Assignment2

April 29, 2022

1 Computer Vision 2022 Assignment 2: Image matching and retrieval

In this assignment, you will experiment with image feature detectors, descriptors and matching. There are 3 main parts to the assignment:

- matching an object in a pair of images
- searching for an object in a collection of images
- analysis and discussion of results

This assignment will have a minimum hurdle of 40%. You will fail if you can not reach the minimum hurdle.

1.1 General instructions

As before, you will use this notebook to run your code and display your results and analysis. Again we will mark a PDF conversion of your notebook, referring to your code if necessary, so you should ensure your code output is formatted neatly.

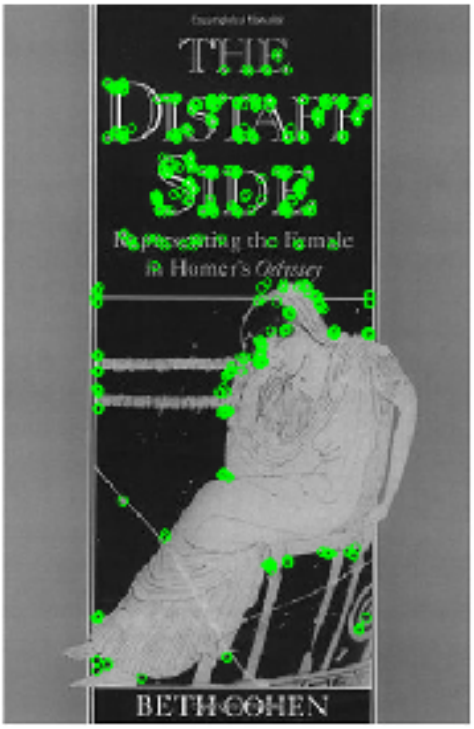
When converting to PDF, include the outputs and analysis only, not your code. You can do this from the command line using the `nbconvert` command (installed as part of Jupyter) as follows:

```
jupyter nbconvert Assignment2.ipynb --to pdf --no-input --TagRemovePreprocessor.remove_cell_tag
# Or
jupyter nbconvert Assignment2.ipynb --TagRemovePreprocessor.remove_cell_tags='{"remove_cell"}'
```

2 Matching an object in a pair of images (45%)

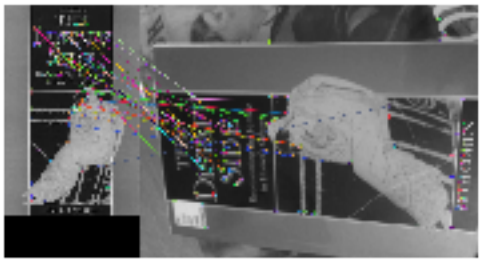
2.0.1 draw key points and macthes by using orb method

keypoints of reference image (orb)

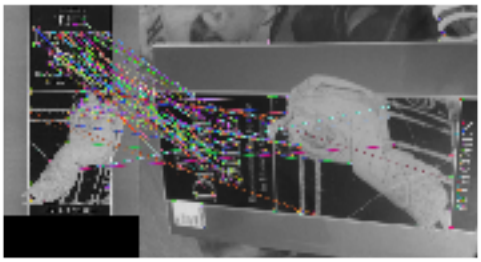


keypoints of query image (orb)

Match descriptors (ratio: 0.6)



Match descriptors (ratio: 0.8)

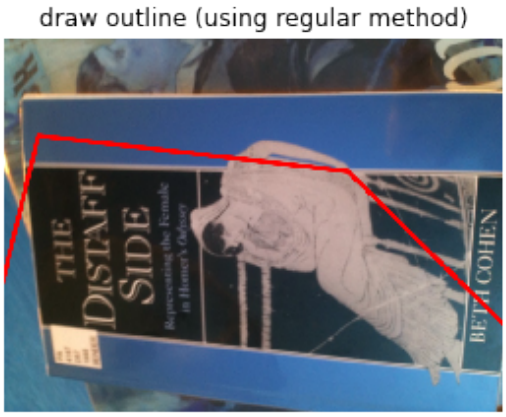


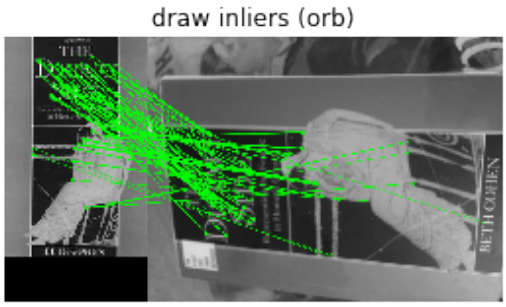
Change the ratio

By compare the ration 0.6 and the rtatio 0.8, we can get:

- when the ratio become small, the keypoints and match numbers become less.
- when the ratio become large, the keypoints and match numbers become more.

2.0.2 draw outline and inliers by using regular method



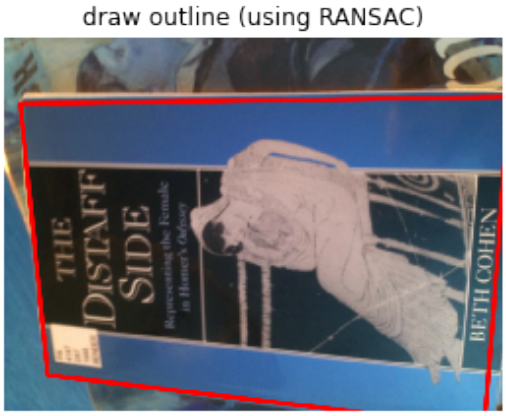


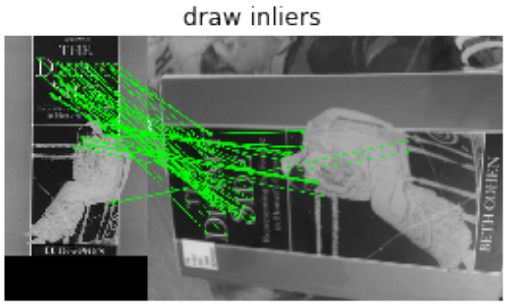

```
number of detected inliers:  131
number of detected outliers:  0.0
```

Summary

When I try to use regular method, I notice draw oulines does not work correctly.

2.0.3 Draw outline and inliers by using RANSAC






```
number of detected inliers:  100
number of detected outliers:  31.0
```

Summary

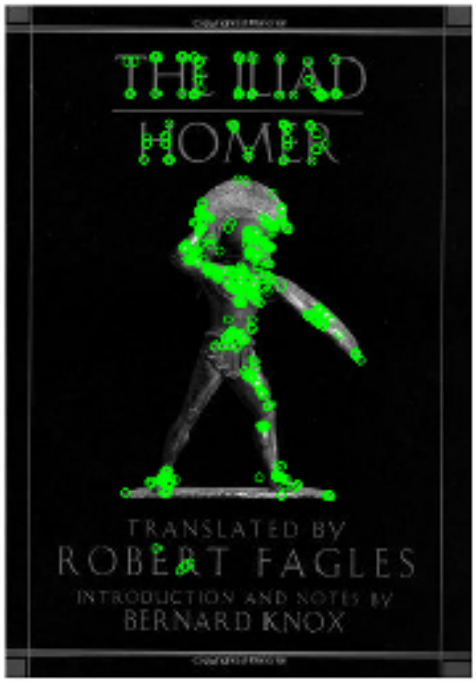
Compare to the RANSAC and the regular method, I notice the number of dectected inliers is different. The ***total number of detected points are 131***, and when I use ***RANSAC*** method, the number of detected inliers are ***only 100***, however, when I use ***regular method***, the number

of detected inliers are ***131***. There is ***a difference of 31 points***. However, it may influence when draw outlines because these 31 points should not be caculated in the inliers.

2.1 Book cover (example book_cover_025)

2.1.1 draw keypoints of reference image and query image (using orb, brisk and sift)

keypoints of reference image (orb)



keypoints of query image (orb)

keypoints of reference image (brisk)

keypoints of query image (brisk)

keypoints of reference image (sift)

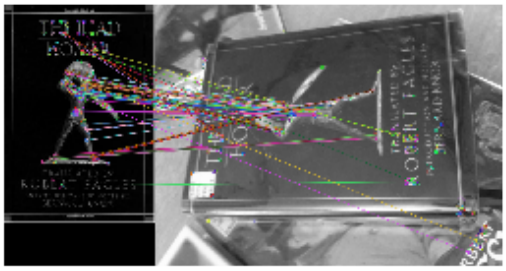
keypoints of query image (sift)

2.1.2 summary of finding key ponits part

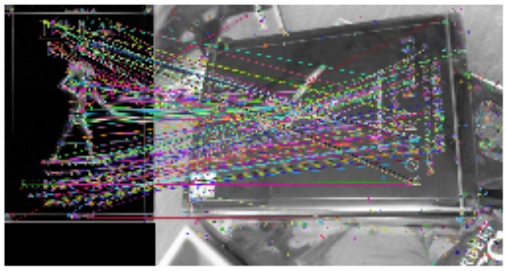
In **getting keypoints**, the shift and brisk are working better than orb, it returns more key points in the query image and the reference image.

