Comparative Evaluation of Binary Features

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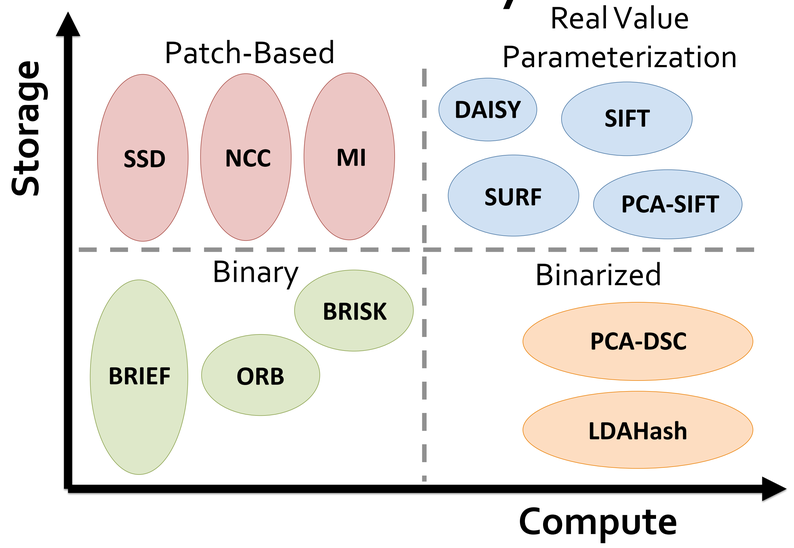
Goals

- Develop benchmark for binary features that is compatible with existing evaluations
- Perform quantitative analysis on detector/descriptor pairings
- Provide a comprehensive set of evaluation datasets

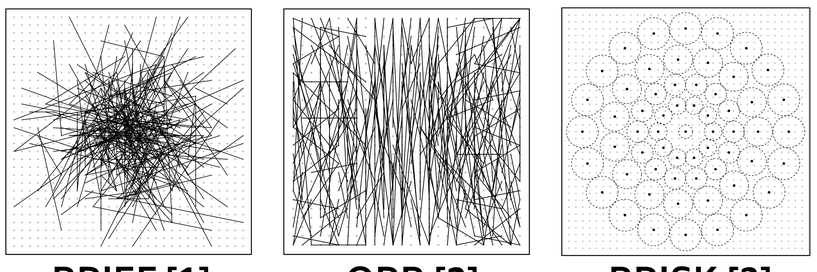
Binary Descriptor Properties

- Descriptor is built from a set of pairwise intensity comparisons
- Each bit in the descriptor is the result of exactly one comparison
- The sampling pattern is fixed (except for possible scaling/rotation)
- Hamming distance can be used as a similarity measure
- Provide robustness as well as high computational efficiency

Taxonomy



Descriptor Patterns



BRIEF [1]

ORB [2]
Rotation Invariant

BRISK [3]
Rotation Invariant
Scale Invariant

Metrics

Putative Match Ratio = # Putative Matches / # Features

Precision = # Correct Matches / # Putative Matches

Matching Score = # Correct Matches / # Features

Recall = # Correct Matches / # Correspondences

 # Correspondences = # Ground Truth Matches

Detector Entropy = Entropy of 2D histogram of feature locations

Datasets

Sample datasets from [4], [5], and our work.

Results

Evaluation of Detector/Descriptor Pairings

Detectors
H = Harris
MR = MSER
FT = FAST
OB = ORB
BK = BRISK
SF = SURF
ST = SIFT

Descriptors
BF = BRIEF
OB = ORB
BK = BRISK
SF = SURF
ST = SIFT

Blur

Putative Match Ratio	BF	OB	BK	SF	ST
H	25	11	11		
MR	19	10	9		
FT	23	10	11		
OB	13	10	8		
BK	20	9	9		
SF	31	15	12	15	
ST	19	8	9		10

Precision	BF	OB	BK	SF	ST
H	67	78	84		
MR	83	88	89		
FT	68	72	85		
OB	70	78	87		
BK	67	77	73		
SF	72	82	79	71	
ST	63	76	76		73

Matching Score	BF	OB	BK	SF	ST
H	17	8	9		
MR	12	7	6		
FT	15	7	9		
OB	9	8	7		
BK	13	7	6		
SF	22	12	9	11	
ST	12	6	7		7

Recall	BF	OB	BK	SF	ST
H	44	22	24		
MR	40	22	19		
FT	39	10	24		
OB	19	16	12		
BK	31	9	14		
SF	55	29	22	28	
ST	38	18	18		24

Compression

Putative Match Ratio	BF	OB	BK	SF	ST
H	68	54	51		
MR	43	31	29		
FT	50	33	35		
OB	35	36	33		
BK	50	35	33		
SF	59	43	30	47	
ST	35	23	28		29

