

Numerical analysis of keypoint detectors and descriptor extractors
prepared by Andrejs Zujevs

MP7 Task Number of detected keypoints within the all images													
ImageID	0	1	2	3	4	5	6	7	8	9	Sum	Avg	Std
Detector	Detected Keypoint Number												
AKAZE	166	157	161	155	163	164	173	175	177	179	1670	303.64	8.06
BRISK	264	282	282	277	297	279	289	272	266	254	2762	502.18	11.98
FAST	121	129	121	124	126	121	142	140	147	146	1317	239.45	10.28
HARRIS	45	58	74	88	124	99	72	188	115	94	957	174.00	38.46
ORB	92	102	106	113	109	125	130	129	127	128	1161	211.09	12.81
SHITOMASI	125	118	123	120	120	113	114	123	111	112	1179	214.36	4.83
SIFT	138	132	124	137	134	140	137	148	159	137	1386	252.00	8.90

MP8 Task Matching rate %													
Detector/	Descr.	BRISK	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE		80.3%	71.3%	78.1%	75.5%	69.9%	72.6%	77.5%	80.0%	71.8%	75.2%	3.5%
	BRISK		52.3%	51.1%	48.0%	52.0%	49.8%	55.6%	50.4%	56.4%	62.2%	53.1%	3.9%
	FAST		48.8%	44.6%	50.4%	53.2%	51.2%	43.8%	55.0%	55.7%	58.9%	51.3%	4.5%
	HARRIS		55.6%	48.3%	48.6%	48.9%	48.5%	59.7%	41.7%	73.9%	71.3%	55.2%	9.9%
	ORB		65.2%	63.7%	61.3%	69.7%	66.1%	66.4%	64.3%	57.5%	56.7%	63.4%	3.8%
	SHITOMASI		71.2%	67.8%	60.8%	64.2%	65.5%	61.9%	69.3%	73.0%	64.9%	66.5%	3.7%
	SIFT		43.2%	50.8%	46.8%	45.5%	41.0%	38.0%	39.4%	42.6%	53.3%	44.5%	4.6%

Detector/	Descr.	BRIEF	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE		68.8%	73.9%	71.0%	70.3%	71.2%	78.7%	76.9%	77.1%	74.0%	73.5%	3.1%
	BRISK		52.3%	58.9%	46.6%	50.9%	53.0%	55.6%	58.1%	60.5%	58.3%	54.9%	4.1%
	FAST		48.8%	51.2%	47.9%	55.6%	47.9%	46.3%	55.7%	57.1%	42.5%	50.3%	4.4%
	HARRIS		55.6%	46.6%	51.4%	52.3%	44.4%	61.1%	47.2%	56.5%	61.7%	53.0%	5.6%
	ORB		40.2%	37.3%	34.9%	48.6%	38.5%	51.2%	45.0%	48.8%	46.5%	43.4%	5.2%
	SHITOMASI		81.4%	78.8%	76.7%	74.2%	81.4%	82.3%	74.6%	82.0%	76.6%	78.6%	2.9%
	SIFT		47.7%	58.1%	51.6%	49.3%	38.8%	41.6%	52.6%	45.3%	61.3%	49.6%	6.5%

Detector/	Descr.	ORB	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE		65.0%	61.1%	61.9%	54.2%	55.2%	70.7%	59.5%	64.6%	66.7%	62.1%	4.8%
	BRISK		35.6%	37.9%	31.8%	35.0%	30.5%	40.9%	41.2%	42.9%	48.0%	38.2%	5.0%

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FAST	47.1%	56.2%	57.9%	58.9%	52.9%	55.4%	57.9%	57.9%	50.7%	55.0%	3.6%
HARRIS	51.1%	53.4%	52.7%	39.8%	43.4%	69.4%	45.8%	72.2%	64.9%	54.8%	10.4%
ORB	43.5%	55.9%	46.2%	49.5%	52.3%	54.4%	55.0%	48.8%	56.7%	51.4%	4.1%
SHITOMASI	72.9%	71.2%	72.5%	75.8%	77.0%	67.3%	71.1%	79.3%	79.3%	74.0%	3.7%
SIFT	-	-	-	-	-	-	-	-	-	-	-

