Robust Feature Matching for Endoscopic Reconstruction

Checkpoint presentation for CIS II Project

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May 2, 2013

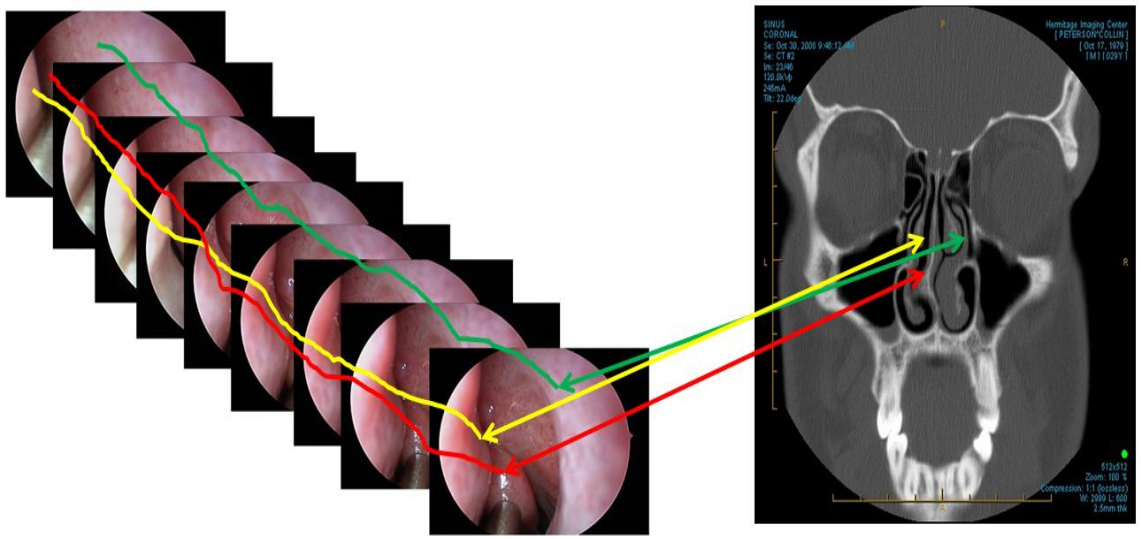
Claim: Do not disclose due to confidential patient data and unpublished work.

Outline

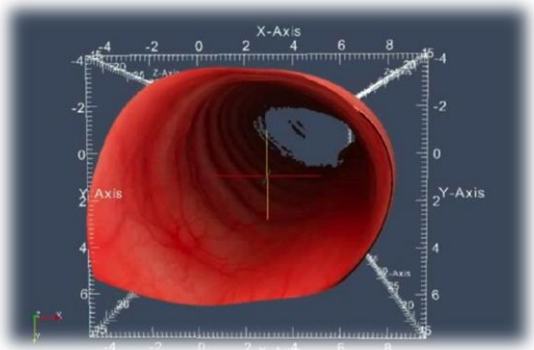
- Project Review
- Progress on feature matching and motion estimation: HMA vs. SIFT
- Deliverables, Milestones and Dependencies

Endoscopic reconstruction

- > 200,000 functional endoscopic (sinus) surgeries per year in US.
- Needs surgical navigation systems to visualize critical structures.
- Structures must not be disturbed during surgery.
- Structures can be smaller than a millimeter in size.
- A qualitative sense of location in need.



Examplar CT image from www.newyorkentspecialist.com



A full 3D reconstruction of a pediatric airway from video imagery acquired with a tracked endoscope. [*Image from a NIH-funded project proposal with permission.*]

Feature matching

- Feature matching is key to 3D reconstruction, stereo, tracking and recognition.
- Features are expected to be
  - invariant to image scaling and rotation,
  - (partially) invariant to changes in illumination and 3D camera viewpoint,
  - highly discriminative,
  - Efficiently extracted.

  ⇒ Scale Invariant Feature Transform (SIFT): key point detection and description

  SIFT provides a feature pool.
- Matching is expected to be
  - robust to outliers and deformation (*e.g.*, non-planar object)

    ⇒ Multiple affine components vs. SIFT matching's global affine
  - Efficient

    ⇒ Hierarchical clustering

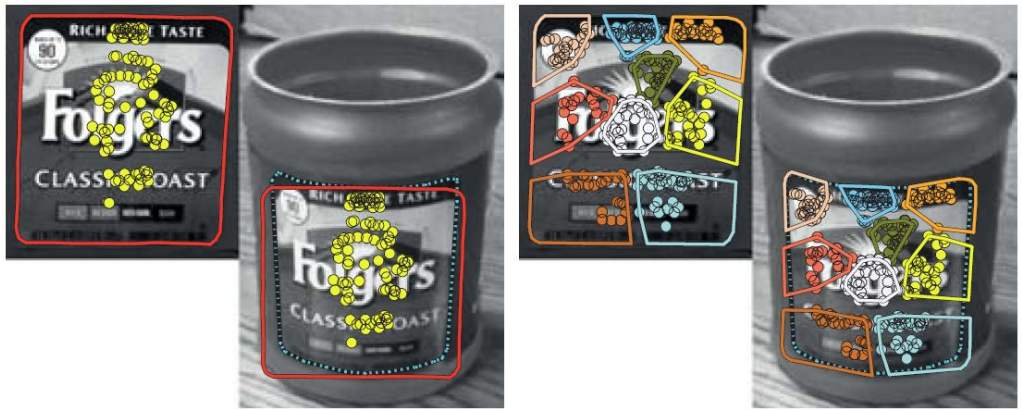
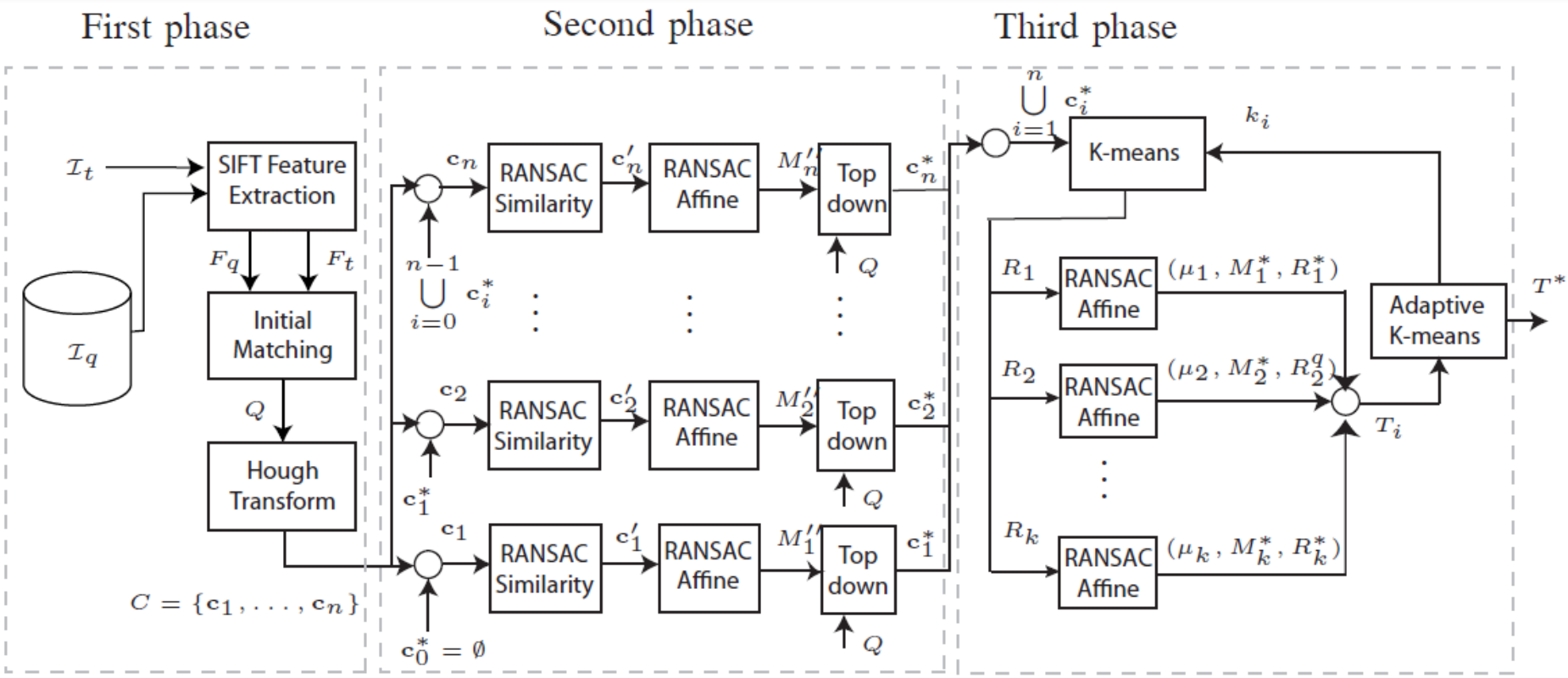


Figure from [Puerto-Souza *etal 2011*]

Estimating multiple affine components

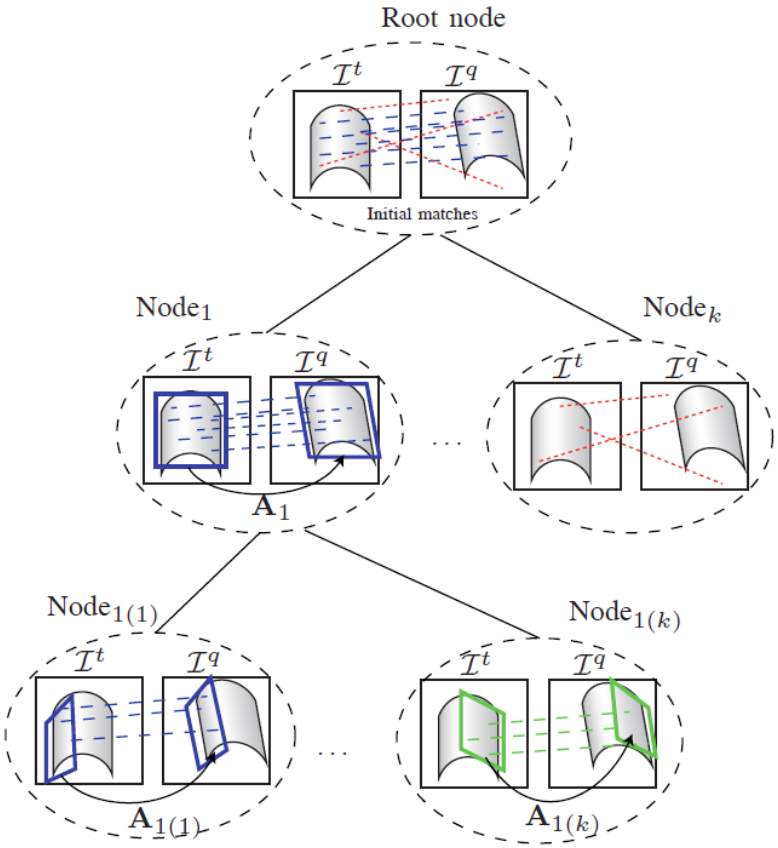


Remarks.
Hough Transform: to cluster SIFT keypoints according to a similarity transformation
RANSAC: first to estimate a similarity model and then to estimate an affine model
to provide a refined list of matches.
Top-down: to recover lost matches

Figure from [Puerto-Souza *etal 2011*]

Hierarchical Multi-Affine (HMA)

- quantizes matches according to their spatial position on the object's surface
- Hierarchical K-means
  - **Binary (tree) search** vs. Exhaustive search



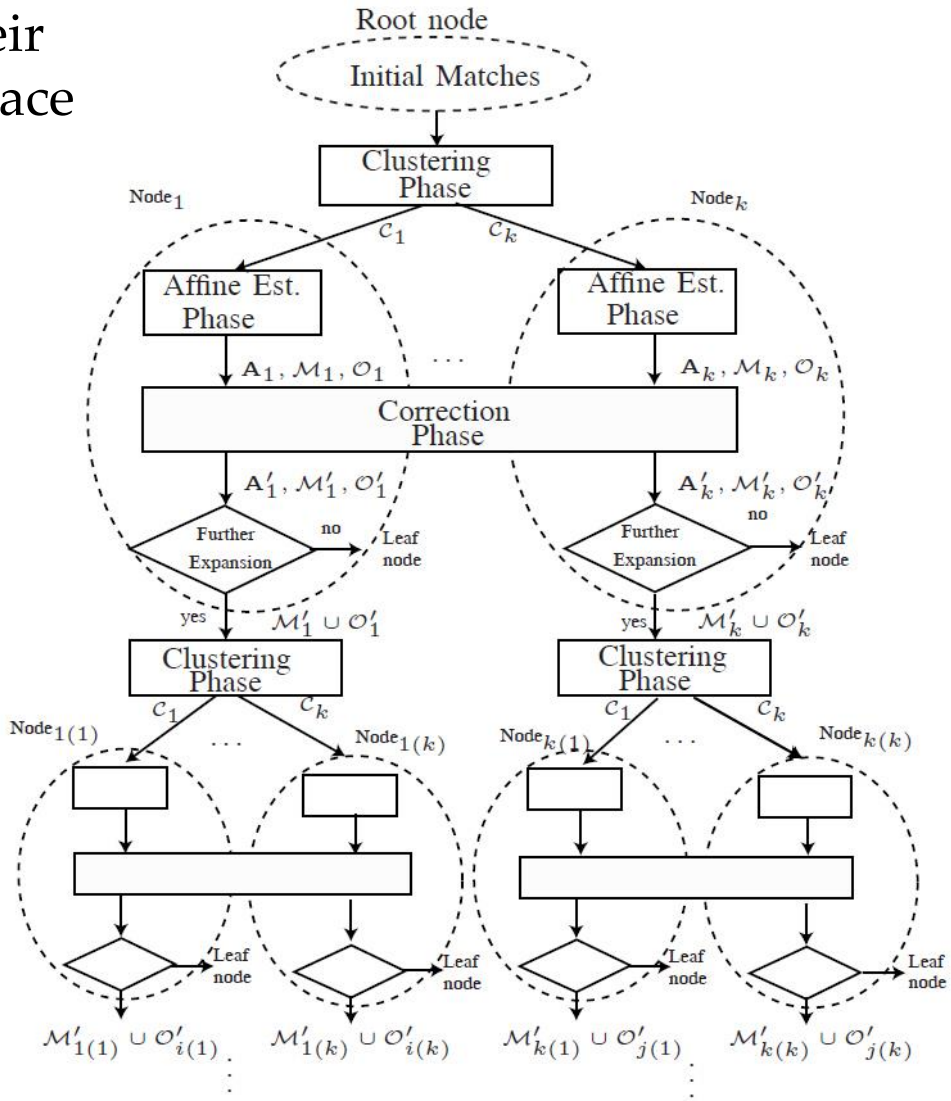


Figure from [Puerto-Souza *etal 2012*]

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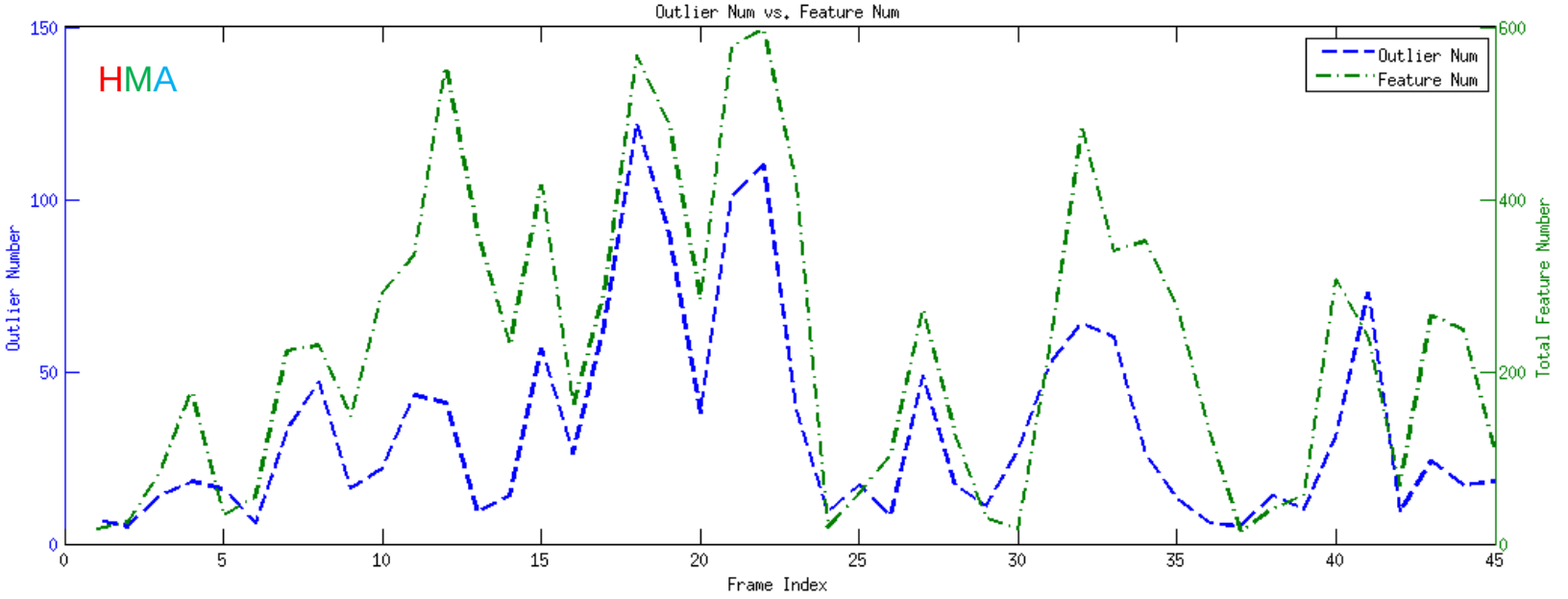
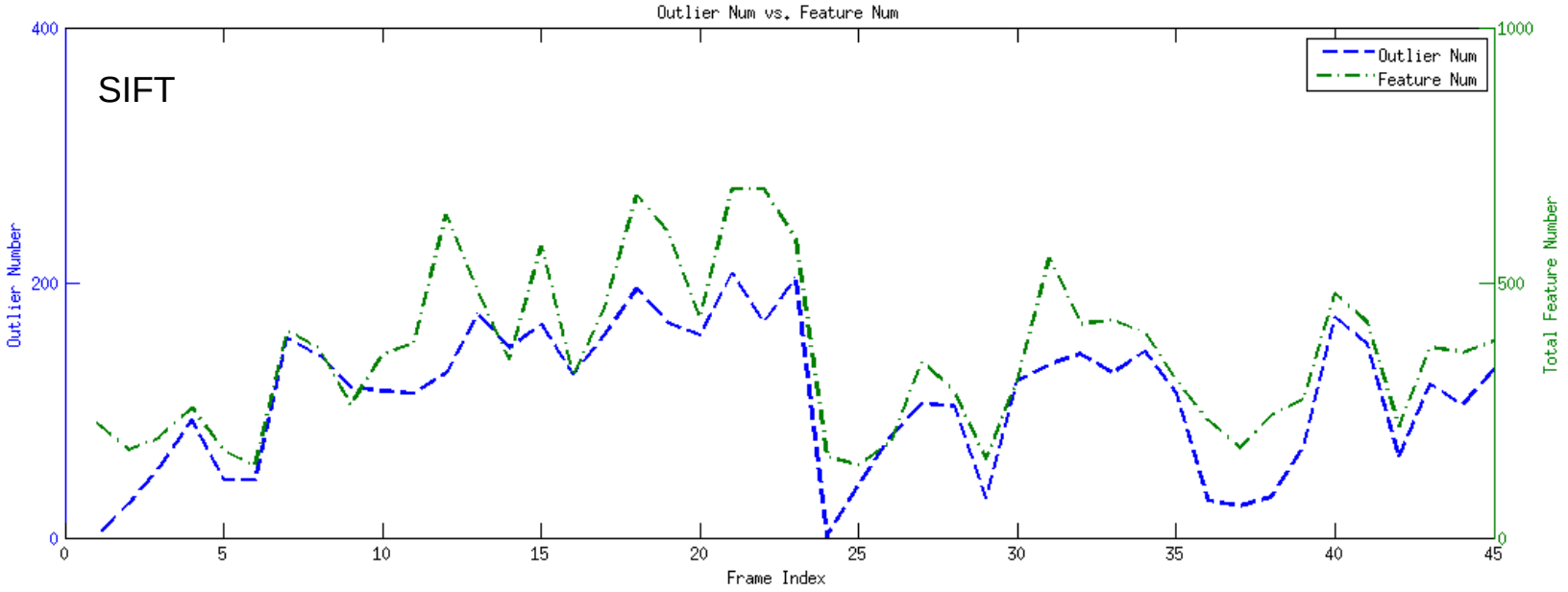
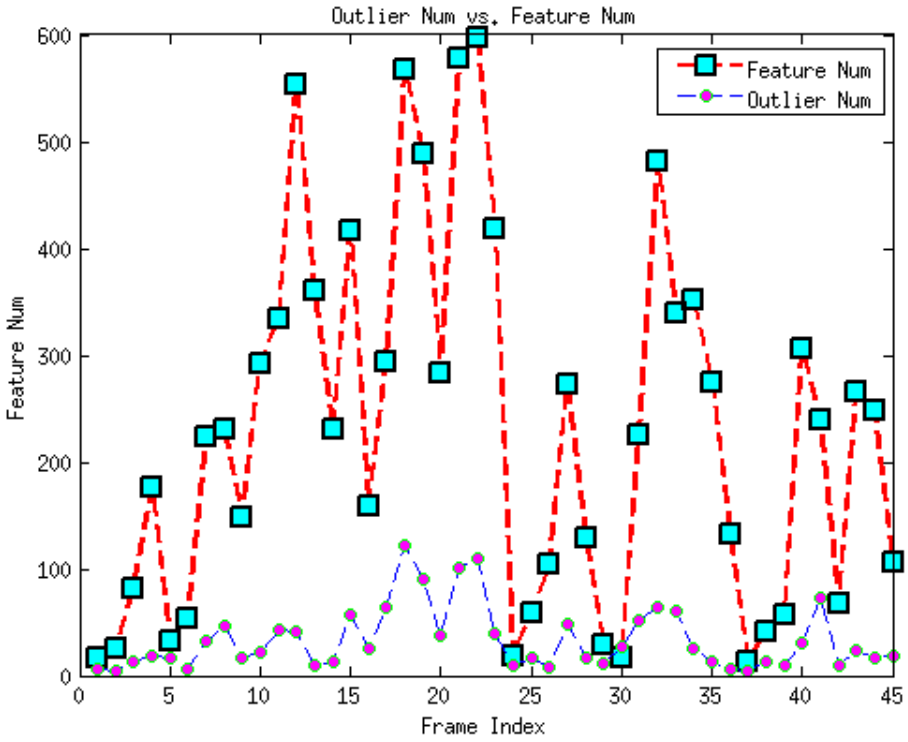
SIFT keypoints with HMA matching vs. SIFT matching

