BRIEF: Computing a Local Binary Descriptor Very Fast

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October 11, 2012

Motivation: A 256-Byte Descriptor?

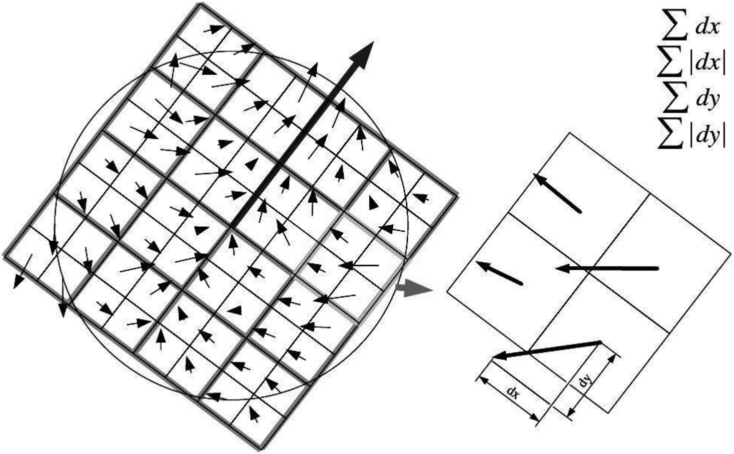


Figure : A SURF descriptor stores 64 orientation values as 4-byte integers.

Problem Definition: Make It Smaller, Compute It Faster

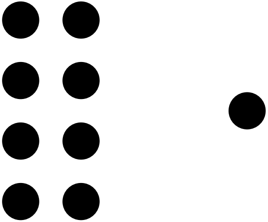


Figure : Reduce the size by a factor of 8.

Previous Work: Principal Component Analysis

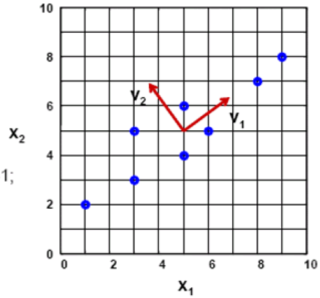
- $X=(x_1,x_2)=\{(1,2),(3,3),(3,5),(5,4),(5,6),(6,5),(8,7),(9,8)\}$

$$\Sigma_x = \begin{bmatrix} 6.25 & 4.25 \\ 4.25 & 3.5 \end{bmatrix}$$

$$\Sigma_x v = \lambda v \Rightarrow |\Sigma_x - \lambda I| = 0 \Rightarrow \begin{vmatrix} 6.25-\lambda & 4.25 \\ 4.25 & 3.5-\lambda \end{vmatrix} = 0 \Rightarrow \lambda_1 = 9.34;\ \lambda_2 = 0.41;$$

$$\begin{bmatrix} 6.25 & 4.25 \\ 4.25 & 3.5 \end{bmatrix}\begin{bmatrix} v_{11} \\ v_{12} \end{bmatrix} = \begin{bmatrix} \lambda_1 v_{11} \\ \lambda_1 v_{12} \end{bmatrix} \Rightarrow \begin{bmatrix} v_{11} \\ v_{12} \end{bmatrix} = \begin{bmatrix} 0.81 \\ 0.59 \end{bmatrix}$$

$$\begin{bmatrix} 6.25 & 4.25 \\ 4.25 & 3.5 \end{bmatrix}\begin{bmatrix} v_{21} \\ v_{22} \end{bmatrix} = \begin{bmatrix} \lambda_2 v_{21} \\ \lambda_2 v_{22} \end{bmatrix} \Rightarrow \begin{bmatrix} v_{21} \\ v_{22} \end{bmatrix} = \begin{bmatrix} -0.59 \\ 0.81 \end{bmatrix}$$



