BRIEF: Computing a Local Binary Descriptor Very Fast

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October 11, 2012

Motivation: A 256-Byte Descriptor?

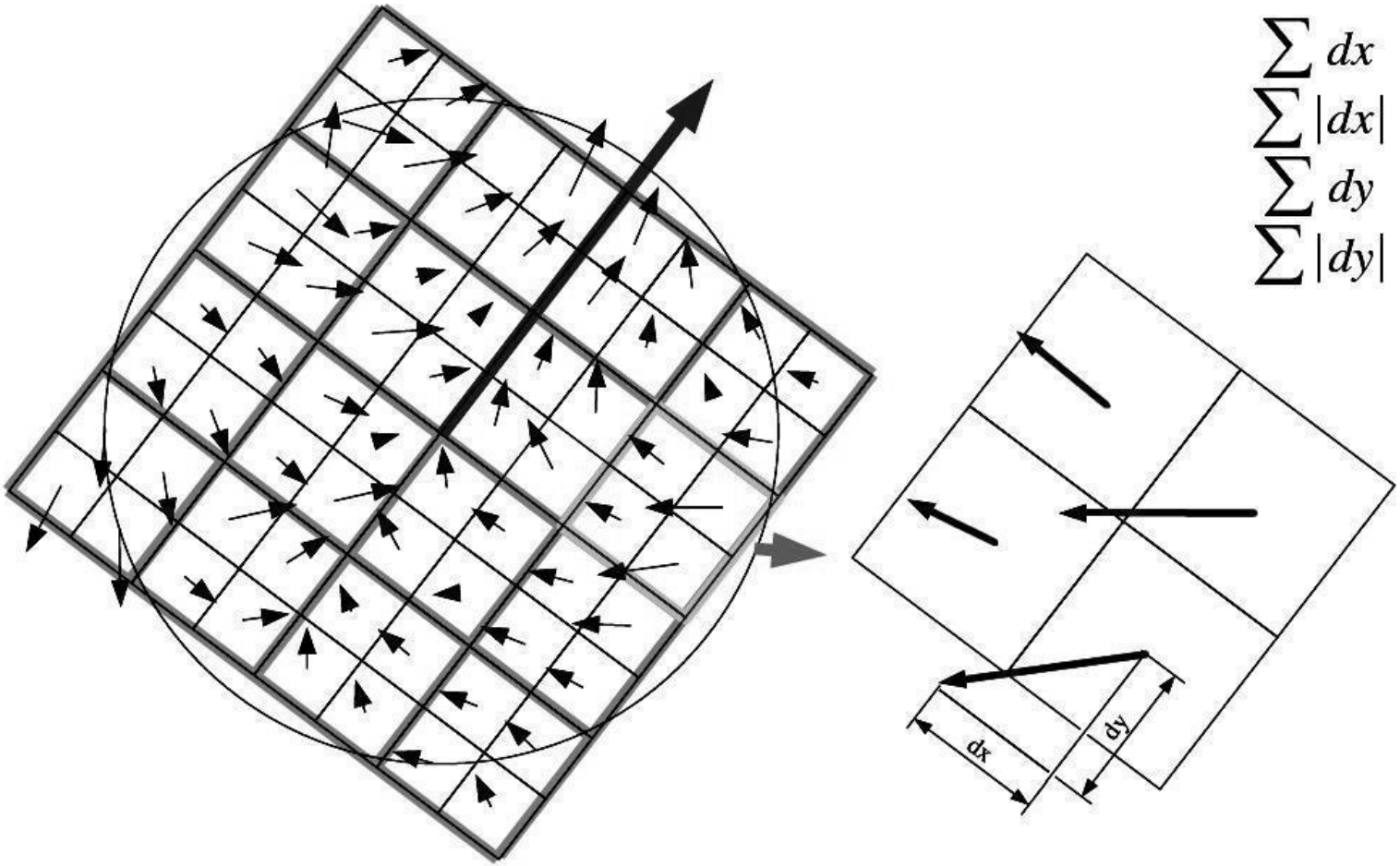


Figure: A SURF descriptor stores 64 orientation values as 4-byte integers.

Problem Definition: Make It Smaller, Compute It Faster

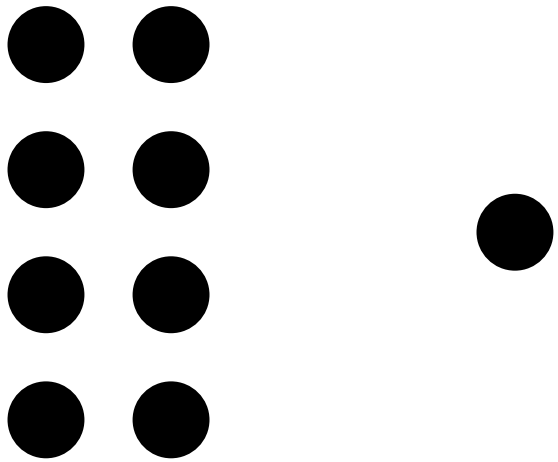
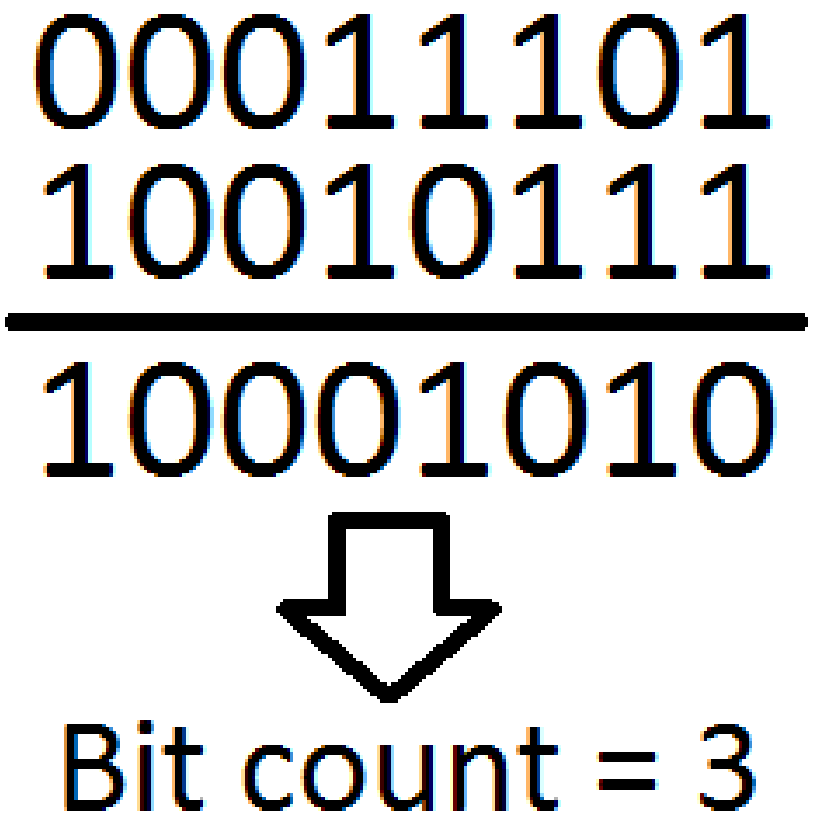
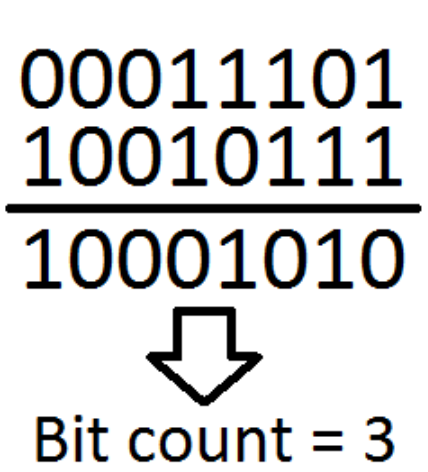


Figure: Reduce the size by a factor of 8.

Background: Hamming Distance



Background: Hamming Distance



XOR EAX, EBX
POPCNT EAX, EAX

01101011101 10010101010	10
10001110101 11000110100	3
11101110111 10101010101	?

Method: Sampling Distributions

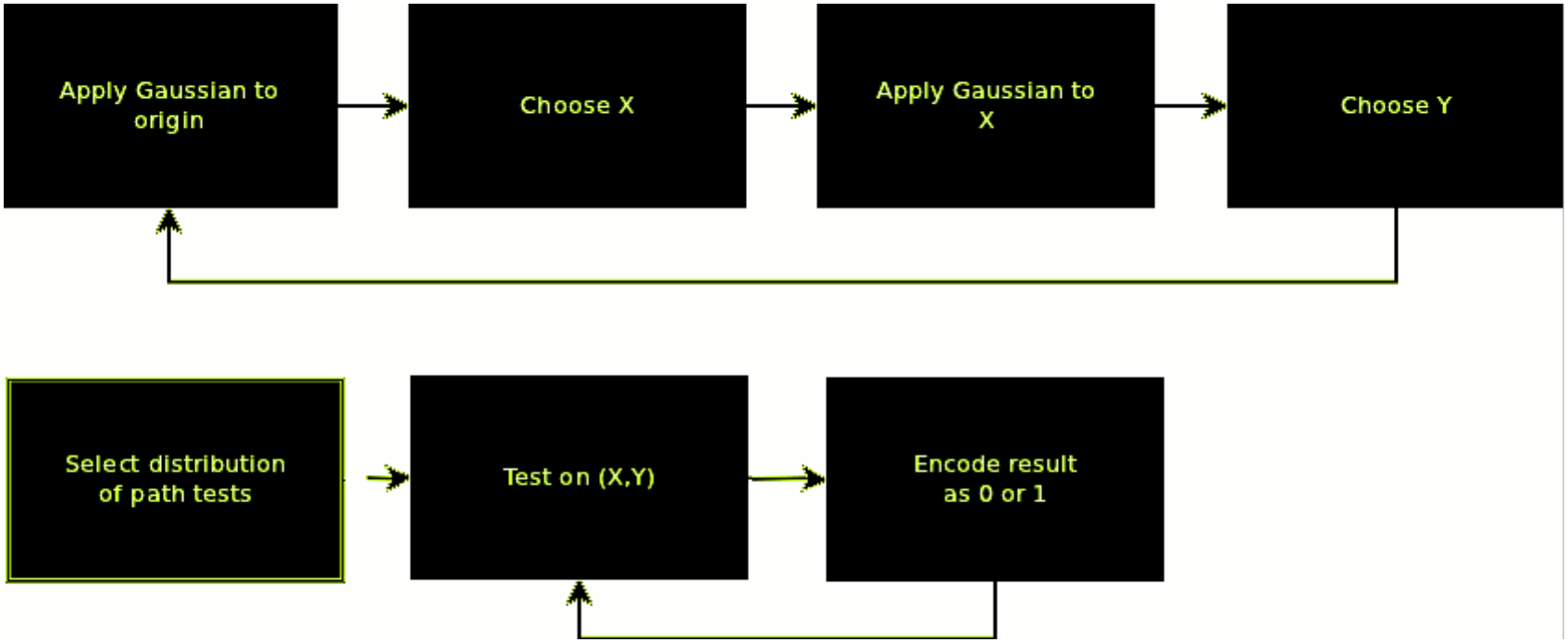


Figure: Sampling distributions.

