISK	1.78543	49	2.770673
5	FAST	1.35855	1793	149	BRISK	1.78381	57	3.14236
6	FAST	0.830765	1796	149	BRISK	1.74875	64	2.579515
7	FAST	0.985418	1788	156	BRISK	1.80623	42	2.791648
8	FAST	0.95159	1695	150	BRISK	1.75997	49	2.71156
9	FAST	1.43211	1749	138	BRISK	1.62988	50	3.06199
10	FAST	1.16268	1770	143	BRISK	1.84958	38	3.01226
1	FAST	1.04229	1824	149	ORB	1.48347		2.52576
2	FAST	0.968536	1832	152	ORB	1.08532	31	2.053856
3	FAST	1.32801	1810	150	ORB	1.20918	29	2.53719
4	FAST	1.40331	1817	155	ORB	1.14551	38	2.54882
5	FAST	0.946173	1793	149	ORB	1.08523	29	2.031403
6	FAST	0.91418	1796	149	ORB	1.23529	43	2.14947
7	FAST	0.879697	1788	156	ORB	1.10768	27	1.987377
8	FAST	0.951038	1695	150	ORB	1.18077	34	2.131808
9	FAST	1.54467	1749	138	ORB	1.66959	27	3.21426
10	FAST	1.39764	1770	143	ORB	1.64818	19	3.04582

1	FAST	1.20381	1824	149	FREAK	39.6671		40.87091
2	FAST	1.01017	1832	152	FREAK	40.2061	51	41.21627
3	FAST	1.33133	1810	150	FREAK	42.0392	53	43.37053
4	FAST	1.35576	1817	155	FREAK	40.2543	59	41.61006
5	FAST	0.973367	1793	149	FREAK	39.8388	57	40.812167
6	FAST	0.956857	1796	149	FREAK	39.9619	64	40.918757
7	FAST	1.13732	1788	156	FREAK	39.8673	50	41.00462
8	FAST	1.04394	1695	150	FREAK	40.3486	54	41.39254
9	FAST	1.4472	1749	138	FREAK	40.4426	49	41.8898
10	FAST	1.41249	1770	143	FREAK	40.1027	33	41.51519
1	BRISK	368.404	2757	264	BRISK	2.9454		371.3494
2	BRISK	365.52	2777	282	BRISK	3.13091	93	368.65091
3	BRISK	364.134	2741	282	BRISK	3.14219	106	367.27619
4	BRISK	366.874	2735	277	BRISK	3.09007	125	369.96407
5	BRISK	368.106	2757	297	BRISK	3.30078	101	371.40678
6	BRISK	363.562	2695	279	BRISK	3.12043	123	366.68243
7	BRISK	362.575	2715	289	BRISK	3.20186	91	365.77686
8	BRISK	362.193	2628	272	BRISK	3.12101	116	365.31401
9	BRISK	364.323	2639	266	BRISK	2.9801	101	367.3031
10	BRISK	365.201	2672	254	BRISK	2.83571	82	368.03671
1	BRISK	366.62	2757	264	ORB	4.63376		371.25376
2	BRISK	363.928	2777	282	ORB	4.63164	102	368.55964
3	BRISK	366.849	2741	282	ORB	4.69731	107	371.54631
4	BRISK	364.29	2735	277	ORB	4.6132	124	368.9032
5	BRISK	366.321	2757	297	ORB	4.67579	110	370.99679
6	BRISK	362.685	2695	279	ORB	4.60426	137	367.28926
7	BRISK	363.205	2715	289	ORB	4.56152	97	367.76652
8	BRISK	364.6	2628	272	ORB	4.58339	122	369.18339
9	BRISK	365.105	2639	266	ORB	4.56506	101	369.67006
10	BRISK	365.182	2672	254	ORB	4.72948	94	369.91148
1	BRISK	364.31	2757	264	FREAK	40.1549		404.4649
2	BRISK	361.996	2777	282	FREAK	40.0458	82	402.0418
3	BRISK	365.745	2741	282	FREAK	40.9876	83	406.7326
4	BRISK	362.049	2735	277	FREAK	40.4232	108	402.4722
5	BRISK	362.443	2757	297	FREAK	40.1253	91	402.5683
6	BRISK	364.244	2695	279	FREAK	39.9651	113	404.2091
7	BRISK	363.253	2715	289	FREAK	40.4553	73	403.7083
8	BRISK	364.111	2628	272	FREAK	40.3415	100	404.4525
9	BRISK	366.362	2639	266	FREAK	40.3204	77	406.6824