Previous Work: Floating-Point Quantization

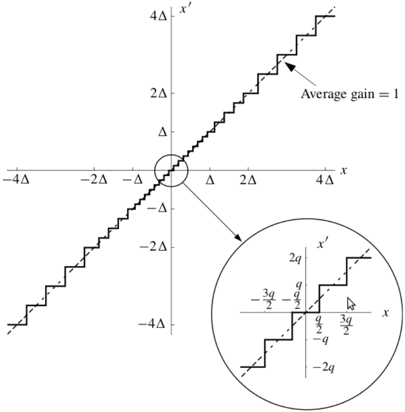
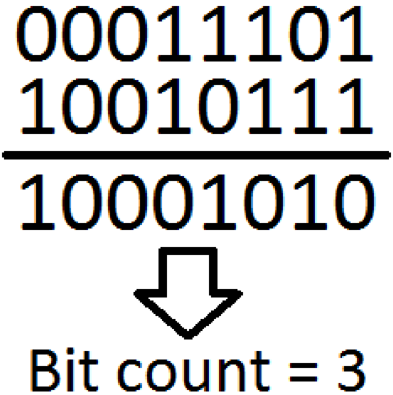


Figure : Quantization with a 3-Bit Mantissa.

Background: Hamming Distance



Background: Hamming Distance

```
 00011101
 10010111
---------
 10001010
    ⇩
Bit count = 3
```

XOR EAX, EBX
POPCNT EAX, EAX

01101011101 10010101010	10
10001110101 11000110100	3
11101110111 10101010101	?

Method: Sampling Distributions

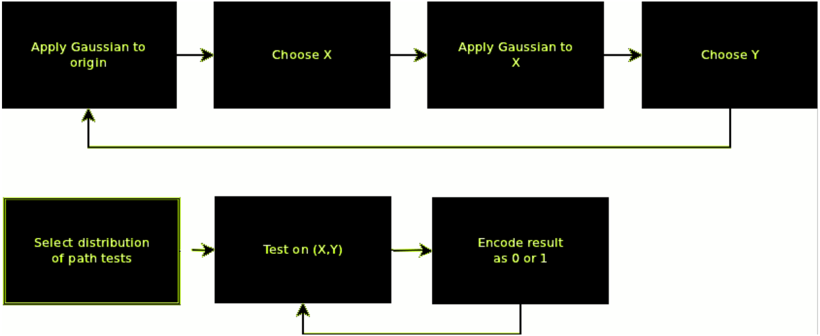


Figure : Sampling distributions.

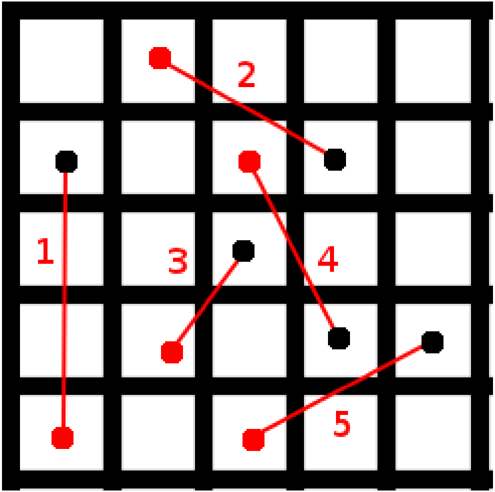
Method: Patch Test

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

Method: Descriptor Formula

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

Method: Example of Distribution



Example of Patch Test on Distribution

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

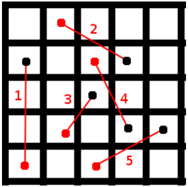


Figure : Sampling distributions.

x	y	τ
2	3	1
3	8	1
9	4	0
1	2	1
6	1	0

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Example of Patch Test on Distribution

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

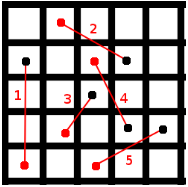

Figure : Sampling distributions.

x	y	τ
2	9	1
2	6	1
3	5	1
4	4	0
6	2	0

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

Hamming distance: 2.