2.1.3 Draw match part (using orb and sift)

matches (orb)



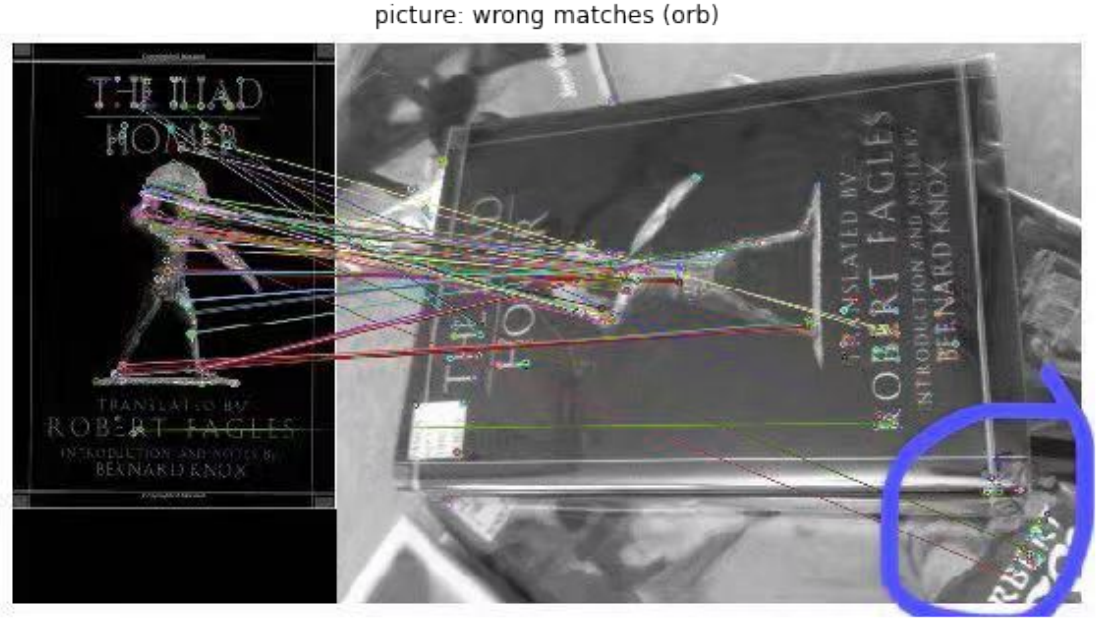
matches (sift)



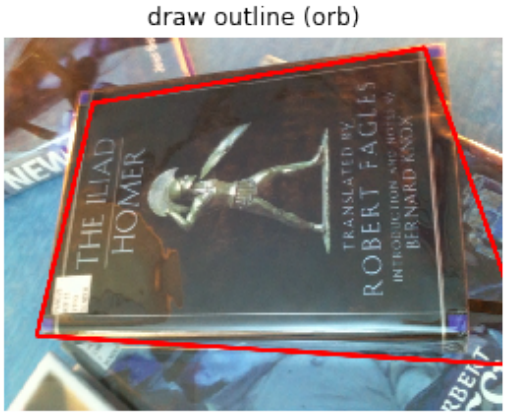
2.1.4 Summary of drawing match part

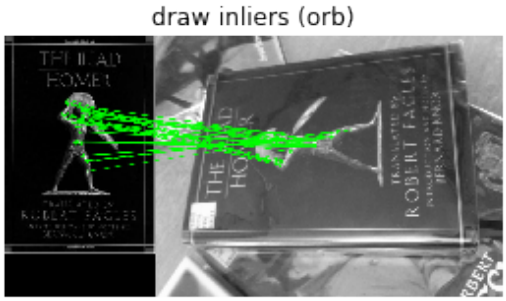
In this part, I notice some macthes in ***orb method*** matches the keypoints ***outside the reference book***, which are ***wrong matches***. (shown in the picture: wrong matches)

picture: wrong matches (orb)



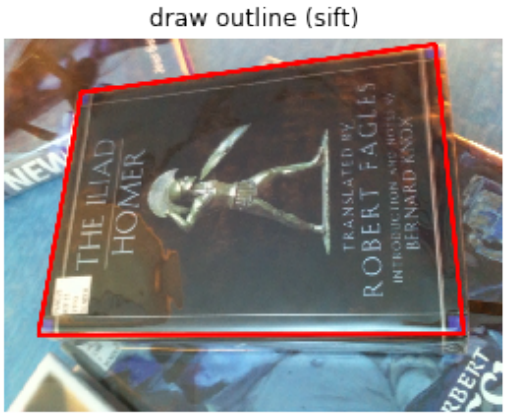
2.1.5 Draw outlines and inliers (using orb)

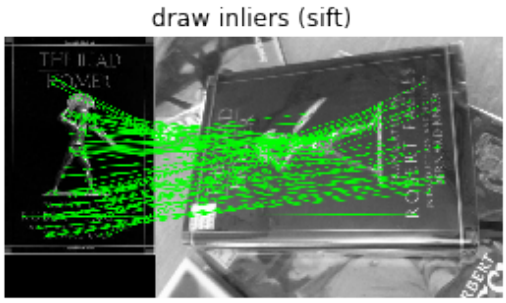





```
number of detected inliers:  57
number of detected outliers:  36.0
Ratio:  0.6129032258064516
```

2.1.6 Draw outlines and inliers (using sift)






```
number of detected inliers:  106
number of detected outliers:  70.0
Ratio:  0.6022727272727273
```

2.1.7 Summary

In image 25 from book_covers. we can see when we use orb method to get the outline, it is not very precise, however, sift method works good.

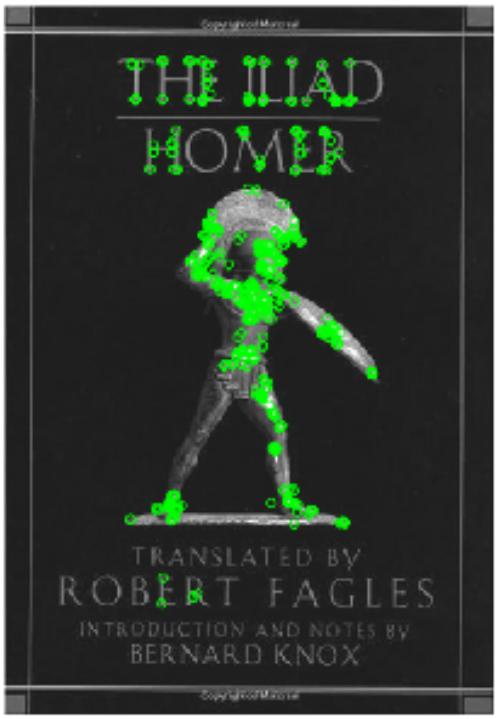
Reason (why orb method will fail): when I use orb method, the keypoints of query image do not detect many keypoints in this area (draw in the picture_01), the key points which are detected

are focus on the person (middle in the book cover). So when do matches, some keypoints which outside the book cover may interfere with drawing outlines, this is why we can not get the correct area when we draw outlines.

2.1.8 Little improvement

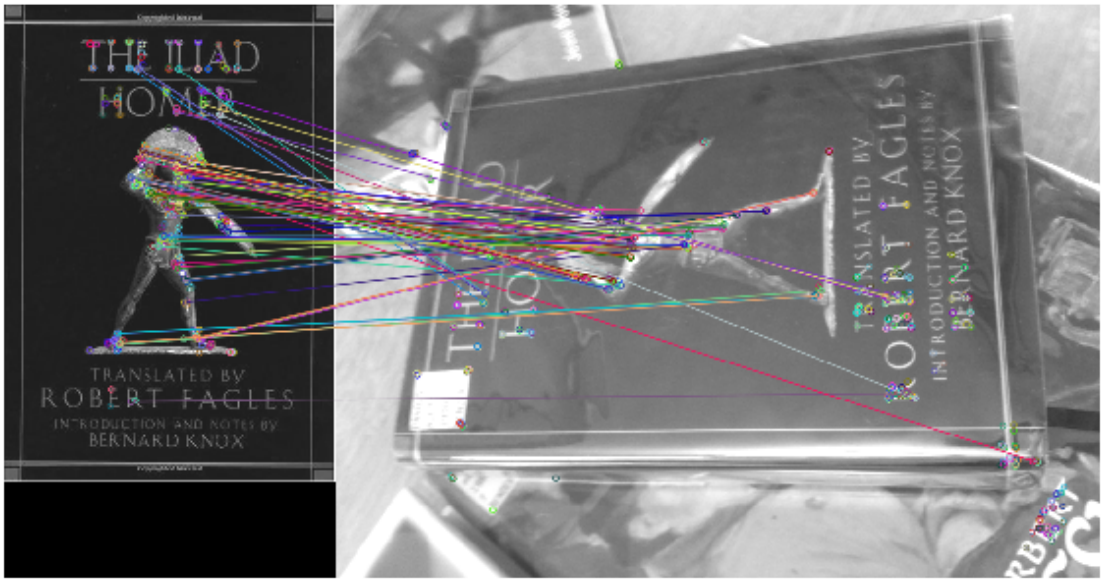
However, changing the brightness of the image can solve this problem (wrong outline with orb).