Detector/	Descr.	FREAK	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE		65.6%	66.9%	60.0%	63.9%	59.5%	70.1%	72.8%	67.4%	66.1%	65.8%	3.9%
	BRISK		43.2%	42.9%	40.8%	42.6%	36.9%	46.2%	49.6%	48.5%	51.6%	44.7%	4.2%
	FAST		47.1%	33.9%	42.1%	46.8%	46.3%	41.3%	49.3%	40.7%	48.6%	44.0%	4.4%
	HARRIS		40.0%	55.2%	37.8%	37.5%	44.4%	52.8%	31.9%	58.3%	56.4%	46.0%	8.7%
	ORB		42.4%	32.4%	34.9%	36.7%	30.3%	32.0%	31.8%	30.7%	34.6%	34.0%	3.4%
	SHITOMASI		55.9%	55.9%	53.3%	52.5%	54.9%	56.6%	53.5%	58.6%	56.8%	55.3%	1.7%
	SIFT		44.7%	50.8%	43.5%	47.8%	38.1%	36.5%	34.3%	35.8%	47.4%	42.1%	5.4%

Detector/	Descr.	AKAZE	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE		81.5%	81.5%	80.6%	75.5%	74.2%	80.5%	79.2%	80.0%	81.4%	79.4%	2.4%
	BRISK		-	-	-	-	-	-	-	-	-	-	-
	FAST		-	-	-	-	-	-	-	-	-	-	-
	HARRIS		-	-	-	-	-	-	-	-	-	-	-
	ORB		-	-	-	-	-	-	-	-	-	-	-
	SHITOMASI		-	-	-	-	-	-	-	-	-	-	-
	SIFT		-	-	-	-	-	-	-	-	-	-	-

Detector/	Descr.	SIFT	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE		85.4%	85.4%	83.9%	87.7%	84.0%	89.6%	85.0%	88.0%	85.3%	86.0%	1.8%
	BRISK		68.9%	68.4%	61.0%	66.1%	61.3%	69.9%	71.3%	66.2%	72.0%	67.2%	3.6%
	FAST		53.7%	48.8%	44.6%	59.7%	56.2%	61.2%	69.3%	59.3%	52.1%	56.1%	6.6%
	HARRIS		44.4%	58.6%	63.5%	55.7%	49.5%	91.7%	59.7%	91.3%	83.0%	66.4%	15.9%
	ORB		72.8%	77.5%	73.6%	72.5%	75.2%	76.0%	73.6%	74.0%	74.0%	74.4%	1.4%
	SHITOMASI		94.9%	92.4%	86.7%	85.8%	87.6%	89.4%	84.2%	95.5%	87.4%	89.3%	3.6%
	SIFT		62.1%	65.3%	68.5%	69.4%	67.2%	59.1%	59.9%	68.9%	75.9%	66.3%	4.8%

