Camera Based 2D Feature Tracking

Mid-Term Project

Performance Evaluation Results

TASK MP.7

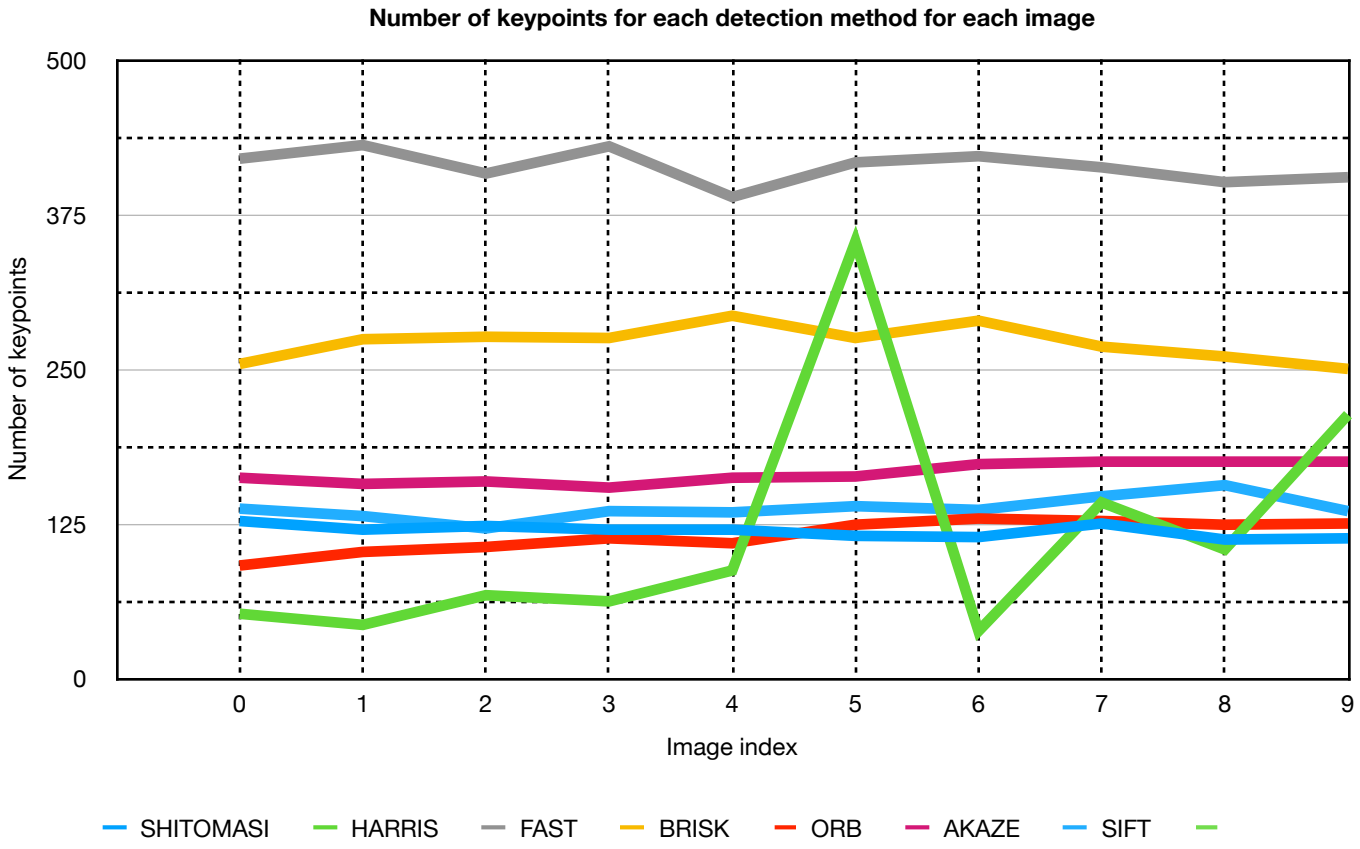
Your seventh task is to count the number of keypoints on the preceding vehicle for all 10 images and take note of the distribution of their neighborhood size. Do this for all the detectors you have implemented

