MLRF Lecture 01

J. Chazalon, LRDE/EPITA, 2021

Introduction to *Twin it!*

Lecture 01 part 03

Twin it! overview

A poster game

- X bubbles, all different but
- Y bubbles, which have 1 (and only 1) twin

Your goals:

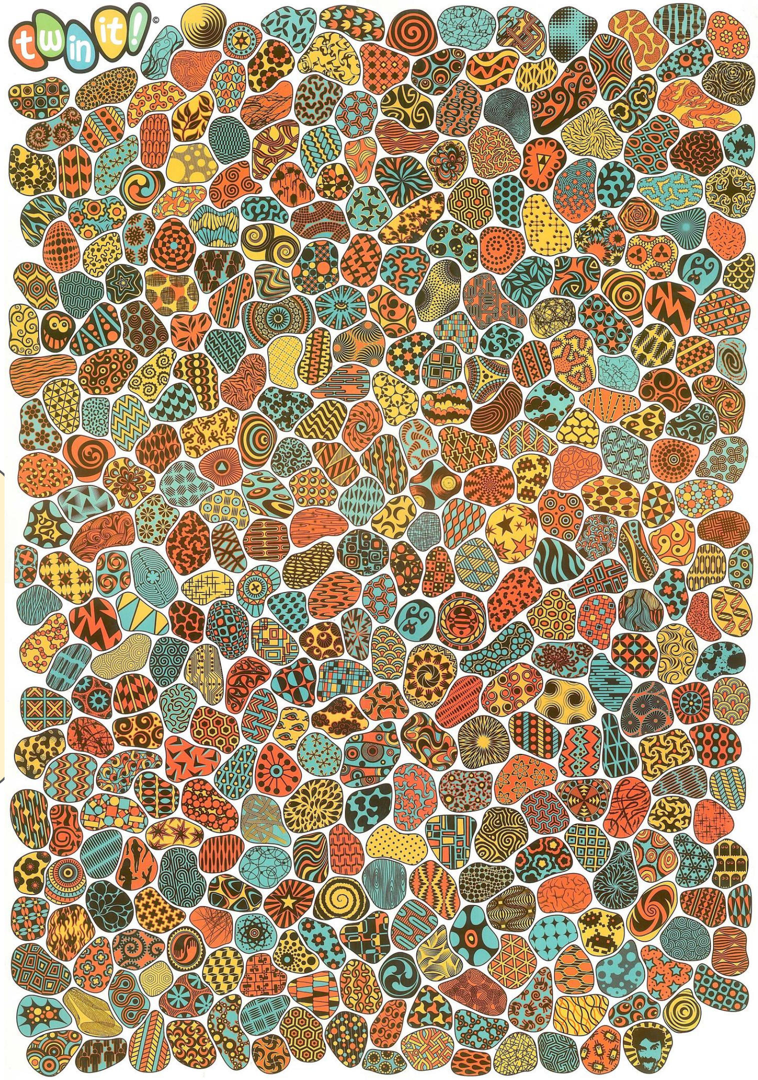
- Find the pairs

Already done

- Scan the poster
- Stitch the tiles
- Normalize the contrast

Discussion (3 minutes):

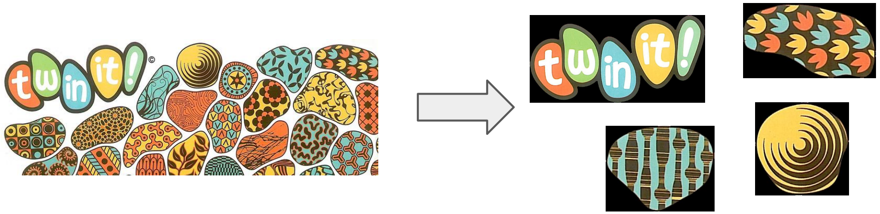
1. **How can we decompose the problem?**
2. **How can we make sure our solution works?**
3. **What should we focus on?**



Twin it! underlying problems

1. Isolate each bubble ⇒ **Segmentation**

   We provide pre-computed results for this step.