Method: Sampling

$$X \leftarrow Uniform\left(-\frac{S}{2}, \frac{S}{2}\right)$$
$$Y \leftarrow Uniform\left(-\frac{S}{2}, \frac{S}{2}\right) \qquad \text{(G I)}$$

$$X \leftarrow Gaussian\left(0, \frac{1}{25}S^2\right)$$
$$Y \leftarrow Gaussian\left(0, \frac{1}{25}S^2\right) \qquad \text{(G II)}$$

$$X \leftarrow Gaussian\left(0, \frac{1}{25}S^2\right)$$
$$Y \leftarrow Gaussian\left(x_i, \frac{1}{100}S^2\right) \qquad \text{(G III)}$$

$$X \leftarrow RandDiscrete(0 < \theta < 360, 0 < r < S/2)$$
$$Y \leftarrow RandDiscrete(0 < \theta < 360, 0 < r < S/2) \qquad \text{(G IV)}$$

$$X \leftarrow (0, 0)$$
$$Y \leftarrow RandDiscrete(0 < \theta < 360, 0 < r < S/2) \qquad \text{(G V)}$$

Method: Sampling Distributions

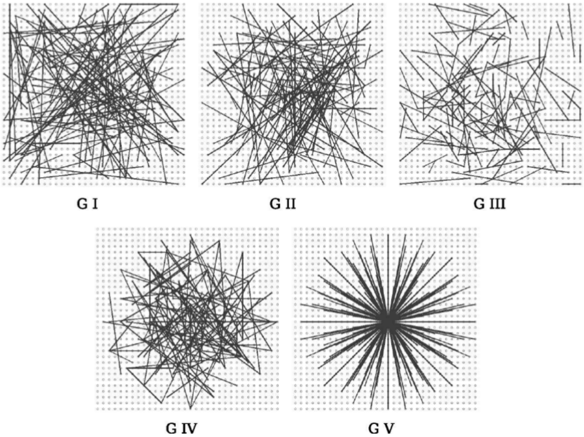
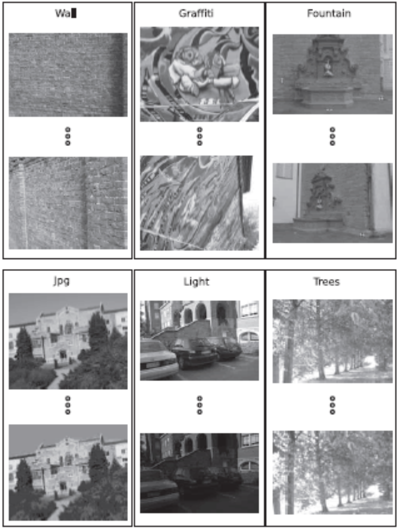


Figure : Sampling distributions.