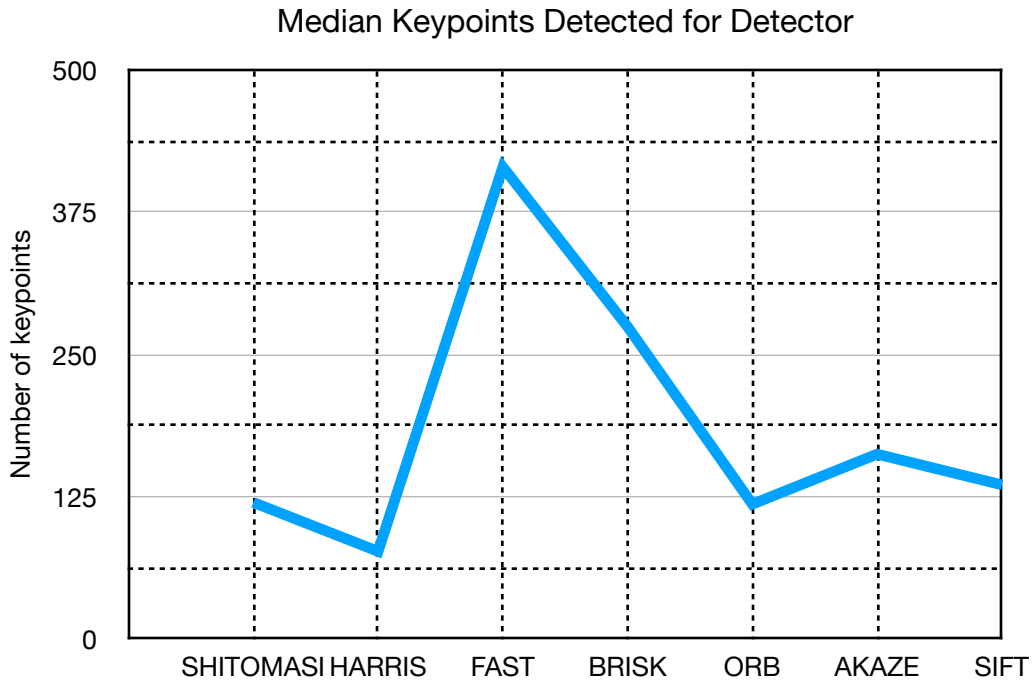
The results for the number of keypoints detected for each detector for each image is as follows:

Number of keypoints for preceding vehicle for various detection methods

IMAGE INDEX	SHITOMASI	HARRIS	FAST	BRISK	ORB	AKAZE	SIFT
	Keypoints	Keypoints	Keypoints	Keypoints	Keypoints	Keypoints	Keypoints
0	127	52	420	254	91	162	137
1	120	43	431	274	102	157	131
2	123	67	408	276	106	159	121
3	120	62	430	275	113	154	135
4	120	87	389	293	109	162	134
5	115	353	417	275	124	163	139
6	114	38	422	289	129	173	136
7	125	142	413	268	127	175	147
8	112	104	401	260	124	175	156
9	113	213	405	250	125	175	135
Median	120	77	415	274.5	118.5	162.5	135.5

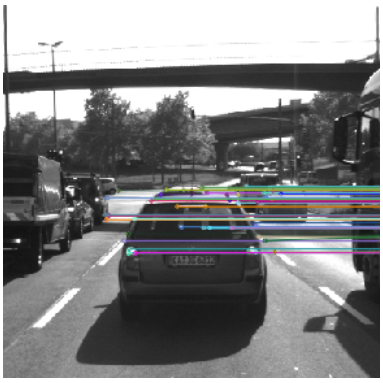
It can be observed that “FAST” detectors give the maximum number of keypoints for each image.


Number of keypoints for each detection method for each image
500
375
250
125
0
Number of keypoints
0
1
2
3
4
5
6
7
8
9
Image index
SHITOMASI
HARRIS
FAST
BRISK
ORB
AKAZE
SIFT


Median Keypoints Detected for Detector
500
375
250
125
0
Number of keypoints
SHITOMASI
HARRIS
FAST
BRISK
ORB
AKAZE
SIFT

Distribution of the keypoints in the preceding car region is as follows:

(1) Shi-Tomasi



The detector detects both the blobs and the edges. It can be seen it detects the edges of the preceding car, taillights, the areas between the car seats

(2) Harris

Harris detector does seem to detect all the edges of the preceding vehicle. It captures keypoints from the roof(upper edge) of the vehicle.