RANSAC detected outlier number
vs. Total 'matched' feature number

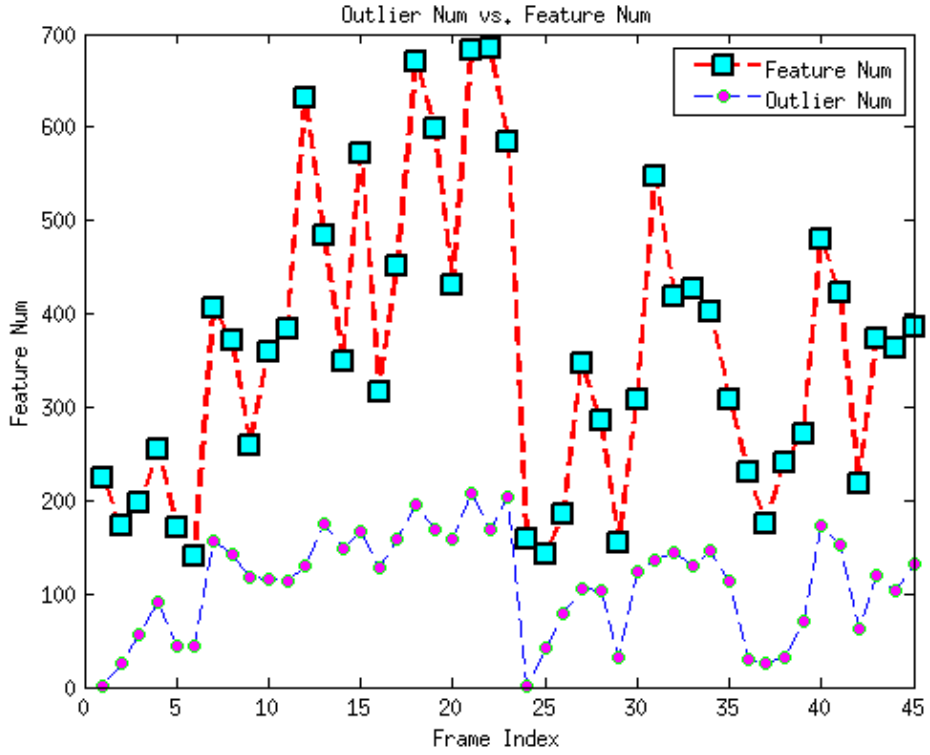




HMA


Outlier Num vs. Feature Num
Feature Num
Outlier Num
Feature Num
Frame Index
0
100
200
300
400
500
600
0
5
10
15
20
25
30
35
40
45

SIFT


Outlier Num vs. Feature Num
Feature Num
Outlier Num
Feature Num
Frame Index
0
100
200
300
400
500
600
700
0
5
10
15
20
25
30
35
40
45

Empirical Covariance Analysis and Motion Estimation Evaluation by Leaving-One-Out Cross Validation

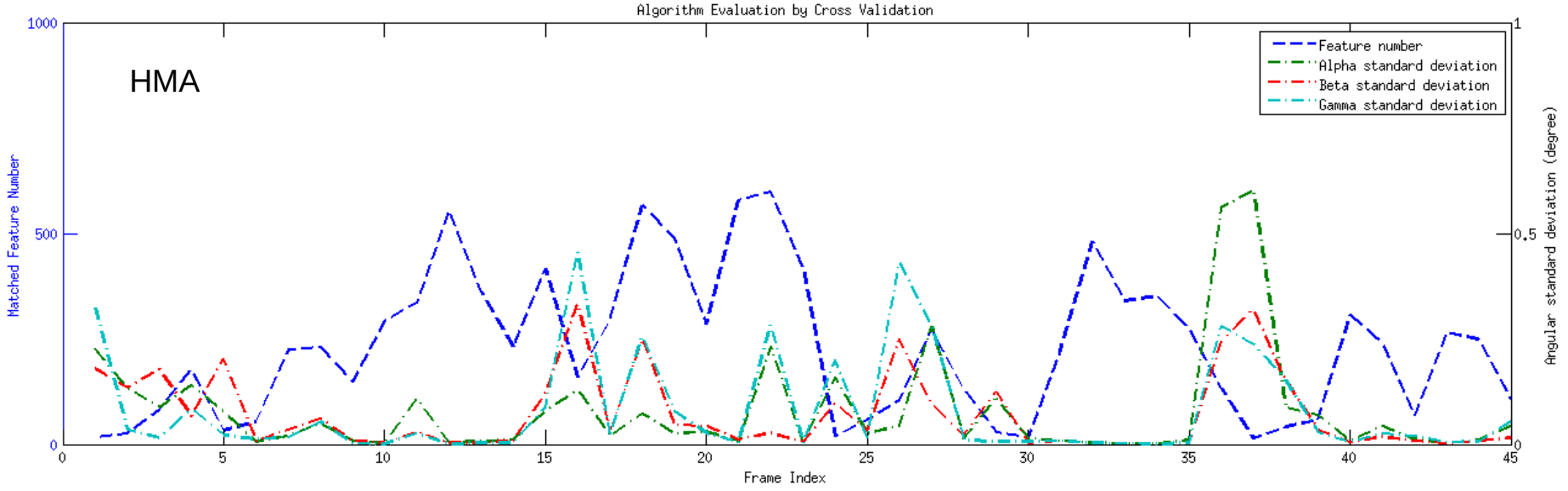
for $k = 1...FrmNum$
  Compute SIFT feature keypoints to form a candidate feature pool.
  Perform HMA matching to select keypoints, which are grouped into affine components.
  Convert image coordinates to World's coordinates using camera's intrinsic parameters.
  if $MatchFeaNum > 4$
    for $trial = 1...MatchFeaNum$
      Leave the $trial$-th keypoint out as a query point.
      Perform RANSAC on the left keypoints to generate an inlier set.
      Perform 5-point algorithm to estimate the essential matrix E using the inlier set.
      Decompose E into a rotation matrix R and a translation vector t.
      Convert R to a quaternion.
      Compute projection error for the hold-out query point:
        $residual = (R * X_{left}^{query} + t) - X_{right}^{query}$
        $sqErr = L2norm(residual)$
    end for
    Compute the mean and standard deviation of a sequence of $sqErr$.
    Compose a R_{mean} from $mean(quaternion)$.
    for $trial = 1...MatchFeaNum$
      $R_{mean} * R^{-1}$ is approximately a skew-symmetric matrix $skew(\alpha, \beta, \gamma)$,
        where α, β, γ are the rotation angle (scalar) in X, Y, Z axis, respectively.
    end for
    Compute the covariance matrix of a sequence of vector $< \alpha, \beta, \gamma >$.
  end if
end for

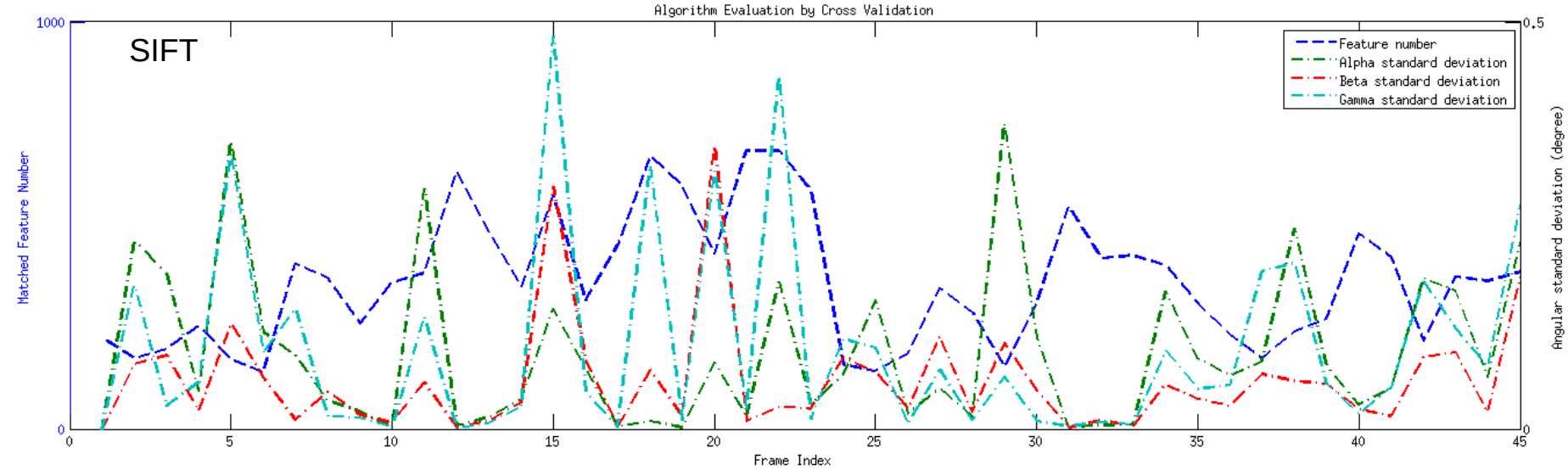
$$\begin{bmatrix} 1 & -\gamma & \beta \\ \gamma & 1 & -\alpha \\ -\beta & \alpha & 1 \end{bmatrix}$$

Remark.
Skew parameters via Cayley's formula.

Overall evaluation

Alpha, beta, gamma with feature number





Covariance matrix

original cov

```
val(:,:,1) =
    0.0507    0.0096   -0.0253
    0.0096    0.0320   -0.0390
   -0.0253   -0.0390    0.1042
val(:,:,2) =
    0.0180   -0.0173   -0.0039
   -0.0173    0.0181    0.0042
   -0.0039    0.0042    0.0012
val(:,:,3) =
    0.0077    0.0092    0.0002
    0.0092    0.0314    0.0019
    0.0002    0.0019    0.0002
val(:,:,4) =
    0.0196    0.0016   -0.0113
    0.0016    0.0044   -0.0026
   -0.0113   -0.0026    0.0072
val(:,:,5) =
    0.0059    0.0155   -0.0014
    0.0155    0.0410   -0.0035
   -0.0014   -0.0035    0.0005
```

sqrt(cov-diag) and convert to degree

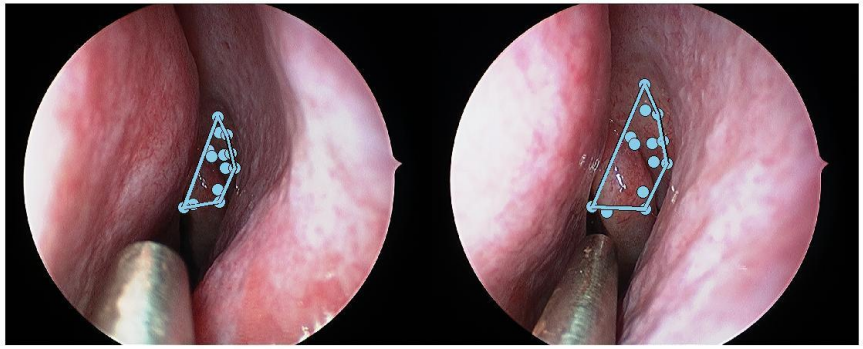
```
val(:,:,1) =
   12.9002   10.2554   18.4927
val(:,:,2) =
    7.6863    7.7102    2.0129
val(:,:,3) =
    5.0384   10.1588    0.8634
val(:,:,4) =
    8.0279    3.8214    4.8564
val(:,:,5) =
    4.4111   11.6050    1.2478
```

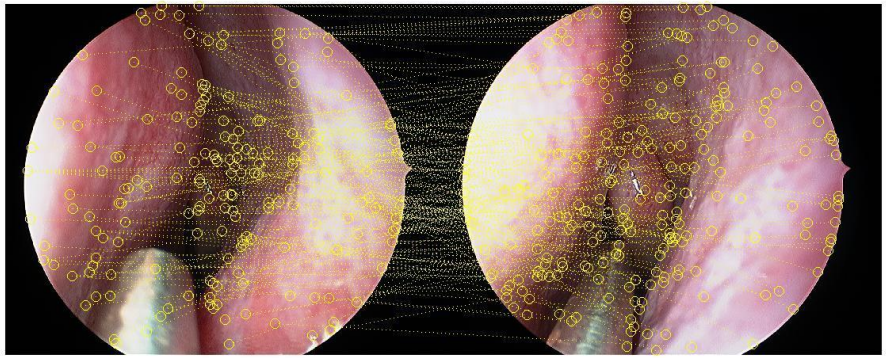
original cov

```
val(:,:,1) =
     0     0     0
     0     0     0
     0     0     0
val(:,:,2) =
    0.0535   -0.0031    0.0117
   -0.0031    0.0064    0.0020
    0.0117    0.0020    0.0310
val(:,:,3) =
    0.0365    0.0068   -0.0019
    0.0068    0.0081    0.0011
   -0.0019    0.0011    0.0008
val(:,:,4) =
    0.0022    0.0008   -0.0026
    0.0008    0.0005   -0.0011
   -0.0026   -0.0011    0.0033
val(:,:,5) =
    0.1248   -0.0313   -0.0843
   -0.0313    0.0168    0.0279
   -0.0843    0.0279    0.1144
```

sqrt(cov-diag) and convert to degree

```
val(:,:,1) =
     0     0     0
     0     0     0
     0     0     0
val(:,:,2) =
   13.2501    4.5710   10.0842
val(:,:,3) =
   10.9486    5.1710    1.6188
val(:,:,4) =
    2.6581    1.2876    3.3025
val(:,:,5) =
   20.2427    7.4315   19.3781
```





HMA

original cov

val(:,:,1) =

0.0507	0.0096	-0.0253
0.0096	0.0320	-0.0390
-0.0253	-0.0390	0.1042

val(:,:,2) =

0.0180	-0.0173	-0.0039
-0.0173	0.0181	0.0042
-0.0039	0.0042	0.0012

val(:,:,3) =

0.0077	0.0092	0.0002
0.0092	0.0314	0.0019
0.0002	0.0019	0.0002

val(:,:,4) =

0.0196	0.0016	-0.0113
0.0016	0.0044	-0.0026
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val(:,:,5) =

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sqrt(cov-diag) and convert to degree

val(:,:,1) =

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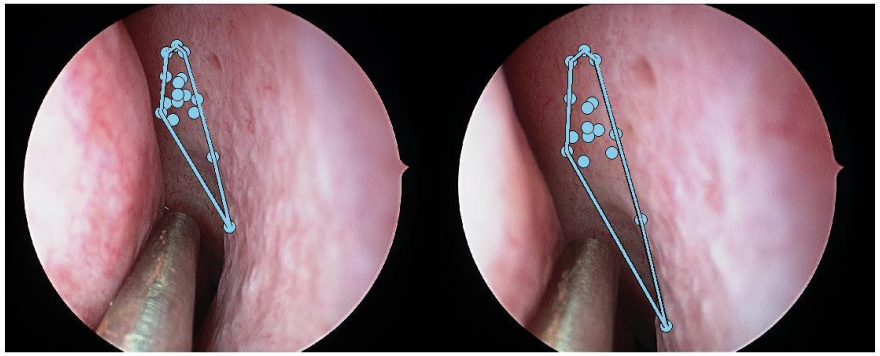

SIFT

original cov

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

0.0535	-0.0031	0.0117
-0.0031	0.0064	0.0020
0.0117	0.0020	0.0310

val(:,:,3) =

0.0365	0.0068	-0.0019
0.0068	0.0081	0.0011
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0.0008	0.0005	-0.0011
-0.0026	-0.0011	0.0033

val(:,:,5) =

0.1248	-0.0313	-0.0843
-0.0313	0.0168	0.0279
-0.0843	0.0279	0.1144

sqrt(cov-diag) and convert to degree

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0	0	0
0	0	0

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13.2501	4.5710	10.0842

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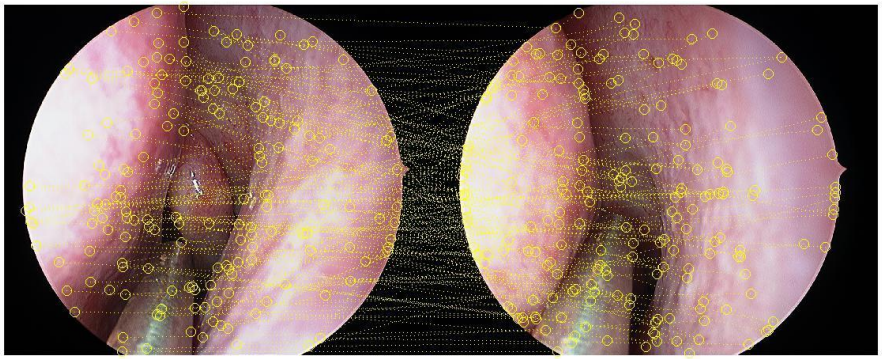