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MP9 Task		Descriptors extraction time in ms											
Descriptor:	BRISK	Time in ms of Descriptors Extraction											
	Detector	0	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE	2.06	2.09	2.54	2.44	2.01	2.83	2.08	2.10	2.15	2.16	2.25	0.24
	BRISK	2.96	3.45	3.19	3.21	3.61	3.26	3.49	3.12	3.21	2.99	3.25	0.19
	FAST	2.39	1.90	2.44	1.49	2.33	2.02	1.67	2.75	2.26	2.39	2.16	0.35
	HARRIS	0.86	1.63	1.83	1.88	2.16	2.13	1.98	3.10	2.15	1.93	1.97	0.50
	ORB	1.25	1.38	1.34	1.58	1.41	1.67	1.66	1.59	1.60	1.93	1.54	0.18
	SHITOMASI	1.56	2.50	1.84	1.57	2.40	2.31	2.37	2.18	2.17	2.29	2.12	0.31
	SIFT	1.61	1.69	1.49	1.76	1.62	1.64	1.73	1.82	1.84	1.71	1.69	0.10
		2.14 avg											
Descriptor:	BRIEF	Time in ms of Descriptors Extraction											
	Detector	0	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE	1.23	1.12	1.14	1.25	1.22	1.12	1.73	1.22	1.66	1.92	1.36	0.26
	BRISK	1.41	2.29	1.45	1.40	1.53	1.40	1.40	1.29	1.17	1.21	1.45	0.28
	FAST	1.12	1.37	0.77	1.81	0.92	0.90	1.40	0.87	0.88	1.01	1.10	0.30
	HARRIS	0.58	1.15	1.23	1.24	1.32	1.27	1.32	1.68	1.51	1.16	1.25	0.26
	ORB	0.60	0.73	0.72	0.82	0.72	0.69	0.77	0.76	0.86	0.75	0.74	0.06
	SHITOMASI	0.74	1.34	0.80	0.79	1.35	0.75	0.67	1.22	1.25	0.68	0.96	0.26
	SIFT	1.08	1.02	0.91	0.94	0.92	1.05	1.08	0.89	1.02	0.92	0.98	0.07
		1.12 avg											
Descriptor:	ORB	Time in ms of Descriptors Extraction											
	Detector	0	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE	3.23	3.05	3.08	2.98	3.12	3.38	3.14	3.04	3.12	3.00	3.11	0.11
	BRISK	4.53	4.56	4.68	4.72	4.63	4.47	4.49	4.61	4.36	4.45	4.55	0.10
	FAST	1.06	1.10	1.17	1.03	1.03	1.12	1.12	1.09	1.20	1.15	1.11	0.05
	HARRIS	0.83	1.03	1.04	1.05	1.05	1.03	1.09	1.24	1.16	1.11	1.06	0.09
	ORB	4.75	4.65	4.54	4.96	4.40	4.79	4.62	4.89	4.86	4.67	4.71	0.15
	SHITOMASI	1.11	1.08	1.14	1.04	1.05	0.99	1.09	1.04	1.07	1.13	1.07	0.04
	SIFT	-	-	-	-	-	-	-	-	-	-	-	-
		2.60 avg											
Descriptor:	FREAK	Time in ms of Descriptors Extraction											
	Detector	0	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE	43.13	43.16	40.39	41.64	41.57	41.61	41.32	40.74	40.57	40.10	41.42	0.96
	BRISK	44.44	41.65	40.32	40.93	41.24	40.15	41.35	41.16	40.15	41.25	41.26	1.12
	FAST	38.96	38.40	39.05	38.23	39.31	38.00	39.00	39.47	39.49	39.61	38.95	0.51

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	HARRIS	38.38	38.78	39.39	39.30	38.65	39.10	39.23	40.44	40.49	38.68	39.24	0.65
	ORB	38.73	38.59	39.53	38.99	38.86	39.24	38.38	38.95	39.65	39.39	39.03	0.37
	SHITOMASI	39.40	39.50	39.04	38.88	38.56	40.14	39.10	38.77	39.33	39.64	39.24	0.42
	SIFT	39.52	40.29	40.65	40.34	41.08	40.90	39.89	40.73	39.49	39.85	40.27	0.51
Descriptor:	AKAZE	Time in ms of Descriptors Extraction										39.92	avg
	Detector	0	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE	66.67	66.14	68.05	64.46	65.67	64.35	66.14	67.78	64.67	68.87	66.28	1.43
	BRISK	-	-	-	-	-	-	-	-	-	-	-	-
	FAST	-	-	-	-	-	-	-	-	-	-	-	-
	HARRIS	-	-	-	-	-	-	-	-	-	-	-	-
	ORB	-	-	-	-	-	-	-	-	-	-	-	-
	SHITOMASI	-	-	-	-	-	-	-	-	-	-	-	-
	SIFT	-	-	-	-	-	-	-	-	-	-	-	-
Descriptor:	SIFT	Time in ms of Descriptors Extraction										66.28	avg
	Detector	0	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE	23.61	26.28	24.00	23.90	23.29	23.51	24.91	23.94	25.00	25.31	24.37	0.87
	BRISK	47.65	38.76	42.28	41.66	43.68	41.62	42.16	42.02	41.93	41.61	42.34	2.01
	FAST	24.38	17.48	18.56	23.31	22.80	20.98	23.67	22.83	18.39	23.49	21.59	2.30
	HARRIS	17.60	20.02	19.53	18.37	19.13	18.84	17.46	19.88	19.40	18.64	18.89	0.80
	ORB	44.78	42.71	45.10	46.09	43.96	45.09	48.21	49.19	50.07	50.96	46.62	2.53
	SHITOMASI	16.05	19.53	21.72	19.28	18.33	19.04	19.58	18.73	20.21	19.19	19.17	1.30
	SIFT	104.52	78.03	76.43	79.60	83.87	79.33	77.31	77.84	82.96	77.25	81.71	7.58
												36.38	avg