(3) FAST

FAST detector is found to be similar in performance to the Shi-Tomasi detectors. It is able to obtain keypoints corresponding to the edges of the preceding car and taillights.

(4) BRISK

The distribution of keypoints is similar to Shi-Tomasi, it detects edges and blobs.

(5) ORB

ORB seems to have more keypoints concentrated on the right edge of the preceding car. It detects the taillights of the preceding car.

(6) AKAZE

The keypoints are distributed on the edges of the preceding car as well as the taillights. The distribution is similar to what is seen for Shi-Tomasi, FAST and BRISK

(7) SIFT

SIFT seems to have large concentration of keypoints on the upper edge vs the sides. Also few keypoints are seen on the taillights of the preceding car.

TASK MP.8

Your eighth task is to count the number of matched keypoints for all 10 images using all possible combinations of detectors and descriptors. In the matching step, use the BF approach with the descriptor distance ratio set to 0.8.

Comparison of Various Descriptor Methods for Harris Detector for matching points

IMAGE INDEX	HARRIS + BRIEF	HARRIS+ORB	HARRIS+FREAK	HARRIS + SIFT
Image 0				
Image 1	20	18	22	15
Image 2	10	7	9	5
Image 3	18	16	13	16
Image 4	5	1	1	1
Image 5	2	1	2	0
Image 6	16	17	13	19
Image 7	2	3	5	3
Image 8	10	6	2	6
Image 9	5	5	5	3
	HARRIS Detector does not work with AKAZE Descriptor			

Comparison of Various Descriptor Methods for SHITOMASI Detector for matching points

IMAGE INDEX	SHITOMASI+BRIEF	SHITOMASI+ORB	SHITOMASI+FREAK	SHITOMASI+SIFT	SHITOMASI+AKAZE
Image 0					
Image 1	47	46	40	46	Does not work
Image 2	49	46	40	47	
Image 3	44	45	40	45	
Image 4	44	40	36	42	
Image 5	46	48	39	45	
Image 6	46	41	36	43	
Image 7	46	42	32	45	
Image 8	46	44	36	47	
Image 9	46	46	40	46	

Comparison of Various Descriptor Methods for FAST Detector for matching points

IMAGE INDEX	FAST + BRIEF	FAST+ORB	FAST+FREAK	FAST+SIFT
Image 0				
Image 1	45	43	35	44
Image 2	47	44	38	44
Image 3	40	40	31	40
Image 4	46	44	35	42
Image 5	40	39	35	42
Image 6	42	42	38	41
Image 7	43	39	33	39
Image 8	43	44	36	40
Image 9	47	47	43	38
	FAST detector does not work with AKAZE descriptor			

Comparison of Various Descriptor Methods for BRISK Detector for matching points

	BRISK + BRIEF	BRISK + ORB	BRISK + FREAK	BRISK + SIFT
Image 0				
Image 1	36	29	35	34
Image 2	30	33	35	35
Image 3	35	32	34	36
Image 4	36	35	38	37
Image 5	33	34	33	33
Image 6	34	39	42	37
Image 7	37	33	33	32
Image 8	35	34	34	37
Image 9	36	35	38	38
	BRISK detector does not work with FREAK descriptor			

Comparison of Various Descriptor Methods for ORB Detector for matching points

	ORB+BRIEF	ORB+ORB	ORB+FREAK	ORB+SIFT
Image 0				
Image 1	31	32	32	39
Image 2	18	37	24	45
Image 3	22	38	28	44
Image 4	29	39	27	40
Image 5	28	40	27	37
Image 6	36	37	25	41
Image 7	34	37	28	41
Image 8	28	37	21	39
Image 9	36	41	27	42
	ORB detector does not work with FREAK descriptor			