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-0.0253	-0.0390	0.1042

val(:,:,2) =

0.0180	-0.0173	-0.0039
-0.0173	0.0181	0.0042
-0.0039	0.0042	0.0012

val(:,:,3) =

0.0077	0.0092	0.0002
0.0092	0.0314	0.0019
0.0002	0.0019	0.0002

val(:,:,4) =

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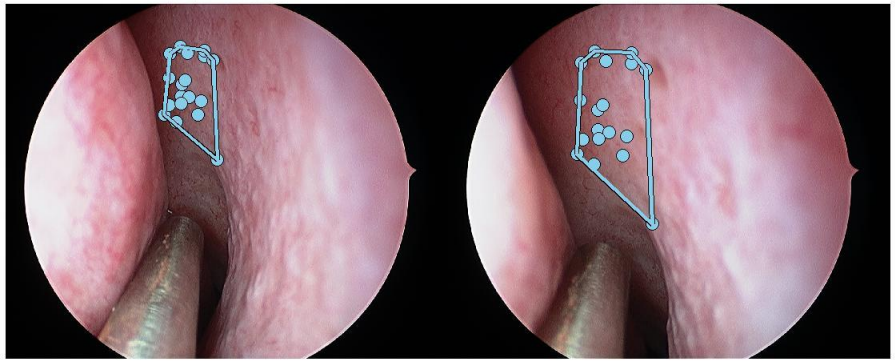

SIFT

original cov

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

0.0535	-0.0031	0.0117
-0.0031	0.0064	0.0020
0.0117	0.0020	0.0310

val(:,:,3) =

0.0365	0.0068	-0.0019
0.0068	0.0081	0.0011
-0.0019	0.0011	0.0008

val(:,:,4) =

0.0022	0.0008	-0.0026
0.0008	0.0005	-0.0011
-0.0026	-0.0011	0.0033

val(:,:,5) =

0.1248	-0.0313	-0.0843
-0.0313	0.0168	0.0279
-0.0843	0.0279	0.1144

sqrt(cov-diag) and convert to degree

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

13.2501	4.5710	10.0842

val(:,:,3) =

10.9486	5.1710	1.6188

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2.6581	1.2876	3.3025

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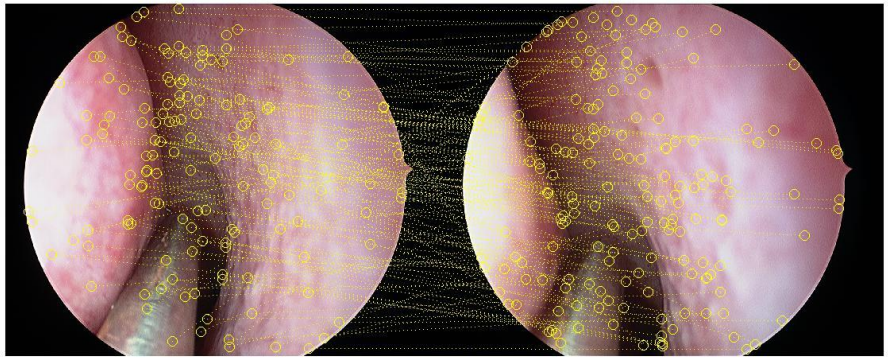

HMA

original cov

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-0.0253	-0.0390	0.1042

val(:,:,2) =

0.0180	-0.0173	-0.0039
-0.0173	0.0181	0.0042
-0.0039	0.0042	0.0012

val(:,:,3) =

0.0077	0.0092	0.0002
0.0092	0.0314	0.0019
0.0002	0.0019	0.0002

val(:,:,4) =

0.0196	0.0016	-0.0113
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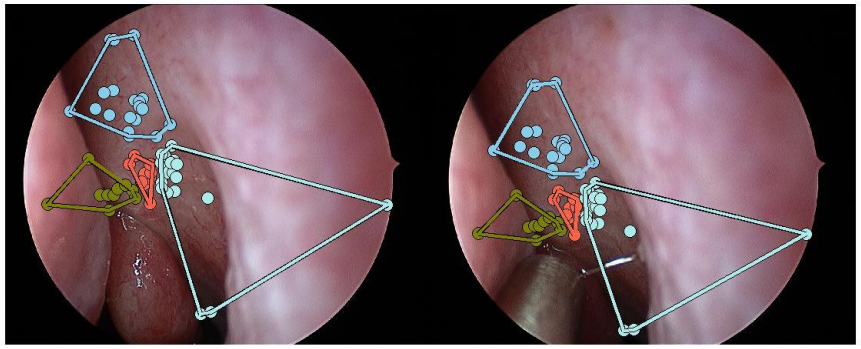
4.4111	11.6050	1.2478



SIFT

original cov

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

0.0535	-0.0031	0.0117
-0.0031	0.0064	0.0020
0.0117	0.0020	0.0310

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0.0365	0.0068	-0.0019
0.0068	0.0081	0.0011
-0.0019	0.0011	0.0008

val(:,:,4) =

0.0022	0.0008	-0.0026
0.0008	0.0005	-0.0011
-0.0026	-0.0011	0.0033

val(:,:,5) =

0.1248	-0.0313	-0.0843
-0.0313	0.0168	0.0279
-0.0843	0.0279	0.1144

sqrt(cov-diag) and convert to degree

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

13.2501	4.5710	10.0842

val(:,:,3) =

10.9486	5.1710	1.6188

val(:,:,4) =

2.6581	1.2876	3.3025

val(:,:,5) =

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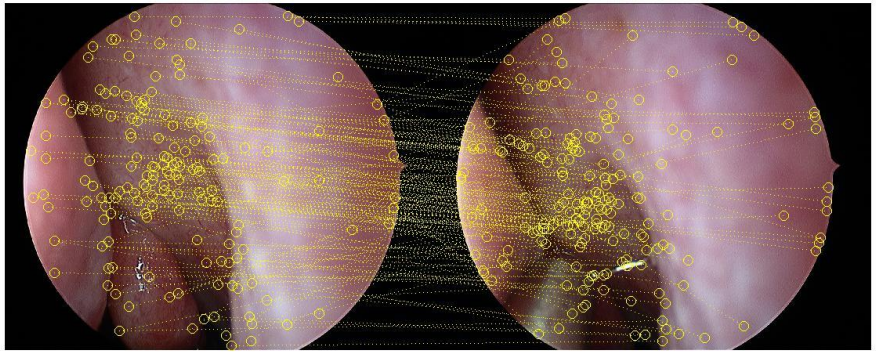

HMA

original cov

val(:,:,1) =

0.0507	0.0096	-0.0253
0.0096	0.0320	-0.0390
-0.0253	-0.0390	0.1042

val(:,:,2) =

0.0180	-0.0173	-0.0039
-0.0173	0.0181	0.0042
-0.0039	0.0042	0.0012

val(:,:,3) =

0.0077	0.0092	0.0002
0.0092	0.0314	0.0019
0.0002	0.0019	0.0002

val(:,:,4) =

0.0196	0.0016	-0.0113
0.0016	0.0044	-0.0026
-0.0113	-0.0026	0.0072

val(:,:,5) =

0.0059	0.0155	-0.0014
0.0155	0.0410	-0.0035
-0.0014	-0.0035	0.0005

sqrt(cov-diag) and convert to degree

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val(:,:,2) =

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val(:,:,3) =

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val(:,:,4) =

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val(:,:,5) =

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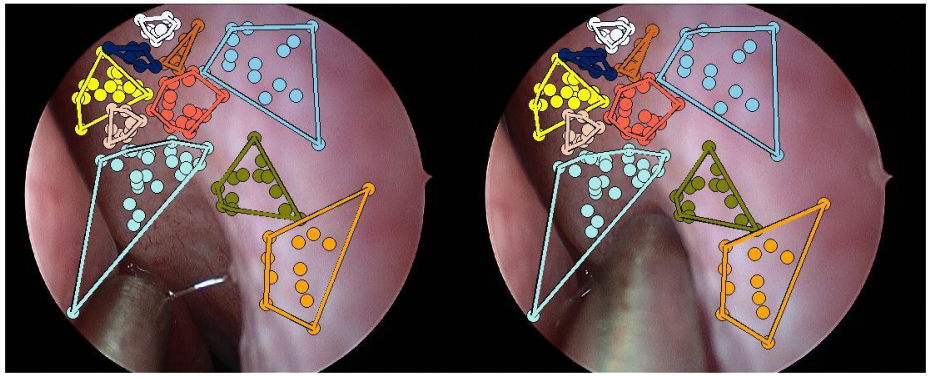