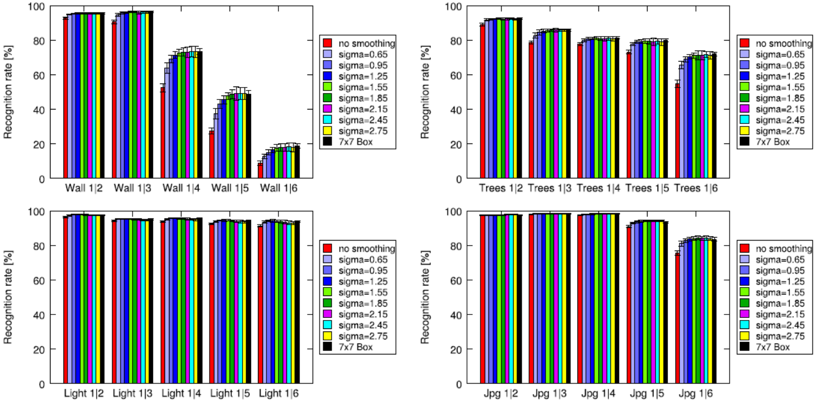


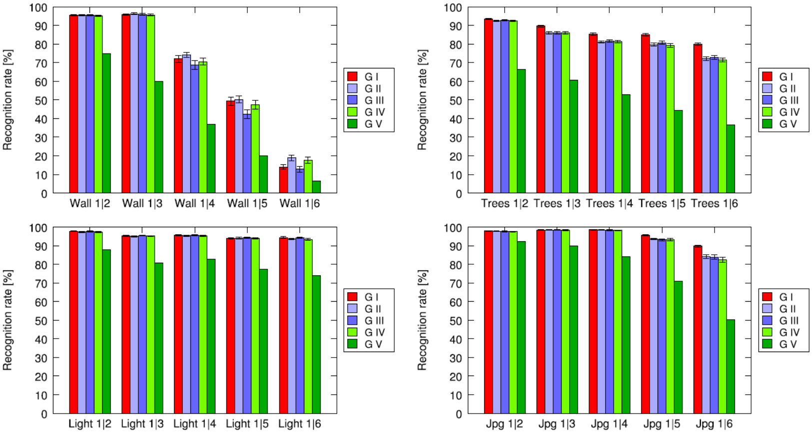
(a)

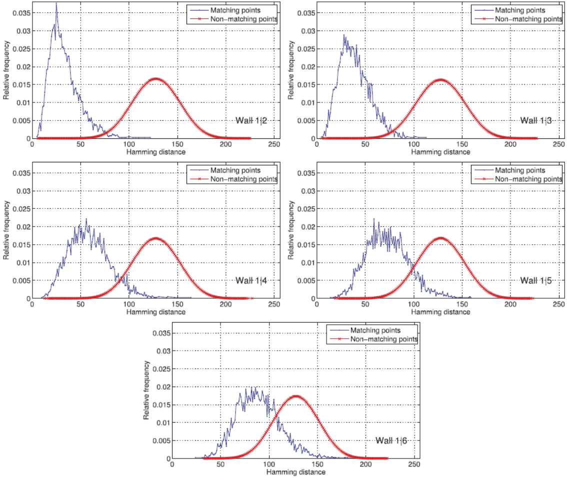
(b)