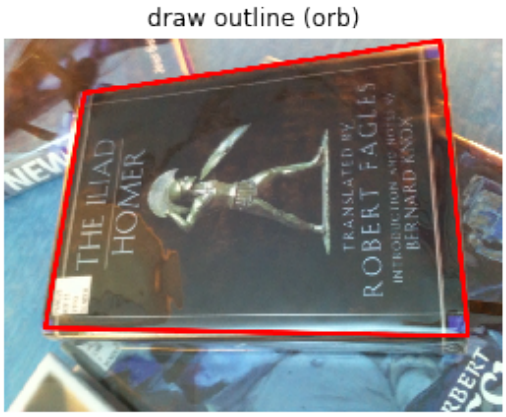
keypoints of reference image (orb)

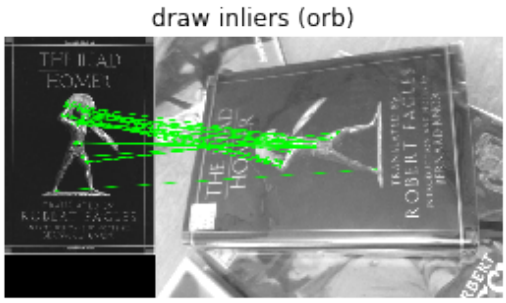


keypoints of query image (orb)

matches (orb)





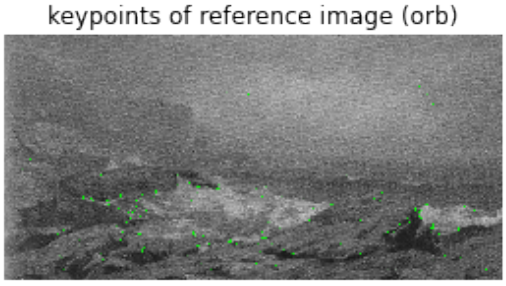


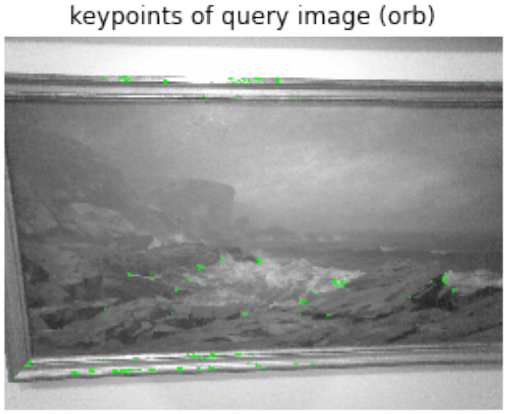

```
number of detected inliers:  52
number of detected outliers:  34.0
Ratio:  0.6046511627906976
```

We can see that when we change the brightness **(using cv2.add(image, 30) and set the value to 30)**, it makes orb method be more accurate and get a correct outline.

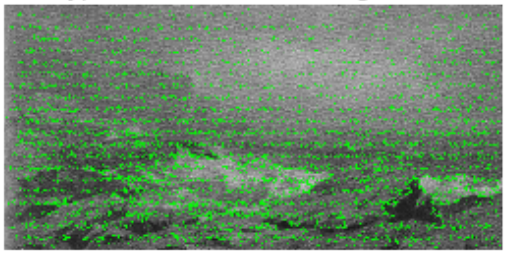
2.2 museum paintings (example museum_paintings_064)

2.2.1 draw keypoints of reference image and query image (using orb, brisk and sift)



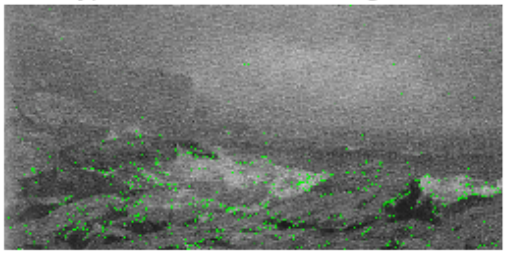


keypoints of reference image (brisk)



keypoints of query image (brisk)

keypoints of reference image (sift)



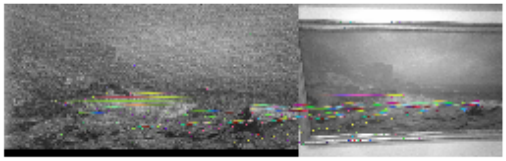
keypoints of query image (sift)

2.2.2 summary of finding key ponits part

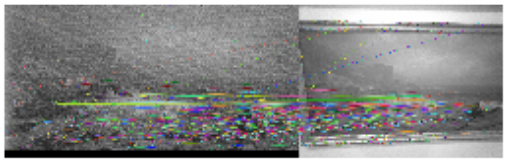
In **getting keypoints**, the shift and brisk are working better than orb, it returns more key points in the query image and the reference image.

2.2.3 Draw match part (using orb and sift)

matches (orb)



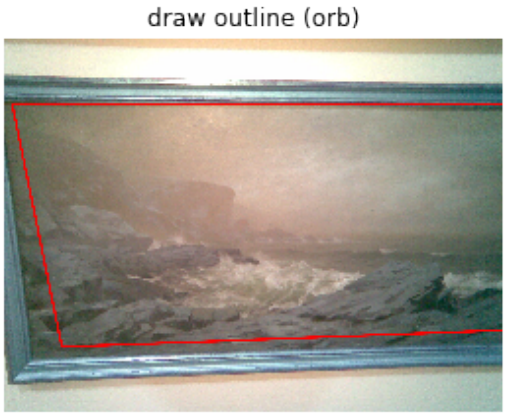
matches (sift)

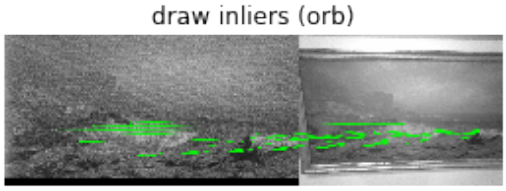


2.2.4 Summary of drawing match part

In this part, two pictures are draw all mactches correctly. However, sift makes more matches than the orb.

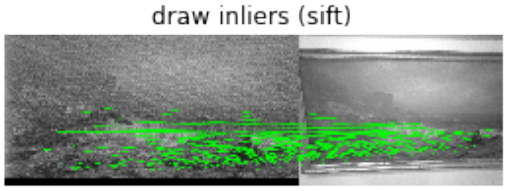
2.2.5 Draw outlines and inliers (using orb)






```
number of detected inliers:  52
number of detected outliers:  9.0
Ratio:  0.8524590163934426
```

2.2.6 Draw outlines and inliers (using sift)




```
number of detected inliers:  142
number of detected outliers:  48.0
Ratio:  0.7473684210526316
```

2.2.7 Summary

Ratio = number of inlier/number of matches

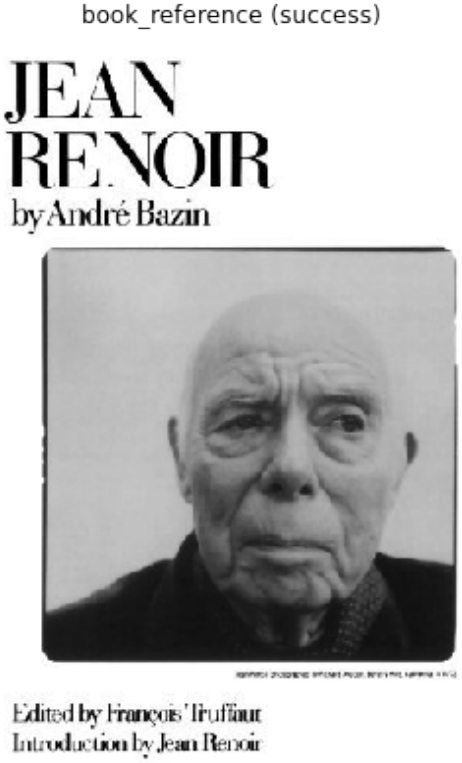
I compare the ratio of two method (orb and sift), when the ratio become smaller (should bigger than 0), the ouline will become more acurrate. By compare ***picture draw outline (orb)*** and ***picture draw outline (sift)***, we can see the **picture draw outline (sift)** works better. By the way, the ratio is 0.747 (sift method) which is smaller than 0.852 (orb method).