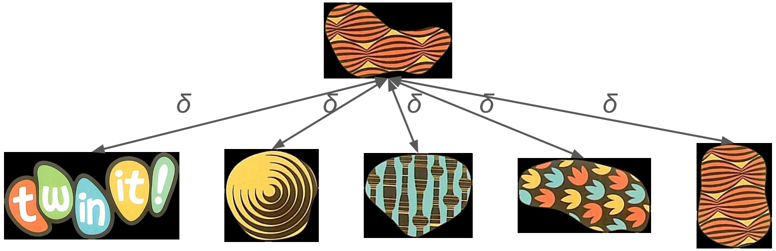


---

2. Compare image pairs ⇒ **Matching**

   We will focus on this one.

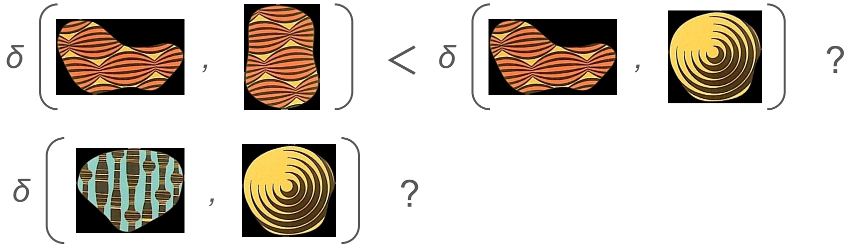
   *We will use **Template Matching.***



---

3. Identify pairs ⇒ **Calibration**

   We will understand the challenges of this one.



Template Matching

Lecture 01 part 04

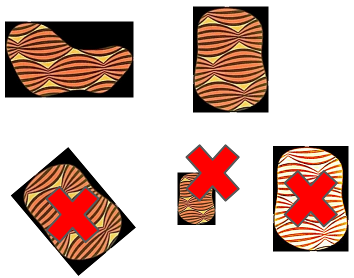
Why template matching?

A simple method which will be useful to understand

- Evaluation challenges
- The ideas behind keypoint detection (next lecture)

It can work in the Twin it! case

- Twice the same texture (in two bubbles of different shape)
- Textures at the **same scale**,
  <u>without</u> rotation
  nor **intensity change**
- Only need to cope with **translation** (and some **small noise**)



Step by step: Compare two images

Two arrays of intensities

128	128	10
126	126	9
126	126	9

I_1

135	130	12
127	128	8
126	128	9

I_2

Step by step: Compare two images

Two arrays of intensities

Take the difference

128	128	10
126	126	9
126	126	9

I_1

135	130	12
127	128	8
126	128	9

I_2

-7	-2	-2
-1	-2	1
0	-2	0

$$R(x, y) = I_1(x, y) - I_2(x, y)$$

R

Step by step: Compare two images

Two arrays of intensities

Take the **absolute** difference

128	128	10
126	126	9
126	126	9

I_1

135	130	12
127	128	8
126	128	9

I_2

7	2	2
1	2	1
0	2	0

$$R(x,y) = |I_1(x,y) - I_2(x,y)|$$

R

Step by step: Compare two images

Two arrays of intensities

Take the **squared** difference

128	128	10
126	126	9
126	126	9

I_1

135	130	12
127	128	8
126	128	9

I_2

49	4	4
1	4	1
0	4	0

R

$$R(x,y) = (I_1(x,y) - I_2(x,y))^2$$

Step by step: Compare two images

Two arrays of intensities

Take the **squared** difference

Sum the differences

128	128	10
126	126	9
126	126	9

I_1

135	130	12
127	128	8
126	128	9

I_2

49	4	4
1	4	1
0	4	0

R

→ S = 67

$$S = \sum_{x,y} (I_1(x,y) - I_2(x,y))^2$$

Step by step: Compare two images

Two arrays of intensities

Take the **squared** difference

Sum the differences

(Opt.) Normalize so the results belongs to [0, 1].