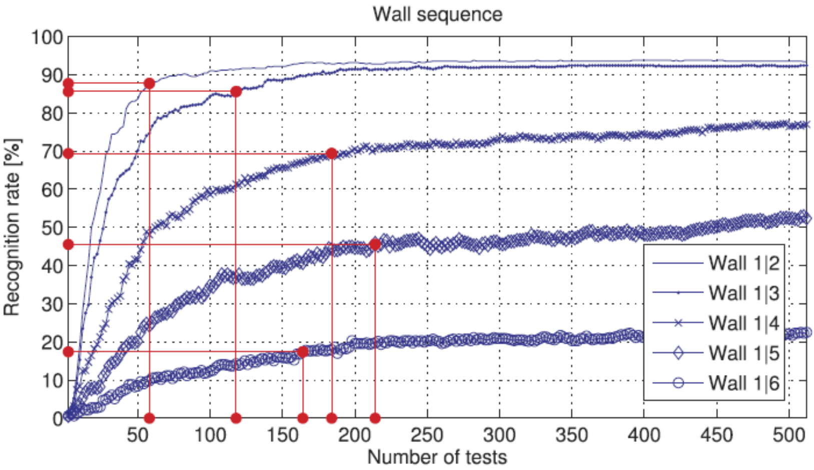
Experimental Setup

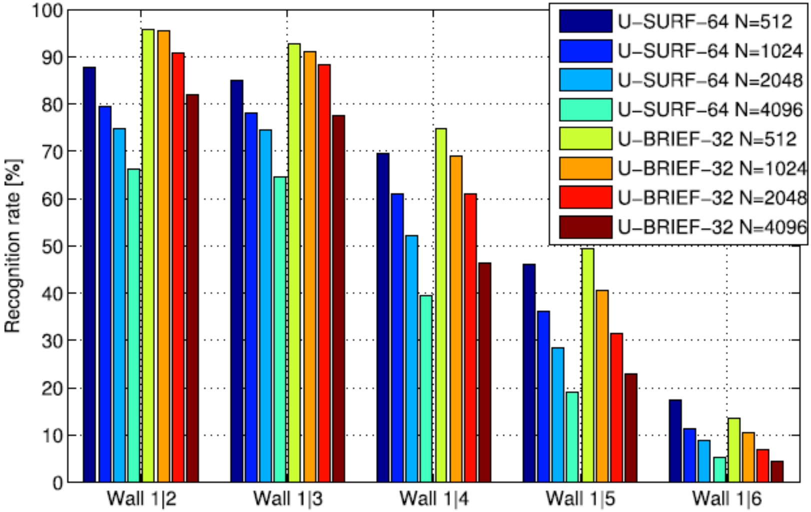
- U-BRIEF
- S-BRIEF
- O-BRIEF
- D-BRIEF

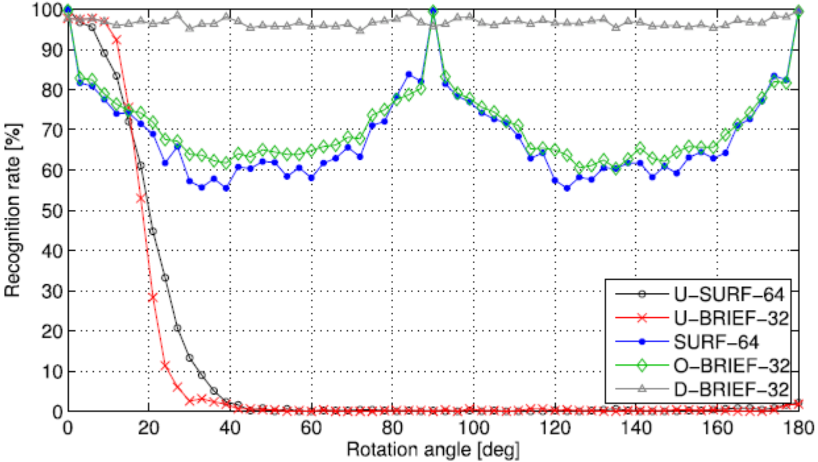

Recognition rate [%]
0
20
40
60
80
100
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6
Trees 1|2
Trees 1|3
Trees 1|4
Trees 1|5
Trees 1|6
Light 1|2
Light 1|3
Light 1|4
Light 1|5
Light 1|6
Jpg 1|2
Jpg 1|3
Jpg 1|4
Jpg 1|5
Jpg 1|6
no smoothing
sigma=0.65
sigma=0.95
sigma=1.25
sigma=1.55
sigma=1.85
sigma=2.15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

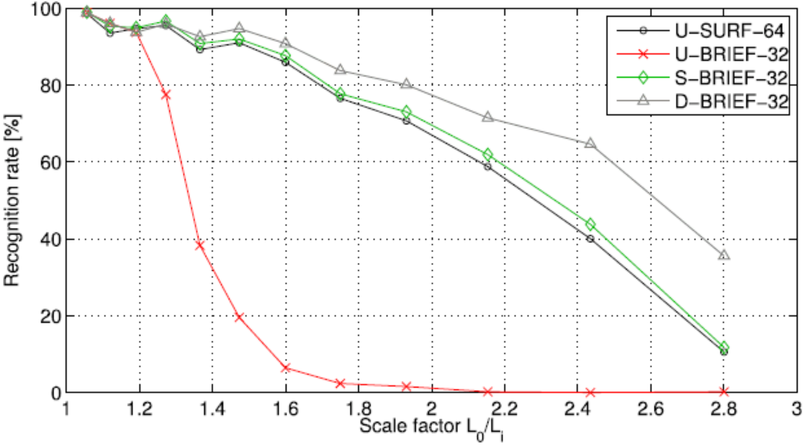

Recognition rate [%]
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6
Trees 1|2
Trees 1|3
Trees 1|4
Trees 1|5
Trees 1|6
Light 1|2
Light 1|3
Light 1|4
Light 1|5
Light 1|6
Jpg 1|2
Jpg 1|3
Jpg 1|4
Jpg 1|5
Jpg 1|6
G I
G II
G III
G IV
G V