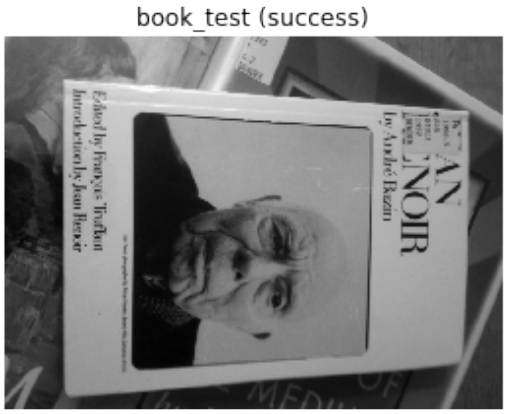
---

3 What am I looking at? (40%)

3.1 Using orb

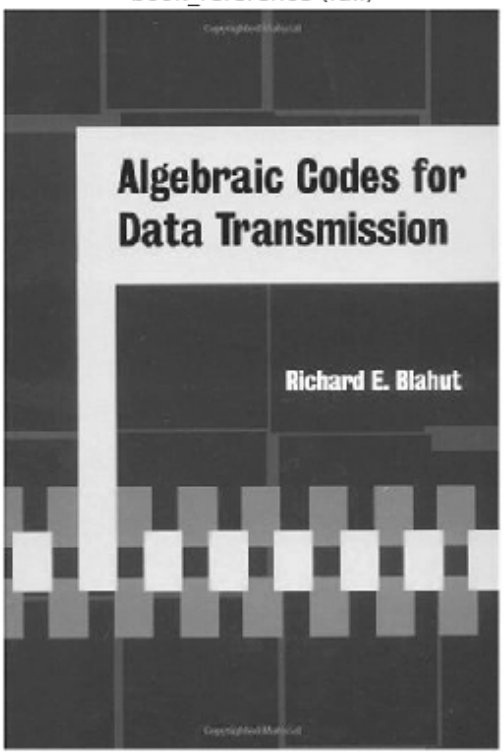
Example –> this case is one of a suucessful cases (book_covers 12) :



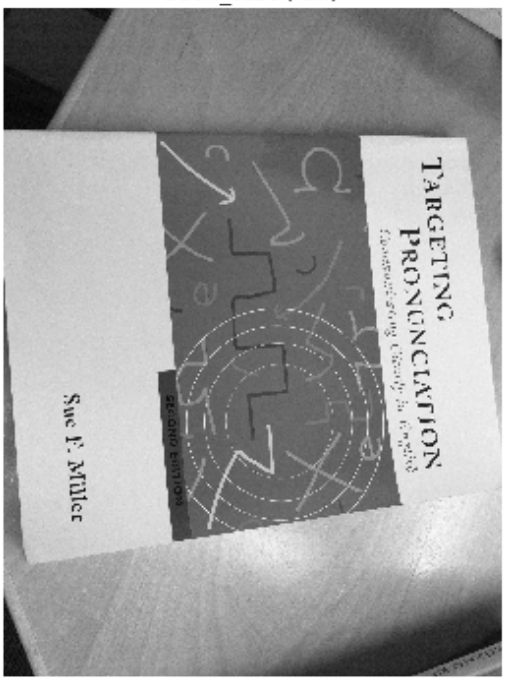


Example –> this case is one of a failed cases (book_covers 59) :

book_reference (fail)



book_test (fail)



3.1.1 Result – use orb some examples)

test case : 01, 12, 13, 23, 59, 73, 56, 89, 46, 81, 86 (random select)

The details are :

```
** case ******* score ********* result **

image 01          100             success

image 12          56              success

image 13          54              success

image 23          48              success

image 59          11              fail

image 73          13              fail

image 56          12              fail

image 89          9               fail
```

```
image 46          9               fail

image 81          23              success

image 86          20              success
```

3.1.2 Summary

```
Total numbers of pairs (orb):  66
Total accuracy (orb):  65.34653465346535 %

Total numbers of pairs (orb + top-5):  70
Total accuracy (orb + top-5):  69.3069306930693 %
```

method we used :

- image size : **orignal**
- feature detector : **orb**
- matching strategy : **KNN**

Total Accuracy : 65.3465% –> (66/101)

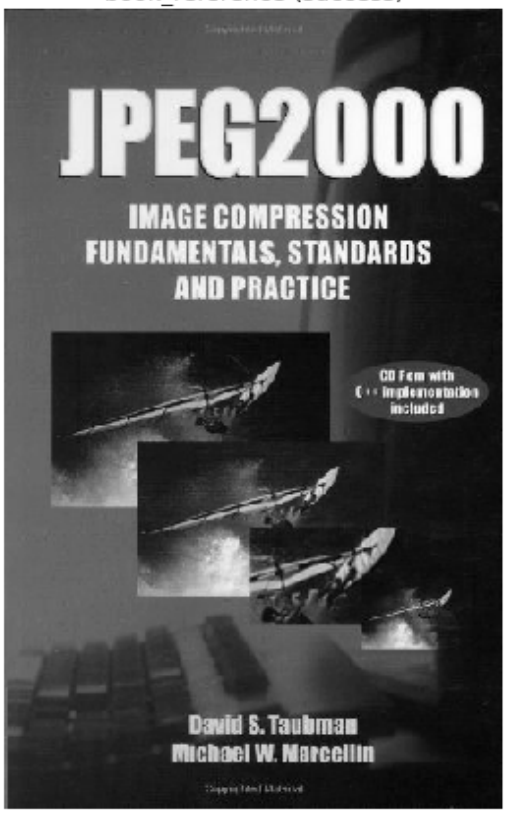
Total Accuracy (top-5): 69.3069% –> (70/101)

Through apply the top-k accuracy method, we get a higher accuracy, it increase almost **4%**! (from 65.3% to 69.3%)

3.2 Using sift

Example –> this case is one of a sucessful cases (book_covers 89)

book_reference (success)



book_test (success)

3.2.1 Result – use sift (some examples)

test case : 01, 12, 13, 23, 59, 73, 56, 89, 46, 81, 86 (randomly select)

The details are (some cases) :

```
** case ******* score ********* result **

image 01          127             success

image 12          163             success

image 13          411             success

image 23          30              fail

image 59          138             success

image 73          160             success

image 56          320             success
```

```
image 89         52             success

image 46         154            success

image 81         155            success

image 86         120            success
```

3.2.2 Summary

```
Total numbers of pairs (sift):  93
Total accuracy (sift):  92.07920792079209 %

Total numbers of pairs (sift + top-5):  98
Total accuracy (sift + top-5):  97.02970297029702 %
```

what we used :

- image size : **orignal**
- feature detector : **sift**
- matching strategy : **KNN**

Total Accuracy : 92.0792% –> (93/101)

Total Accuracy (top-5): 97.0297% –> (98/101)

When we use top-5 accuracy to measuer, we can get a high accuracy with sift method. It increase **4.95%**. (from 92.08% to 97.03%)

I change the moethod of **feature detector**, from orb method to sift method. It works good and the accuracy increase almost **27.7%** (from 69.3% to 97%).

Small thing :

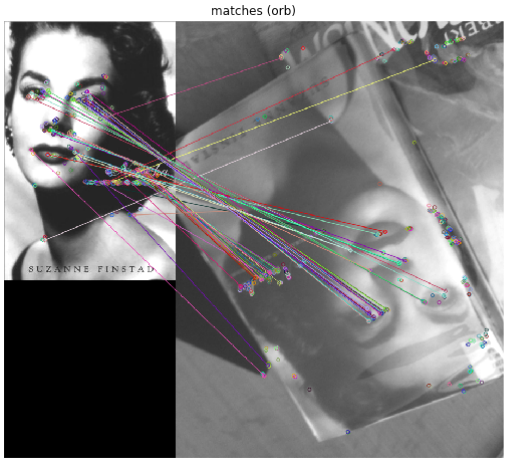
- However, I discover that the image (book_covers 23) failed in sift method (which has a high accuracy), success in the orb method (which has a low accuracy).