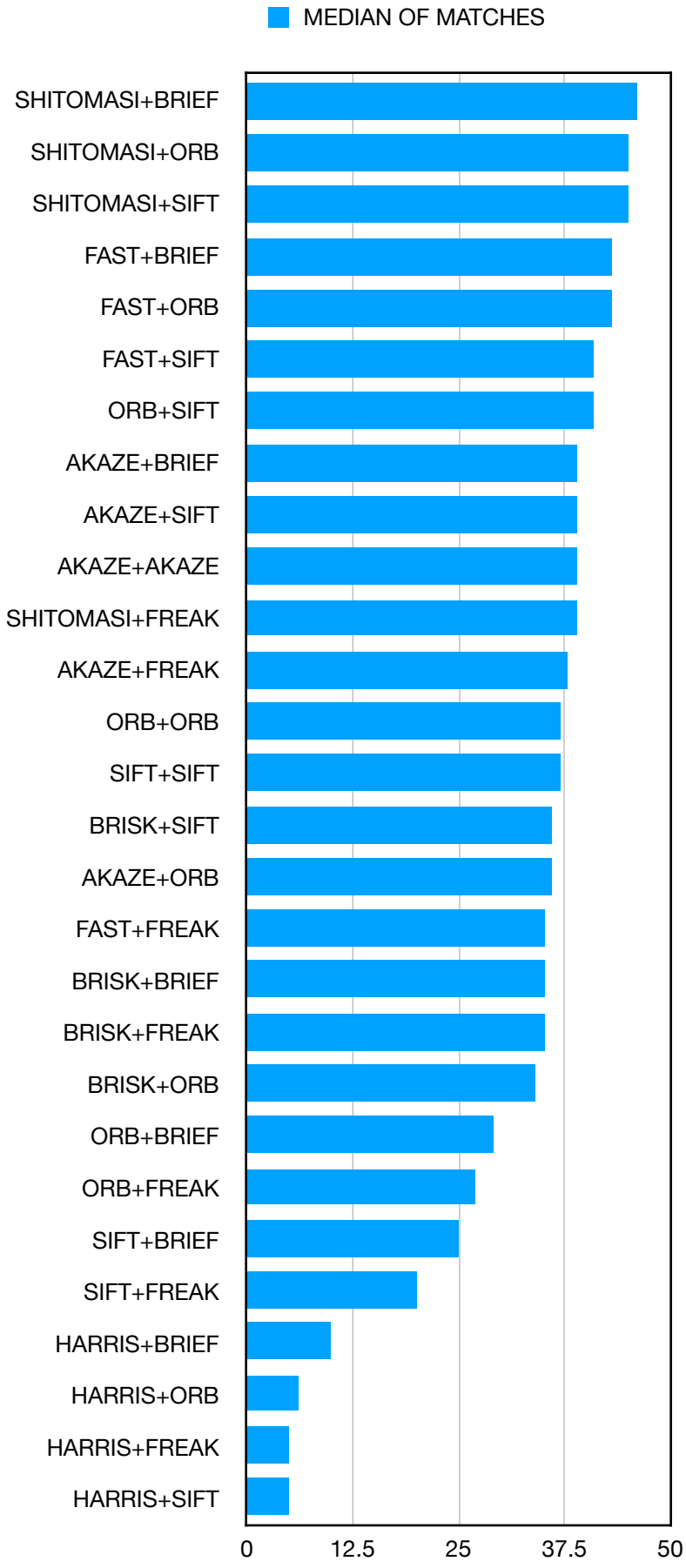
Comparison of Various Descriptor Methods for AKAZE Detector for matching points

IMAGE INDEX	AKAZE+BRIEF	AKAZE+ORB	AKAZE+FREAK	AKAZE+SIFT	AKAZE+AKAZE
Image 0					
Image 1	38	36	31	36	39
Image 2	37	37	39	39	39
Image 3	39	36	40	37	42
Image 4	39	34	31	42	41
Image 5	39	36	33	39	37
Image 6	44	35	38	42	46
Image 7	39	33	37	39	39
Image 8	39	36	40	36	37
Image 9	45	41	41	45	46

Comparison of Various Descriptor Methods for SIFT Detector for matching

IMAGE INDEX	SIFT + BRIEF	SIFT + ORB	SIFT + FREAK	SIFT + SIFT	SIFT + AKAZE
Image 0					
Image 1	25	Did not work	18	37	Did not work
Image 2	26		23	36	
Image 3	21		20	34	
Image 4	29		23	40	
Image 5	21		14	36	
Image 6	31		24	37	
Image 7	19		17	30	
Image 8	20		15	37	
Image 9	29		32	37	