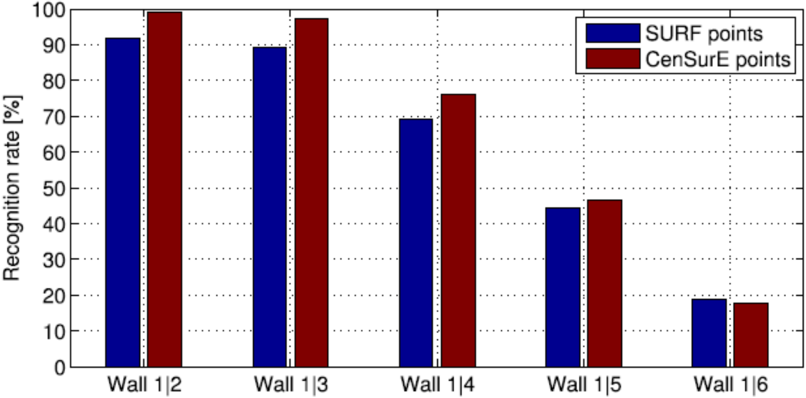

Matching points
Non–matching points
Relative frequency
Hamming distance
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6

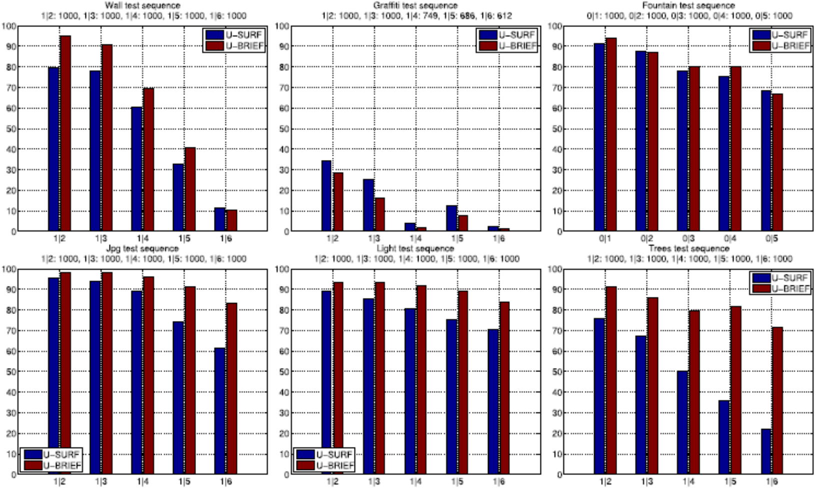

Wall sequence
Recognition rate [%]
Number of tests
100
90
80
70
60
50
40
30
20
10
0
50
100
150
200
250
300
350
400
450
500
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6