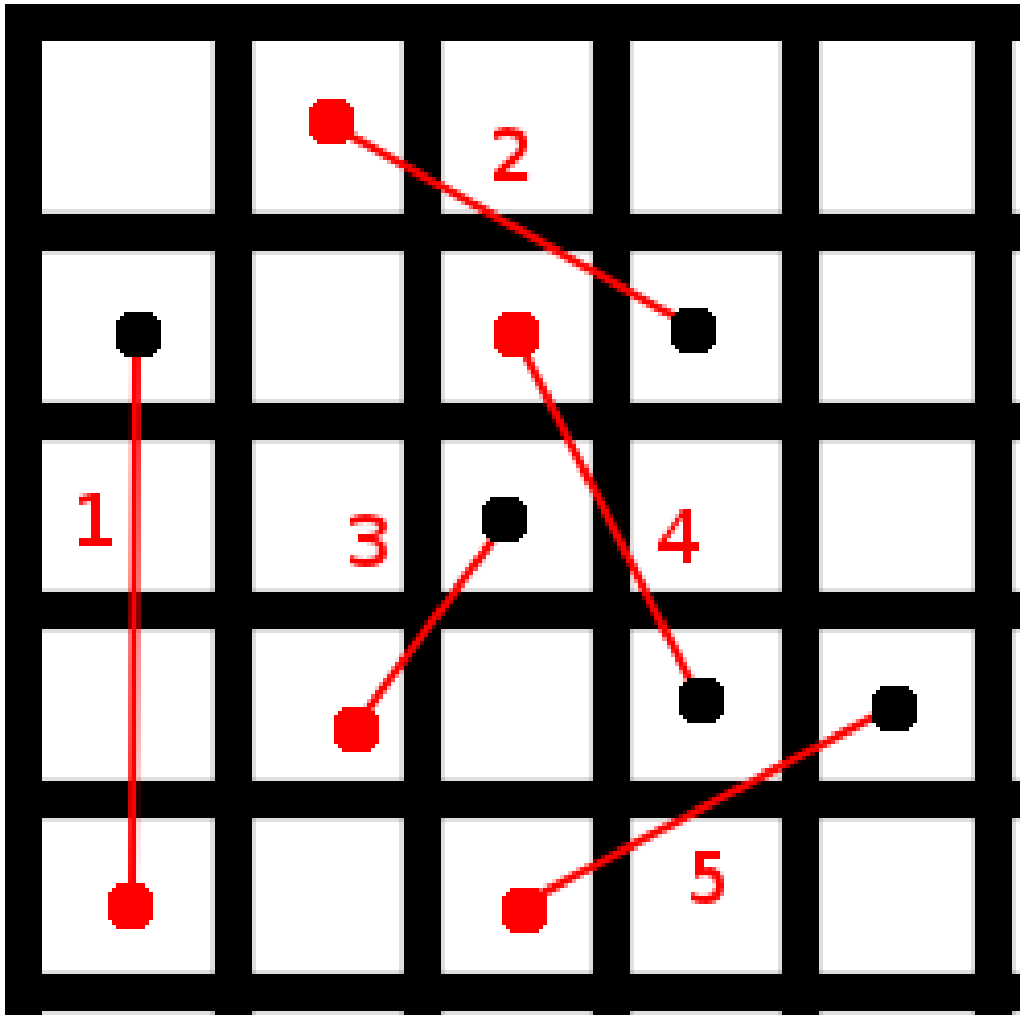
Method: Patch Test

$$\tau(p; \mathbf{x}, y) := \begin{cases} 1 & \text{if } I(\mathbf{p}, \mathbf{x}) < I(\mathbf{p}, \mathbf{y}) \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

Method: Descriptor Formula

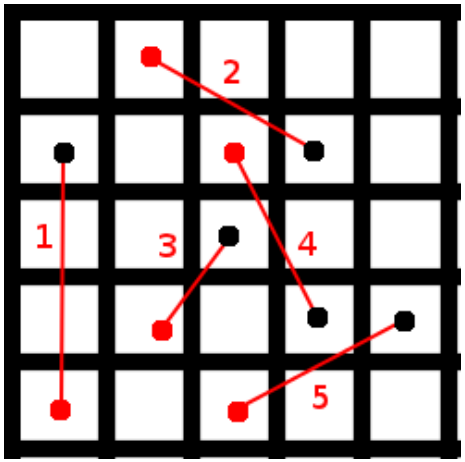
$$\sum_{I \leq i \leq n_d} 2^{i-1} \tau(p; x_i, y_i) \tag{2}$$

Method: Example of Distribution



Example of Patch Test on Distribution

$$\begin{bmatrix} 1 & 3 & 5 & 4 & 2 \\ 3 & 2 & 1 & 8 & 7 \\ 9 & 5 & 4 & 6 & 4 \\ 7 & 9 & 5 & 2 & 1 \\ 2 & 3 & 6 & 5 & 4 \end{bmatrix}$$



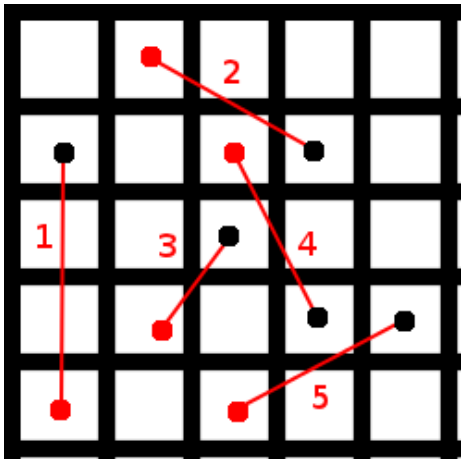
x	y	τ
2	3	1
3	8	1
9	4	0
1	2	1
6	1	0

11010

Figure: Sampling distributions

Example of Patch Test on Distribution

$$\begin{bmatrix} 3 & 2 & 1 & 8 & 7 \\ 9 & 5 & 4 & 6 & 4 \\ 7 & 9 & 5 & 2 & 1 \\ 1 & 3 & 5 & 4 & 2 \\ 2 & 3 & 6 & 5 & 4 \end{bmatrix}$$



x	y	τ
2	9	1
2	6	1
3	5	1
4	4	0
6	2	0

11100

Figure: Sampling distributions

1	1	0	1	0
1	1	1	0	0
y	y	n	n	y

Hamming distance: 2.

Method: Sampling

$$\begin{aligned} \mathbf{X} &\leftarrow Gaussian(0, \frac{1}{25} S^2) \\ \mathbf{Y} &\leftarrow Gaussian(0, \frac{1}{25} S^2) \end{aligned} \tag{3}$$

$$\begin{aligned} \mathbf{X} &\leftarrow Gaussian(0, \frac{1}{25} S^2) \\ \mathbf{Y} &\leftarrow Gaussian(x, \frac{1}{100} S^2) \end{aligned} \tag{4}$$

Method: Sampling Distributions

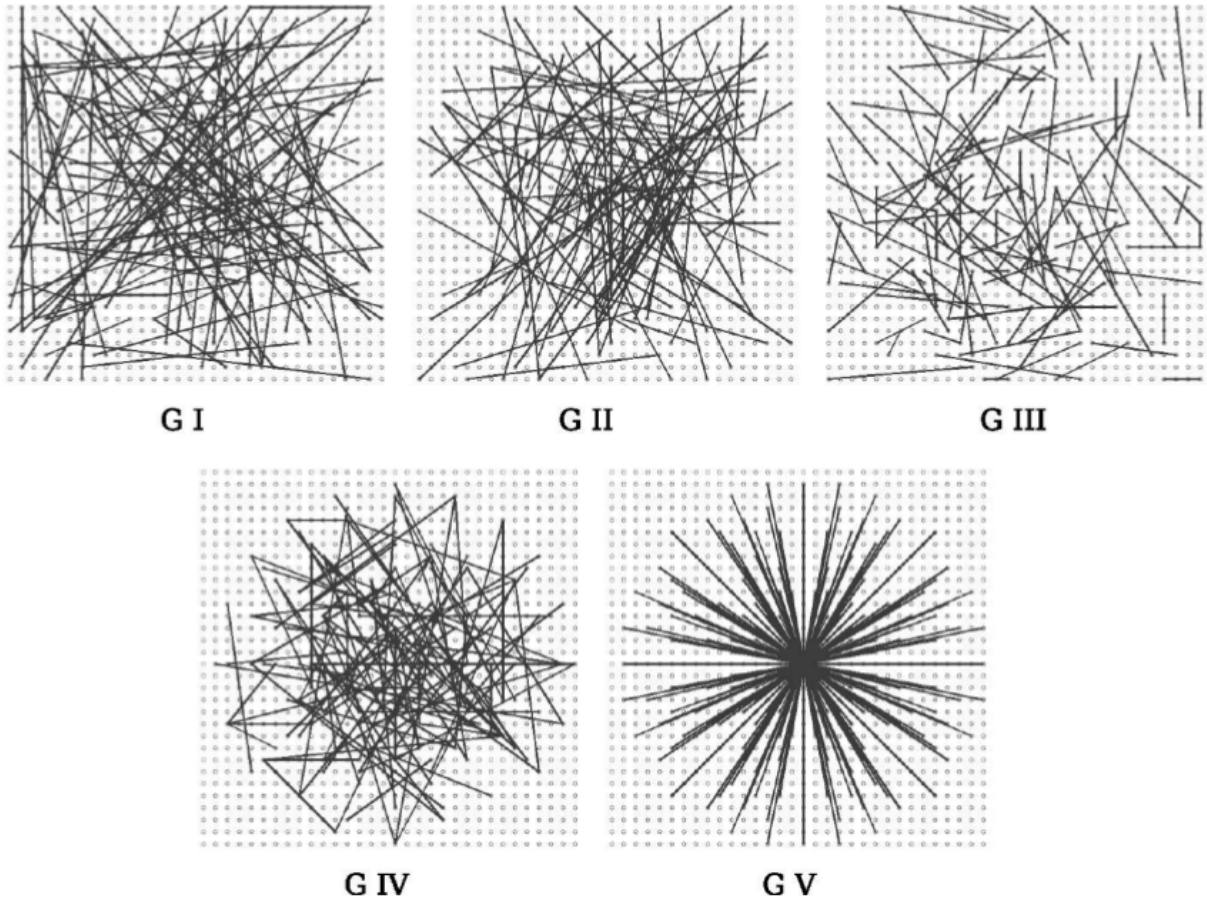
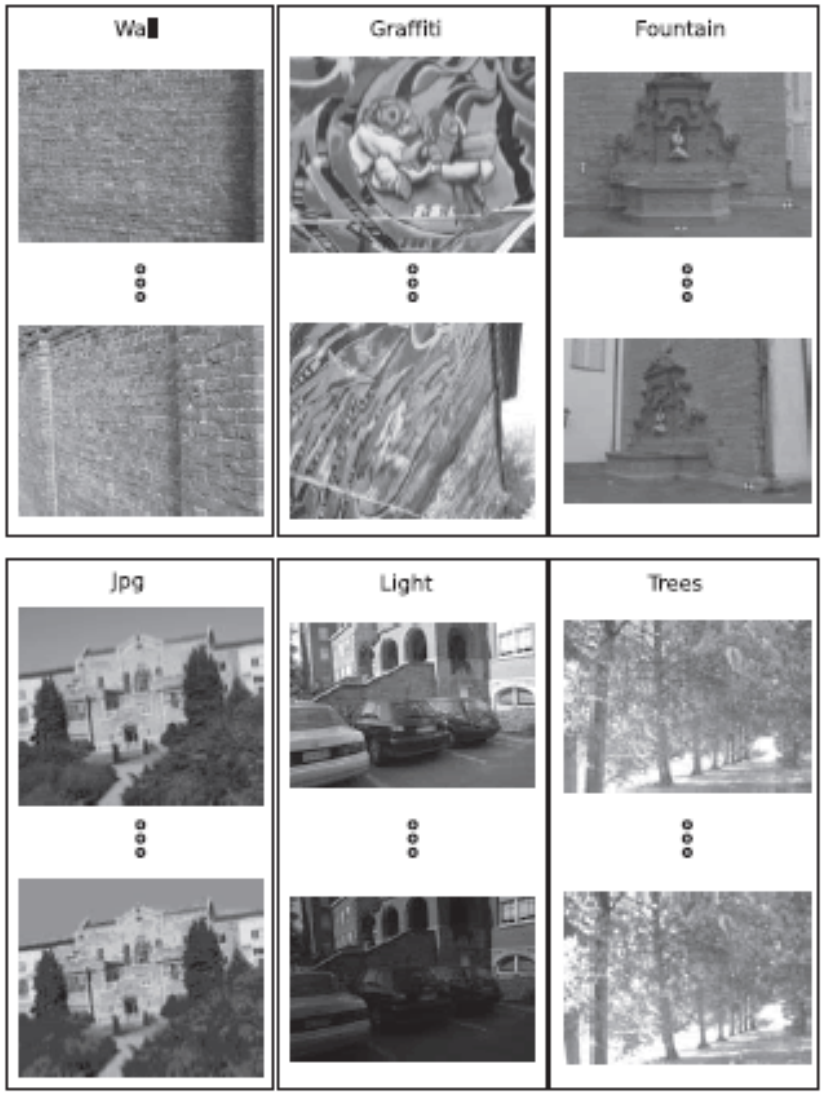


Figure: Sampling distributions.