DETECTOR+DESCRIPTOR	MEDIAN OF MATCHES
SHITOMASI+BRIEF	46
SHITOMASI+ORB	45
SHITOMASI+SIFT	45
FAST+BRIEF	43
FAST+ORB	43
FAST+SIFT	41
ORB+SIFT	41
AKAZE+BRIEF	39
AKAZE+SIFT	39
AKAZE+AKAZE	39
SHITOMASI+FREAK	39
AKAZE+FREAK	38
ORB+ORB	37
SIFT+SIFT	37
BRISK+SIFT	36
AKAZE+ORB	36
FAST+FREAK	35
BRISK+BRIEF	35
BRISK+FREAK	35
BRISK+ORB	34
ORB+BRIEF	29
ORB+FREAK	27
SIFT+BRIEF	25
SIFT+FREAK	20
HARRIS+BRIEF	10
HARRIS+ORB	6
HARRIS+FREAK	5
HARRIS+SIFT	5



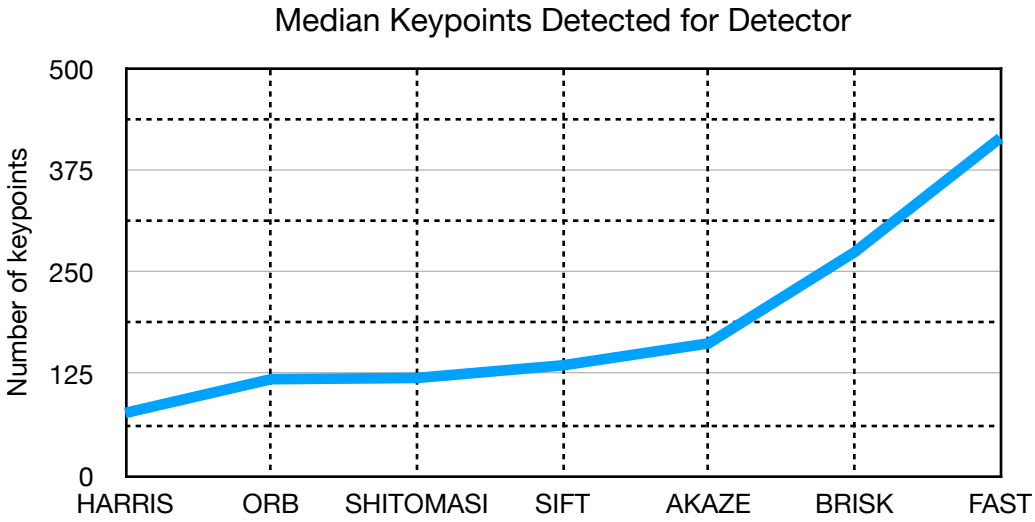
TASK MP.9

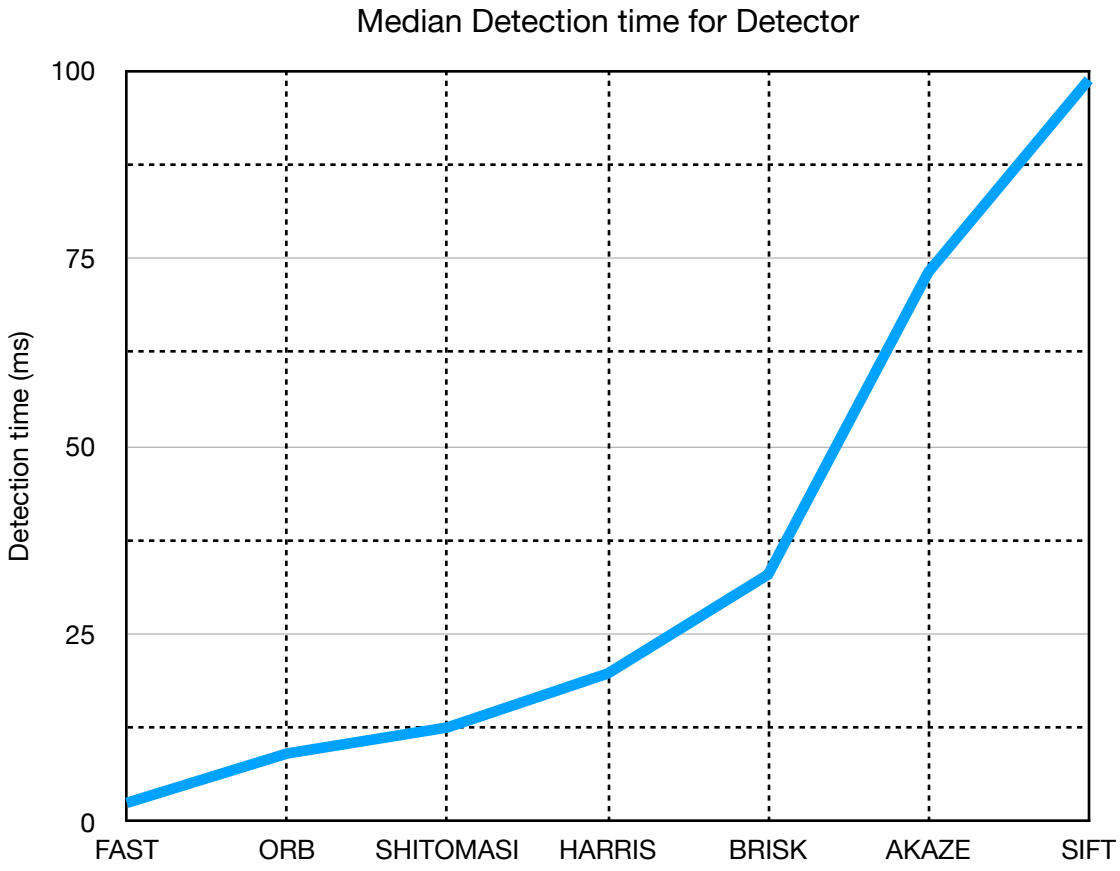
Your ninth task is to log the time it takes for keypoint detection and descriptor extraction. The results must be entered into a spreadsheet and based on this information you will then suggest the TOP3 detector / descriptor combinations as the best choice for our purpose of detecting keypoints on vehicles. Finally, in a short text, please justify your recommendation based on your observations and on the data you collected.

Detector Selection:

Following results were obtained for the median of keypoints detected and median of detection times of the detectors,

Detector	Median Keypoints	Median Detection Time(ms)
SHITOMASI	120	12.58135