MP9 Task	Keypoints detection avg. time in ms for the all descriptor extractors												
	Detector	0	1	2	3	4	5	6	7	8	9	Avg	Std
	AKAZE	86.70	77.58	79.10	77.54	76.87	77.74	76.72	78.13	76.36	76.16	78.29	2.79
	BRISK	41.98	41.20	40.96	40.53	40.55	40.96	40.69	39.63	40.52	40.32	40.74	0.55
	FAST	0.44	0.37	0.37	0.35	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.02
	HARRIS	13.98	12.57	12.93	12.83	12.90	12.94	12.87	13.23	12.72	12.88	12.99	0.35
	ORB	7.73	7.59	7.36	7.28	7.34	7.23	7.25	7.24	7.64	7.30	7.40	0.17
	SHITOMASI	13.62	13.01	13.70	12.25	12.81	13.63	13.02	13.28	13.75	13.69	13.28	0.45
	SIFT	128.87	121.35	122.12	121.35	121.85	129.81	118.00	122.38	124.34	122.99	123.31	3.23

TOP3 keypoint detection and descriptor extraction

Detector	Desc.	Percent.	Desc.Ext.	KeyP.Ext.	TotalTim	Visual Analysis
AKAZE	BRISK	75.2%	2.25	78.29	80.54	Have a lot of errors
SHITOMAS	BRIEF	78.6%	0.96	13.28	14.24	Have errors
SHITOMAS	ORB	74.0%	1.07	13.28	14.35	Have some errors
AKAZE	FREAK	65.8%	41.42	78.29	119.71	Have some errors
AKAZE	AKAZE	79.4%	66.28	78.29	144.57	Good
SHITOMAS	SIFT	89.3%	19.17	13.28	32.44	Good
AKAZE	SIFT	86.0%	24.37	78.29	102.66	Good

Summary:

The TOP3 keypoint detector and extractor pairs were provided accordingly to keypoints matching rate for all keypoint detectors and descriptor extractors combinations. The results also were provided by comparison of time utilized in keypoints and descriptors extraction. Finally, the TOP3 pairs also were suggested by involving visual analysis of pairs candidates.

The matching rate of the keypoints of two pairs of frames is the main quality criteria for the preceding vehicle detection and threshold 75% was considered a good choice. At the same time, we should take into account the time used for the keypoints detection and the descriptors extraction. Also, we should consider standard deviation of the number of detected keypoints which is stability criteria of a keypoint detector.

From the best combination matching rate and utilized time view of point Shi-Tomasi keypoint detector and SIFT descriptor extractor are best choice, where matching rate is 89.3% and the total time is 32.44 ms. The second one is AKAZE keypoint detector and SIFT descriptor extractor, where matching rate is 86.3% and the total time 102.66. Finally, the last one is the AKAZE-AKAZE pair.