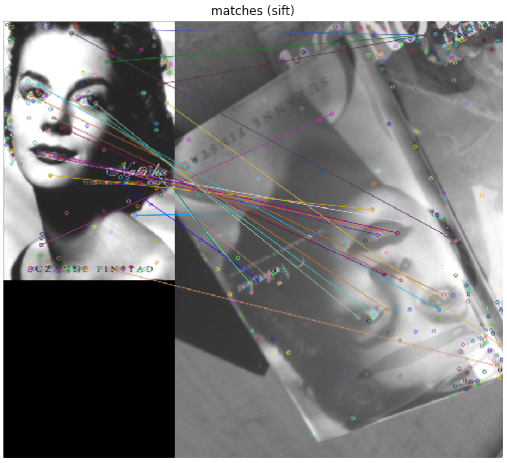
keypoints of reference image (orb)

keypoints of query image (orb)

keypoints of reference image (sift)

keypoints of query image (sift)





From the images (macthes (orb), matches (sift)), we can see orb method works better than the sift method in finding keypoints in objects, but in finding keypoints in text area, sift method works better.

3.2.3 Summary

After searching the internet, I discover that the difference between ORB and SIFT method.

ORB: It computes the intensity weighted centroid of the patch with located corner at center.

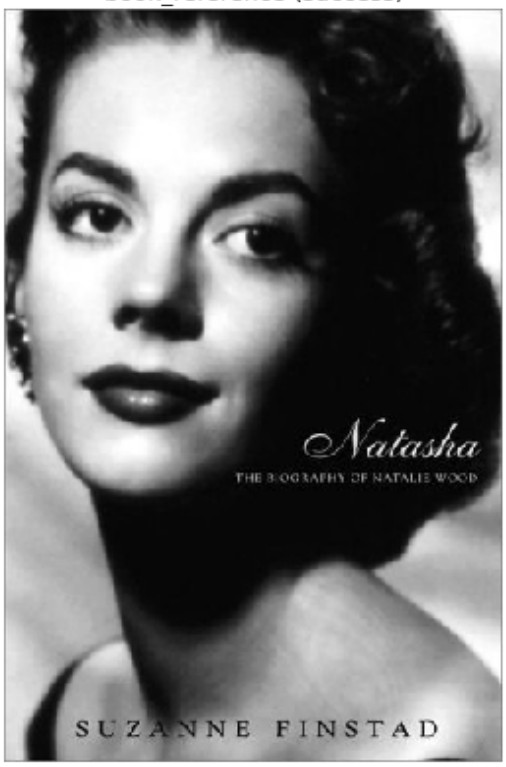
In case(book_covers 023), we can see the reference image shows a strong intensity contrast. So I think this is a reason that orb works better.

So I get an idea that if we resize the image or change the brightness then use orb method, would the accuracy increase?

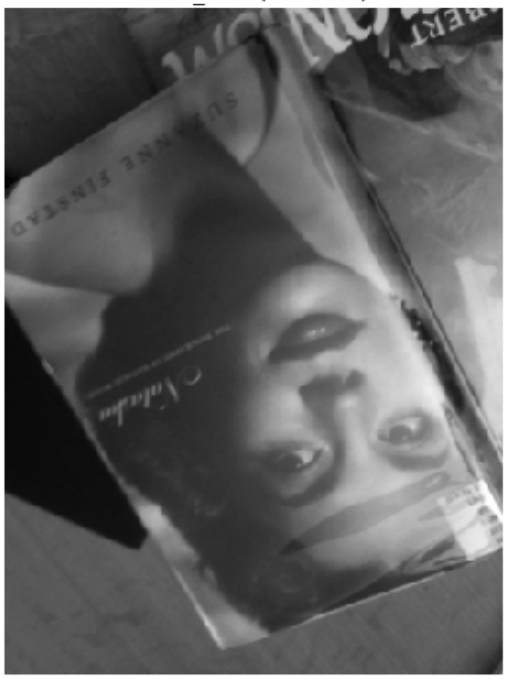
3.3 Changing the size (using orb)

Example –> this case is one of a sucessful cases (book_covers 23)

book_reference (success)



book_test (success)



3.3.1 Result – change size with factor 0.5 (some examples)

test case : 01, 12, 13, 23, 59, 73, 56, 89, 46, 81, 86 (random select)

The details are :

```
** case ******* score ********* result **

image 01          142             success

image 12          53              success

image 13          71              success

image 23          54              success

image 59          44              success

image 73          47              success

image 56          68              success

image 89          26              success
```

```
image 46          19              success

image 81          115             success

image 86          48              success
```

3.3.2 Summary

```
numbers of successful pairs (resize - 0.3) : 94
accuracy : 93.06930693069307 %

numbers of successful pairs (resize - 0.5) : 94
accuracy : 93.06930693069307 %

numbers of successful pairs (resize - 0.8) : 94
accuracy : 93.06930693069307 %
```

what we used :

- image size : **0.3, 0.5, 0.8**
- feature detector : **orb**
- matching strategy : **KNN**

Total Accuracy(with factor 0.3 + top-5): 93.0693% –> (94/101)

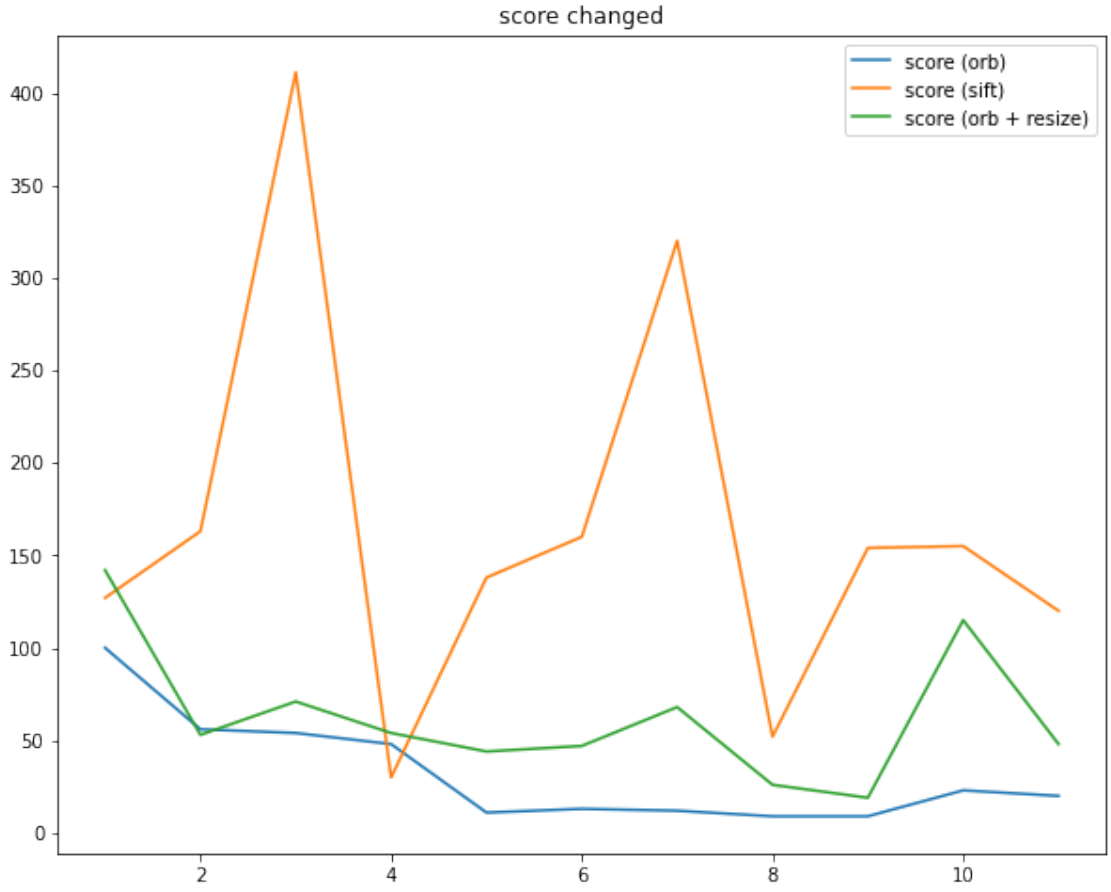
Total Accuracy(with factor 0.5 + top-5): 95.0495% –> (96/101)

Total Accuracy(with factor 0.8 + top-5): 89.1089% –> (90/101)

I notice I solve the problem of the image (book_covers 23) with resizing the image with factor 0.5.