10	BRISK	366.964	2672	254	FREAK	40.1946	75	407.1586
1	ORB	8.76794	500	92	BRISK	1.17107		9.93901
2	ORB	7.46206	500	102	BRISK	1.34566	10	8.80772
3	ORB	8.46789	500	106	BRISK	1.29937	19	9.76726
4	ORB	10.568	500	113	BRISK	1.37258	16	11.94058
5	ORB	8.57997	500	109	BRISK	1.46104	18	10.04101
6	ORB	9.48202	500	125	BRISK	1.49315	22	10.97517
7	ORB	9.77773	500	130	BRISK	1.56008	24	11.33781
8	ORB	8.85179	500	129	BRISK	1.55181	30	10.4036
9	ORB	8.45091	500	127	BRISK	1.53559	32	9.9865
10	ORB	10.4584	500	128	BRISK	1.56704	28	12.02544
1	ORB	9.7067	500	92	ORB	4.66641		14.37311
2	ORB	7.29028	500	102	ORB	4.53182	25	11.8221
3	ORB	9.18971	500	106	ORB	4.66009	32	13.8498
4	ORB	7.97601	500	113	ORB	4.71646	34	12.69247
5	ORB	8.70536	500	109	ORB	4.58518	29	13.29054
6	ORB	8.31605	500	125	ORB	4.75996	18	13.07601
7	ORB	8.89268	500	130	ORB	5.47026	24	14.36294
8	ORB	8.36994	500	129	ORB	4.72556	38	13.0955
9	ORB	8.95663	500	127	ORB	5.16297	36	14.1196
10	ORB	8.5685	500	128	ORB	4.6586	34	13.2271
1	ORB	8.60859	500	92	FREAK	39.4173		48.02589
2	ORB	7.55453	500	102	FREAK	39.5627	4	47.11723
3	ORB	8.67407	500	106	FREAK	38.7625	17	47.43657
4	ORB	8.73089	500	113	FREAK	39.5833	12	48.31419
5	ORB	9.2778	500	109	FREAK	38.9282	18	48.206
6	ORB	9.35916	500	125	FREAK	38.8097	11	48.16886
7	ORB	8.89084	500	130	FREAK	39.4493	13	48.34014
8	ORB	8.89157	500	129	FREAK	39.187	14	48.07857
9	ORB	9.38168	500	127	FREAK	38.841	23	48.22268
10	ORB	8.86349	500	128	FREAK	39.0614	17	47.92489
1	AKAZE	419.431	1826	206	AKAZE	79.2374		498.6684
2	AKAZE	420.881	1804	184	AKAZE	65.7707	23	486.6517
3	AKAZE	419.48	1772	197	AKAZE	71.0831	20	490.5631
4	AKAZE	419.317	1795	193	AKAZE	72.2381	25	491.5551
5	AKAZE	411.898	1782	199	AKAZE	67.4773	20	479.3753
6	AKAZE	431.381	1751	193	AKAZE	73.2735	26	504.6545
7	AKAZE	422.683	1756	207	AKAZE	76.3725	17	499.0555
8	AKAZE	408.688	1743	211	AKAZE	58.114	23	466.802

9	AKAZE	395.264	1817	220	AKAZE	52.1867	21	447.4507
10	AKAZE	417.649	1817	216	AKAZE	64.5986	20	482.2476
1	SIFT	139.03	1438	138	BRISK	1.6647		140.6947
2	SIFT	123.912	1371	132	BRISK	1.57071	73	125.48271
3	SIFT	131.665	1380	124	BRISK	1.50505	66	133.17005
4	SIFT	112.796	1335	137	BRISK	1.66186	62	114.45786
5	SIFT	128.852	1305	134	BRISK	1.66088	71	130.51288
6	SIFT	135.48	1370	140	BRISK	1.64444	75	137.12444
7	SIFT	132.653	1396	137	BRISK	1.62547	76	134.27847
8	SIFT	135.442	1382	148	BRISK	1.70766	73	137.14966
9	SIFT	135.099	1463	159	BRISK	1.93073	81	137.02973
10	SIFT	137.282	1422	137	BRISK	1.59846	79	138.88046
1	SIFT	128.525	1438	138	FREAK	39.3765		167.9015
2	SIFT	125.178	1371	132	FREAK	40.1752	72	165.3532
3	SIFT	130.233	1380	124	FREAK	40.7417	59	170.9747
4	SIFT	129.517	1335	137	FREAK	39.6548	59	169.1718
5	SIFT	127.975	1305	134	FREAK	39.7212	70	167.6962
6	SIFT	135.026	1370	140	FREAK	39.6608	74	174.6868
7	SIFT	132.169	1396	137	FREAK	39.7393	80	171.9083
8	SIFT	133.536	1382	148	FREAK	39.4509	71	172.9869
9	SIFT	126.346	1463	159	FREAK	39.3894	82	165.7354
10	SIFT	130.108	1422	137	FREAK	39.5488	79	169.6568