SIFT

original cov

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

0.0535	-0.0031	0.0117
-0.0031	0.0064	0.0020
0.0117	0.0020	0.0310

val(:,:,3) =

0.0365	0.0068	-0.0019
0.0068	0.0081	0.0011
-0.0019	0.0011	0.0008

val(:,:,4) =

0.0022	0.0008	-0.0026
0.0008	0.0005	-0.0011
-0.0026	-0.0011	0.0033

val(:,:,5) =

0.1248	-0.0313	-0.0843
-0.0313	0.0168	0.0279
-0.0843	0.0279	0.11

sqrt(cov-diag) and convert to degree

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

13.2501	4.5710	10.0842

val(:,:,3) =

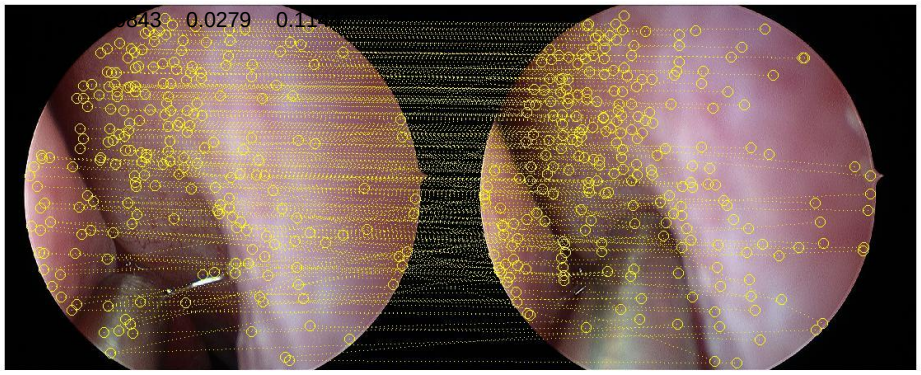
10.9486	5.1710	1.6188

val(:,:,4) =

2.6581	1.2876	3.3025

val(:,:,5) =

20.2427	7.4315	19.3781



HMA

original cov

val(:,:,1) =

0.0507	0.0096	-0.0253
0.0096	0.0320	-0.0390
-0.0253	-0.0390	0.1042

val(:,:,2) =

0.0180	-0.0173	-0.0039
-0.0173	0.0181	0.0042
-0.0039	0.0042	0.0012

val(:,:,3) =

0.0077	0.0092	0.0002
0.0092	0.0314	0.0019
0.0002	0.0019	0.0002

val(:,:,4) =

0.0196	0.0016	-0.0113
0.0016	0.0044	-0.0026
-0.0113	-0.0026	0.0072

val(:,:,5) =

0.0059	0.0155	-0.0014
0.0155	0.0410	-0.0035
-0.0014	-0.0035	0.0005

sqrt(cov-diag) and convert to degree

val(:,:,1) =

12.9002	10.2554	18.4927

val(:,:,2) =

7.6863	7.7102	2.0129

val(:,:,3) =

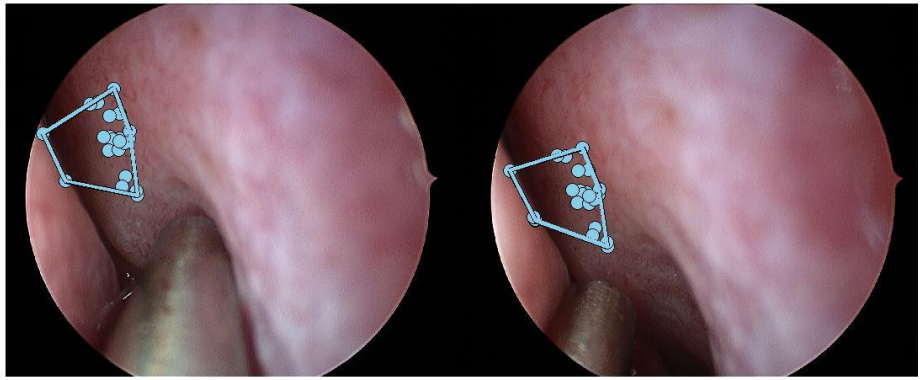
5.0384	10.1588	0.8634

val(:,:,4) =

8.0279	3.8214	4.8564

val(:,:,5) =

4.4111	11.6050	1.2478



SIFT

original cov

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

0.0535	-0.0031	0.0117
-0.0031	0.0064	0.0020
0.0117	0.0020	0.0310

val(:,:,3) =

0.0365	0.0068	-0.0019
0.0068	0.0081	0.0011
-0.0019	0.0011	0.0008

val(:,:,4) =

0.0022	0.0008	-0.0026
0.0008	0.0005	-0.0011
-0.0026	-0.0011	0.0033

val(:,:,5) =

0.1248	-0.0313	-0.0843
-0.0313	0.0168	0.0279
-0.0843	0.0279	0.1144

sqrt(cov-diag) and convert to degree

val(:,:,1) =

0	0	0
0	0	0
0	0	0

val(:,:,2) =

13.2501	4.5710	10.0842

val(:,:,3) =

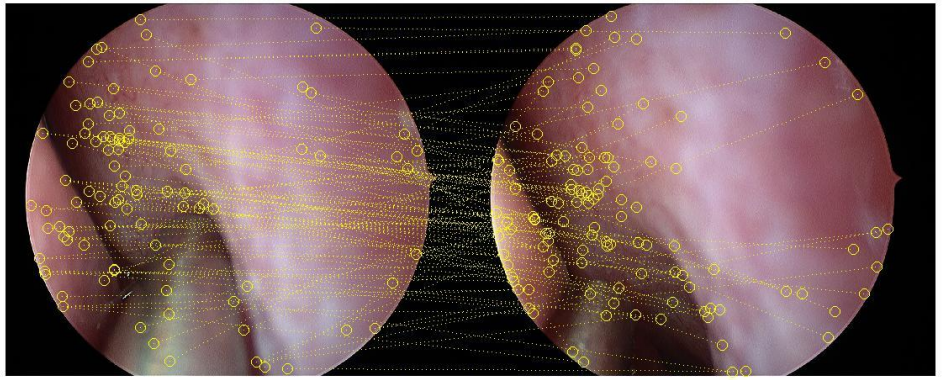
10.9486	5.1710	1.6188

val(:,:,4) =

2.6581	1.2876	3.3025

val(:,:,5) =

20.2427	7.4315	19.3781



HMA

original cov

val(:,:,6) =

1.0e-03 *

0.0347 0.0259 -0.0625

0.0259 0.0732 -0.0755

-0.0625 -0.0755 0.1588

val(:,:,7) =

0.0004 -0.0001 -0.0002

-0.0001 0.0012 -0.0002

-0.0002 -0.0002 0.0003

val(:,:,8) =

0.0024 -0.0006 -0.0012

-0.0006 0.0036 -0.0002

-0.0012 -0.0002 0.0029

val(:,:,9) =

1.0e-04 *

0.7090 -0.2440 -0.0874

-0.2440 0.5469 -0.0552

-0.0874 -0.0552 0.0384

val(:,:,10) =

1.0e-04 *

0.1001 0.0929 0.0045

0.0929 0.1485 0.0131

0.0045 0.0131 0.0072

sqrt(cov-diag) and convert to degree

val(:,:,6) =

0.3377 0.4903 0.7221

val(:,:,7) =

1.0910 1.9899 0.9586

val(:,:,8) =

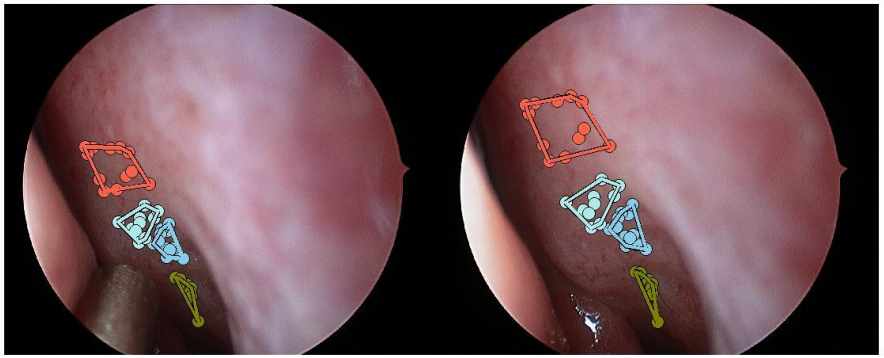
2.7816 3.4329 3.0840

val(:,:,9) =

0.4825 0.4237 0.1122

val(:,:,10) =

0.1812 0.2208 0.0487



SIFT

original cov

val(:,:,6) =

0.0141 0.0027 -0.0050

0.0027 0.0039 0.0036

-0.0050 0.0036 0.0085

val(:,:,7) =

0.0081 0.0009 -0.0132

0.0009 0.0001 -0.0015

-0.0132 -0.0015 0.0217

val(:,:,8) =

0.0012 -0.0016 -0.0005

-0.0016 0.0020 0.0007

-0.0005 0.0007 0.0002

val(:,:,9) =

1.0e-03 *

0.4813 -0.3411 -0.2652

-0.3411 0.3088 0.1746

-0.2652 0.1746 0.1868

val(:,:,10) =

1.0e-04 *

0.0334 -0.0028 0.0222

-0.0028 0.5534 -0.1232

0.0222 -0.1232 0.0550

sqrt(cov-diag) and convert to degree

val(:,:,6) =

6.8132 3.5875 5.2930

val(:,:,7) =

5.1675 0.6281 8.4446

val(:,:,8) =

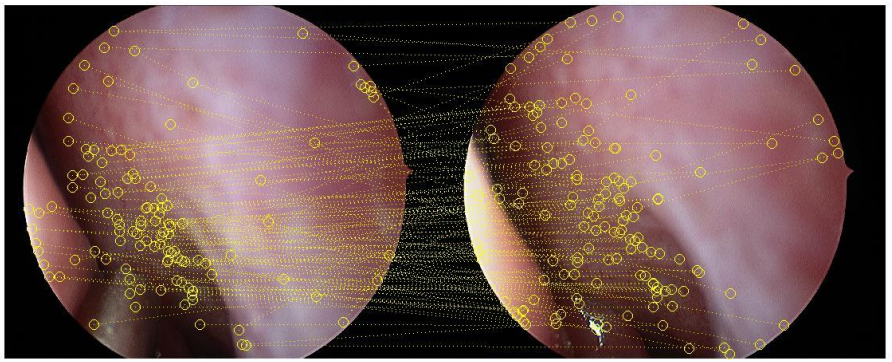
1.9925 2.5732 0.8993

val(:,:,9) =

1.2570 1.0068 0.7831

val(:,:,10) =

0.1047 0.4262 0.1344



HMA

original cov

val(:,:,6) =

1.0e-03 *

0.0347	0.0259	-0.0625
0.0259	0.0732	-0.0755
-0.0625	-0.0755	0.1588

val(:,:,7) =

0.0004	-0.0001	-0.0002
-0.0001	0.0012	-0.0002
-0.0002	-0.0002	0.0003

val(:,:,8) =

0.0024	-0.0006	-0.0012
-0.0006	0.0036	-0.0002
-0.0012	-0.0002	0.0029

val(:,:,9) =

1.0e-04 *

0.7090	-0.2440	-0.0874
-0.2440	0.5469	-0.0552
-0.0874	-0.0552	0.0384

val(:,:,10) =

1.0e-04 *

0.1001	0.0929	0.0045
0.0929	0.1485	0.0131
0.0045	0.0131	0.0072

sqrt(cov-diag) and convert to degree

val(:,:,6) =

0.3377	0.4903	0.7221

val(:,:,7) =

1.0910	1.9899	0.9586

val(:,:,8) =

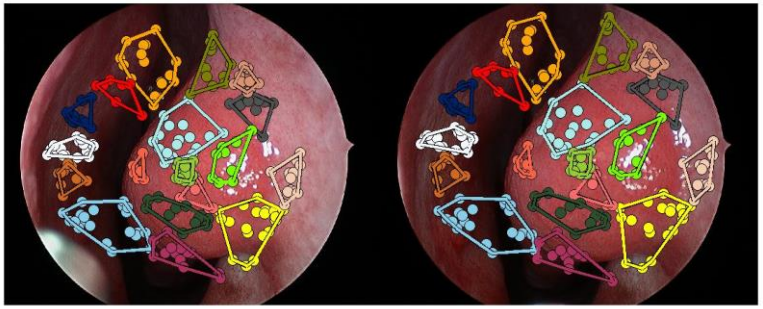
2.7816	3.4329	3.0840

val(:,:,9) =

0.4825	0.4237	0.1122

val(:,:,10) =

0.1812	0.2208	0.0487



SIFT

original cov

val(:,:,6) =

0.0141	0.0027	-0.0050
0.0027	0.0039	0.0036
-0.0050	0.0036	0.0085

val(:,:,7) =

0.0081	0.0009	-0.0132
0.0009	0.0001	-0.0015
-0.0132	-0.0015	0.0217

val(:,:,8) =

0.0012	-0.0016	-0.0005
-0.0016	0.0020	0.0007
-0.0005	0.0007	0.0002

val(:,:,9) =

1.0e-03 *

0.4813	-0.3411	-0.2652
-0.3411	0.3088	0.1746
-0.2652	0.1746	0.1868

val(:,:,10) =

1.0e-04 *

0.0334	-0.0028	0.0222
-0.0028	0.5534	-0.1232
0.0222	-0.1232	0.0550

sqrt(cov-diag) and convert to degree

val(:,:,6) =

6.8132	3.5875	5.2930

val(:,:,7) =

5.1675	0.6281	8.4446

val(:,:,8) =

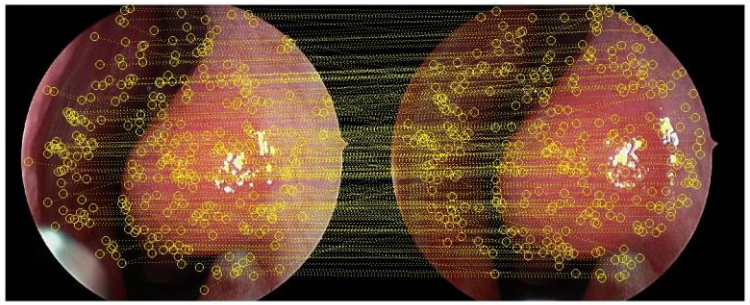
1.9925	2.5732	0.8993

val(:,:,9) =

1.2570	1.0068	0.7831

val(:,:,10) =

0.1047	0.4262	0.1344



HMA

original cov

val(:,:,11) =

0.0118	-0.0033	-0.0025
-0.0033	0.0009	0.0007
-0.0025	0.0007	0.0007

val(:,:,12) =

1.0e-04 *

0.1464	-0.0920	-0.0310
-0.0920	0.0990	0.0329
-0.0310	0.0329	0.0126

val(:,:,13) =

1.0e-04 *

0.4442	-0.0785	-0.1743
-0.0785	0.0929	-0.0061
-0.1743	-0.0061	0.1624

val(:,:,14) =

1.0e-03 *

0.1337	-0.0766	-0.0387
-0.0766	0.0770	0.0258
-0.0387	0.0258	0.0145

val(:,:,15) =

0.0060	0.0091	0.0018
0.0091	0.0142	0.0016
0.0018	0.0016	0.0075

sqrt(cov-diag) and convert to degree

val(:,:,11) =

6.2301 1.7545 1.4977

val(:,:,12) =

0.2192 0.1803 0.0643

val(:,:,13) =

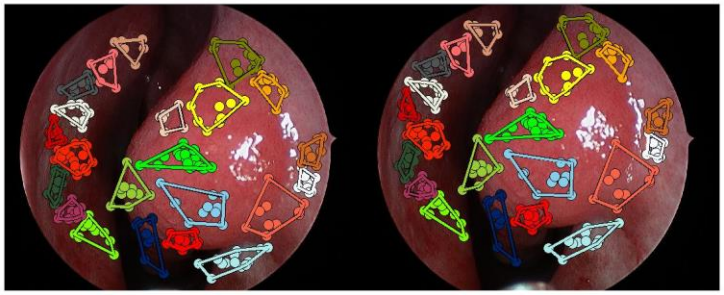
0.3819 0.1746 0.2309

val(:,:,14) =

0.6625 0.5028 0.2182

val(:,:,15) =

4.4278 6.8243 4.9622



SIFT

original cov

val(:,:,11) =

0.0870	-0.0161	-0.0088
-0.0161	0.0032	0.0020
-0.0088	0.0020	0.0189

val(:,:,12) =

1.0e-04 *

0.1544	-0.1018	-0.0222
-0.1018	0.0760	0.0120
-0.0222	0.0120	0.0070

val(:,:,13) =

1.0e-03 *

0.2057	-0.0942	0.0326
-0.0942	0.0987	-0.0473
0.0326	-0.0473	0.0427

val(:,:,14) =

0.0014	-0.0009	-0.0010
-0.0009	0.0010	0.0006
-0.0010	0.0006	0.0007

val(:,:,15) =

0.0217	0.0433	0.0050
0.0433	0.0891	-0.0115
0.0050	-0.0115	0.2319

sqrt(cov-diag) and convert to degree

val(:,:,11) =

16.8958 3.2474 7.8724

val(:,:,12) =

0.2251 0.1580 0.0481

val(:,:,13) =

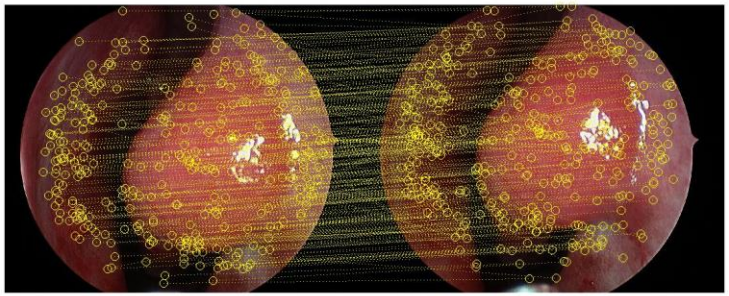
0.8217 0.5691 0.3744

val(:,:,14) =

2.1287 1.8484 1.5288

val(:,:,15) =

8.4441 17.1055 27.5938



HMA

original cov

val(:,:,11) =

0.0118	-0.0033	-0.0025
-0.0033	0.0009	0.0007
-0.0025	0.0007	0.0007

val(:,:,12) =

1.0e-04 *

0.1464	-0.0920	-0.0310
-0.0920	0.0990	0.0329
-0.0310	0.0329	0.0126

val(:,:,13) =

1.0e-04 *

0.4442	-0.0785	-0.1743
-0.0785	0.0929	-0.0061
-0.1743	-0.0061	0.1624

val(:,:,14) =

1.0e-03 *

0.1337	-0.0766	-0.0387
-0.0766	0.0770	0.0258
-0.0387	0.0258	0.0145

val(:,:,15) =

0.0060	0.0091	0.0018
0.0091	0.0142	0.0016
0.0018	0.0016	0.0075

sqrt(cov-diag) and convert to degree

val(:,:,11) =

6.2301	1.7545	1.4977

val(:,:,12) =

0.2192	0.1803	0.0643

val(:,:,13) =

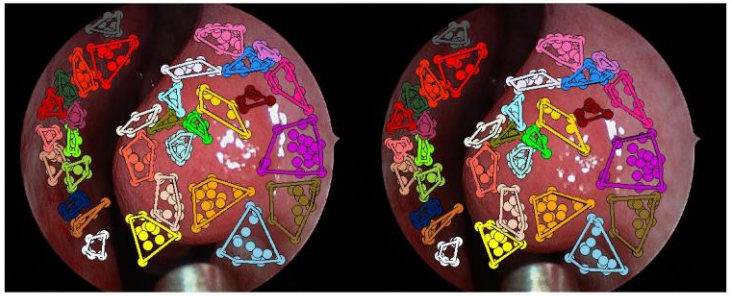
0.3819	0.1746	0.2309

val(:,:,14) =

0.6625	0.5028	0.2182

val(:,:,15) =

4.4278	6.8243	4.9622



SIFT

original cov

val(:,:,11) =

0.0870	-0.0161	-0.0088
-0.0161	0.0032	0.0020
-0.0088	0.0020	0.0189

val(:,:,12) =

1.0e-04 *

0.1544	-0.1018	-0.0222
-0.1018	0.0760	0.0120
-0.0222	0.0120	0.0070

val(:,:,13) =

1.0e-03 *

0.2057	-0.0942	0.0326
-0.0942	0.0987	-0.0473
0.0326	-0.0473	0.0427

val(:,:,14) =

0.0014	-0.0009	-0.0010
-0.0009	0.0010	0.0006
-0.0010	0.0006	0.0007

val(:,:,15) =

0.0217	0.0433	0.0050
0.0433	0.0891	-0.0115
0.0050	-0.0115	0.2319

sqrt(cov-diag) and convert to degree

val(:,:,11) =

16.8958	3.2474	7.8724

val(:,:,12) =

0.2251	0.1580	0.0481

val(:,:,13) =

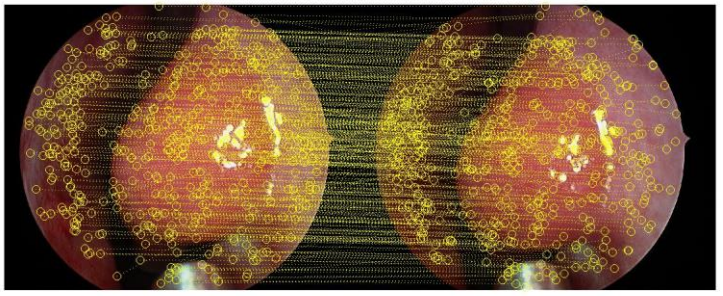
0.8217	0.5691	0.3744

val(:,:,14) =

2.1287	1.8484	1.5288

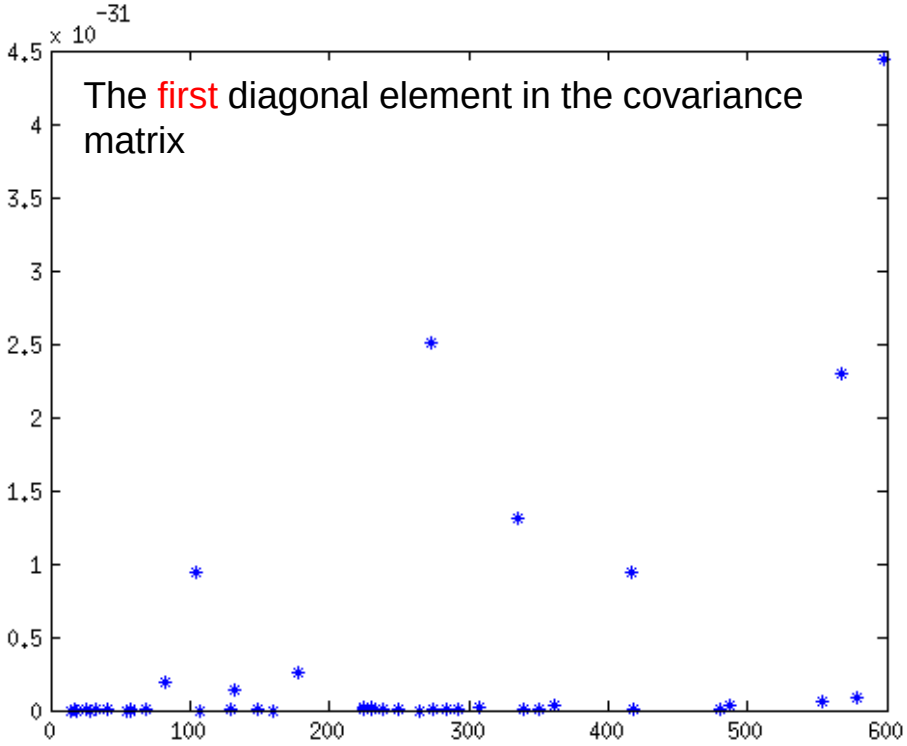
val(:,:,15) =

8.4441	17.1055	27.5938



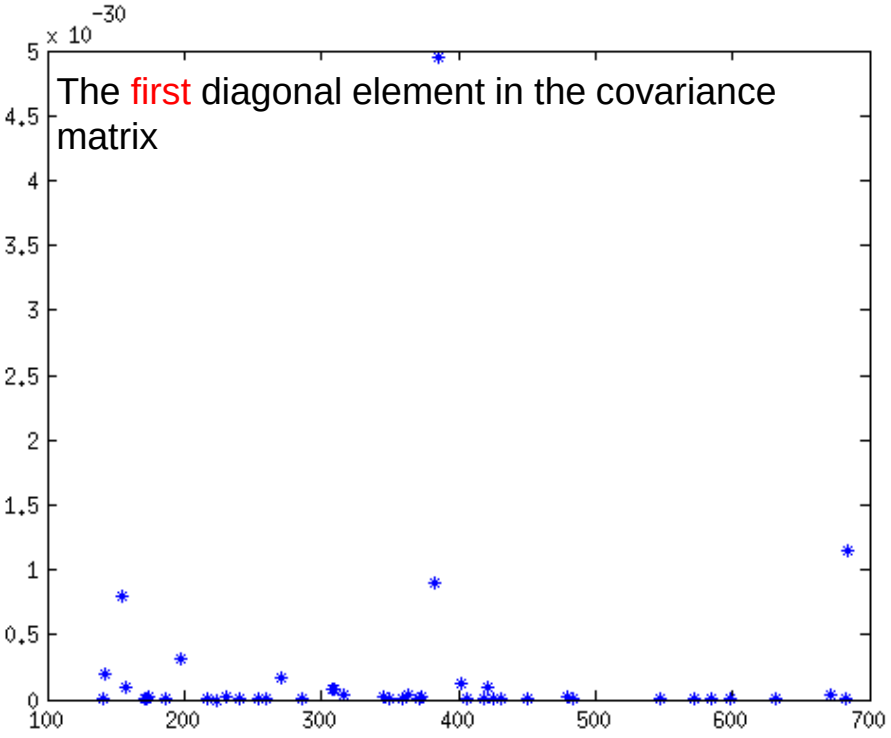
Analysis of diagonal elements in covariance matrix (1/3)

HMA



Number of matched features in one frame

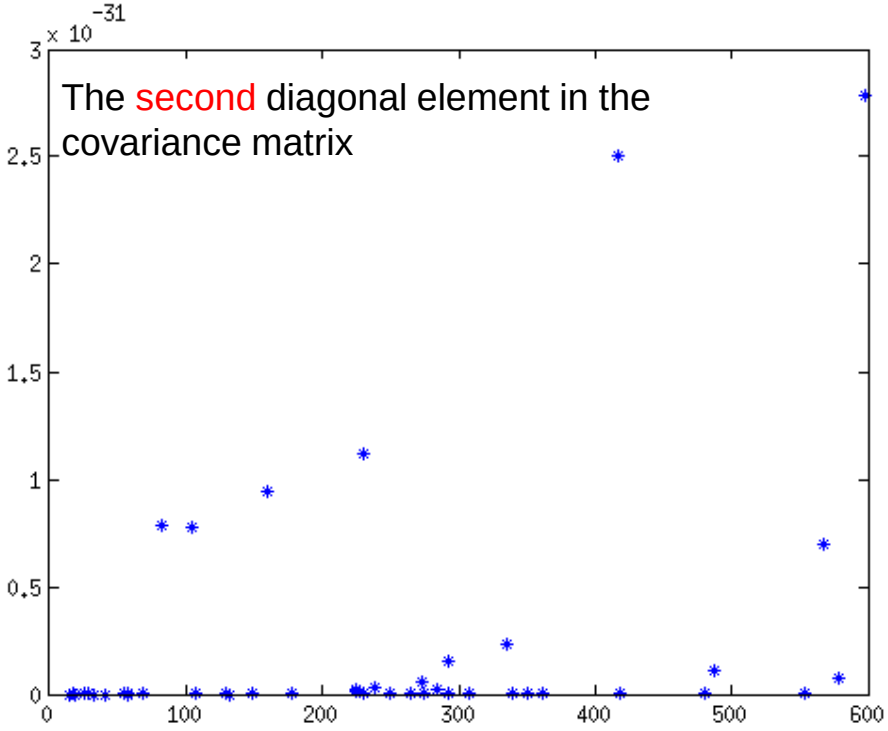
SIFT



Number of matched features in one frame

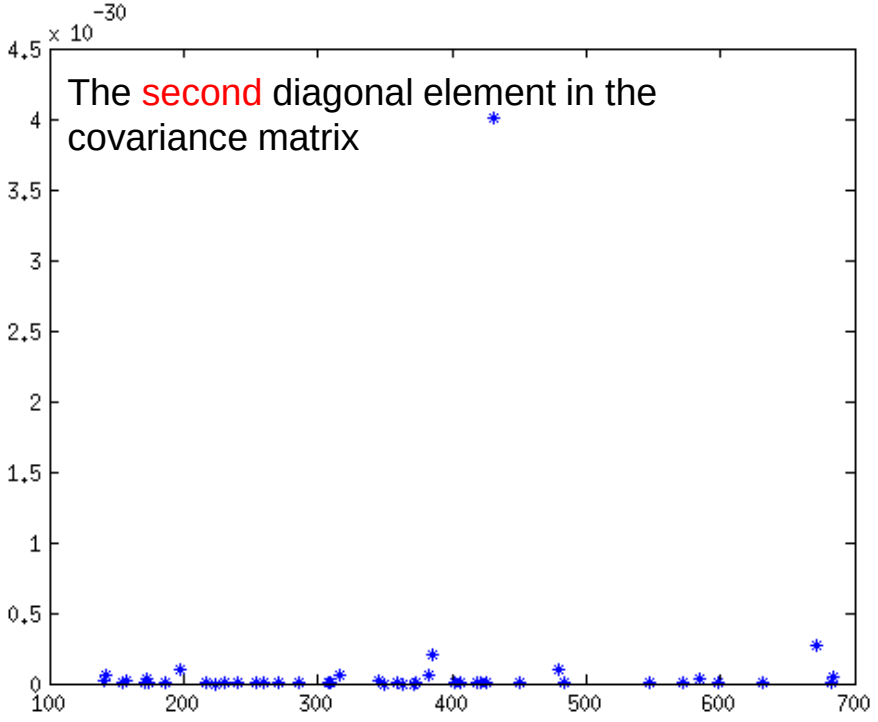
Analysis of diagonal elements in covariance matrix (2/3)