When we resize the book covers with factor 0.5, the accuracy is become 95.0693%. Compare to use the orb method without resziing, the accuracy increase **35.74%** (from 69.31% to 95.05%) after resize the image size. Although the total accuracy is lower than the sift method,

3.3.3 Graph –> score changed (orb, sift, orb + resize)



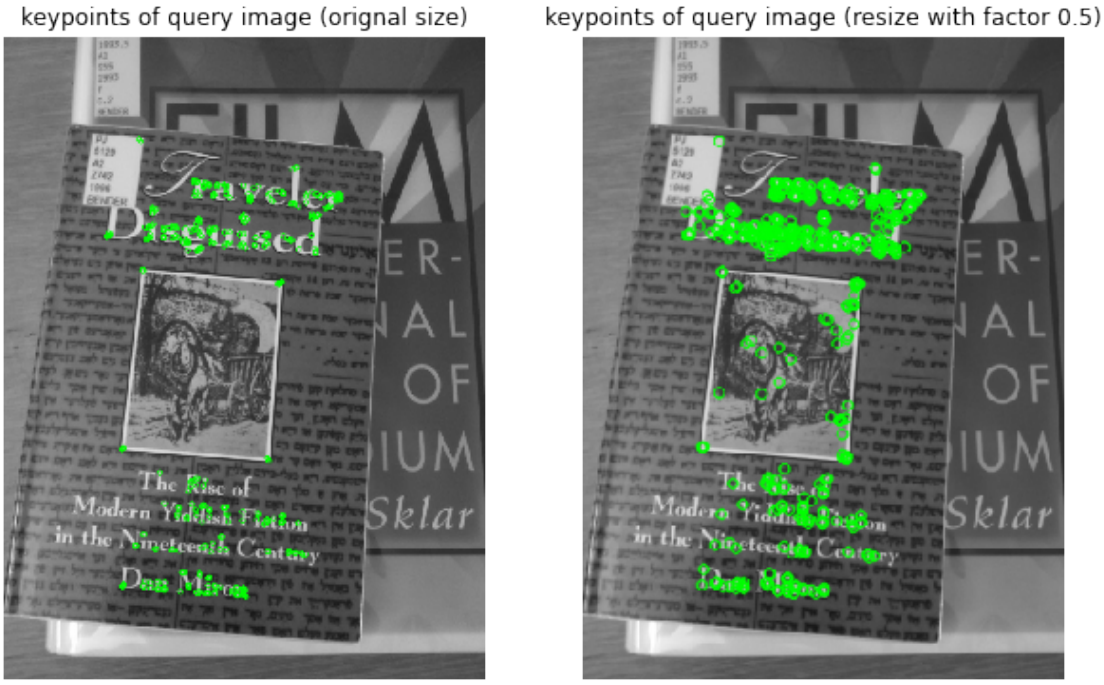
From the image, we can clearly see that sift method works perfect (expect some cases). However, when we use orb method, resize the image with factor 0.5 can increase the score. It helps a lot.

3.3.4 Discuss

Here we discuss a case which fail in the original size but success after resizing.

Let's see what differnece between resize and the orignal size.

Here is a case book_covers 046 –> which fail in the original size but success after resizing



Compare these two iamges, we can see the key points **increase** a lot when after we resize the image, espically in text area. It is the main reason we can success.

---

4 Not in the data set

```
[ WARN:0@122.652] global /Users/runner/work/opencv-python/opencv-
python/opencv_contrib/modules/xfeatures2d/misc/python/shadow_sift.hpp (15)
SIFT_create DEPRECATED: cv.xfeatures2d.SIFT_create() is deprecated due SIFT
tranfer to the main repository. https://github.com/opencv/opencv/issues/16736
```

```
min score (orb) --> 11
min score (sift) --> 37
```

4.1 Using orb

Result – using orb

test case : 01, 02, 03, 04, 05, 06, 07, 08, 09

Accuracy : 77.78% –> 7/9

The details are :

```
** case ******* score ************* result **

image 01          N             not in the set
```

```
image 02          N             not in the set

image 03          N             not in the set

image 04          N             not in the set

image 05          25                success

image 06          N             not in the set

image 07          28                success

image 08          N             not in the set

image 09          N             not in the set
```

4.1.1 Summary

What we used :

- image size : **original**
- image brightness : **original**
- feature detector : **orb**
- matching strategy : **KNN**

I set a value (11) to the threshold, and the accuracy is **77.78%**.

If the threshold is smaller than the threshold, I identify it is not in the data set. If the threshold is larger than the threshold, I identify it is in the data set.

4.2 Using sift

Result – using sift

test case : 01, 02, 03, 04, 05, 06, 07, 08, 09

Accuracy : 77.78% –> (7/9)

The details are :

```
** case ******* score ************ result **

image 01          N             not in the set

image 02         69               success

image 03         157              success
```

```
image 04          N             not in the set

image 05          N             not in the set

image 06          N             not in the set

image 07          N             not in the set

image 08          N             not in the set

image 09          N             not in the set
```

4.2.1 Summary

What we used :

- image size : **original**
- image brightness : **original**
- feature detector : **sift**
- matching strategy : **KNN**

I set a value (37) to the threshold, and the accuracy is still **77.78%**.

If the threshold is smaller than the threshold, I identify it is not in the data set. If the threshold is larger than the threshold, I identify it is in the data set.

4.3 Change the brightness

Result – change the brightness

test case : 01, 02, 03, 04, 05, 06, 07, 08, 09

Accuracy : 100.00% –> (9/9)

The details are :

```
** case ******* score ************ result **

image 01          N             not in the set

image 02          N             not in the set

image 03          N             not in the set

image 04          N             not in the set

image 05          N             not in the set

image 06          N             not in the set
```

```
image 07          N             not in the set

image 08          N             not in the set

image 09          N             not in the set
```

Summary What we used :

- image size : **original**
- image brightness : **add 20**
- feature detector : **orb**
- matching strategy : **KNN**

I change the **image brightness**. And I set a value (11) to the threshold, and the accuracy is **100%**!

If the threshold is smaller than the threshold, I identify it is not in the data set. If the threshold is larger than the threshold, I identify it is in the data set.

---

5 Landmarks

5.1 In data set

5.1.1 Using orb method

```
numbers of pairs (orb):  20
accuracy (orb):  19.801980198019802 %

numbers of pairs (orb + top_5):  28
accuracy (orb + top_5):  27.722772277227726 %
```

What we used :

- image size : **original**
- image brightness : **original**
- feature detector : **orb**
- matching strategy : **KNN**

Total Accuracy : 19.8% –> (20/101)

Total Accuracy (top-5): 27.72% –> (28/101)

5.1.2 Using sift method

```
[ WARN:0@12.113] global /Users/runner/work/opencv-python/opencv-
python/opencv_contrib/modules/xfeatures2d/misc/python/shadow_sift.hpp (15)
SIFT_create DEPRECATED: cv.xfeatures2d.SIFT_create() is deprecated due SIFT
tranfer to the main repository. https://github.com/opencv/opencv/issues/16736
```

```
numbers of pairs (sift):  8
accuracy (sift):  7.920792079207921 %
```

```
numbers of pairs (sift + top_5):  31
accuracy (sift + top_5):  30.693069306930692 %
```

What we used :

- image size : **original**
- image brightness : **original**
- feature detector : **sift**
- matching strategy : **KNN**

Total Accuracy : 7.92% –> (8/101)

Total Accuracy (top-5): 30.69% –> (31/101)

5.1.3 Improvement

I think we can improve the accuracy by adding the nfeatures in orb dector.

```
numbers of pairs (orb improved):  57
accuracy (orb improved):  56.43564356435643 %
```

What we used :

- image size : **original**
- image brightness : **original**
- feature detector : **orb (nfeatures -> 5000)**
- matching strategy : **KNN**

Total Accuracy (top-5): 56.44% –> (57/101)

We can see that the Total accuracy increase almost **29%** when we modify the orb detector (nfeatures -> 5000). I think the accracy will increase by increasing the nfeatures number in orb detector, however, the speed will get slow.

5.1.4 Efficiency

By the way, we can also see the accuracy changed and the time cost.