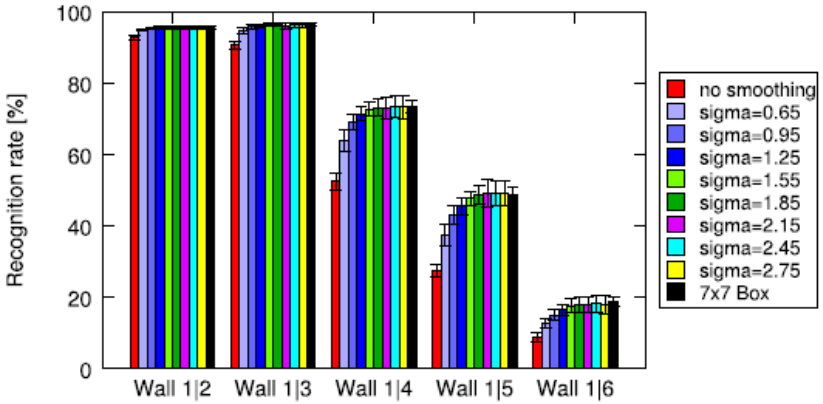


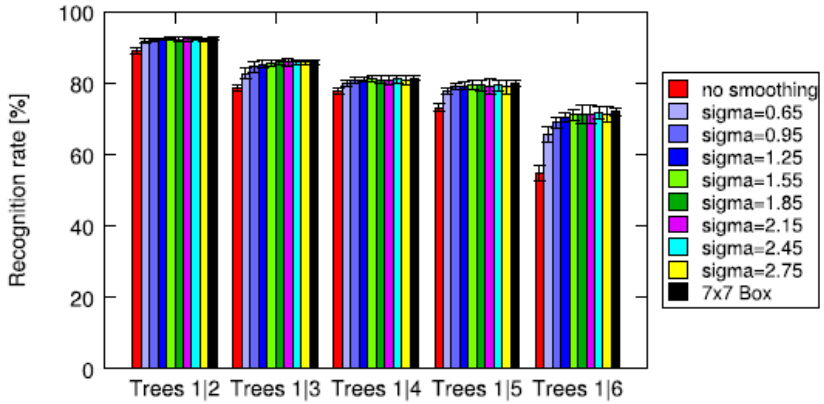
(a)

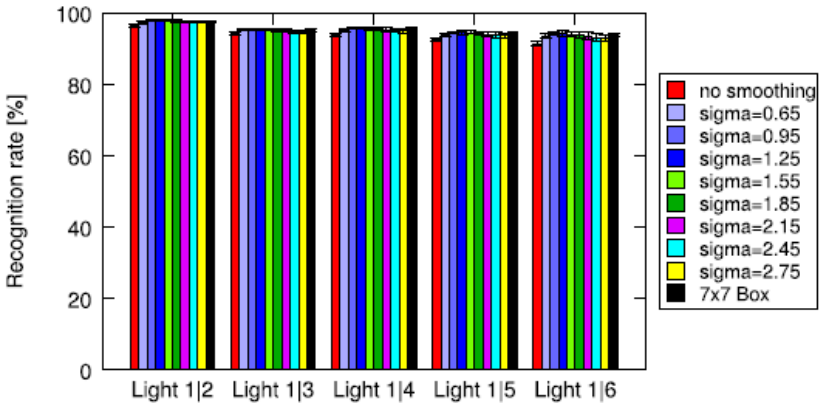
(b)

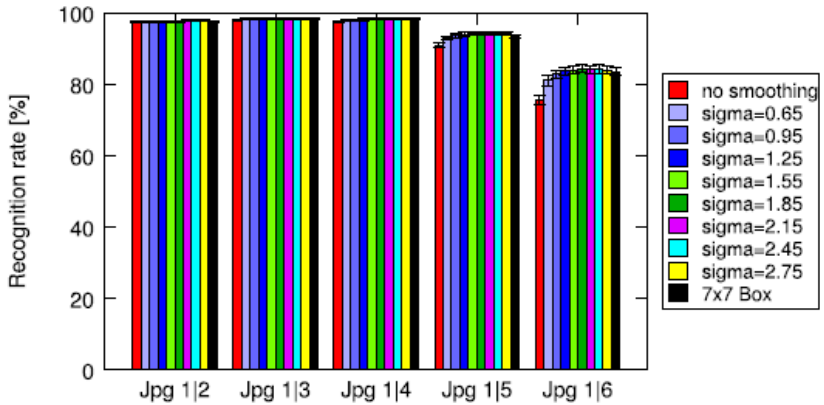
Experimental Setup

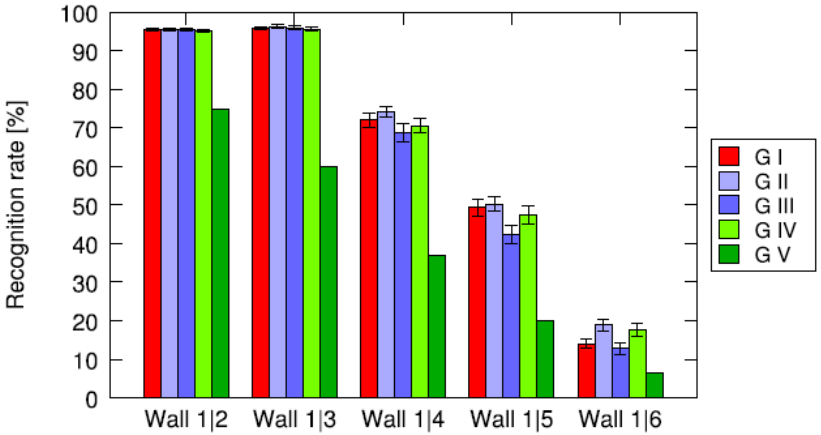
- U-BRIEF
- S-BRIEF
- O-BRIEF
- D-BRIEF

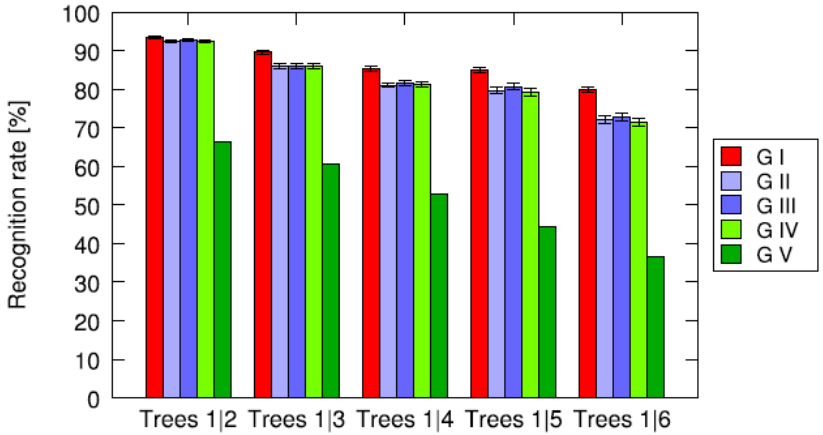

Recognition rate [%]
100
80
60
40
20
0
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6
no smoothing
sigma=0.65
sigma=0.95
sigma=1.25
sigma=1.55
sigma=1.85
sigma=2.15
sigma=2.45
sigma=2.75
7x7 Box

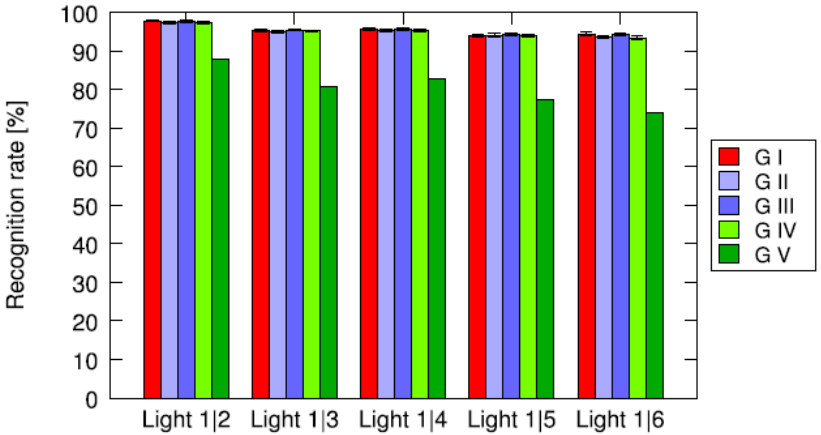

Recognition rate [%]
100
80
60
40
20
0
Trees 1|2
Trees 1|3
Trees 1|4
Trees 1|5
Trees 1|6
no smoothing
sigma=0.65
sigma=0.95
sigma=1.25
sigma=1.55
sigma=1.85
sigma=2.15
sigma=2.45
sigma=2.75
7x7 Box

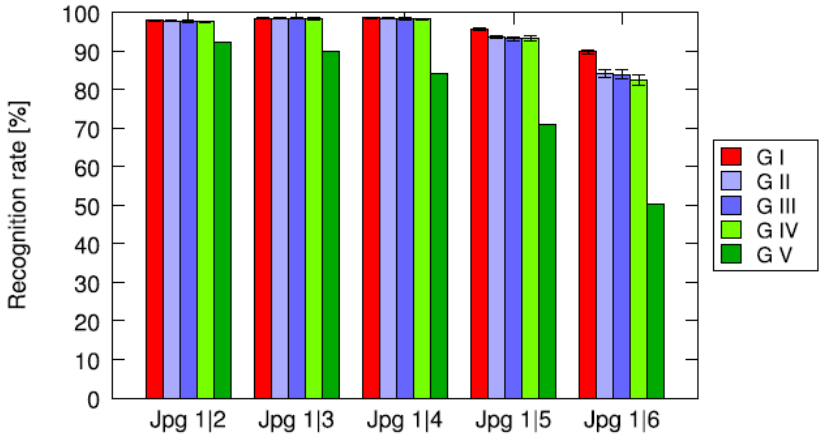

Recognition rate [%]
100
80
60
40
20
0
Light 1|2
Light 1|3
Light 1|4
Light 1|5
Light 1|6
no smoothing
sigma=0.65
sigma=0.95
sigma=1.25
sigma=1.55
sigma=1.85
sigma=2.15
sigma=2.45
sigma=2.75
7x7 Box