HMA



Number of matched features in one frame

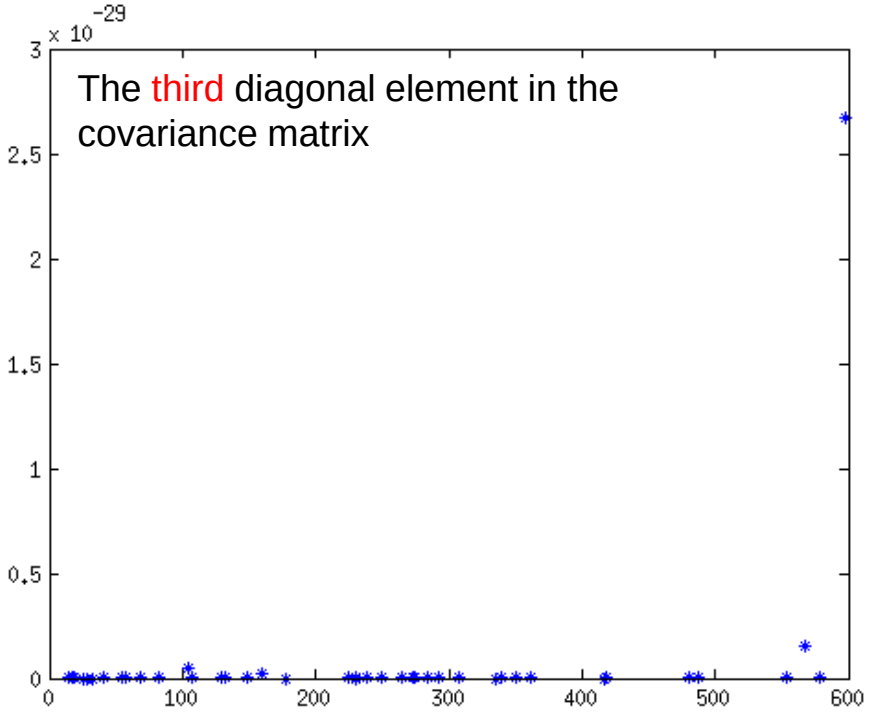
SIFT



Number of matched features in one frame

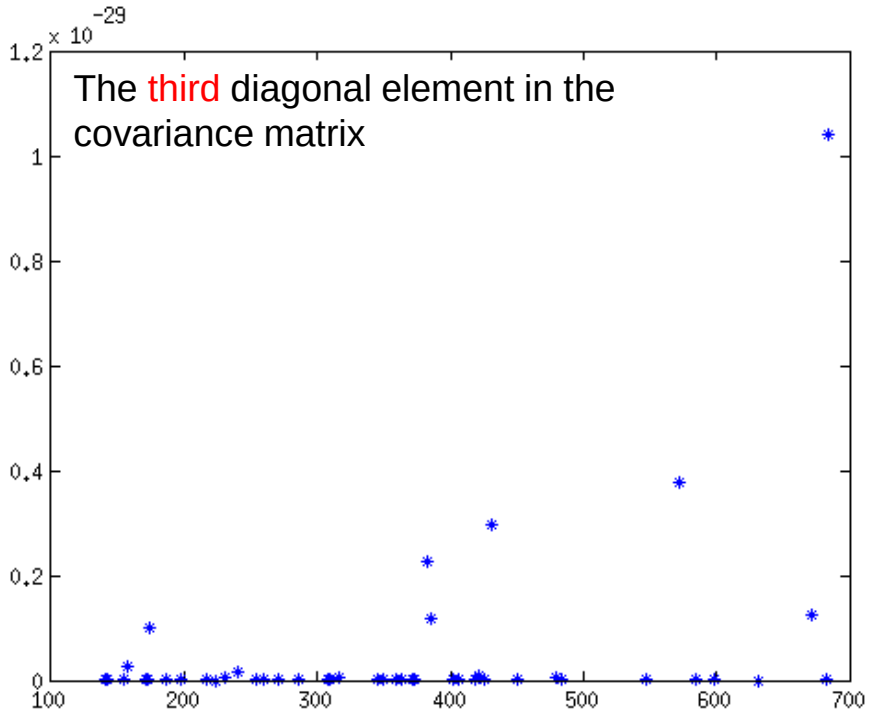
Analysis of diagonal elements in covariance matrix (3/3)

HMA



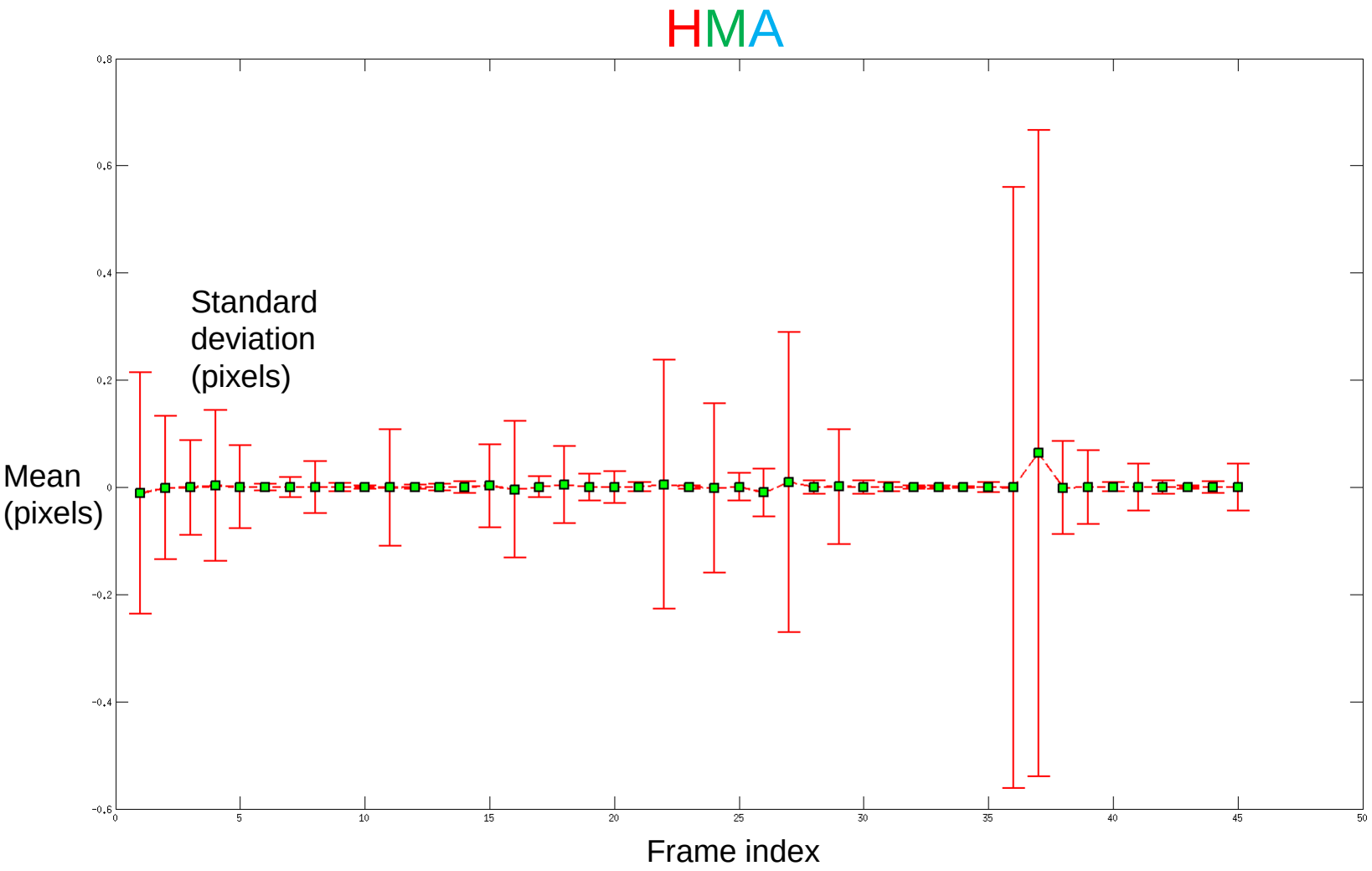
Number of matched features in one frame

SIFT

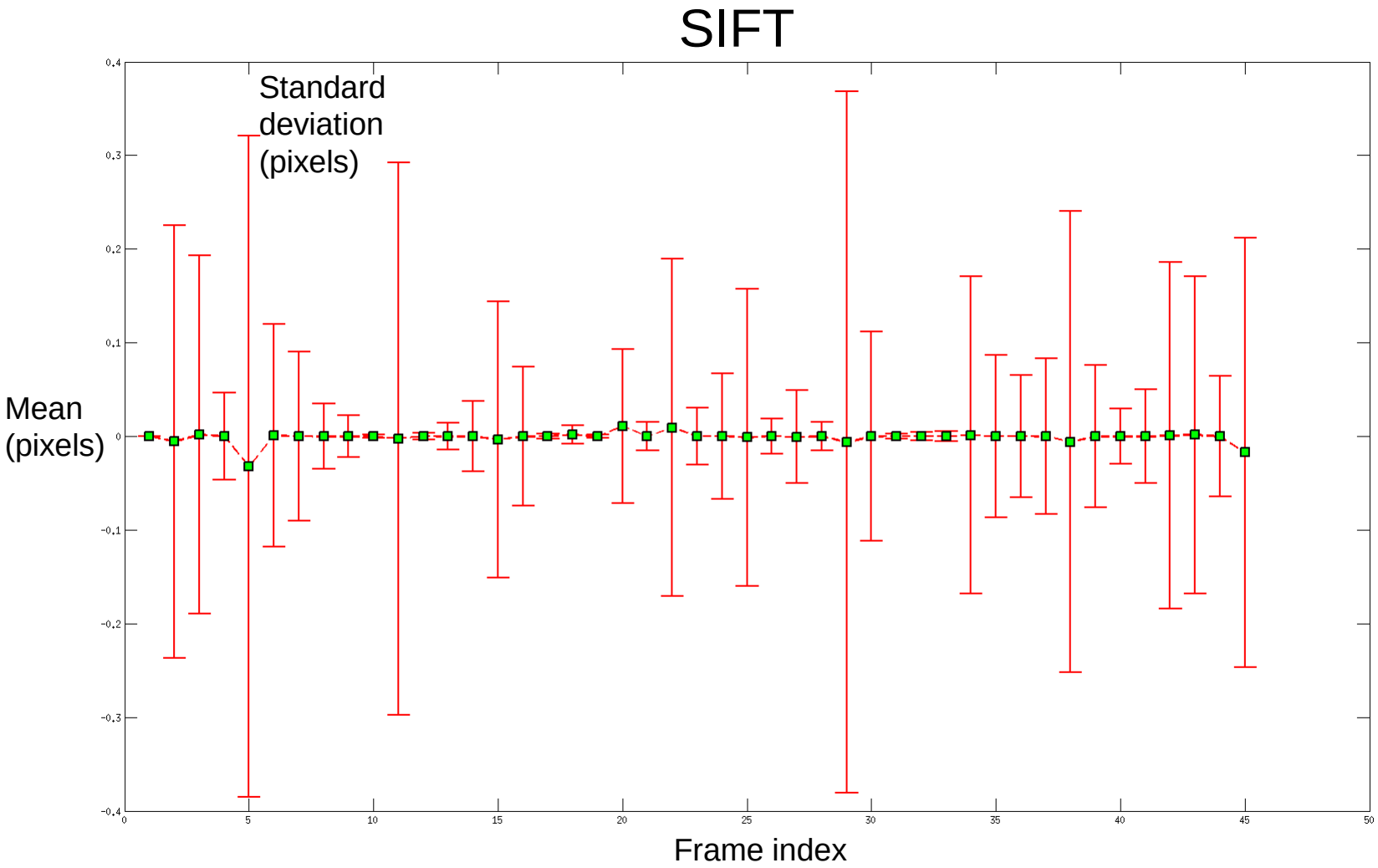


Number of matched features in one frame

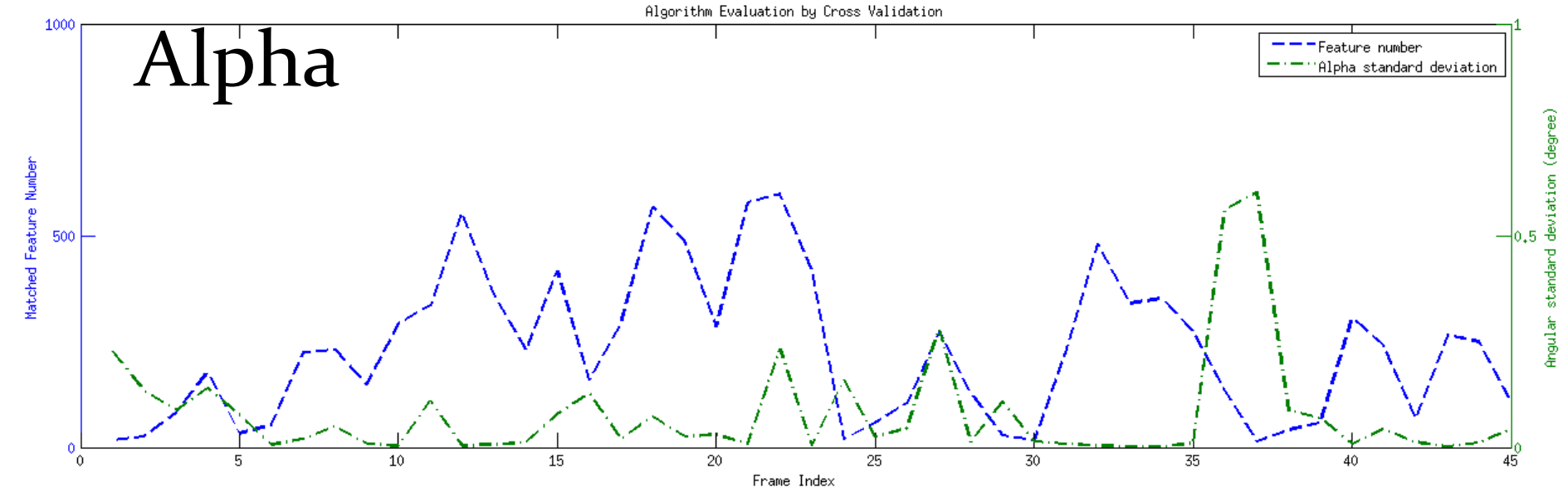
Analysis of rotation angles: Alpha (1/5)



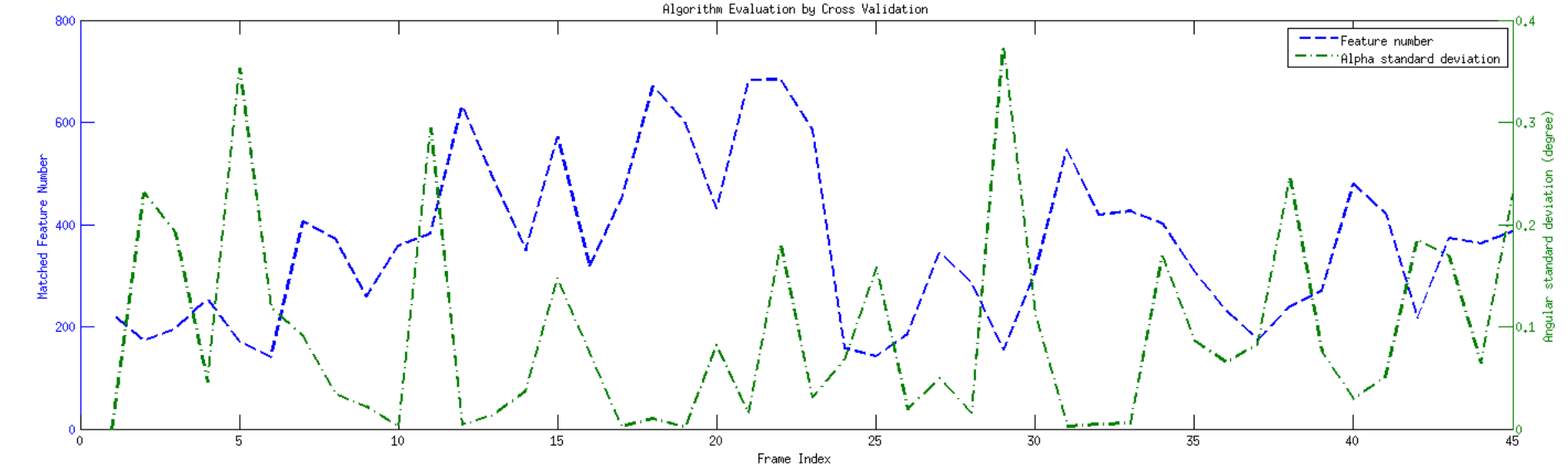
Analysis of rotation angles: Alpha (2/5)



HMA


Algorithm Evaluation by Cross Validation
Alpha
Feature number
Alpha standard deviation
Matched Feature Number
Angular standard deviation (degree)
Frame Index
0
500
1000
0.5
1
0
5
10
15
20
25
30
35
40
45

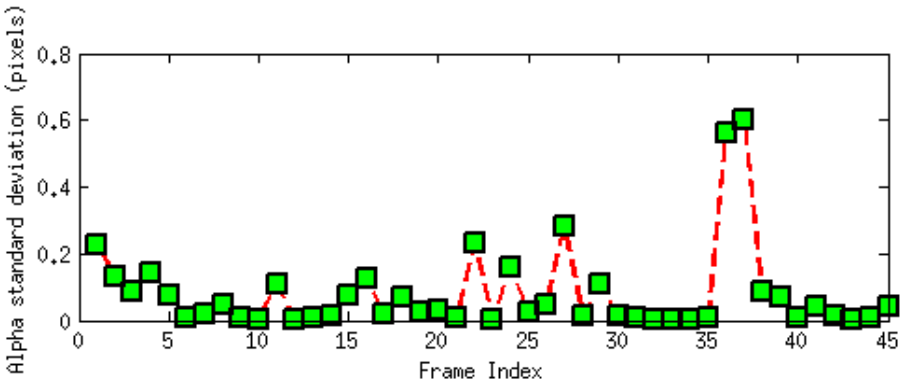
SIFT

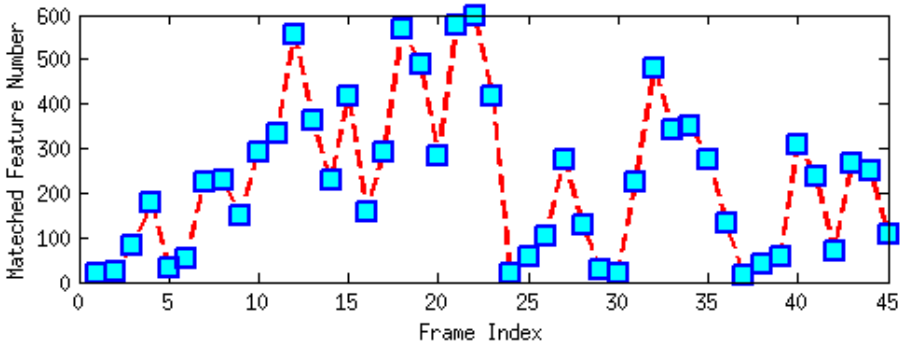

Algorithm Evaluation by Cross Validation
Feature number
Alpha standard deviation
Matched Feature Number
Angular standard deviation (degree)
Frame Index
0
200
400
600
800
0.1
0.2
0.3
0.4
0
5
10
15
20
25
30
35
40
45

Analysis of rotation angles: Alpha (4/5)

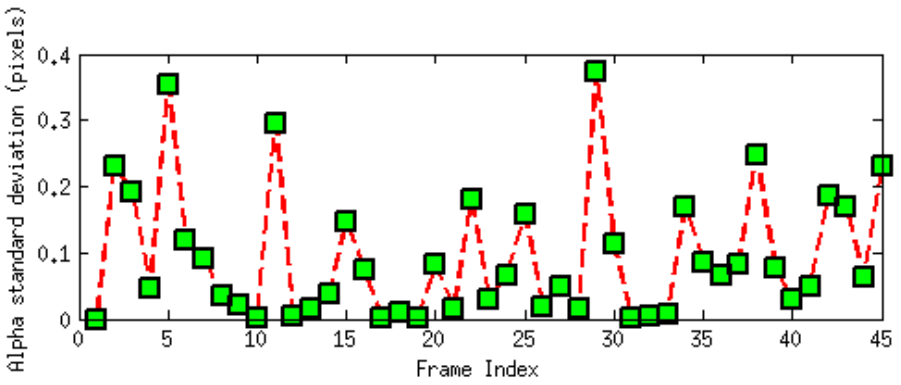
Alpha standard deviation with feature number