0: closest / match
1: farthest / no match

128	128	10
126	126	9
126	126	9

I_1

135	130	12
127	128	8
126	128	9

I_2

49	4	4
1	4	1
0	4	0

R

⇒ $S = 6.8*10^{-4}$

$$S = \frac{\sum_{x,y}(I_1(x,y) - I_2(x,y))^2}{\sqrt{\sum_{x,y} I_1(x,y)^2 \cdot \sum_{x,y} I_2(x,y)^2}}$$

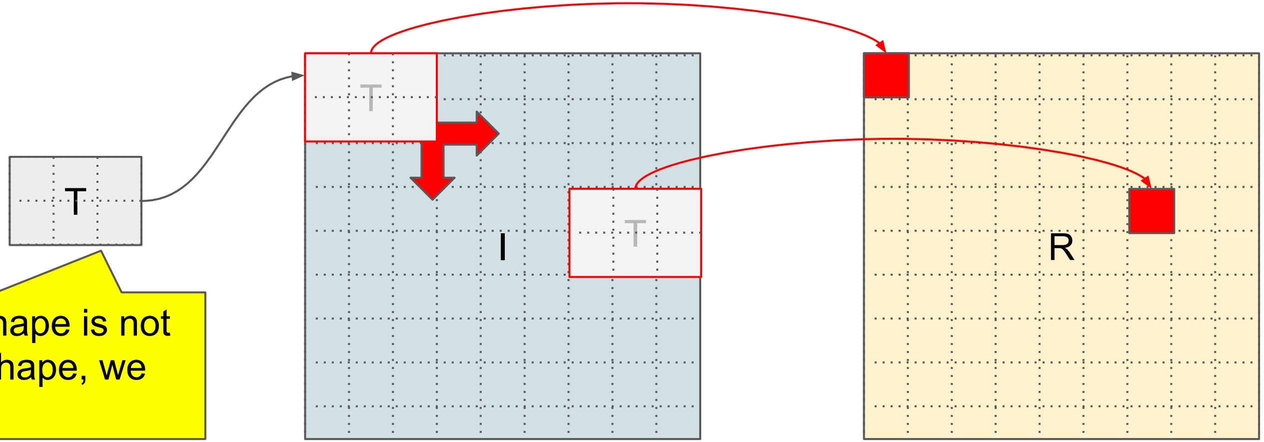
"Sum of squared differences" or "SSD"

Template Matching: Sliding comparison

I_1 is a small template T to match against I_2 (just I after).

We rewrite the preceding formula to compute a map R of the shape of I.

Each pixel of R will have the value of the SSD when the top-left pixel of T in on the pixel (x,y) of I.



Warning: If I's shape is not bigger than T's shape, we need **padding**.

Several approaches ⇒ Practice session

Sum of squared differences

$$R(r,c) = \sum_{r',c'} (T(r',c') - I(r+r',c+c')^2$$

Cross correlation

$$R(r,c) = \sum_{r',c'} (T(r',c') \cdot I(r+r',c+c'))$$

Correlation coefficient

$$R(r,c) = \sum_{r',c'} (T'(r',c') \cdot I'(r+r',c+c'))$$

where:

$$T'(r',c') = T(r',c') - 1/(w \cdot h) \cdot \textstyle\sum_{r'',c''} T(r'',c'')$$

$$I'(r+r',c+c') = I(r+r',c+c') - 1/(w \cdot h) \cdot \textstyle\sum_{r'',c''} I(r+r'',c+c'')$$

Simply divide by the mean of pixel values

Normed SSD

$$R(r,c) = \frac{\sum_{r',c'} (T(r',c') - I(r+r',c+c')^2}{\sqrt{\sum_{r',c'} (T(r',c'))^2 \cdot \sum_{r',c'} I(r+r',c+c')^2}}$$

Normed CCORR

$$R(r,c) = \frac{\sum_{r',c'} (T(r',c') \cdot I(r+r',c+c'))}{\sqrt{\sum_{r',c'} T(r',c')^2 \cdot \sum_{r',c'} I(r+r',c+c')^2}}$$

Normed CCOEFF

$$R(r,c) = \frac{\sum_{r',c'} (T'(r',c') \cdot I'(r+r',c+c'))}{\sqrt{\sum_{r',c'} T'(r',c')^2 \cdot \sum_{r',c'} I'(r+x',c+c')^2}}$$