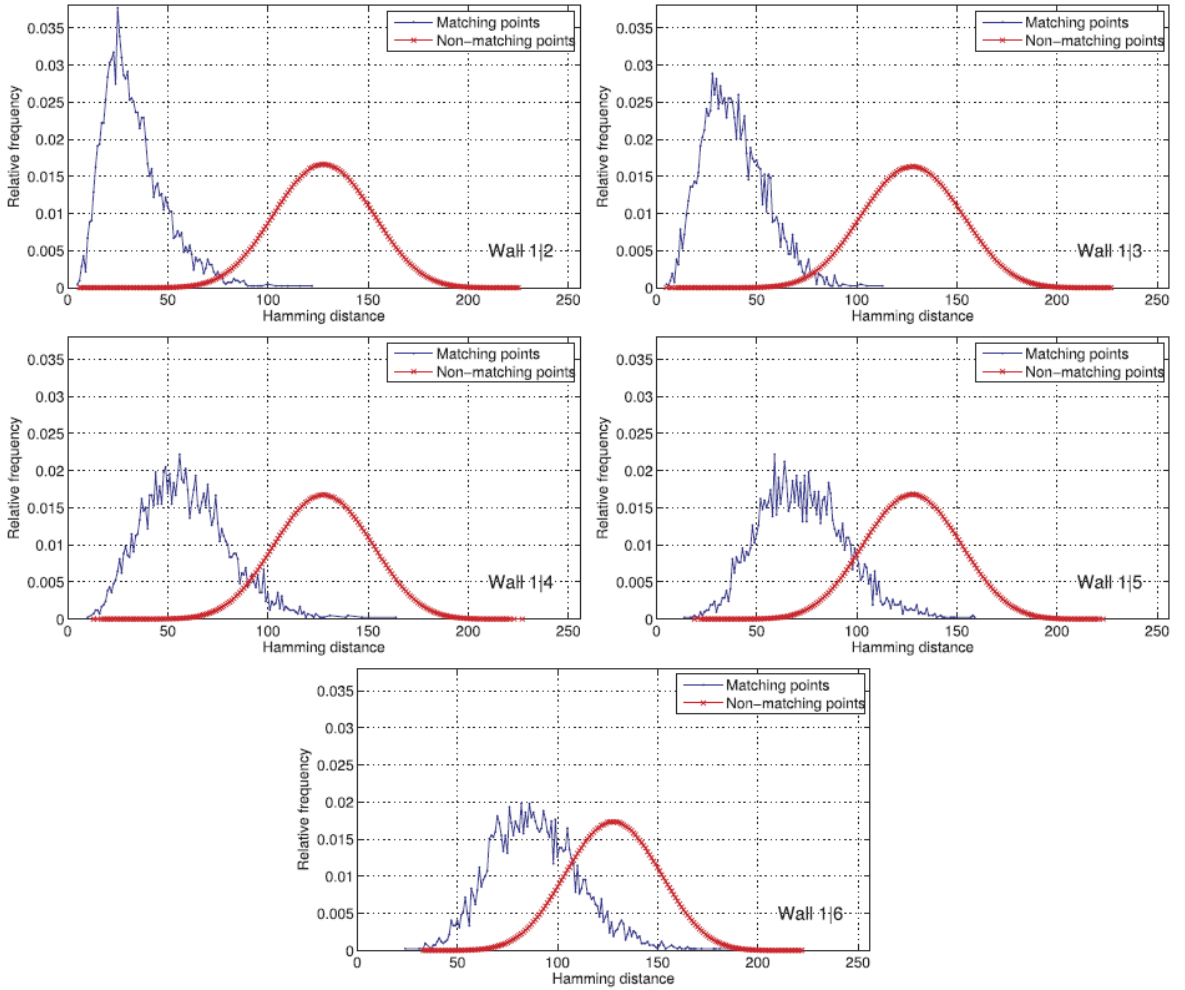

Recognition rate [%]
100
80
60
40
20
0
Jpg 1|2
Jpg 1|3
Jpg 1|4
Jpg 1|5
Jpg 1|6
no smoothing
sigma=0.65
sigma=0.95
sigma=1.25
sigma=1.55
sigma=1.85
sigma=2.15
sigma=2.45
sigma=2.75
7x7 Box

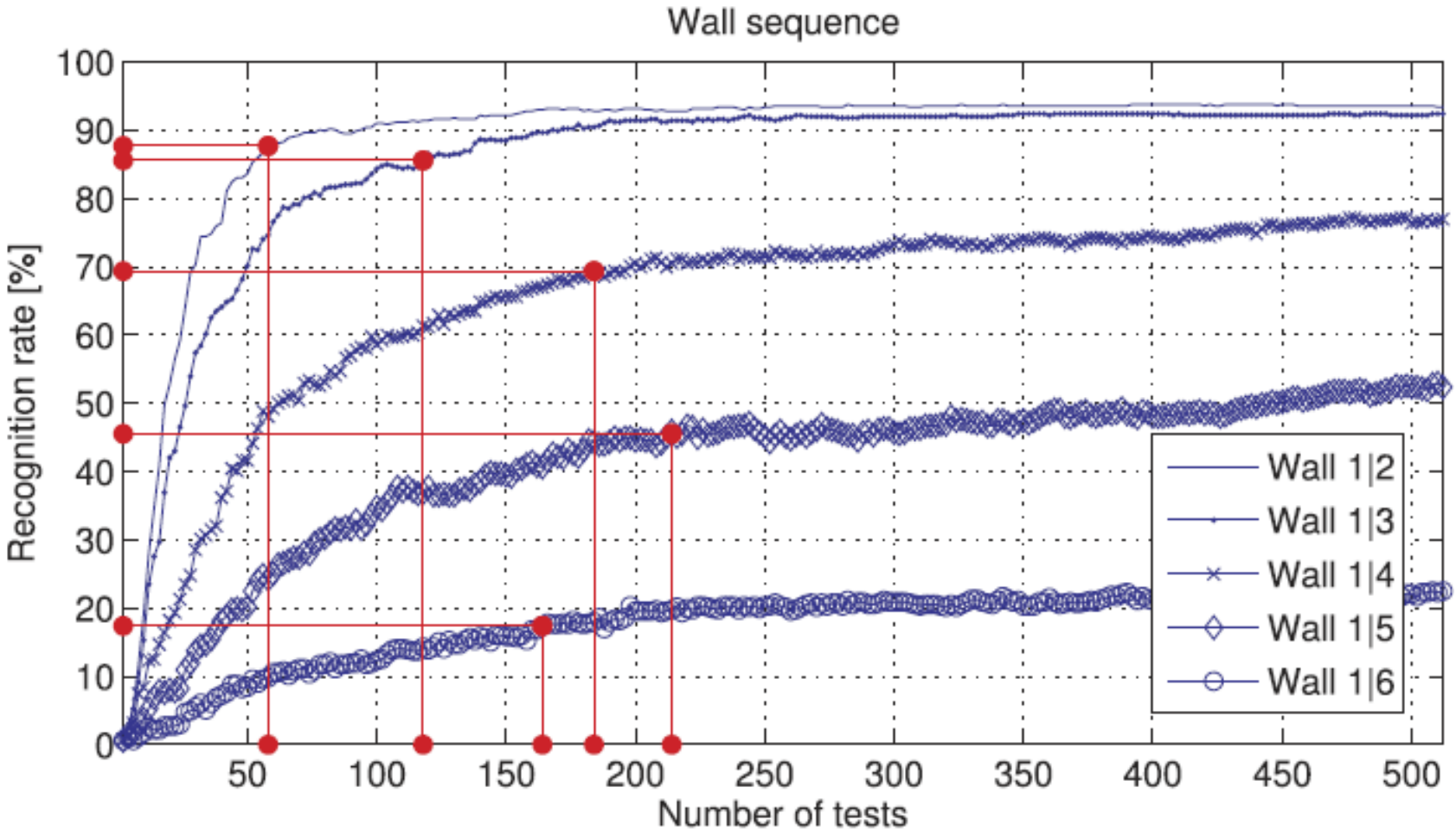

Recognition rate [%]
100
90
80
70
60
50
40
30
20
10
0
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6
G I
G II
G III
G IV
G V

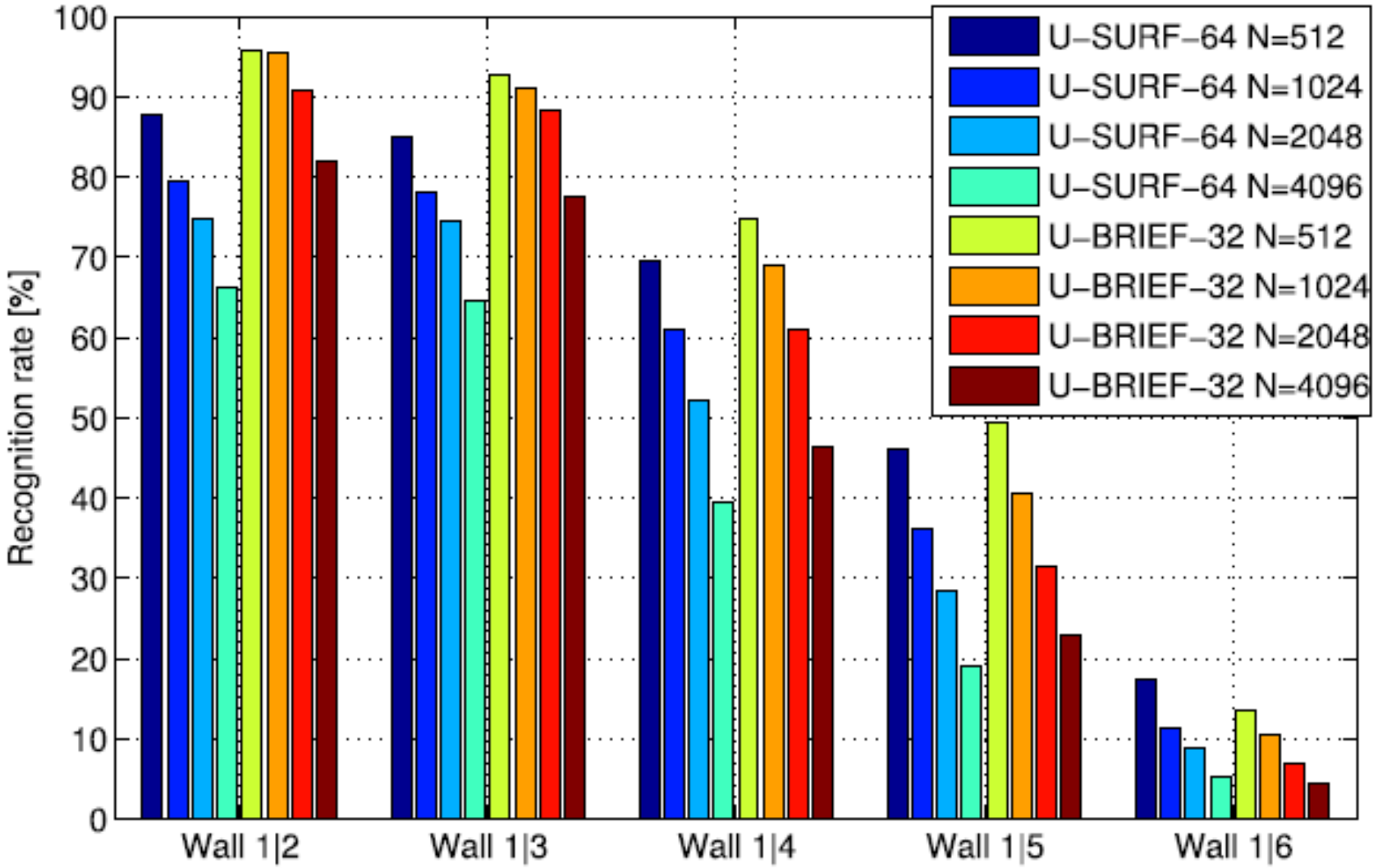

Recognition rate [%]
100
90
80
70
60
50
40
30
20
10
0
Trees 1|2
Trees 1|3
Trees 1|4
Trees 1|5
Trees 1|6
G I
G II
G III
G IV
G V