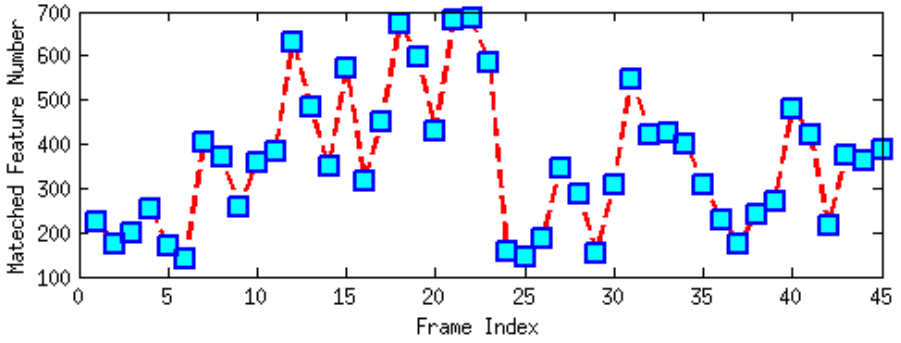
HMA





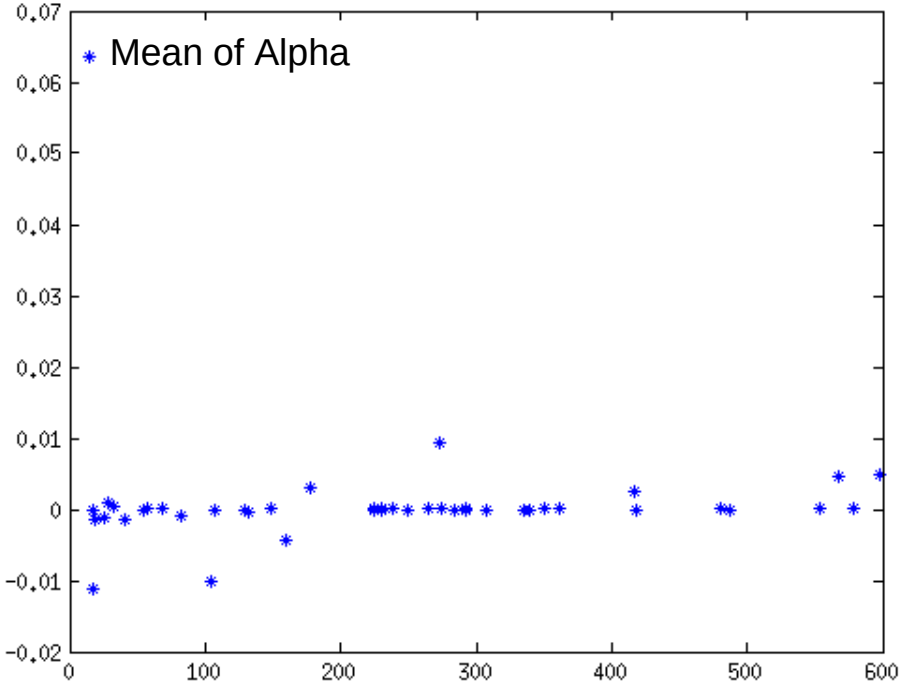
SIFT





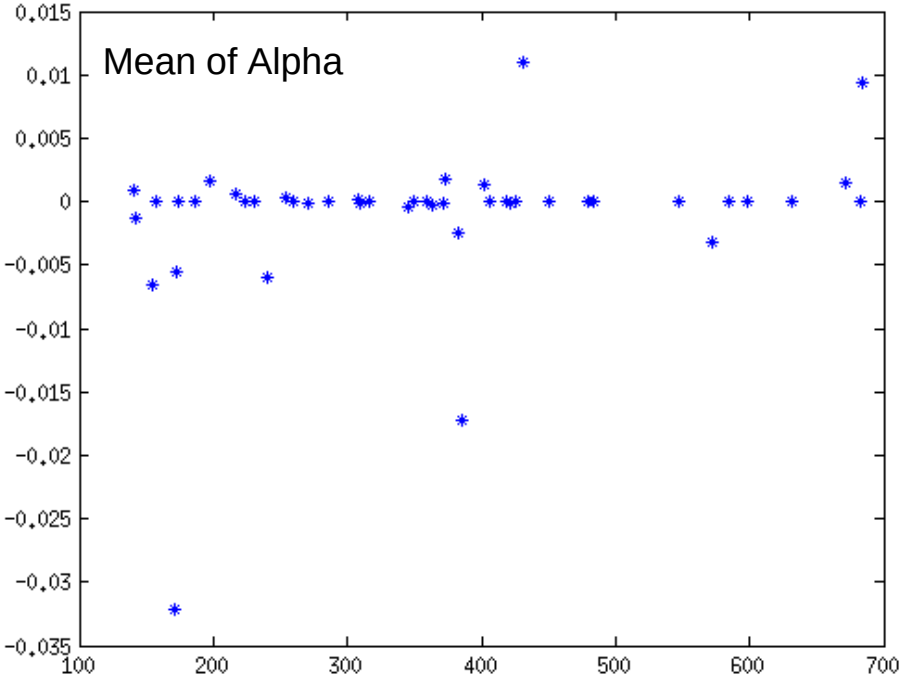
Analysis of rotation angles: Alpha (5/5)

HMA



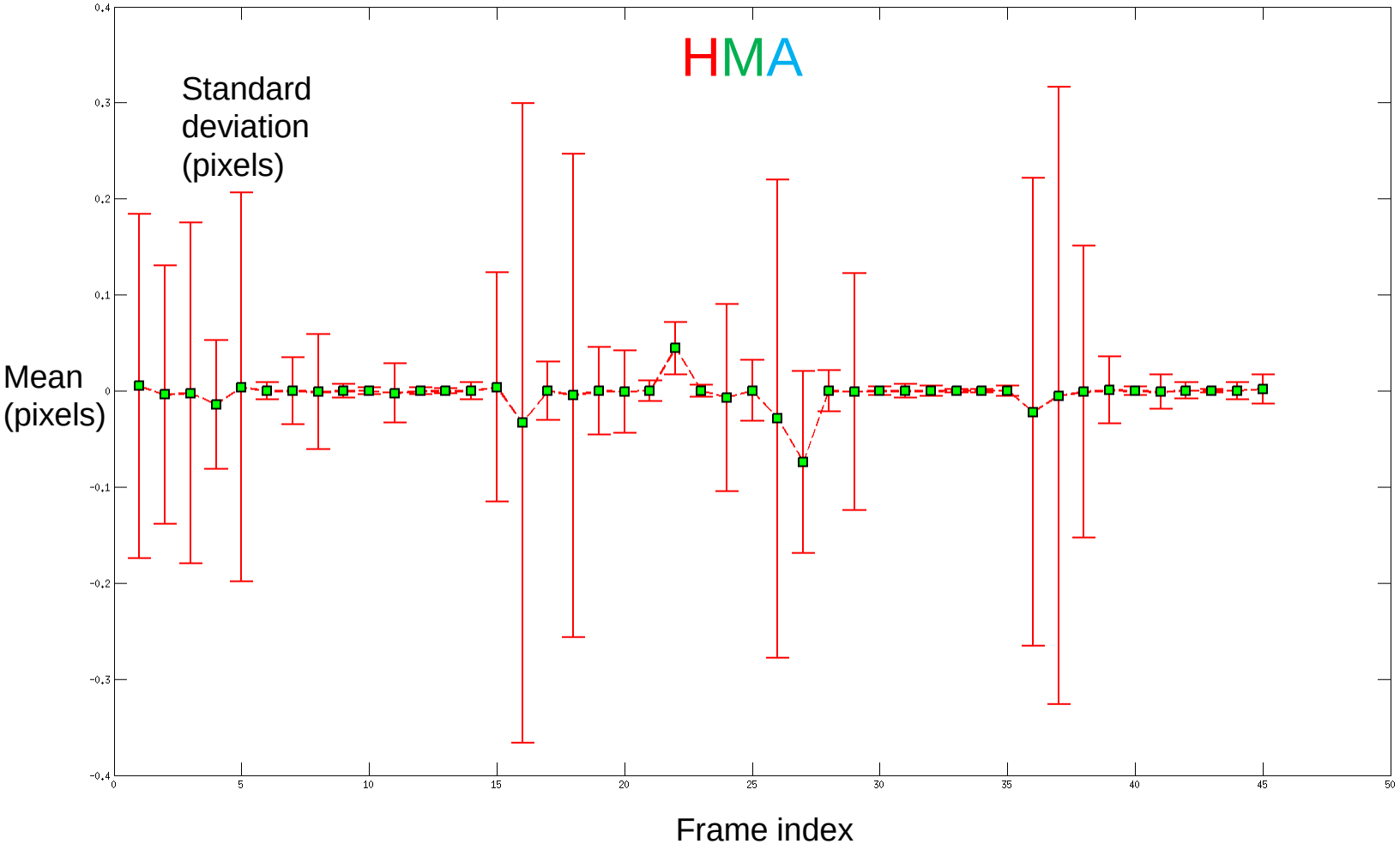
Matched feature number in one frame

SIFT

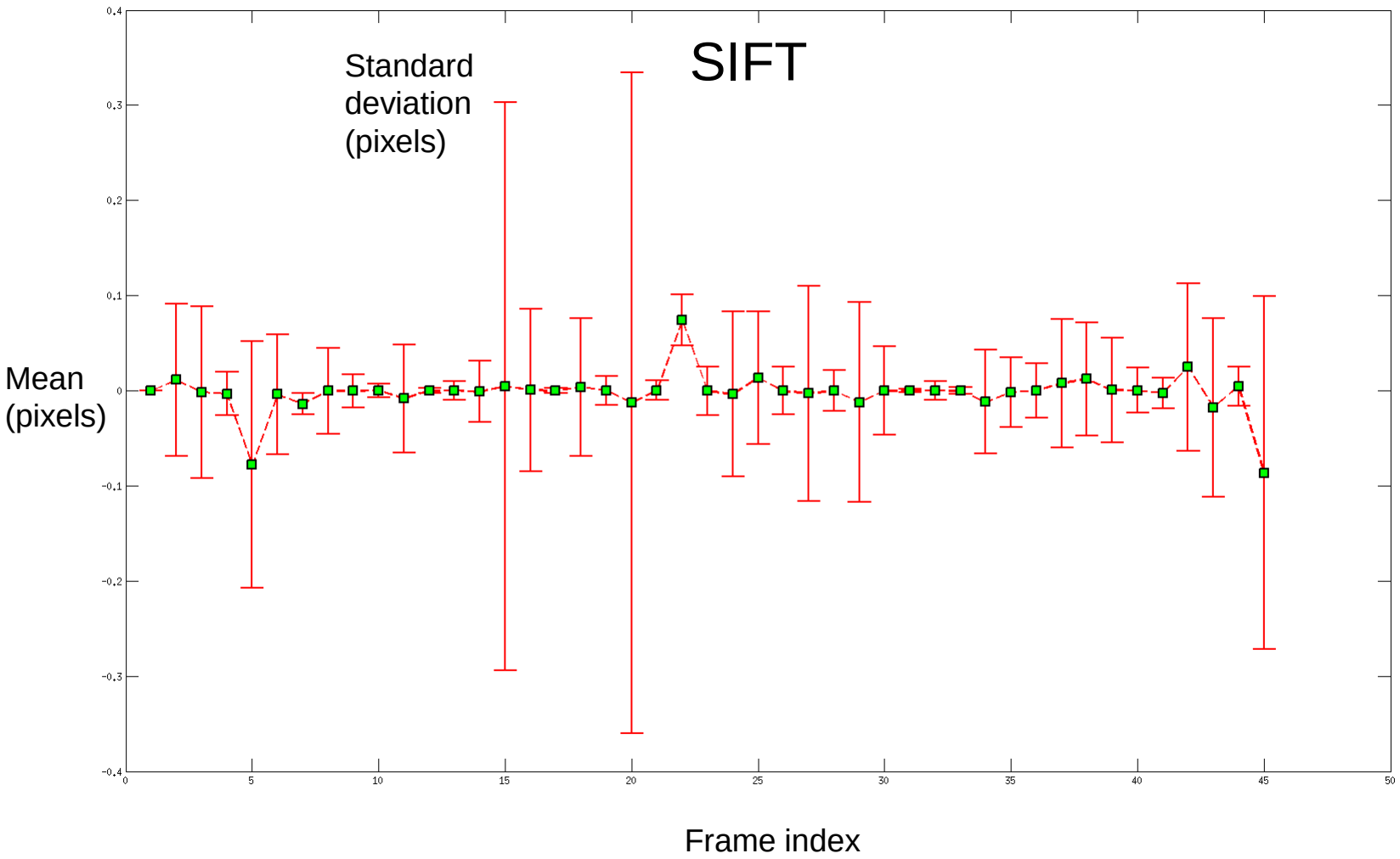


Matched feature number in one frame

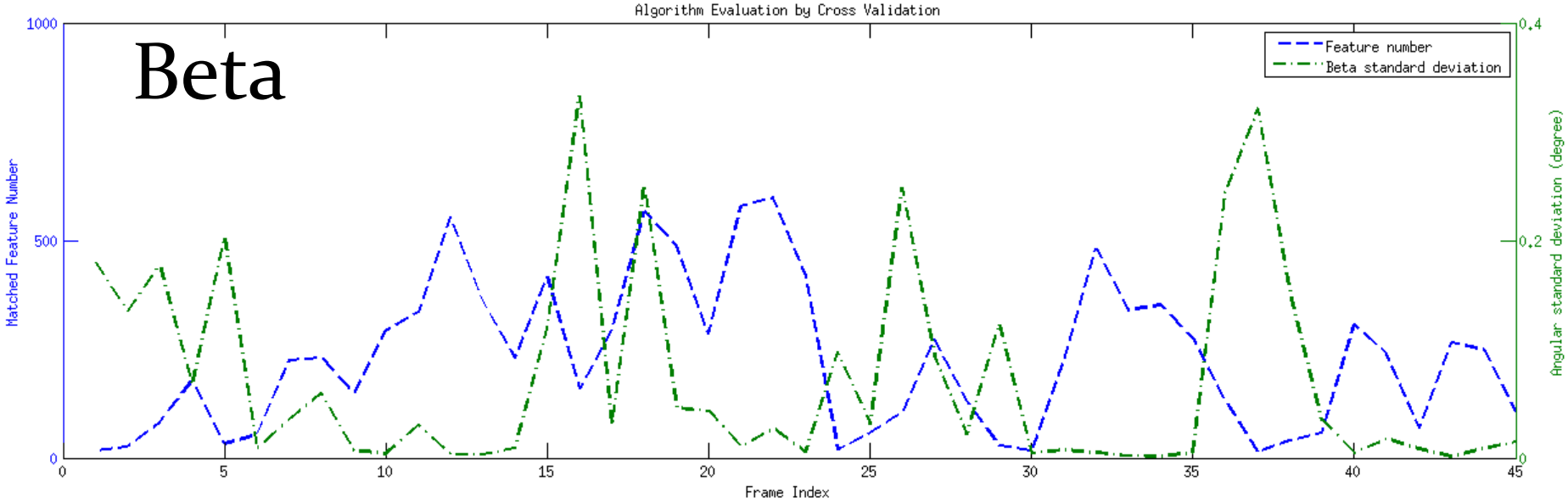
Analysis of rotation angles: Beta (1/5)



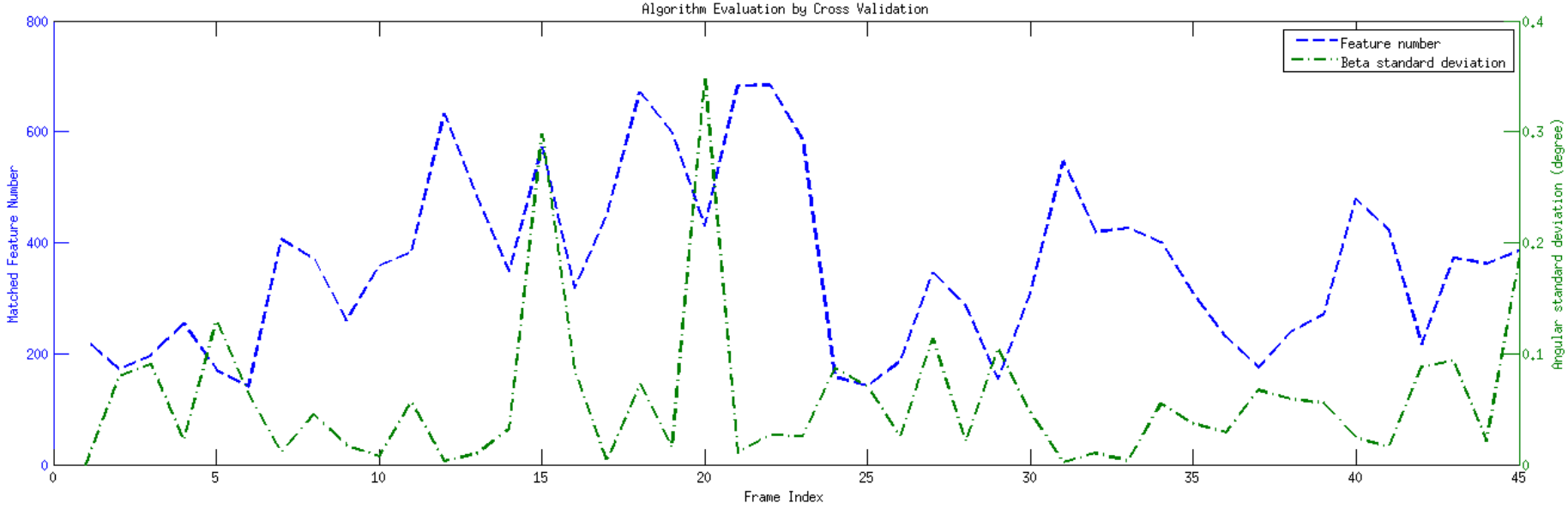
Analysis of rotation angles: Beta (2/5)



HMA


Algorithm Evaluation by Cross Validation
Beta
Feature number
Beta standard deviation
Matched Feature Number
Angular standard deviation (degree)
Frame Index
0
500
1000
0.2
0.4
0
5
10
15
20
25
30
35
40
45

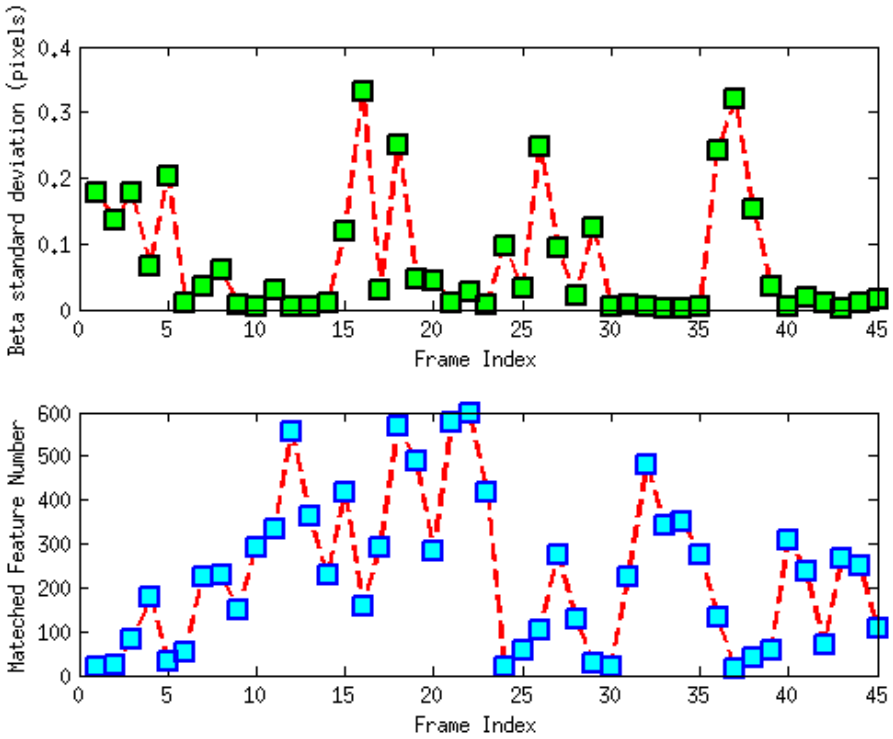
SIFT


Algorithm Evaluation by Cross Validation
Feature number
Beta standard deviation
Matched Feature Number
Angular standard deviation (degree)
Frame Index
0
200
400
600
800
0.1
0.2
0.3
0.4
0
5
10
15
20
25
30
35
40
45