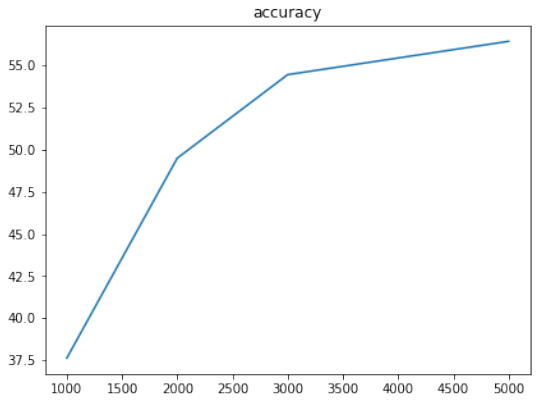
nfeatures –> (1000, 2000, 3000, 4000)

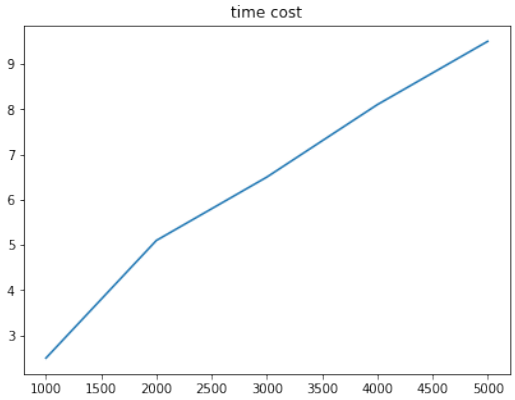
```
orb + top_5, n = 1000
accuracy:  37.62376237623762 %

orb + top_5, n = 2000
accuracy:  49.504950495049506 %

orb + top_5, n = 3000
accuracy:  54.45544554455446 %

orb + top_5, n = 4000
accuracy:  55.44554455445545 %
```

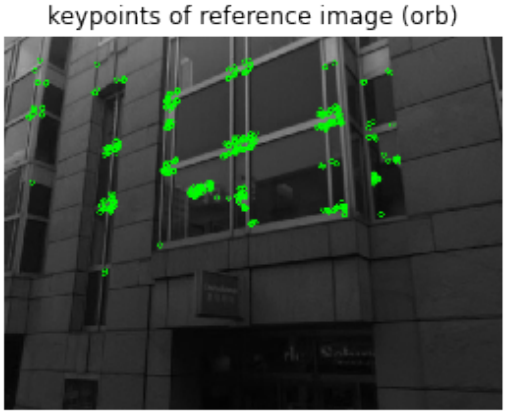




5.1.5 Summary

From the images (Accuracy Changed), we can see that the curve become smooth at the point (nfeatures = 3000).

5.1.6 Discuss –> landmarks_018



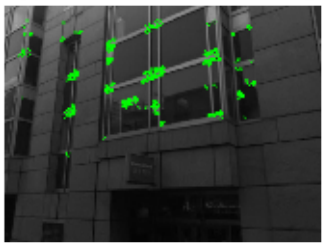
keypoints of reference image (orb)

keypoints of query image (sift)

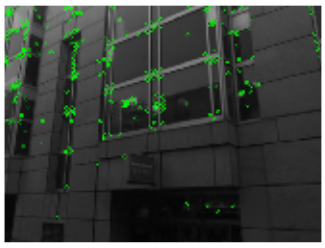
draw outline (orb)

draw outline (sift)

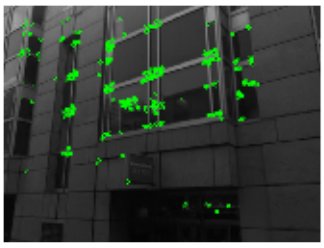
keypoints of reference image

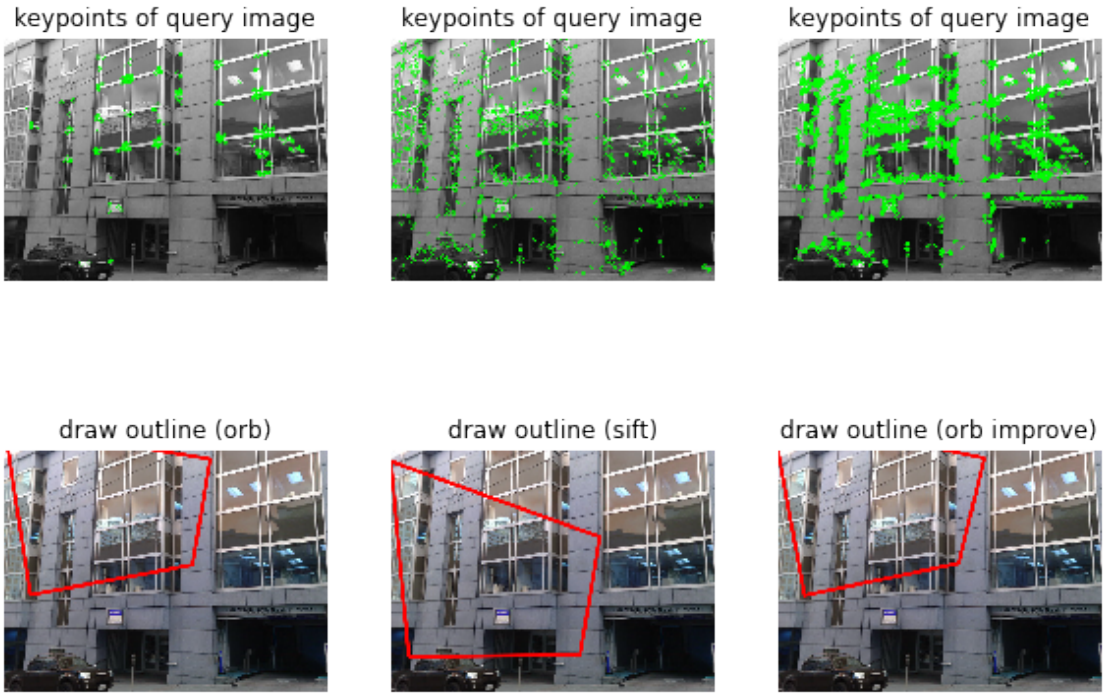


keypoints of reference image



keypoints of reference image





In this case, we can see if we use orb, it fails. However, if we use sift, we can get the correct area. In dectecting key points part, we can see orb method can not detect many key points below the windows (including the wall and the signage). So we can not get the correct area when we use orb mehod because of the poor quantity of key points.

5.2 Not in data set

```
min score (orb) : 63
```

5.2.1 Using orb

```
number of not in data set (orb) : 1
number of not in data set (orb + top_5) : 1
```

5.2.2 Case –> image 1

```
[8, 8, 8, 7, 7]
```

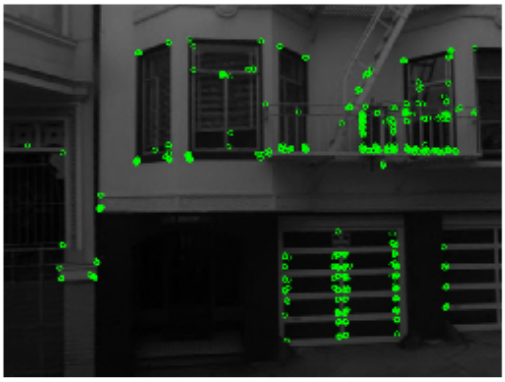
```
7
```

land test

land reference

land test

land reference



8

In this case, we can see these two images are quite

Result – using orb (not use top-k method)

test case : 1, 2, 3, 4, 5, 6, 7

The details are :

```
** case ******* score ************* result **

image 01          11                success

image 02           N              not in the set

image 03          14                success

image 04          13                success

image 05          18                success

image 06          11                success

image 07          11                success
```

Total Accuracy: 14.3% –> (1/7)

Total Accuracy (top-5): 71.4% –> (5/7)

5.2.3 using sift

```
number of not in data set (sift) : 1
number of not in data set (sift + top_5) : 5
```

Result – using sift (not use top-k method)

test case : 1, 2, 3, 4, 5, 6, 7

The details are :

```
** case ******* score ************* result **

image 01          27                success

image 02          141               success

image 03          28                success
```

```
image 04          27                success

image 05          51                success

image 06          31                success

image 07           N             not in the set
```

Total Accuracy: 14.3% –> (1/7)

Total Accuracy (top-5): 71.4% –> (5/7)

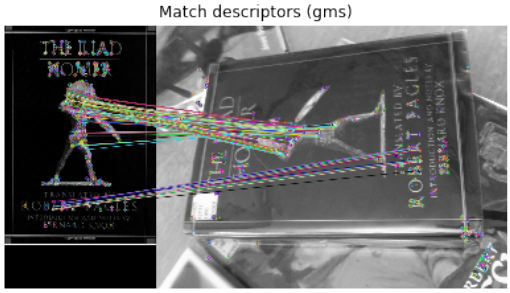
5.2.4 Summary

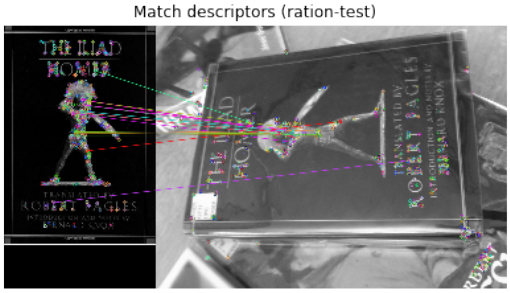
We can see that wether we use orb or sift method, the accuracy do not improved.