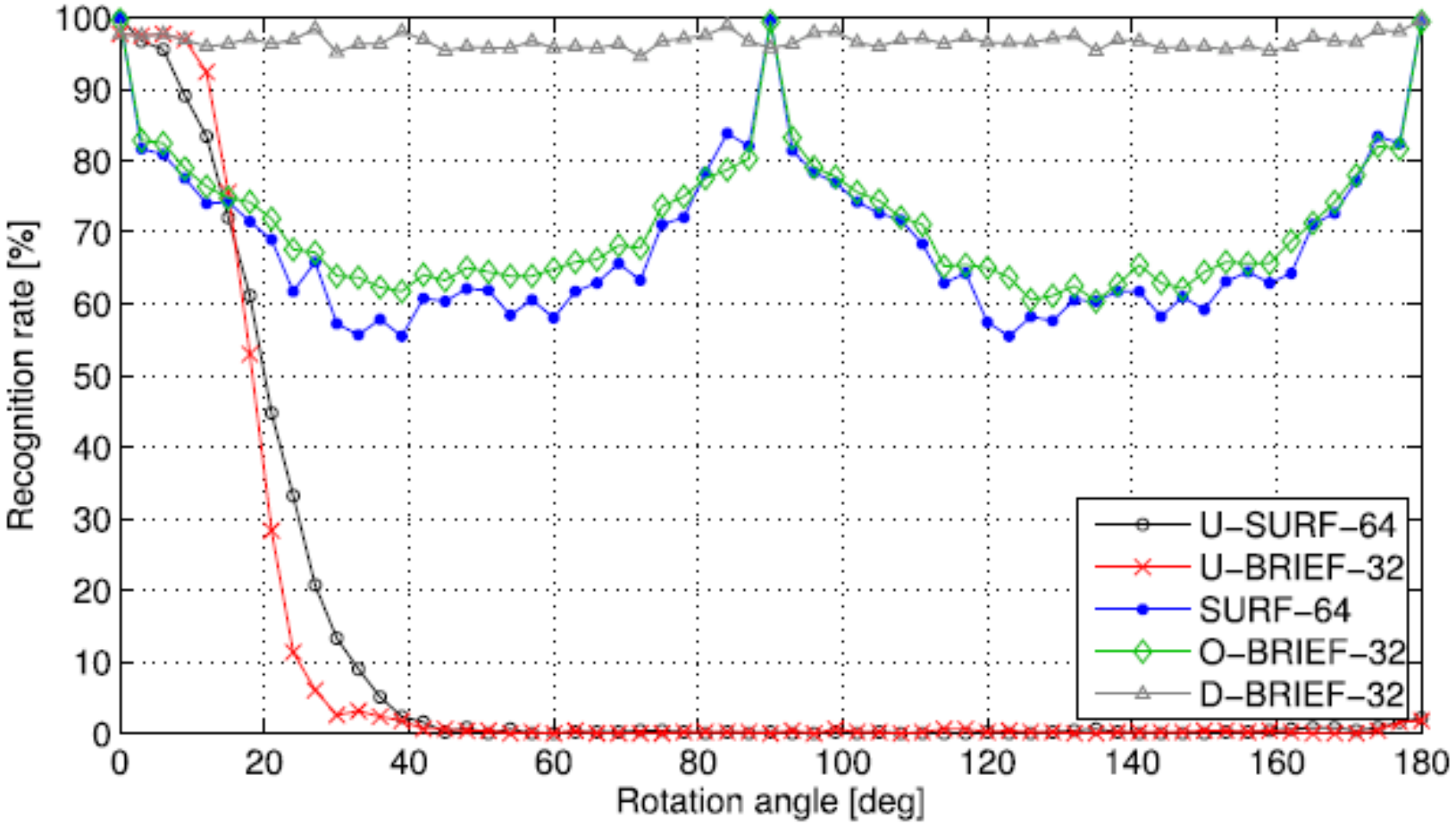

Recognition rate [%]
100
90
80
70
60
50
40
30
20
10
0
Light 1|2
Light 1|3
Light 1|4
Light 1|5
Light 1|6
G I
G II
G III
G IV
G V

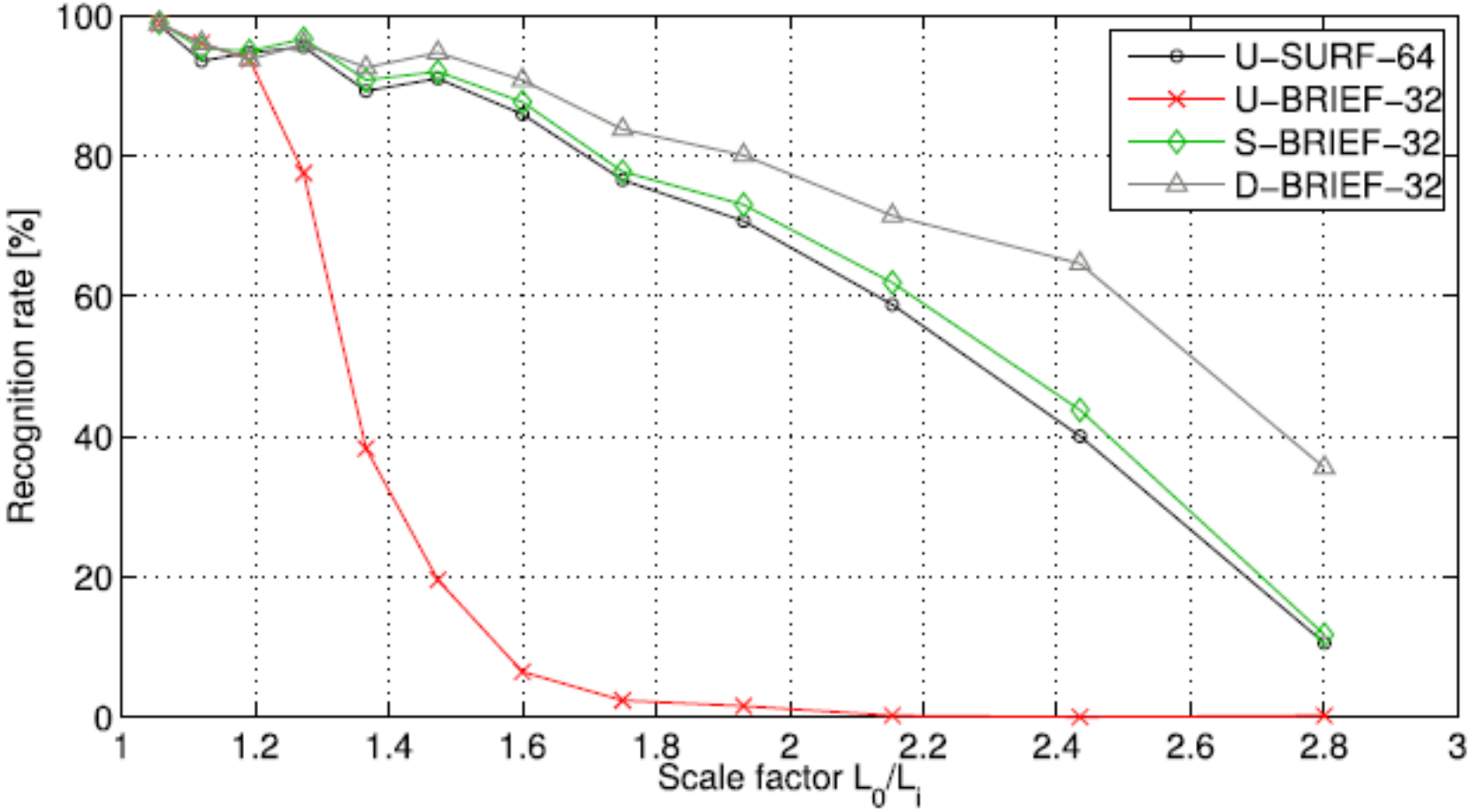

Recognition rate [%]
100
90
80
70
60
50
40
30
20
10
0
Jpg 1|2
Jpg 1|3
Jpg 1|4
Jpg 1|5
Jpg 1|6
G I
G II
G III
G IV
G V

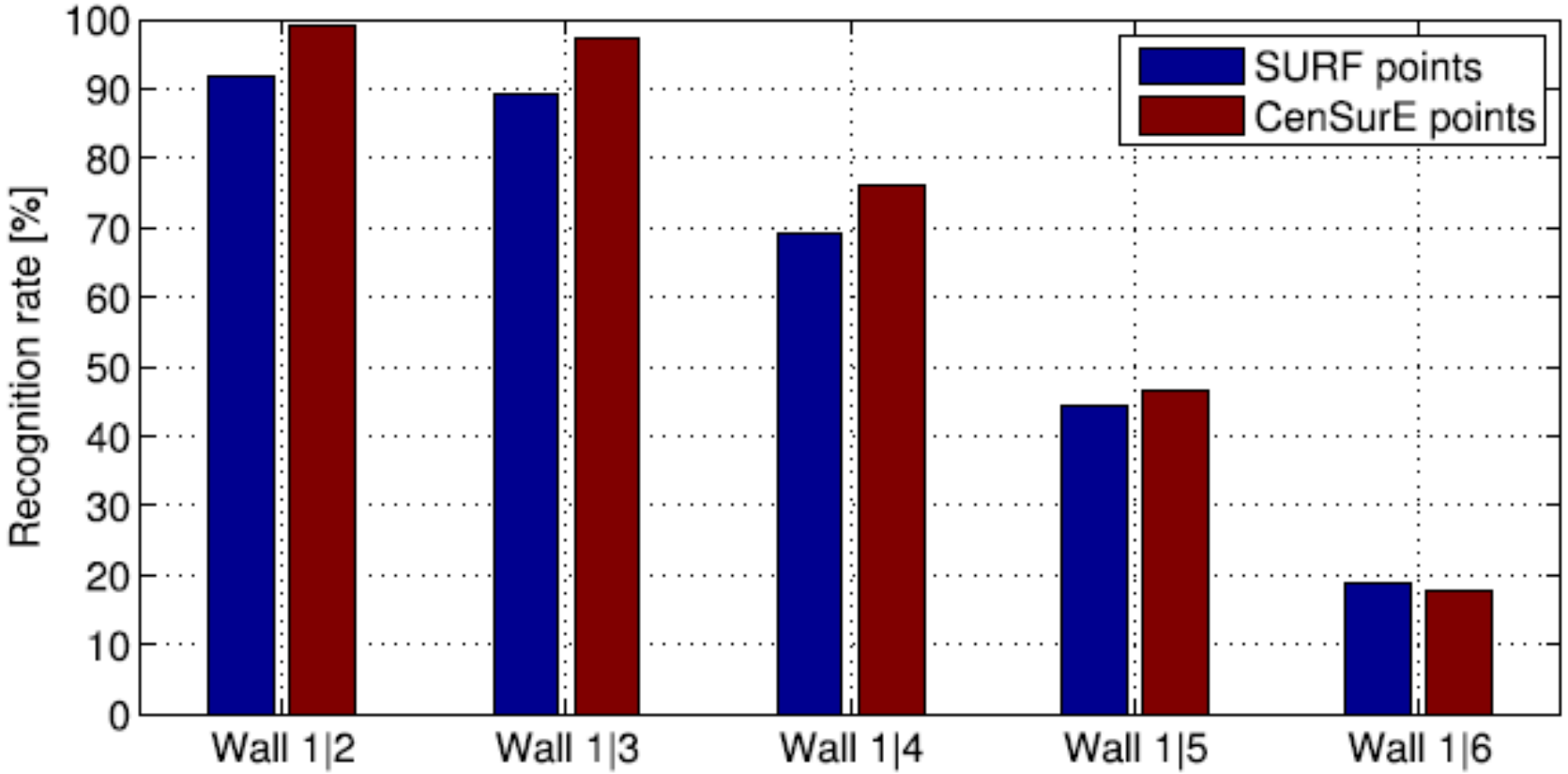

Matching points
Non−matching points
Relative frequency
Hamming distance
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6