HARRIS	77	19.7593
FAST	415	2.547985
BRISK	274.5	32.92265
ORB	118.5	9.11777
AKAZE	162.5	73.1769
SIFT	135.5	98.7673





FAST provides the maximum number of keypoints in the least amount of time. Also the distribution of the keypoints are on the edges and taillights of the preceding vehicle.

Even though ORB has low detection time, I won't be considering it as the keypoints obtained were concentrated on one side of the preceding car compared to the other.

Shi-Tomasi detector is other good option which performs well with low detection time. Also the keypoints obtained are distributed on the edges and the taillights of the preceding car, contrary to ORB.

Harris does not provide good distribution of keypoints and must not be used for this purpose.

BRISK and AKAZE both provide good distribution of keypoints but have a higher detection time and will not be considered.

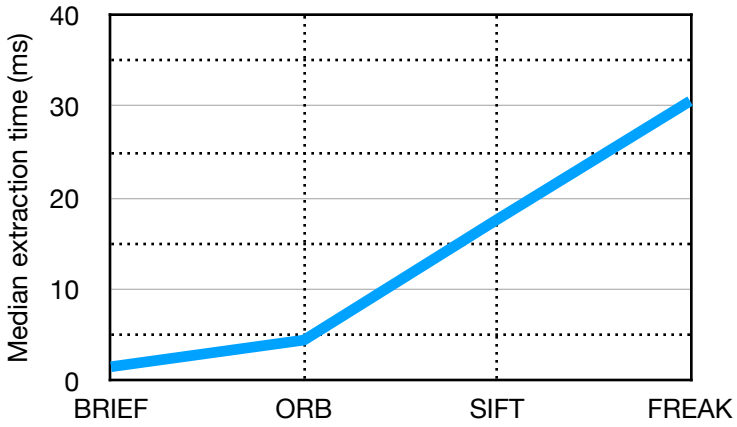
So in terms of detectors, I will be using FAST and Shi-Tomasi.

Descriptor Selection:

In OpenCV, AKAZE descriptor only works with AKAZE detector(https://knowledge.udacity.com/questions/163998). So I won't be considering AKAZE for descriptor.