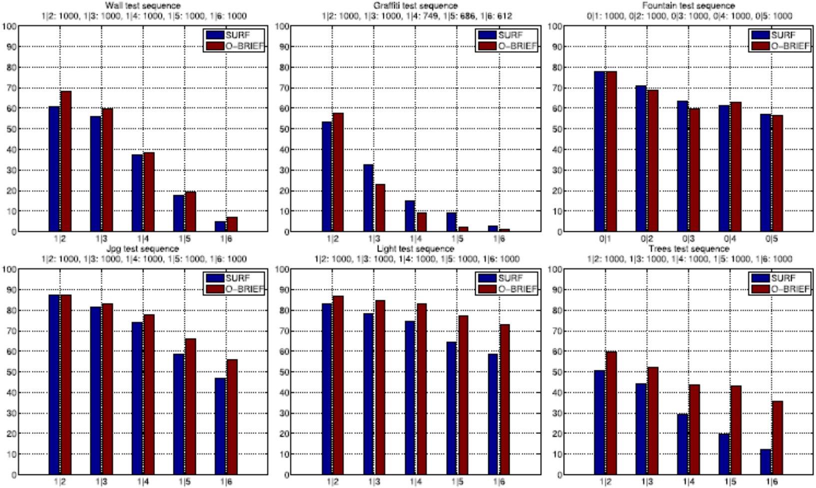

100
90
80
70
60
50
40
30
20
10
0
Recognition rate [%]
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6
U–SURF–64 N=512
U–SURF–64 N=1024
U–SURF–64 N=2048
U–SURF–64 N=4096
U–BRIEF–32 N=512
U–BRIEF–32 N=1024
U–BRIEF–32 N=2048
U–BRIEF–32 N=4096

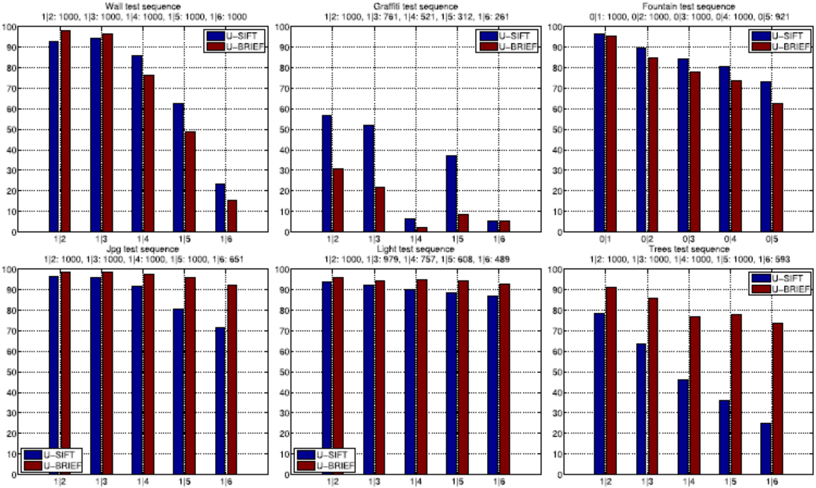

Recognition rate [%]
Rotation angle [deg]
U–SURF–64
U–BRIEF–32
SURF–64
O–BRIEF–32
D–BRIEF–32

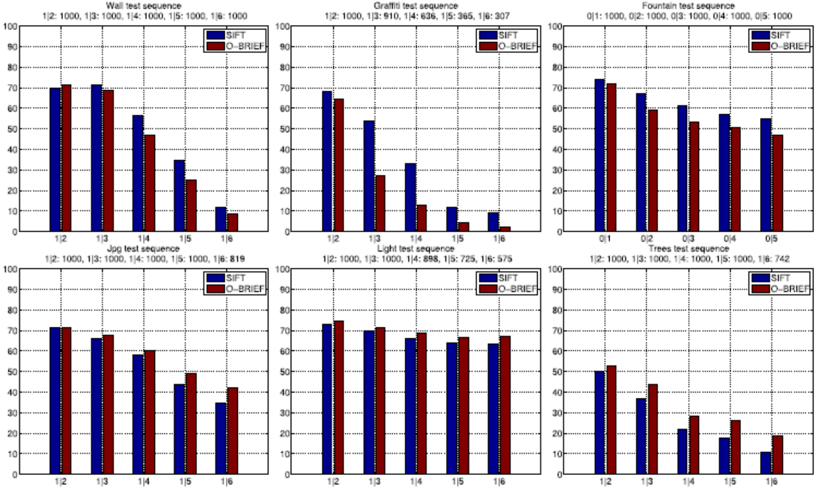

U–SURF–64
U–BRIEF–32
S–BRIEF–32
D–BRIEF–32
Recognition rate [%]
0
20
40
60
80
100
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Scale factor L_0/L_i