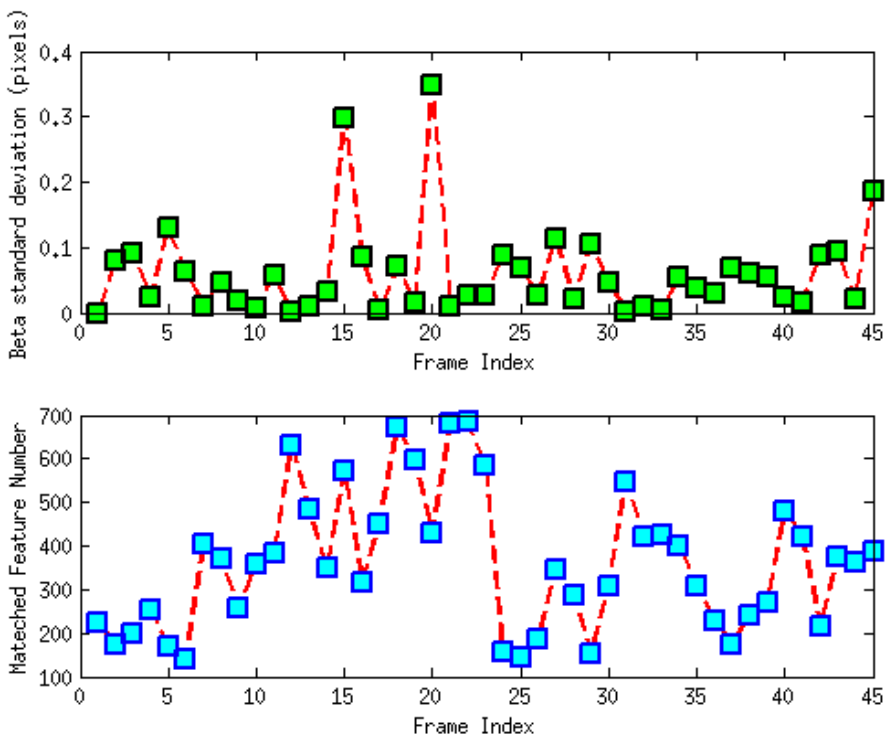
Analysis of rotation angles: Beta (4/5)

Beta standard deviation with feature number

HMA

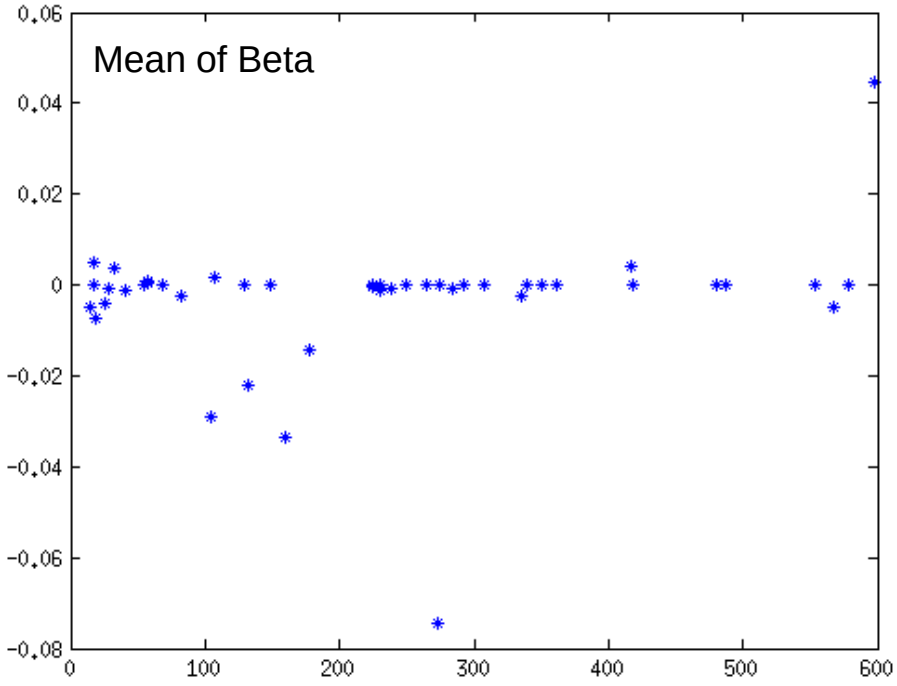


SIFT



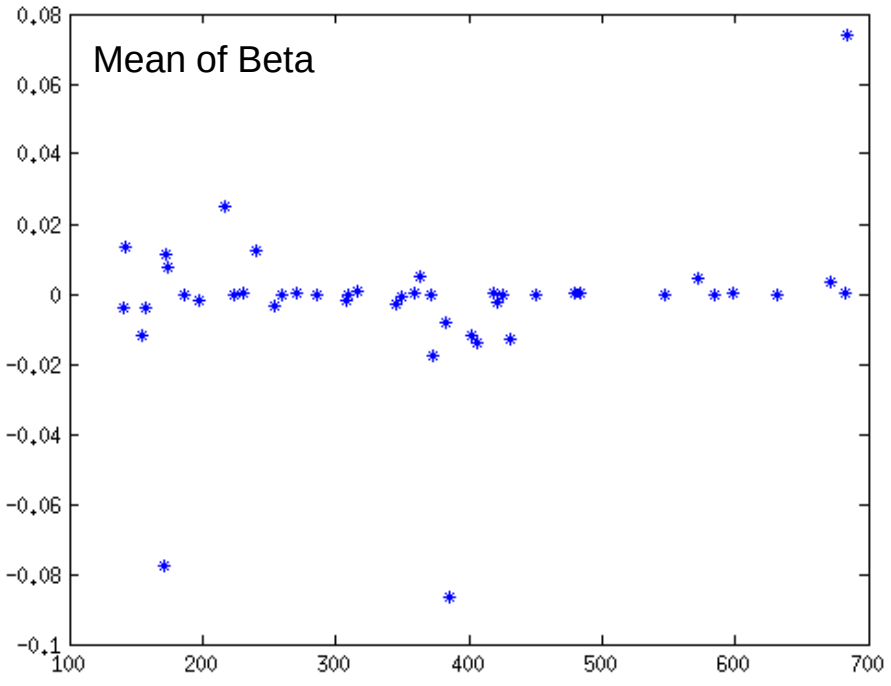
Analysis of rotation angles: Beta (5/5)

HMA



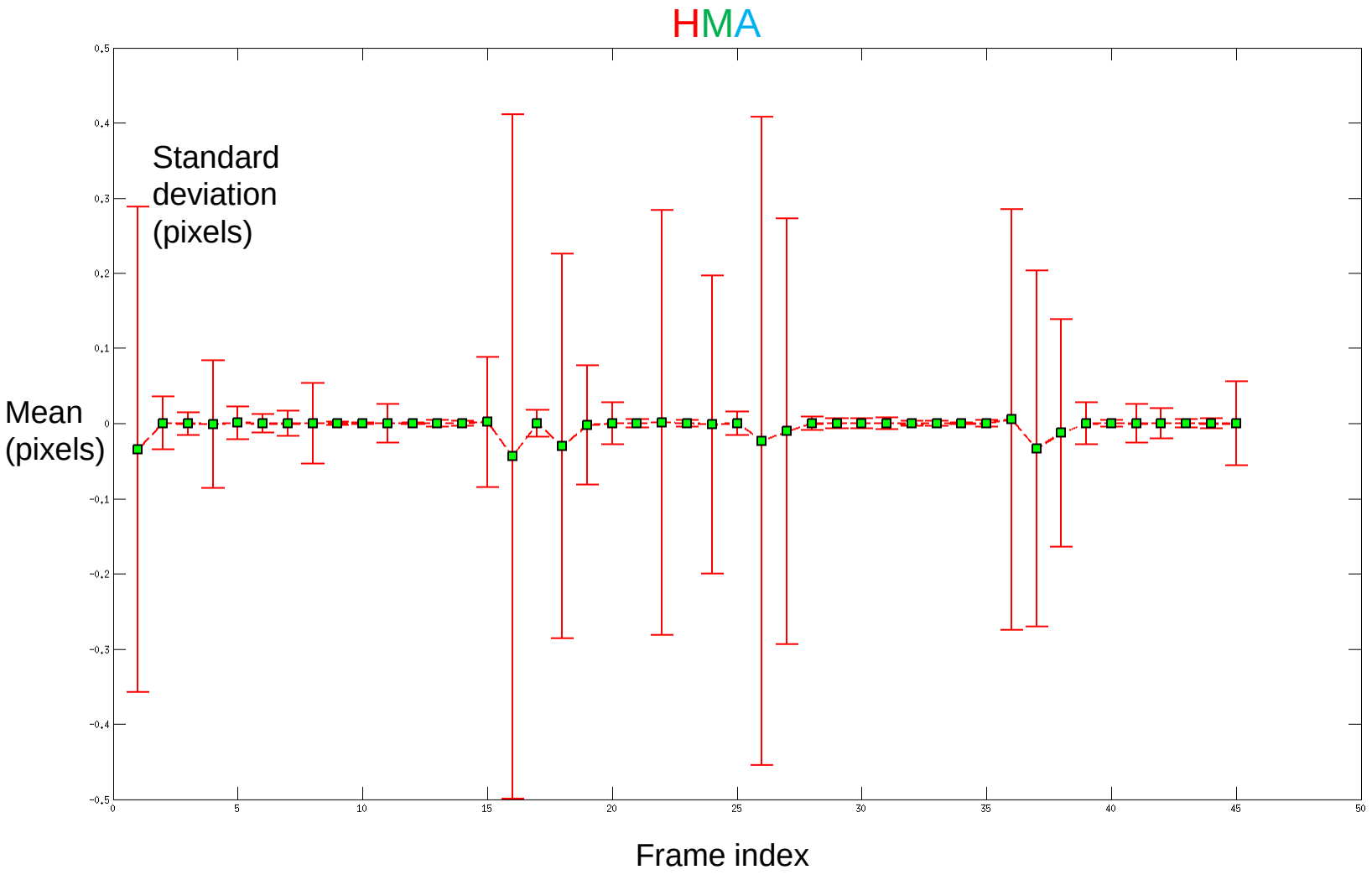
Matched feature number in one frame

SIFT

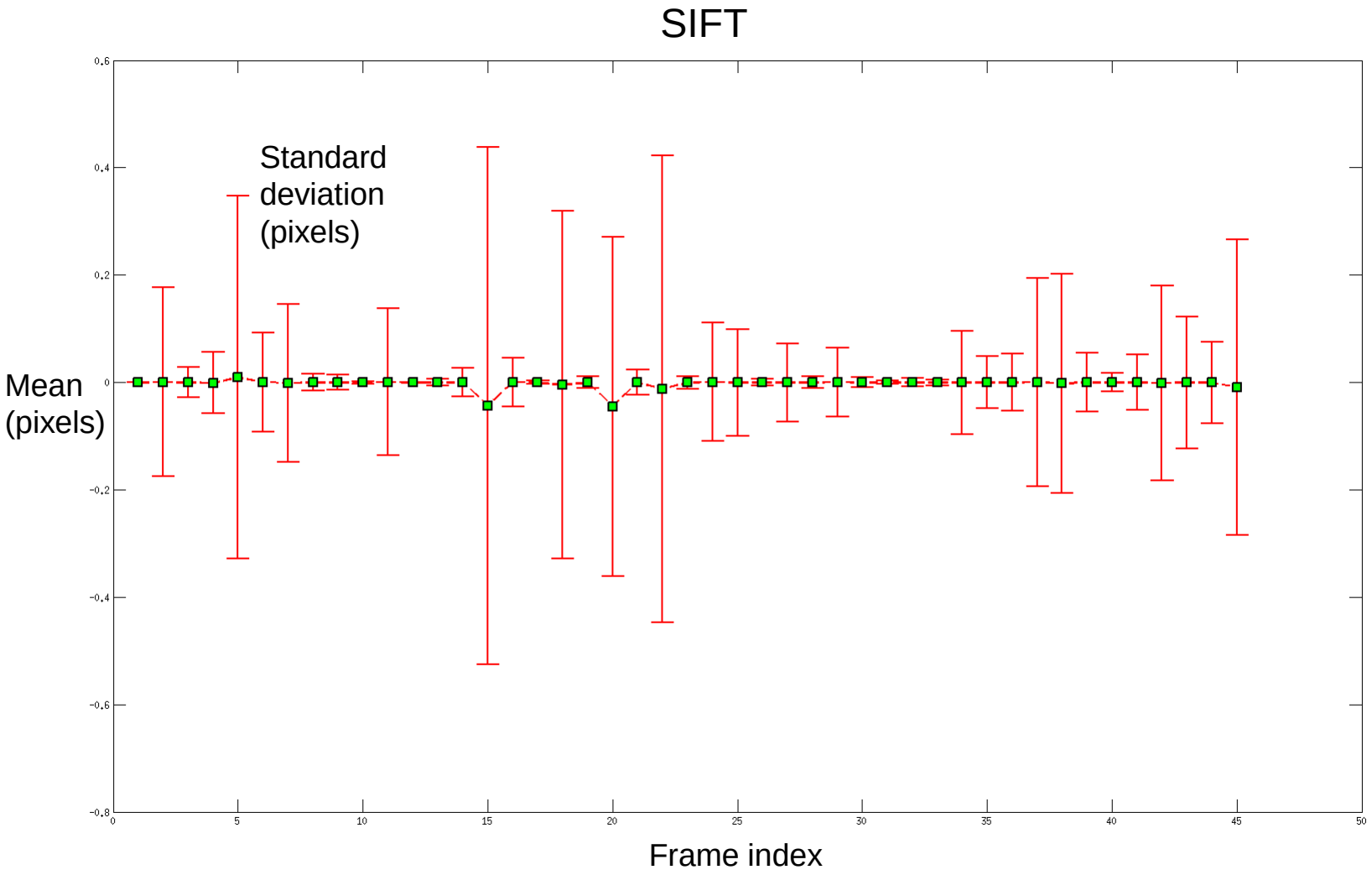


Matched feature number in one frame

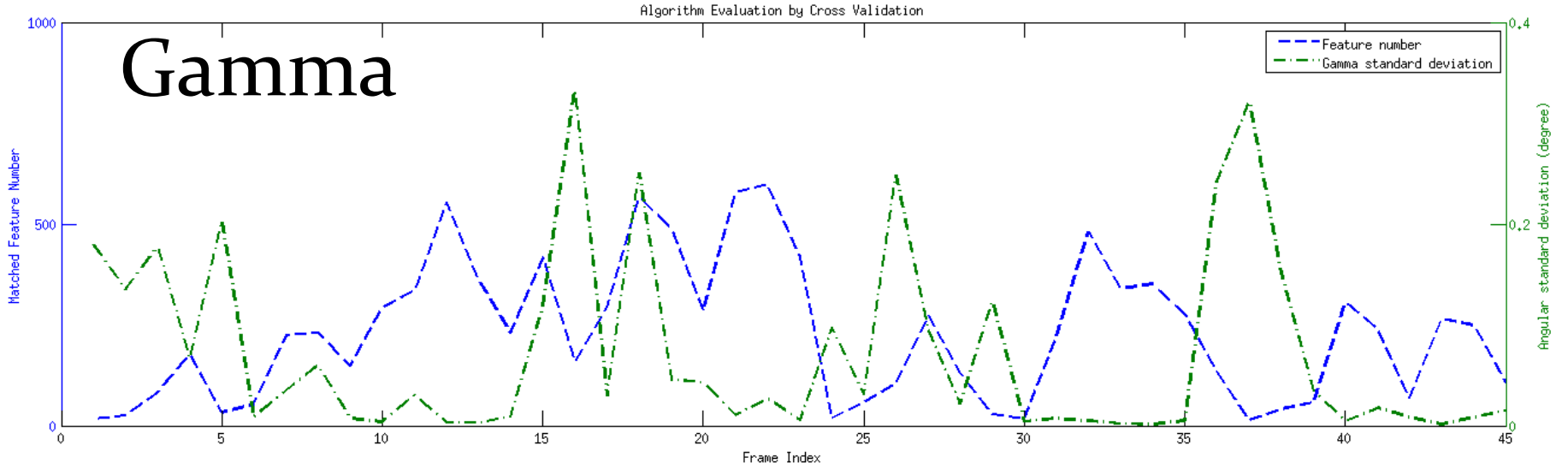
Analysis of rotation angles: Gamma (1/5)



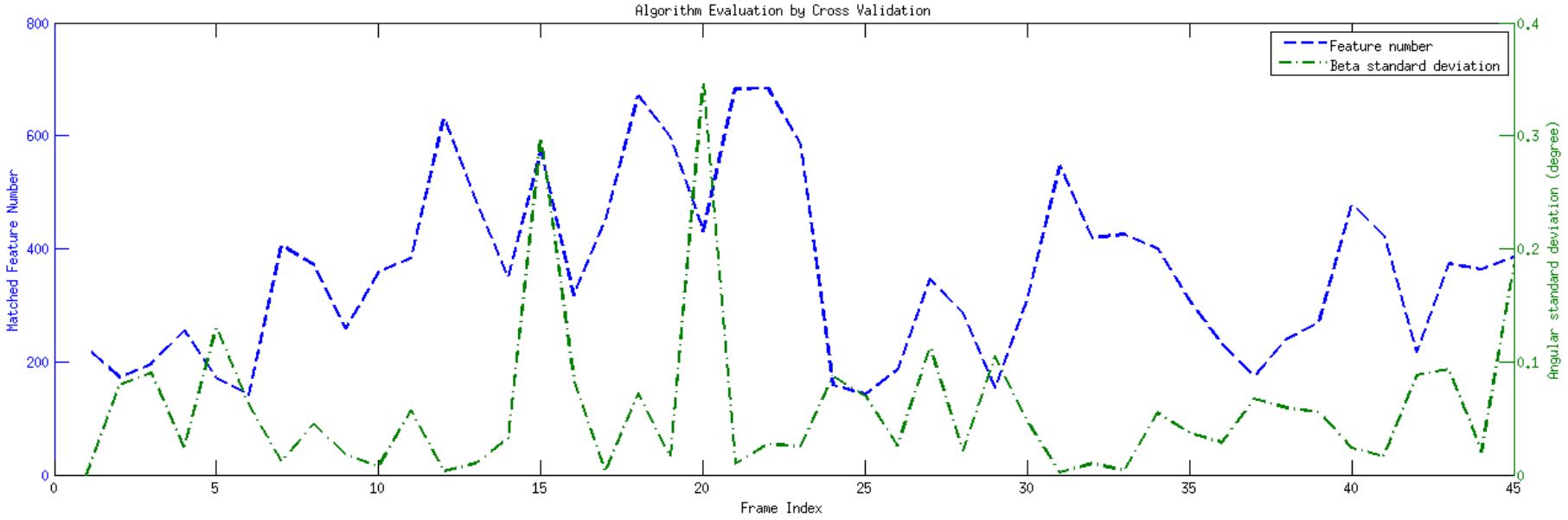
Analysis of rotation angles: Gamma (2/5)



HMA


Algorithm Evaluation by Cross Validation
Gamma
Feature number
Gamma standard deviation
Matched Feature Number
Angular standard deviation (degree)
Frame Index
0
500
1000
0
0.2
0.4
0
5
10
15
20
25
30
35
40
45

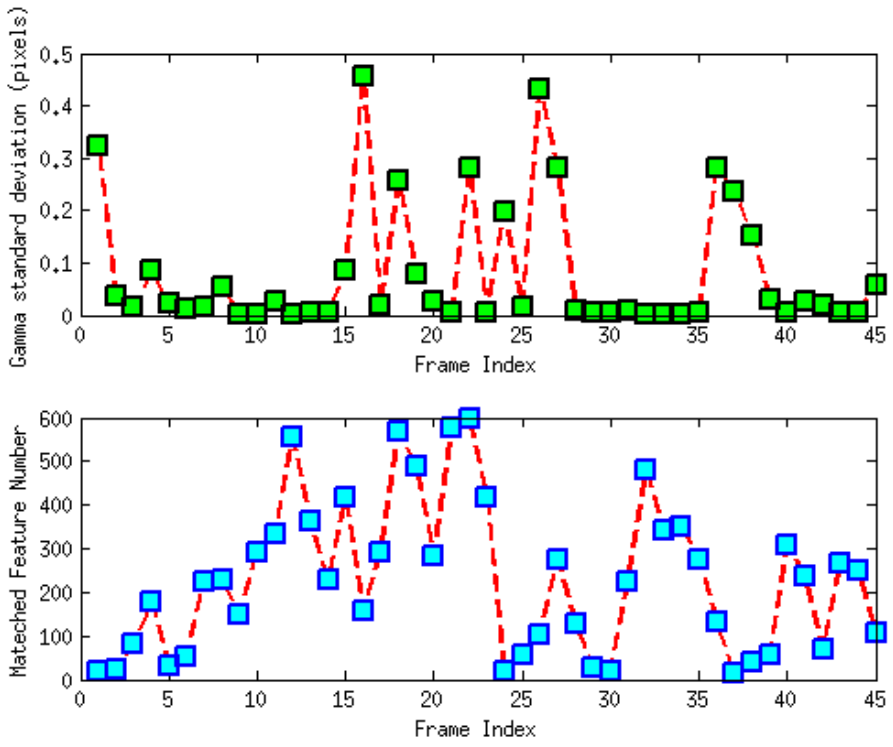
SIFT


Algorithm Evaluation by Cross Validation
Feature number
Beta standard deviation
Matched Feature Number
Angular standard deviation (degree)
Frame Index
0
200
400
600
800
0
0.1
0.2
0.3
0.4
0
5
10
15
20
25
30
35
40
45