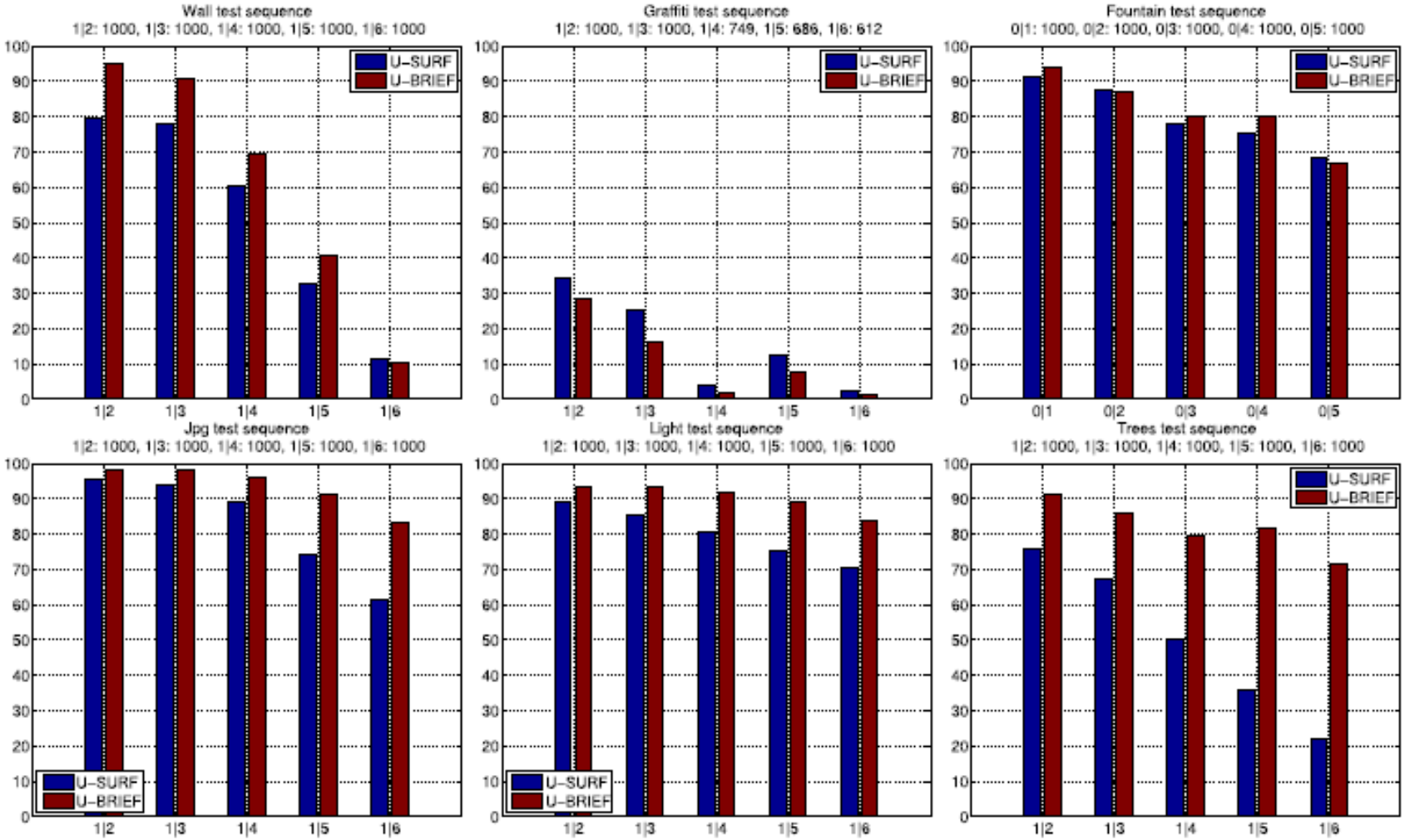

Wall sequence
Recognition rate [%]
Number of tests
100
90
80
70
60
50
40
30
20
10
0
50
100
150
200
250
300
350
400
450
500
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6

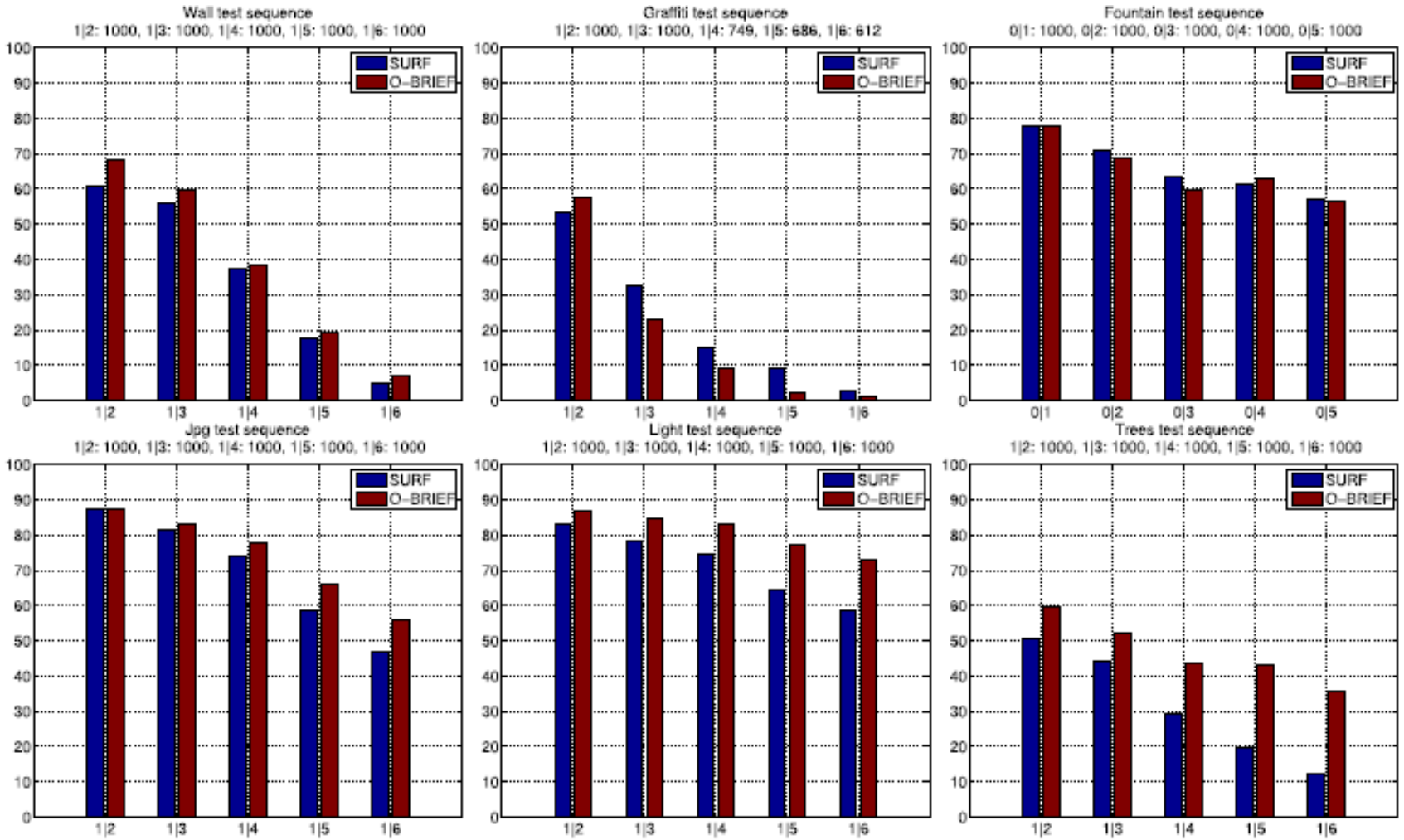

Recognition rate [%]
100
90
80
70
60
50
40
30
20
10
0
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6
U–SURF–64 N=512
U–SURF–64 N=1024
U–SURF–64 N=2048
U–SURF–64 N=4096
U–BRIEF–32 N=512
U–BRIEF–32 N=1024
U–BRIEF–32 N=2048
U–BRIEF–32 N=4096

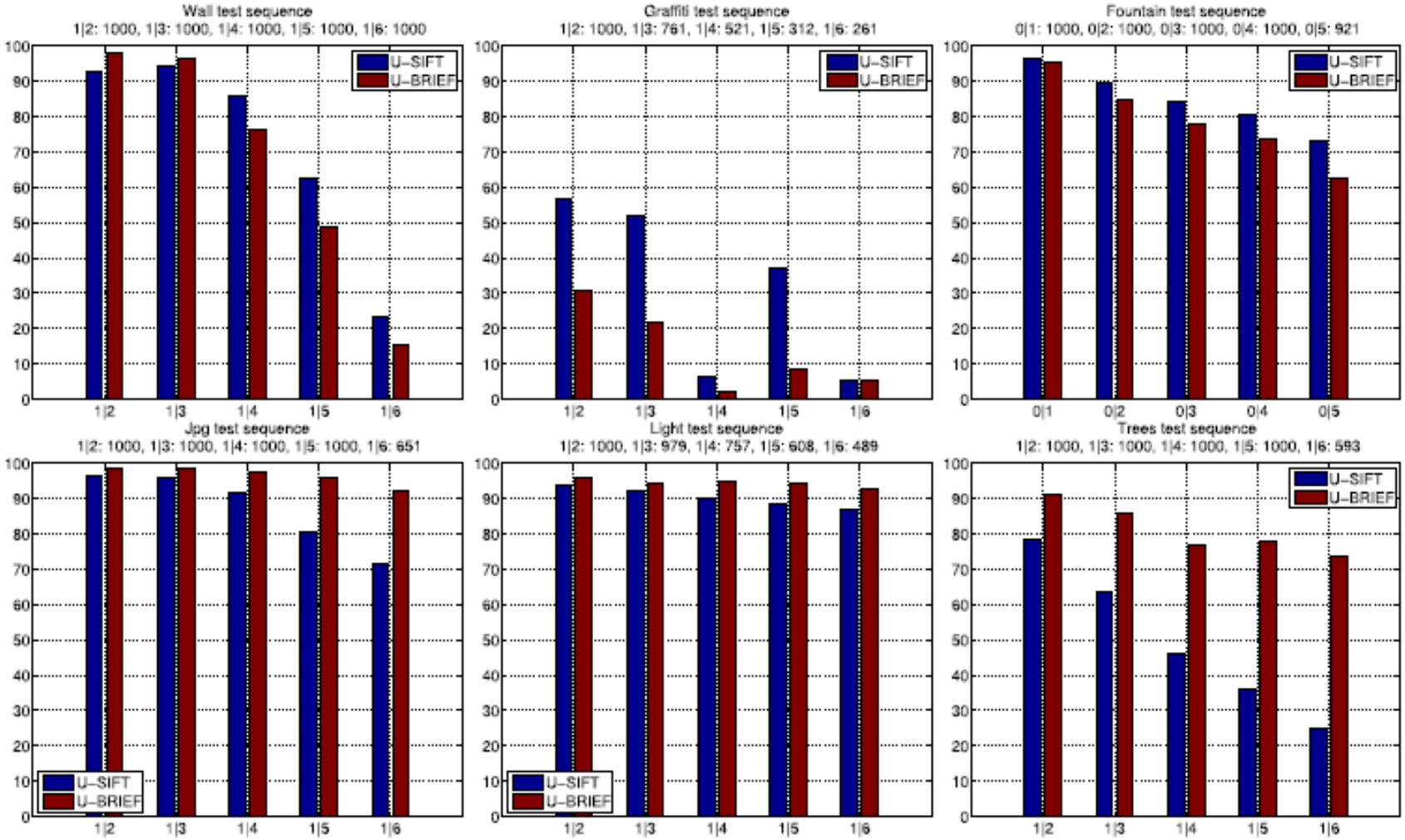

Recognition rate [%]
Rotation angle [deg]
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
U–SURF–64
U–BRIEF–32
SURF–64
O–BRIEF–32
D–BRIEF–32