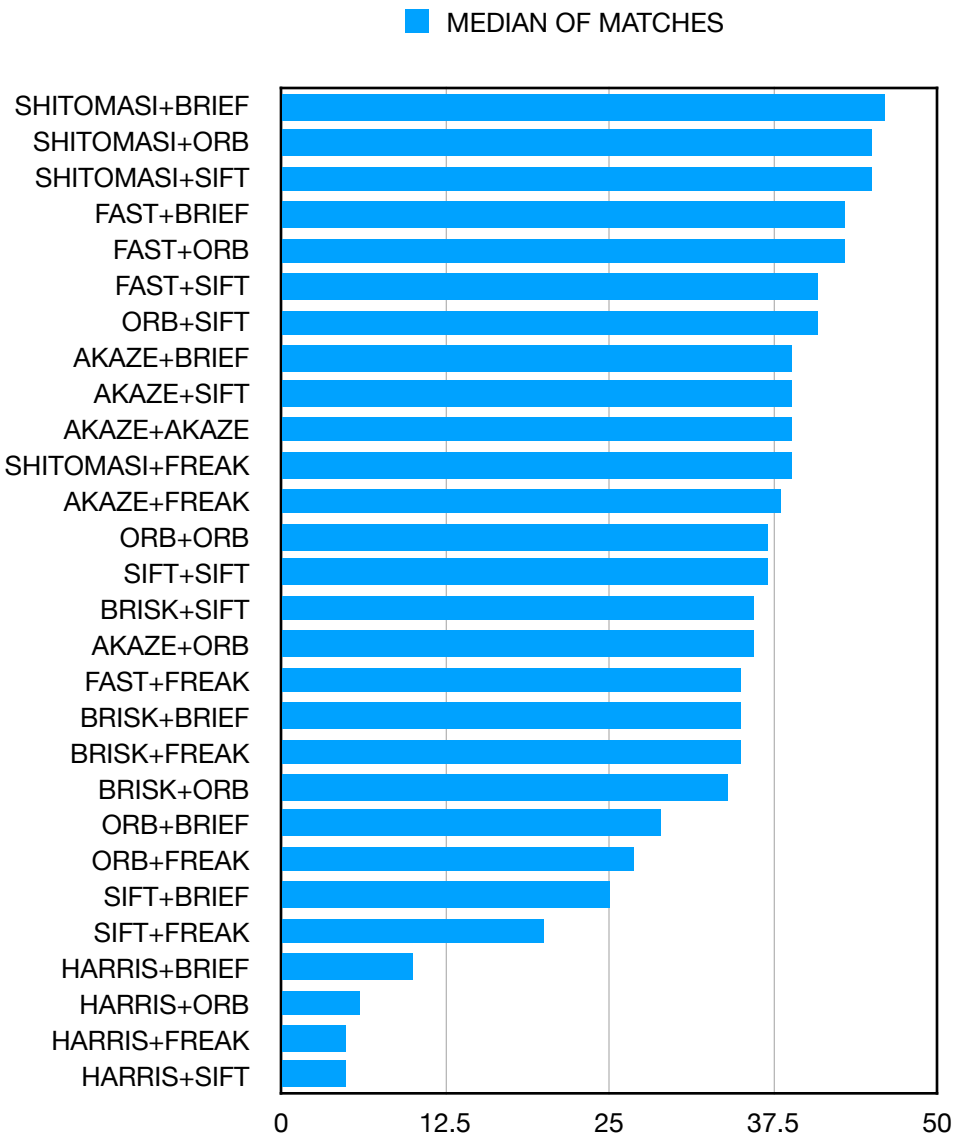
Following results were obtained for the median descriptor extraction times(for these the detector used was FAST):

Descriptor	Median Descriptor Extraction Time(ms)
BRIEF	1.536015
ORB	4.45128
SIFT	17.63655
FREAK	30.59755



BRIEF and ORB are providing lower descriptor extraction time and will be used.

Combination of Detector and Descriptor:



In the previous sections, the detectors were narrowed down to FAST and Tsi-Tomasi and descriptors were narrowed down to BRIEF and ORB. Now going by the number of matches produced by these combinations, my recommendation for top three combinations of Detector and Descriptor would be :

(1) FAST and BRIEF

(2) FAST and ORB

(3) Shi-Tomasi and BRIEF