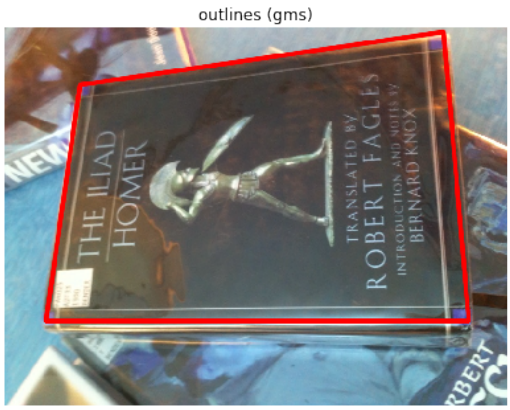
6 GMS and ratio_test (10%)

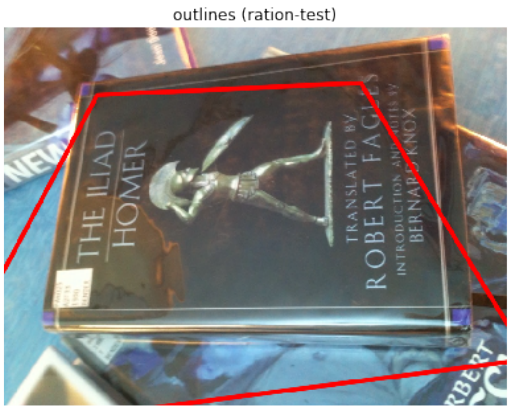
6.1 Book covers

case: book_covers 025







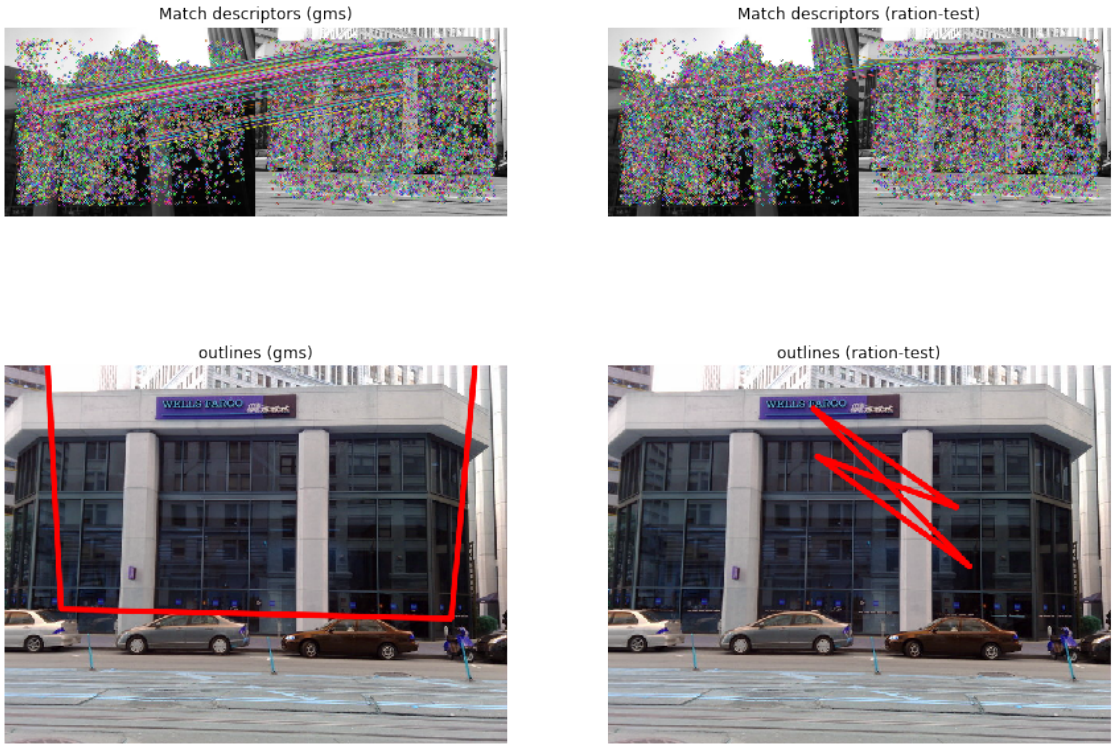


6.1.1 Discovery

At first time, I set numbers of features be **10,000**, GMS and ratio-test method all returns correct outlines. However, when I set number of features be **1000**, GMS do better than the ratio-test method.

6.2 Landmarks

case: landmarks 0000

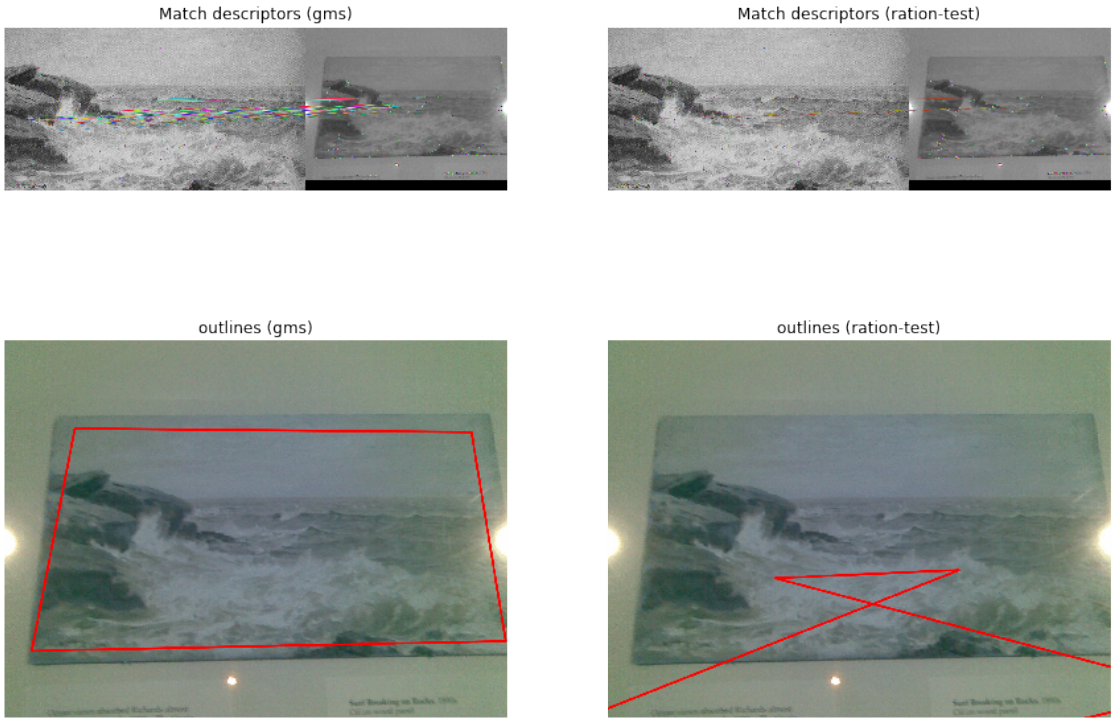


6.2.1 Discovery

At first time, I set numbers of features be **20,000**, we can easily see that GMS works better than the ration-test.

6.3 Museum paintings

case: museum_paintings 055



6.3.1 Discovery

At first time, I set numbers of features be **10,000**, GMS and ratio-test method all returns correct outlines. However, when I set number of features be **1,300**, GMS do better than the ratio-test method.

6.4 Summary

All in all, compare to the GMS and ratio-test, GMS works better if two pictures return same numbers of keypoints. Sometimes, when the numbers of keypoints are limited, GMS works better than the ratio-test because GMS has a better matching strategy.

7 Reflection Questions (5%)

- Describe the hardest situation you faced during the first two assignments. And how you overcome it? (3%)
  - The hardest part of assignment 1, I think it is implement the convolution part. The algorithm is quite complex, so I need to learn more about the convolution, I searched a lot in the internet and I get lots of useful information to help me to implement the convolution function. resize function also very tricky, I got mix the width and height.
  - The haradest part of assignment 2, I think it has to explain many reasons and how you get improved. I have to write them step by step with the truth (real data), and test

them again and again until I find the correct way to improve. By the way, I have to do lots of research in this part to find some inspirations which can help me.

  - However, I think this process is pretty good because through these two assignments, I can study deeper and make many boring knowledge visualization.

- How do you plan to finish the assignment to meet tight deadline? (2%)

  - I start the assignment when the assignment release, although it takes me a lot of time, but still not feel tight.