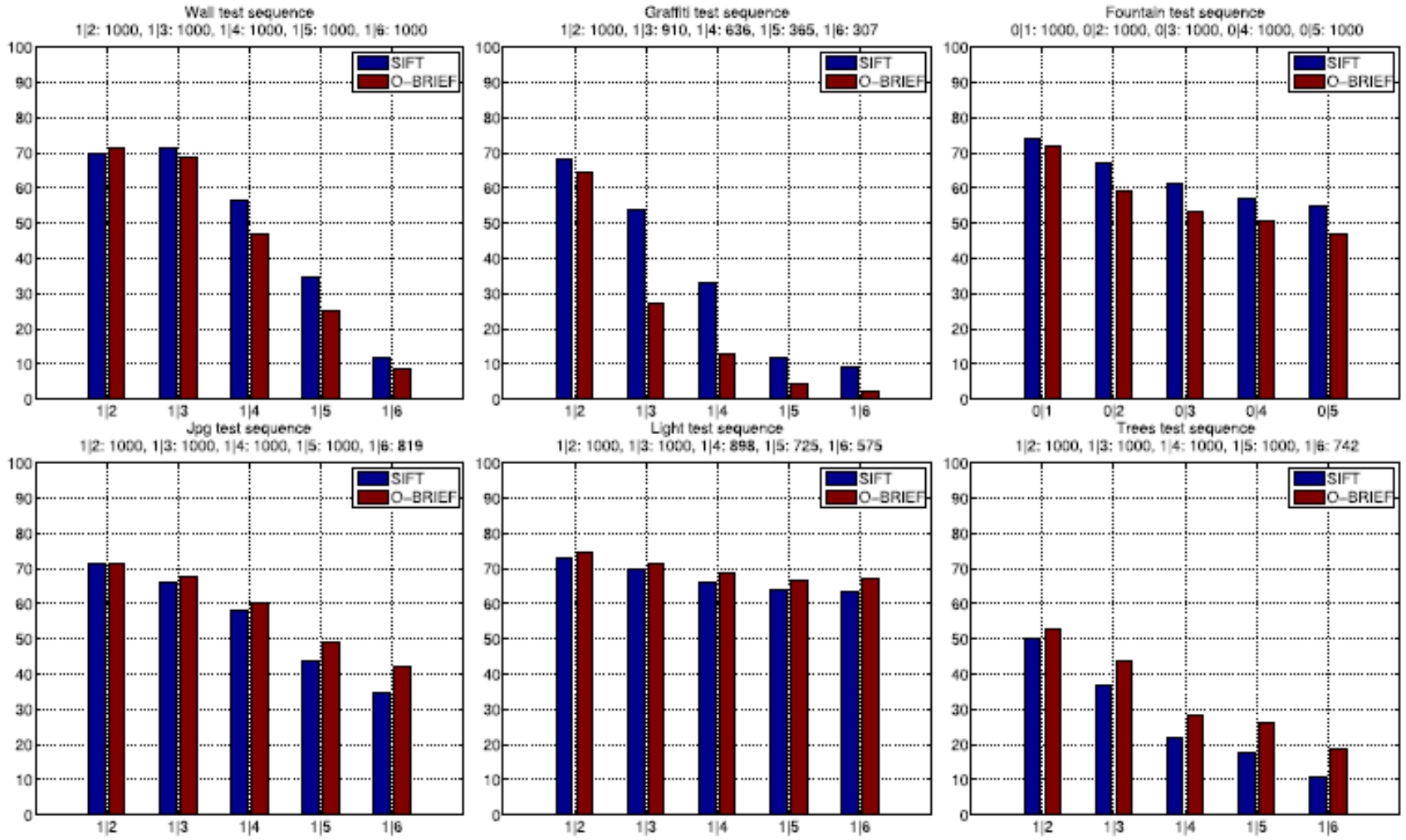

U–SURF–64
U–BRIEF–32
S–BRIEF–32
D–BRIEF–32
Recognition rate [%]
Scale factor L_0/L_i
100
80
60
40
20
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3

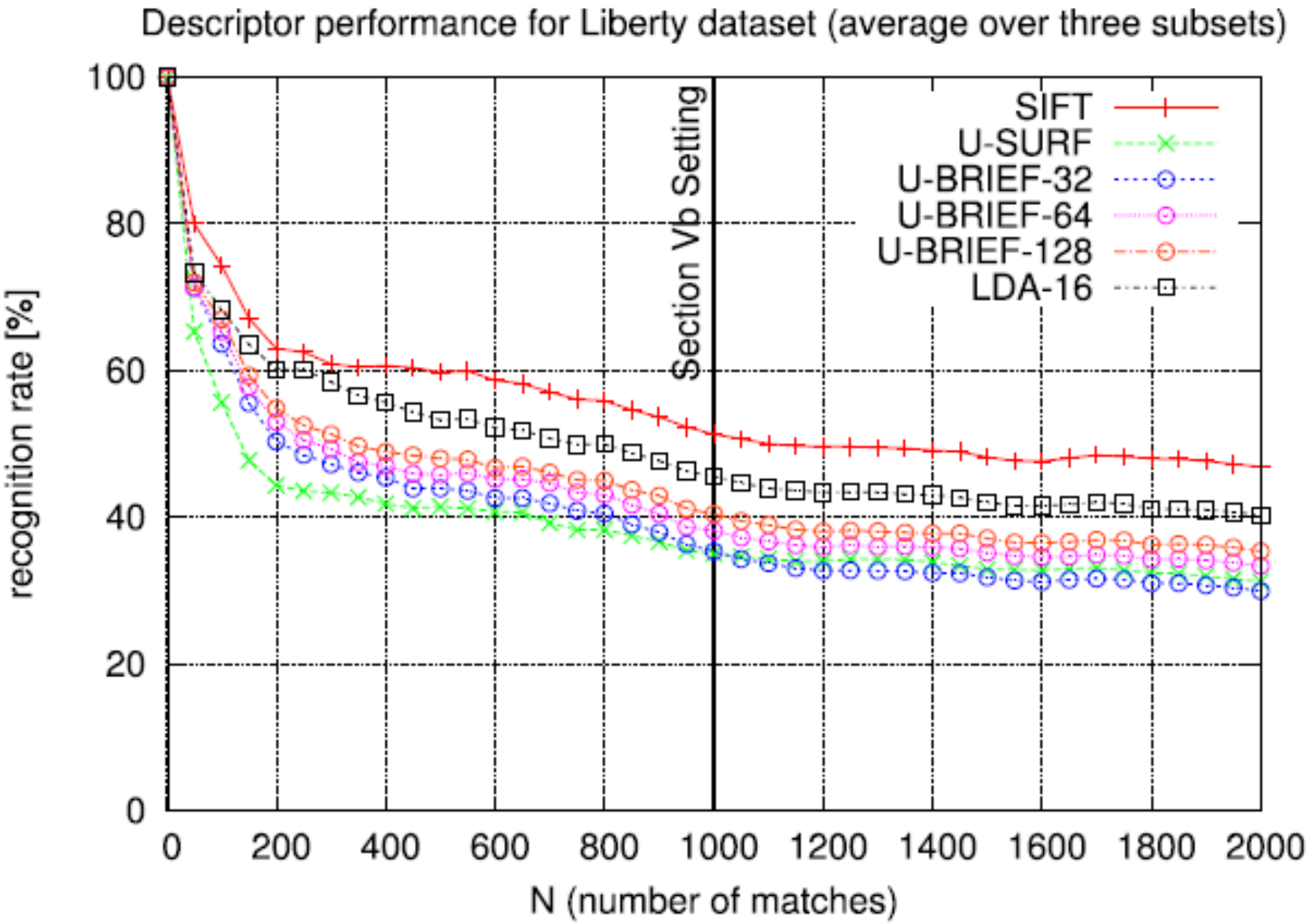

Recognition rate [%]
100
90
80
70
60
50
40
30
20
10
0
SURF points
CenSurE points
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6

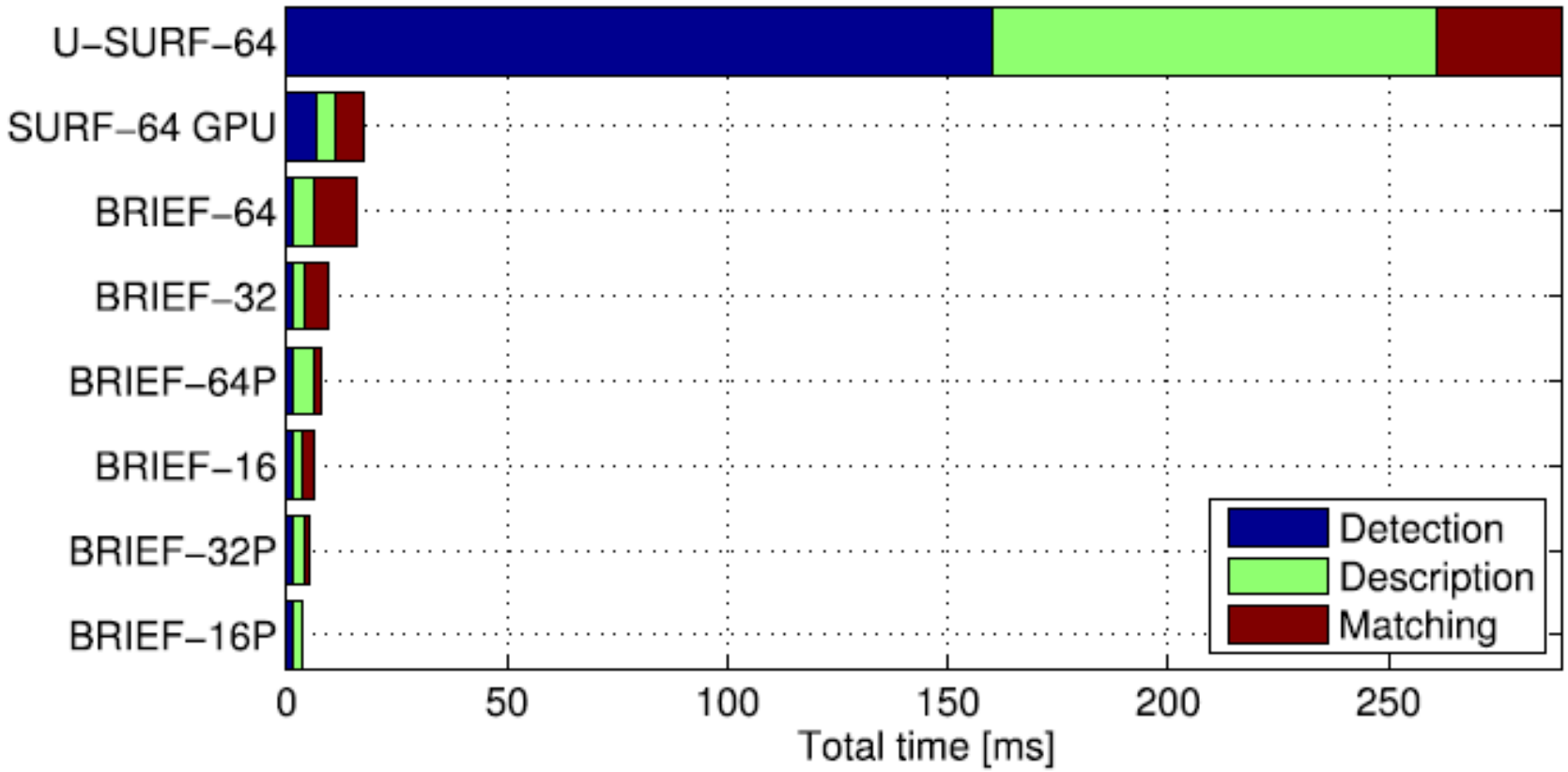

Wall test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Graffiti test sequence
1|2: 1000, 1|3: 1000, 1|4: 749, 1|5: 686, 1|6: 612
Fountain test sequence
0|1: 1000, 0|2: 1000, 0|3: 1000, 0|4: 1000, 0|5: 1000
Jpg test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Light test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Trees test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
U-SURF
U-BRIEF
1|2
1|3
1|4
1|5
1|6
0|1
0|2
0|3
0|4
0|5