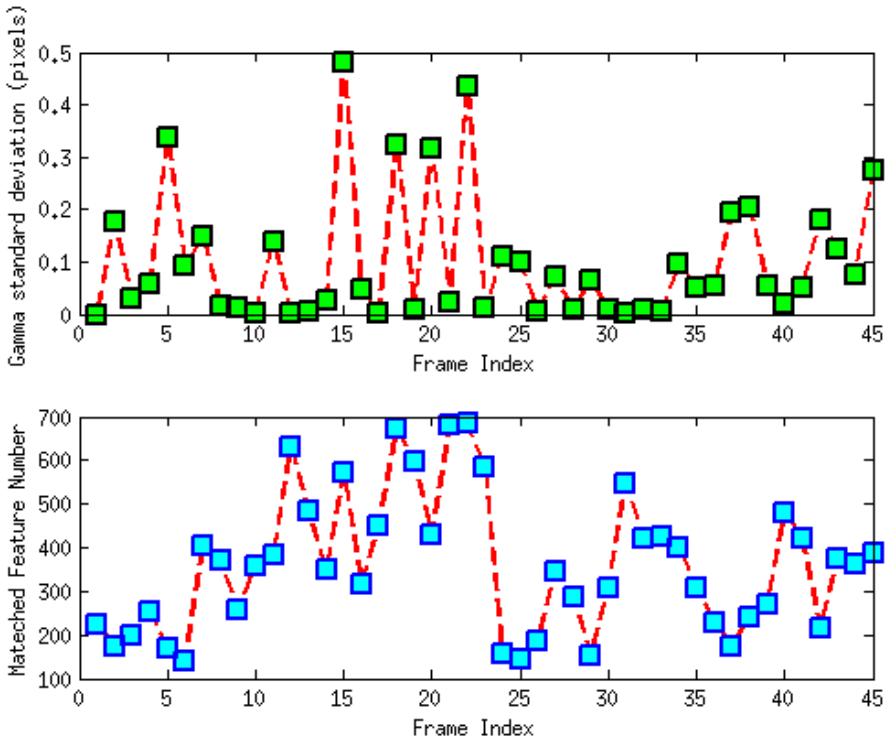
Analysis of rotation angles: Gamma (4/5)

Gamma standard deviation with feature number

HMA

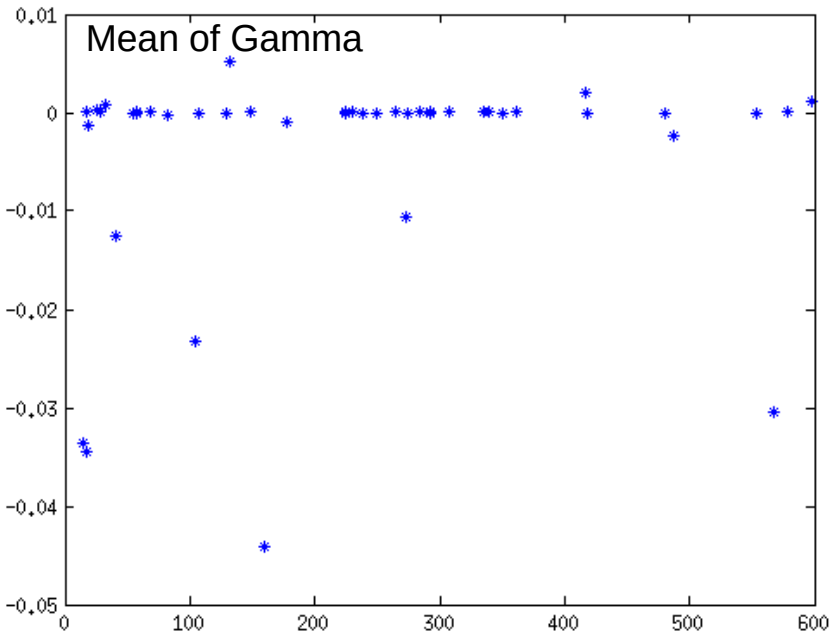


SIFT



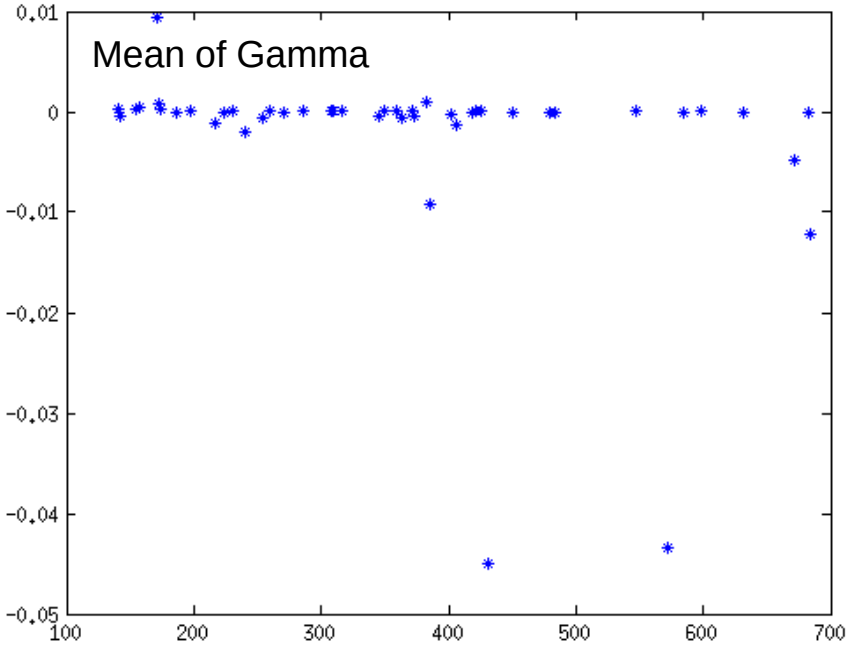
Analysis of rotation angles: Gamma (5/5)

HMA



Matched feature number in one frame

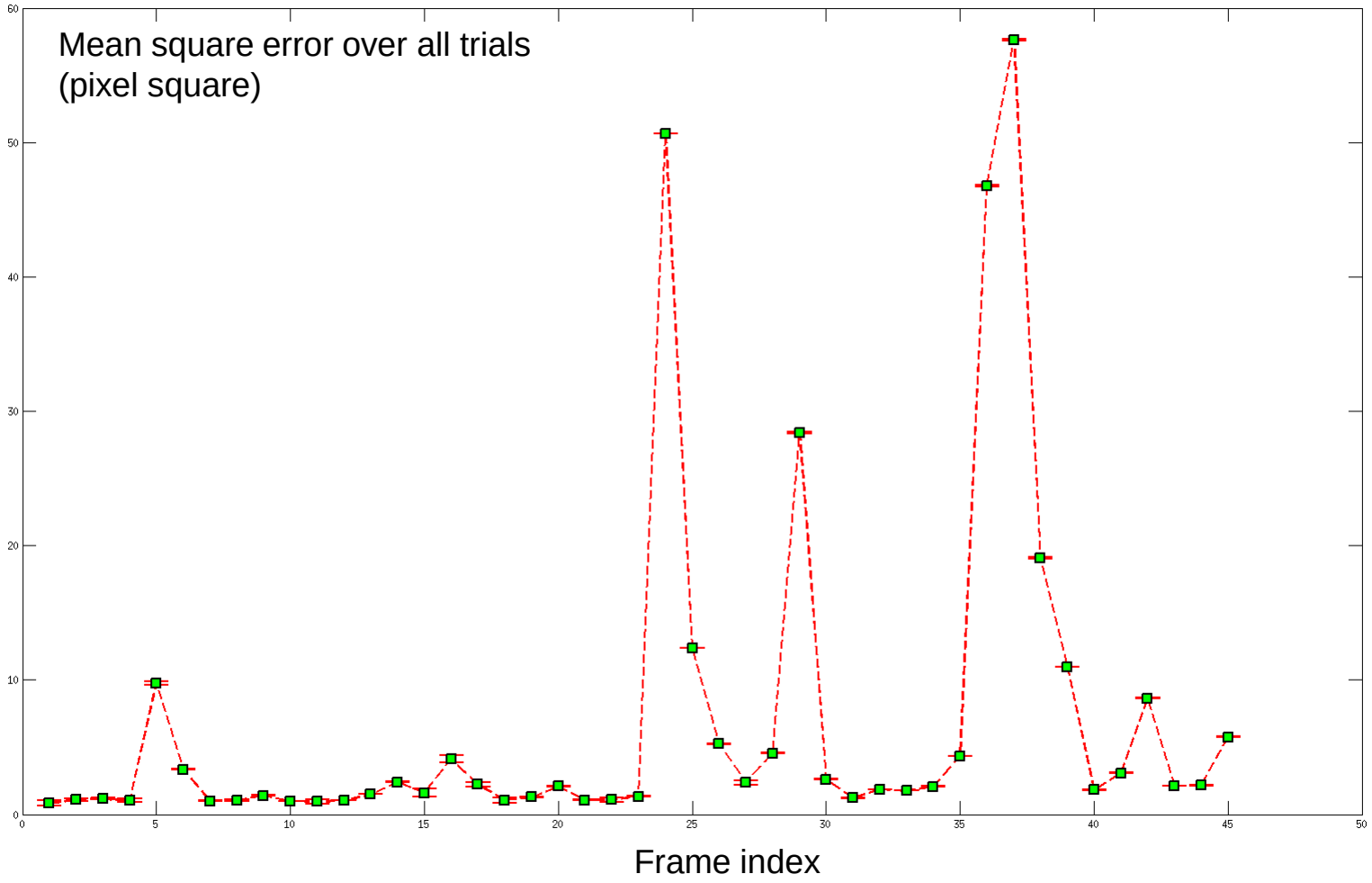
SIFT



Matched feature number in one frame

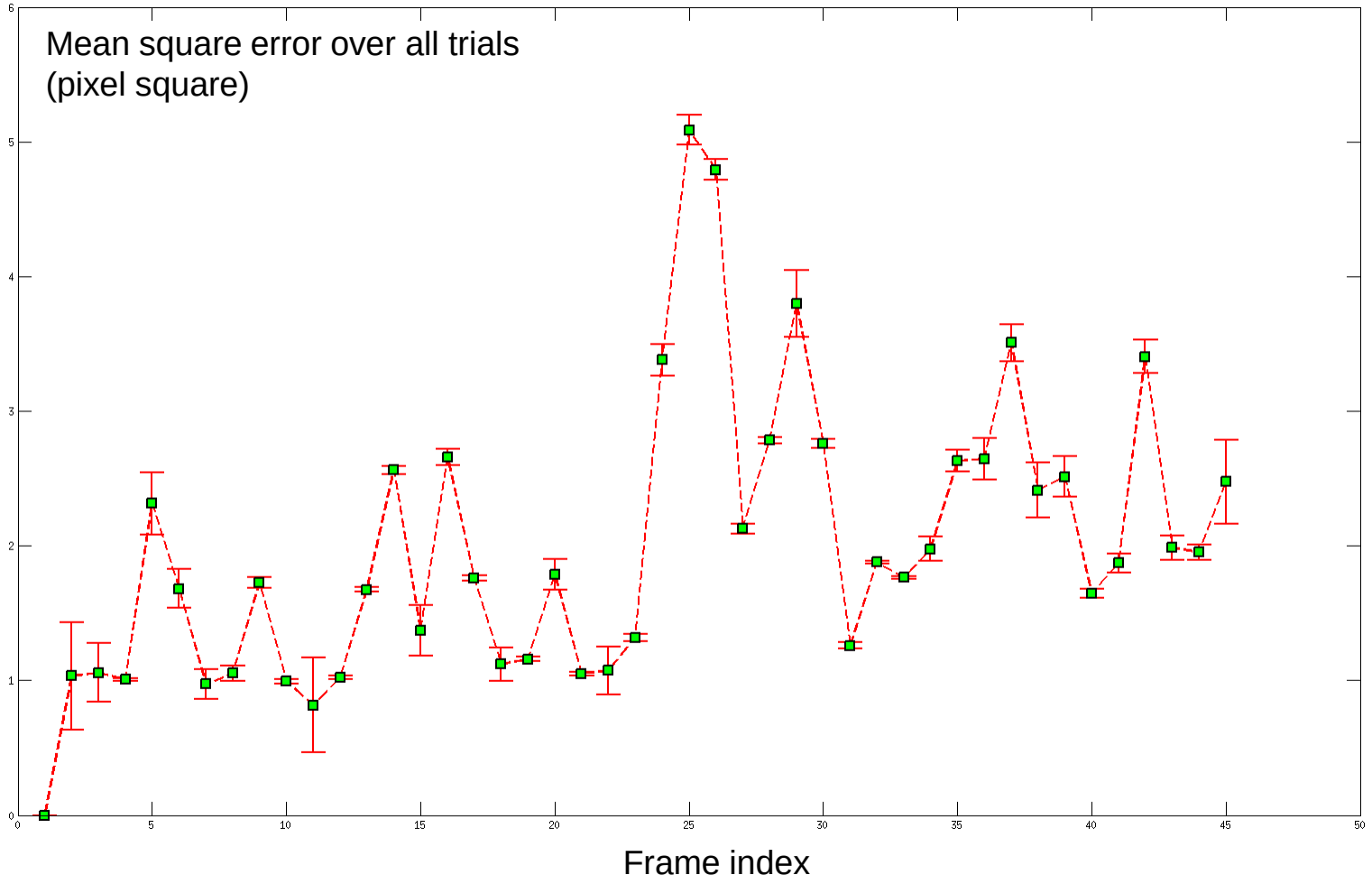
Projection error of the hold-out testing point

HMA

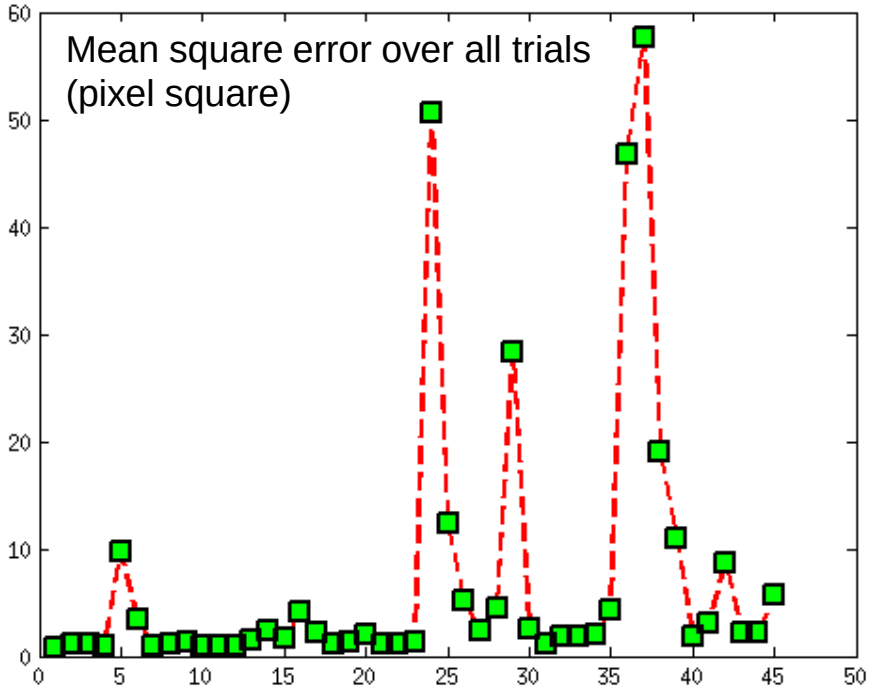


Projection error of the hold-out testing point

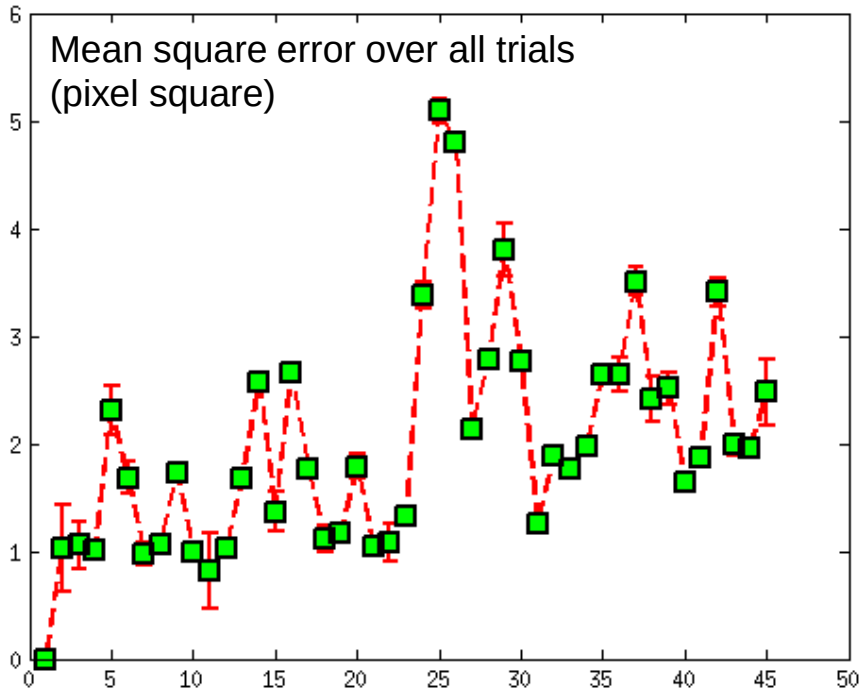
SIFT



HMA


Mean square error over all trials
(pixel square)
Frame index

SIFT


Mean square error over all trials
(pixel square)
Frame index

Deliverables

- **Minimum:** (Expected by 7th April - 14th April)
  1. Matlab program for robust feature matching by HMA algorithm.
  2. Feature matching validation experiments, analysis and documentation.
  3. C++ Program for motion estimation by RANSAC and 5 point algorithm.
  4. Motion estimation validation experiments, analysis and documentation.
  5. Empirical quantitative comparison of HMA and SIFT algorithms.
- **Expected:** (Expected by 21st April - 28th April)
  1. C++ program for image registration by Trimmed ICP algorithm.
- **Maximum:** (Expected by 9th May)
  1. Video-CT registration validation experiments, analysis and documentation.

Milestones

1. Milestone 1: Program for robust feature matching by HMA algorithm.
   - Planned Date: 28th February
   - Expected Date: 7nd March
   - Status: Done
2. Milestone 2: Program for motion estimation by RANSAC and 5 point algorithm.
   - Planned Date: 14th March
   - Expected Date: 14th March
   - Status: Done
3. Milestone 3: Empirical quantitaive comparison of HAM and SIFT algorithms
   - Planned Date: 2nd May
   - Expected Date: 9th May
   - Status: Done
4. Milestone 4: Program for video-CT registration by Trimmed ICP algorithm
   - Planned Date: 9th May
   - Expected Date: 12nd May
   - Status: pending

Dependency

- Sample CT data: still not available.

Reference

- D. Mirota, H. Wang, R. H. Taylor, M. Ishii, G. L. Gallia and G. D. Hager. A System for Video-Based Navigation for Endoscopic Endonasal Skull Base Surgery. IEEE Trans. Med. Imaging, 31(4), 963-976, 2012.
- G. Puerto, M. Adibi, J. Cadeddu1 and G. L. Mariottini, Adaptive Multi-Affine (AMA) Feature-Matching Algorithm and its Application to Minimally-Invasive Surgery Images. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 2371 - 2376, Sept. 25-30, San Francisco, California, 2011.
- G. A. Puerto-Souza and G. L. Mariottini. Hierarchical Multi-Affine (HMA) algorithm for fast and accurate feature matching in minimally-invasive surgical images. 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems October 7-12, 2012. Vilamoura, Algarve, Portugal.

Thank you! Comments!