Precision	BF	OB	BK	SF	ST
H	93	87	97		
MR	83	88	86		
FT	91	96	97		
OB	95	97	98		
BK	93	97	94		
SF	92	96	94	90	
ST	85	93	94		91

Matching Score	BF	OB	BK	SF	ST
H	64	53	49		
MR	36	27	25		
FT	46	32	34		
OB	34	35	30		
BK	46	34	32		
SF	54	41	28	42	
ST	30	22	27		26

Recall	BF	OB	BK	SF	ST
H	80	64	63		
MR	53	40	33		
FT	69	47	54		
OB	47	49	35		
BK	59	43	41		
SF	74	56	39	61	
ST	55	40	40		55

Exposure

Putative Match Ratio	BF	OB	BK	SF	ST
H	39	28	26		
MR	45	31	30		
FT	53	38	39		
OB	46	36	35		
BK	44	32	28		
SF	43	31	25	30	
ST	34	25	29		34

Precision	BF	OB	BK	SF	ST
H	90	91	93		
MR	78	76	72		
FT	84	93	95		
OB	89	93	96		
BK	81	90	87		
SF	80	88	82	78	
ST	76	88	87		86

Matching Score	BF	OB	BK	SF	ST
H	31	26	24		
MR	34	24	22		
FT	44	36	37		
OB	32	34	34		
BK	36	29	24		
SF	34	28	21	23	
ST	26	22	25		29

Recall	BF	OB	BK	SF	ST
H	63	51	52		
MR	63	44	39		
FT	65	51	58		
OB	51	53	45		
BK	55	43	37		
SF	73	58	44	53	
ST	58	48	48		74

Day-Night Illumination

Putative Match Ratio	BF	OB	BK	SF	ST
H	13	8	7		
MR	15	10	9		
FT	11	7	7		
OB	6	5	5		
BK	7	6	6		
SF	10	5	4	8	
ST	7	5	6		10

Precision	BF	OB	BK	SF	ST
H	64	76	82		
MR	52	61	66		
FT	71	76	84		
OB	78	80	89		
BK	69	73	79		
SF	57	60	57	37	
ST	49	54	61		55

Matching Score	BF	OB	BK	SF	ST
H	8	6	5		
MR	8	4	3		
FT	7	5	6		
OB	6	4	4		
BK	6	4	4		
SF	6	3	2	3	
ST	4	3	3		6

Recall	BF	OB	BK	SF	ST
H	32	21	22		
MR	47	24	18		
FT	25	17	21		
OB	13	13	11		
BK	20	14	15		
SF	35	21	15	19	
ST	24	17	18		40

Scale

Putative Match Ratio	BF	OB	BK	SF	ST
H	19	10	12		
MR	10	8	9		
FT	15	7	12		
OB	8	21	5		
BK	11	7	40		
SF	15	8	8	56	
ST	14	7	10		57

Precision	BF	OB	BK	SF	ST
H	80	80	87		
MR	69	68	53		
FT	77	73	89		
OB	79	92	91		
BK	74	73	78		
SF	75	67	70	81	
ST	76	72	82		96

Matching Score	BF	OB	BK	SF	ST
H	15	8	11		
MR	7	4	5		
FT	11	6	10		
OB	4	19	5		
BK	8	5	31		
SF	11	5	6	45	
ST	11	5	8		54

Recall	BF	OB	BK	SF	ST
H	24	13	17		
MR	10	6	7		
FT	19	9	17		
OB	6	29	6		
BK	11	7	42		
SF	17	8	8	69	
ST	16	7	10		80

Rotation

Putative Match Ratio	BF	OB	BK	SF	ST
H	3	69	64		
MR	5	44	42		
FT	3	62	68		
OB	1	62	58		
BK	2	52	51		
SF	4	44	38	43	
ST	3	41	50		58

Precision	BF	OB	BK	SF	ST
H	14	93	88		
MR	18	90	76		
FT	15	91	93		
OB	12	86	94		
BK	12	89	86		
SF	13	88	79	82	
ST	13	93	84		96

Matching Score	BF	OB	BK	SF	ST
H	0	64	56		
MR	1	40	33		
FT	0	57	64		
OB	0	53	55		
BK	0	38	30		
SF	0	38	35	55	
ST	0	38	42		55

Recall	BF	OB	BK	SF	ST
H	31	68	62		
MR	1	50	39		
FT	0	63	74		
OB	0	62	53		
BK	0	52	48		
SF	1	57	45	55	
ST	1	50	48		79

Scale & Rotation

Putative Match Ratio	BF	OB	BK	SF	ST
H	4	6	6		
MR	6	6	5		
FT	2	4	6		
OB	1	8	3		
BK	2	4	13		
SF	3	4	4	14	
ST	3	4	4		13