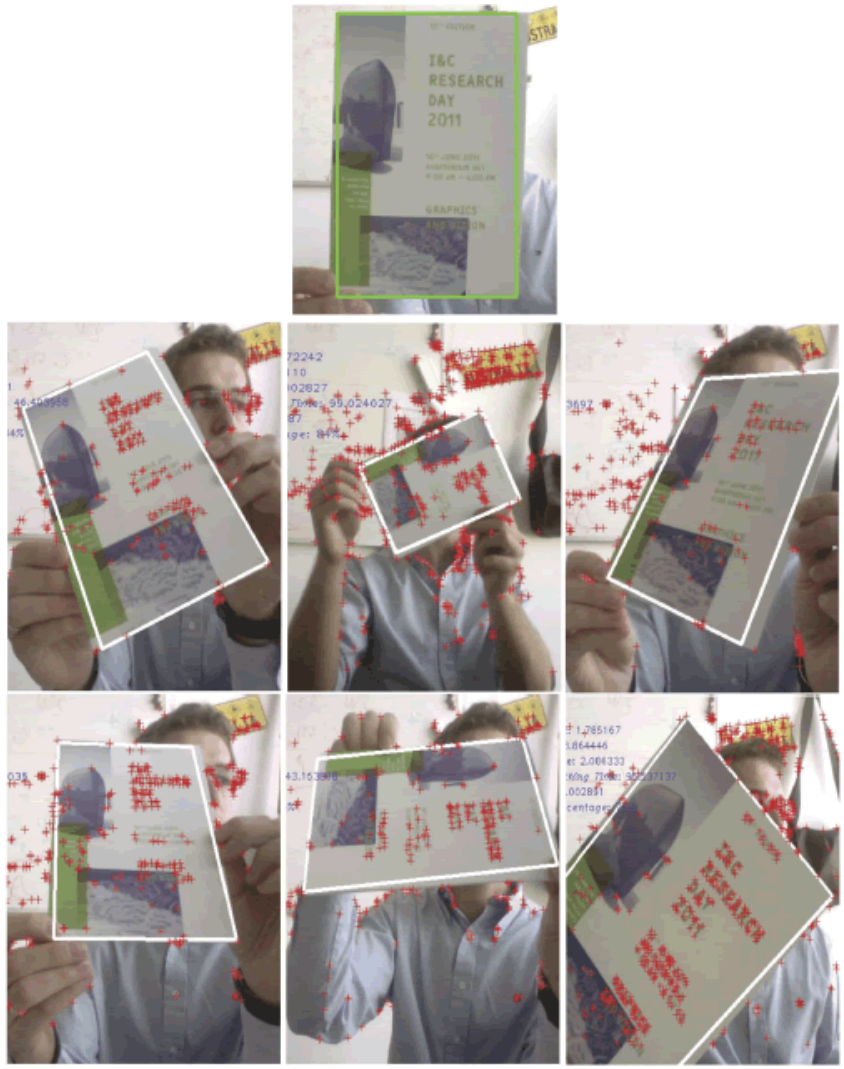

Wall test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Graffiti test sequence
1|2: 1000, 1|3: 1000, 1|4: 749, 1|5: 686, 1|6: 612
Fountain test sequence
0|1: 1000, 0|2: 1000, 0|3: 1000, 0|4: 1000, 0|5: 1000
Jpg test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Light test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Trees test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
SURF
O-BRIEF
1|2
1|3
1|4
1|5
1|6
0|1
0|2
0|3
0|4
0|5


Wall test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Graffiti test sequence
1|2: 1000, 1|3: 761, 1|4: 521, 1|5: 312, 1|6: 261
Fountain test sequence
0|1: 1000, 0|2: 1000, 0|3: 1000, 0|4: 1000, 0|5: 921
Jpg test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 651
Light test sequence
1|2: 1000, 1|3: 979, 1|4: 757, 1|5: 608, 1|6: 489
Trees test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 593
U-SIFT
U-BRIEF


Wall test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Graffiti test sequence
1|2: 1000, 1|3: 910, 1|4: 636, 1|5: 365, 1|6: 307
Fountain test sequence
0|1: 1000, 0|2: 1000, 0|3: 1000, 0|4: 1000, 0|5: 1000
Jpg test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 819
Light test sequence
1|2: 1000, 1|3: 1000, 1|4: 898, 1|5: 725, 1|6: 575
Trees test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 742
SIFT
O-BRIEF


Descriptor performance for Liberty dataset (average over three subsets)
recognition rate [%]
N (number of matches)
Section Vb Setting
SIFT
U-SURF
U-BRIEF-32
U-BRIEF-64
U-BRIEF-128
LDA-16
0
20
40
60
80
100
0
200
400
600
800
1000
1200
1400
1600
1800
2000


U–SURF–64
SURF–64 GPU
BRIEF–64
BRIEF–32
BRIEF–64P
BRIEF–16
BRIEF–32P
BRIEF–16P
Detection
Description
Matching
0
50
100
150
200
250
Total time [ms]


I&C
RESEARCH
DAY
2011

Conclusion

$$BRIEF > SURF.$$

Previous Work: Principal Component Analysis

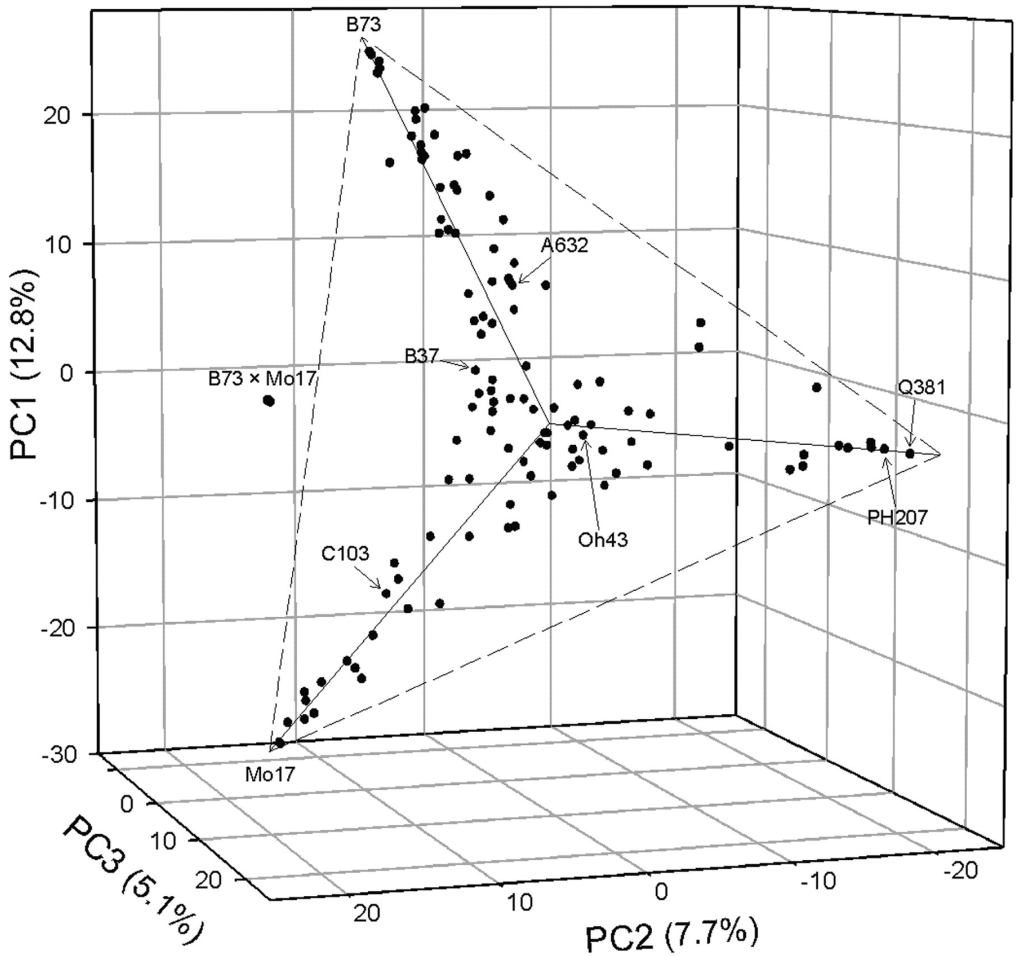


Figure: PCA with Three Components.

Previous Work: Floating-Point Quantization

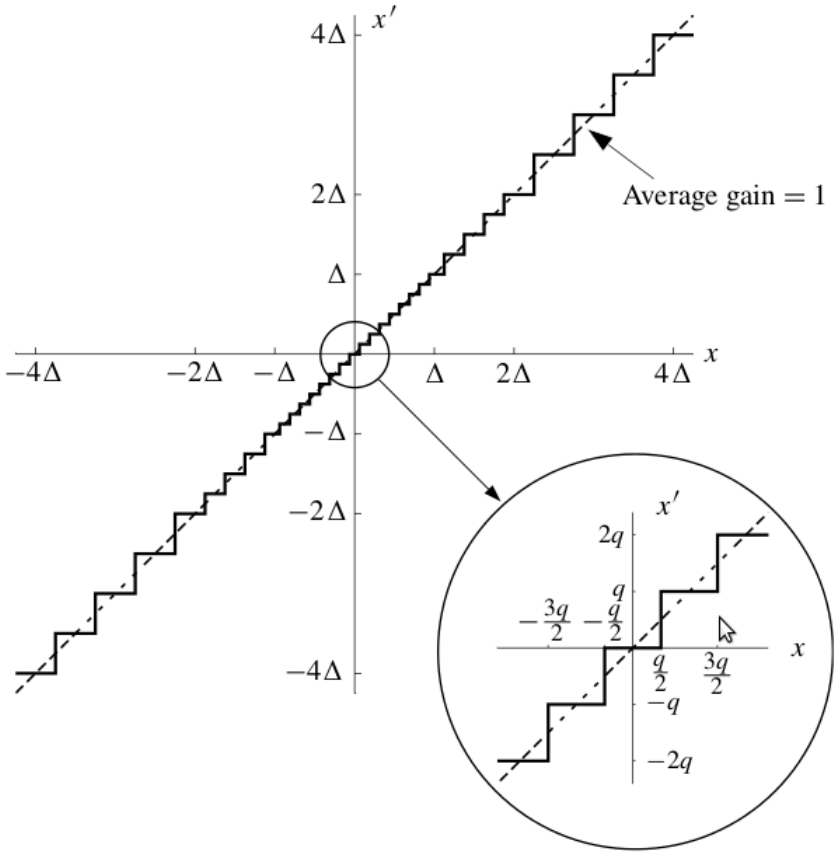


Figure: Quantization with a 3-Bit Mantissa.