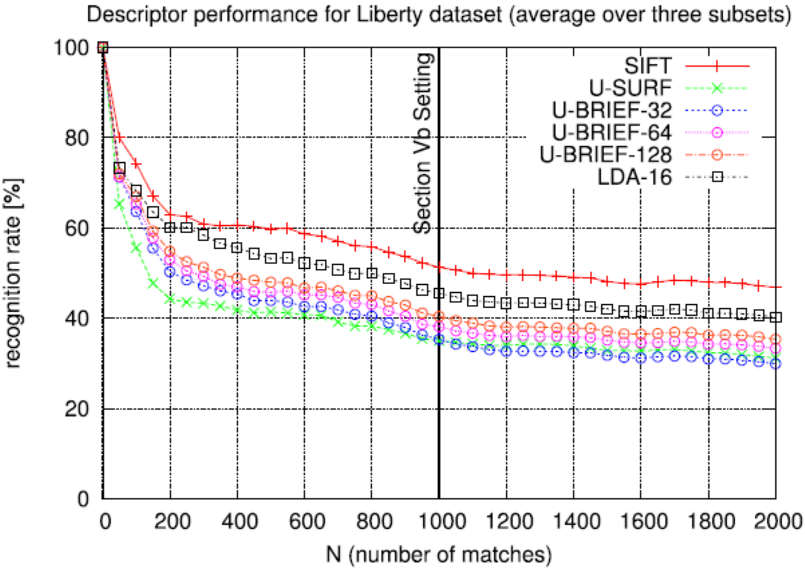

100
90
80
70
60
50
40
30
20
10
0
Recognition rate [%]
Wall 1|2
Wall 1|3
Wall 1|4
Wall 1|5
Wall 1|6
SURF points
CenSurE points

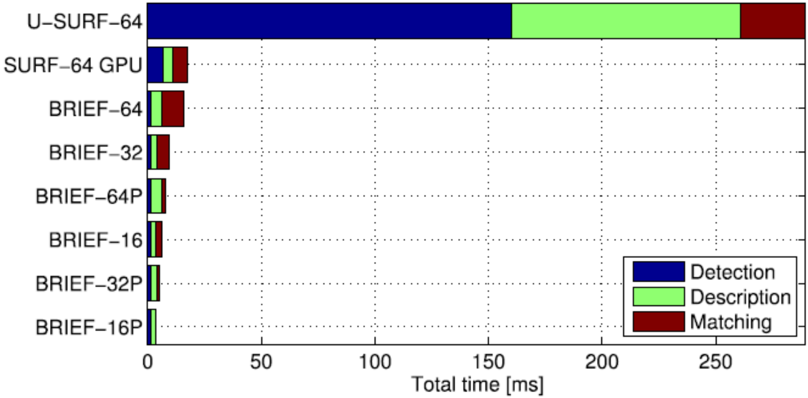

Wall test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Graffiti test sequence
1|2: 1000, 1|3: 1000, 1|4: 749, 1|5: 686, 1|6: 612
Fountain test sequence
0|1: 1000, 0|2: 1000, 0|3: 1000, 0|4: 1000, 0|5: 1000
Jpg test sequence
1|2: 1000, 1|3: 1000, 1|4: 1000, 1|5: 1000, 1|6: 1000
Light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


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]

Conclusion

 >  > 

References

- http://www.embege.com/gauss/
- http://cvlab.epfl.ch/ strecha/multiview/denseMVS.html
- http://www.cs.ubc.ca/ mbrown/patchdata/patchdata.html
- http://www.robots.ox.ac.uk/ vgg/research/affine/
- Dr. Gunturk's "Machine Recognition of Patterns" class notes