Always the same normalization

Several approaches ⇒ Practice session

Sum of squared differences

$$R(r,c) = \sum_{r',c'}(T(r',c') - I(r+r',c$$

Normed SSD

$$, c) = \frac{\sum_{r',c'}(T(r',c') - I(r+r',c+c')^2}{\sqrt{\sum_{r',c'}(T(r',c'))^2 \cdot \sum_{r',c'} I(r+r',c+c')^2}}$$

Both very similar: just a local normalization

Cross correlation

$$R(r,c) = \sum_{r',c'}(T(r',c') \cdot I(r+r',c+c'))$$

Normed CCORR

$$R(r,c) = \frac{\sum_{r',c'}(T(r',c') \cdot I(r+r',c+c'))}{\sqrt{\sum_{r',c'} T(r',c')^2 \cdot \sum_{r',c'} I(r+r',c+c')^2}}$$

Correlation coefficient

$$R(r,c) = \sum_{r',c'}(T'(r',c') \cdot I'(r+r',c+c'))$$

Normed CCOEFF

$$R(r,c) = \frac{\sum_{r',c'}(T'(r',c') \cdot I'(r+r',c+c'))}{\sqrt{\sum_{r',c'} T'(r',c')^2 \cdot \sum_{r',c'} I'(r+x',c+c')^2}}$$

where:

$$T'(r',c') = T(r',c') - 1/(w \cdot h) \cdot \sum_{r'',c''} T(r'',c'')$$

$$I'(r+r',c+c') = I(r+r',c+c') - 1/(w \cdot h) \cdot \sum_{r'',c''} I(r+r'',c+c'')$$

Simply divide by the mean of pixel values

Always the same normalization

Several approaches ⇒ Practice session

The smaller (close to 0),
the more similar

Sum of squared differences

$$R(r,c) = \sum_{r',c'} (T(r',c') - I(r+r',c+c'))^2$$

rmed SSD

$$R(r,c) = \frac{\sum_{r',c'} (T(r',c') - I(r+r',c+c'))^2}{\sqrt{\sum_{r',c'} (T(r',c'))^2 \cdot \sum_{r',c'} I(r+r',c+c')^2}}$$

The larger,
the more similar

Cross correlation

$$R(r,c) = \sum_{r',c'} (T(r',c') \cdot I(r+r',c+c'))$$

rmed CCORR

$$R(r,c) = \frac{\sum_{r',c'} (T(r',c') \cdot I(r+r',c+c'))}{\sqrt{\sum_{r',c'} T(r',c')^2 \cdot \sum_{r',c'} I(r+r',c+c')^2}}$$

The larger,
the more similar

Correlation coefficient

$$R(r,c) = \sum_{r',c'} (T'(r',c') \cdot I'(r+r',c+c'))$$

rmed CCOEFF

$$R(r,c) = \frac{\sum_{r',c'} (T'(r',c') \cdot I'(r+r',c+c'))}{\sqrt{\sum_{r',c'} T'(r',c')^2 \cdot \sum_{r',c'} I'(r+x',c+c')^2}}$$

where:

$$T'(r',c') = T(r',c') - 1/(w \cdot h) \cdot \textstyle\sum_{r'',c''} T(r'',c'')$$

$$I'(r+r',c+c') = I(r+r',c+c') - 1/(w \cdot h) \cdot \textstyle\sum_{r'',c''} I(r+r'',c+c'')$$

Simply divide by the
mean of pixel values

Always the same
normalization

About the denominator

Normalization by the sum of values (copes with negatives values)

$$R(x,y) = \frac{\sum_{x',y'}(T(x',y')}{\sqrt{\sum_{x',y'} T(x',y')^2}} \mathbf{x} \frac{I(x+x',y+y'))}{\sqrt{\sum_{x',y'} I(x+x',y+y')^2}}$$

Ensures we get [0,1] results.