Precision	BF	OB	BK	SF	ST
H	54	65	81		
MR	19	40	35		
FT	23	64	83		
OB	20	83	86		
BK	27	68	84		
SF	20	48	58	68	
ST	18	55	72		84

Matching Score	BF	OB	BK	SF	ST
H	1	4	5		
MR	1	2	2		
FT	1	3	5		
OB	0	7	3		
BK	0	3	11		
SF	1	2	2	9	
ST	0	2	3		11

Recall	BF	OB	BK	SF	ST
H	2	6	15		
MR	5	9	8		
FT	1	4	7		
OB	0	8	3		
BK	1	3	14		
SF	1	5	6	25	
ST	1	5	7		30

Perspective Planar Scene

Putative Match Ratio	BF	OB	BK	SF	ST
H	29	14	17		
MR	15	9	9		
FT	21	12	15		
OB	12	15	13		
BK	19	11	13		
SF	18	10	10	15	
ST	18	9	13		24

Precision	BF	OB	BK	SF	ST
H	88	87	90		
MR	76	68	72		
FT	84	85	89		
OB	89	88	92		
BK	86	83	87		
SF	78	73	75	73	
ST	83	80	81		86

Matching Score	BF	OB	BK	SF	ST
H	26	13	15		
MR	11	6	6		
FT	21	11	15		
OB	10	7	8		
BK	16	9	11		
SF	14	7	7	11	
ST	15	7	11		20

Recall	BF	OB	BK	SF	ST
H	66	38	49		
MR	25	13	14		
FT	28	8	21		
OB	13	15	12		
BK	22	7	15		
SF	32	17	17	25	
ST	28	14	17		42

Perspective Non-Planar

Putative Match Ratio	BF	OB	BK	SF	ST
H	22	13	14		
MR	17	11	11		
FT	21	12	15		
OB	10	13	9		
BK	15	9	15		
SF	16	9	9	18	
ST	15	9	13		22

Precision	BF	OB	BK	SF	ST
H	60	66	73		
MR	55	39	37		
FT	73	73	81		
OB	77	80	85		
BK	63	62	72		
SF	58	54	58	61	
ST	69	68	75		84

Matching Score	BF	OB	BK	SF	ST
H	13	9	10		
MR	9	4	4		
FT	15	9	12		
OB	7	10	8		
BK	9	5	11		
SF	10	5	5	11	
ST	11	6	10		19

Recall	BF	OB	BK	SF	ST
H	30	19	23		
MR	32	15	13		
FT	30	17	24		
OB	12	18	11		
BK	19	10	20		
SF	28	14	15	33	
ST	24	13	18		44

Photo Collection

Putative Match Ratio	BF	OB	BK	SF	ST
H	11	6	6		
MR	11	7	7		
FT	9	5	5		
OB	4	6	4		
BK	4	4	7		
SF	10	6	5	11	
ST	8	4	5		11

Precision	BF	OB	BK	SF	ST
H	81	78	84		
MR	76	72	63		
FT	84	77	86		
OB	87	84	88		
BK	83	77	86		
SF	79	73	75	79	
ST	76	71	75		83

Matching Score	BF	OB	BK	SF	ST
H	9	5	5		
MR	8	5	4		
FT	7	4	5		
OB	4	5	3		
BK	6	3	6		
SF	8	4	4	8	
ST	6	3	4		10

Recall	BF	OB	BK	SF	ST
H	8	5	5		
MR	8	5	4		
FT	7	4	5		
OB	4	5	3		
BK	6	3	6		
SF	8	4	4	9	
ST	6	3	3		10

Computation Requirements

Detector/Descriptor	BRIEF	ORB	BRISK	SURF	SIFT	FAST	Harris	MSER
Detector ms/image	n/a	17	43	377	572	2.7	78	117
Descriptor µs/feature	4.4	4.8	12.9	143	314	n/a	n/a	n/a
Storage bytes/feature	16,32,64	32	64	64(256)	128(512)	n/a	n/a	n/a

Feature Distribution

Detector	FAST	SIFT	BRISK	SURF	ORB	Harris	MSER
Avg # Features	8166	4788	7771	3766	13427	2543	693
Entropy	12.52	12.34	12.33	12.26	12.10	11.84	10.74

Conclusions

- Avoid using descriptors that are invariant to a transform not present in your dataset
- Use a detector/descriptor pairing where both are invariant to the same set of transforms
- Order-of-magnitude speed gains are achievable by binary descriptors, resulting (at worse) in marginal matching performance penalties

Bibliography

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