Cross correlation: 2 things to know

$$R(r,c) = \sum_{r',c'} (T(r',c') \cdot I(r+r', c+c'))$$

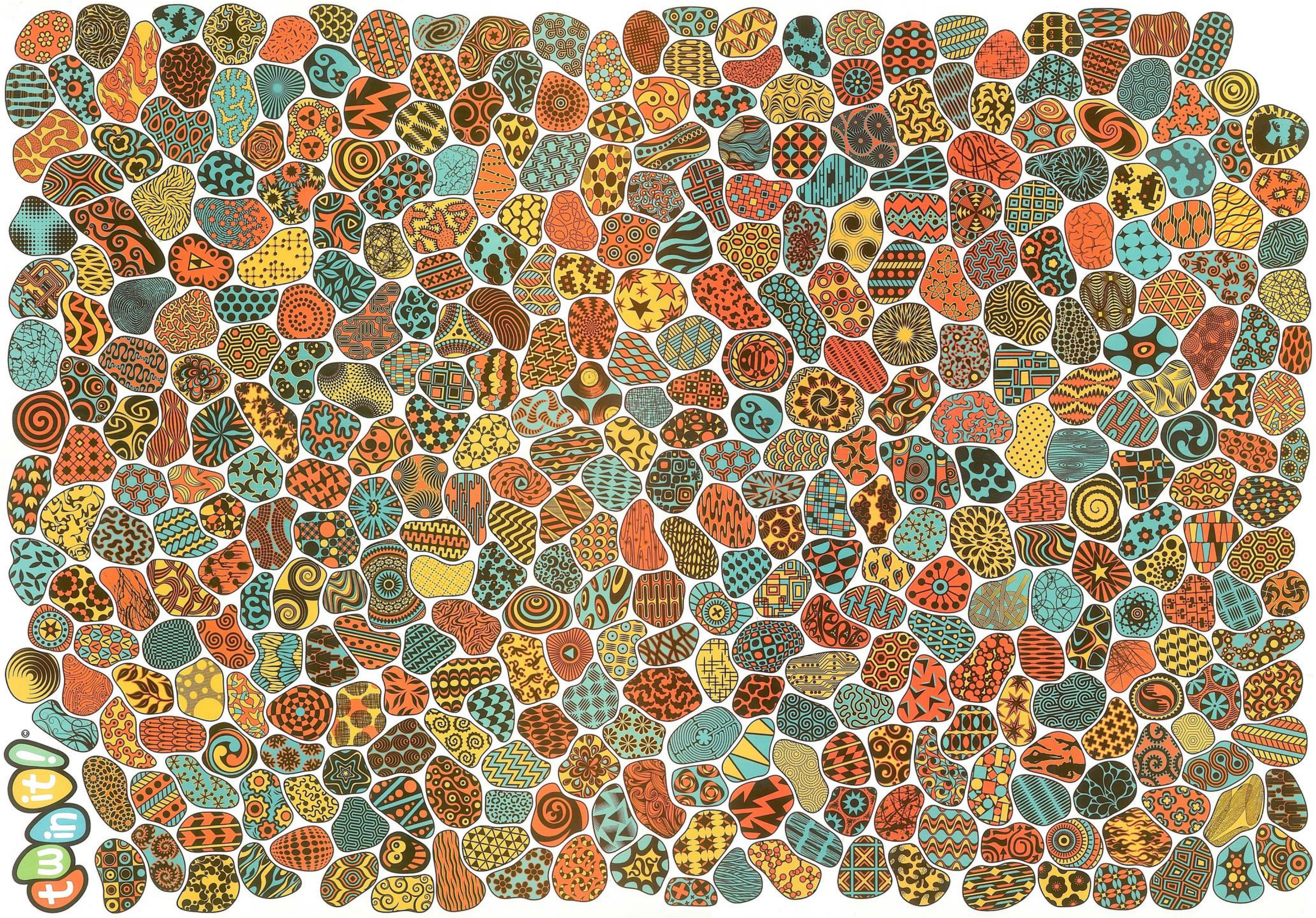
More robust to intensity shifts (as long as gradients “agree”) than SSD

SSD: X+offset - X = offset   CCORR: (X+offset) · X ≅ X^2

Base version requires to **normalize T by its mean**

Otherwise large image values always produce better matches

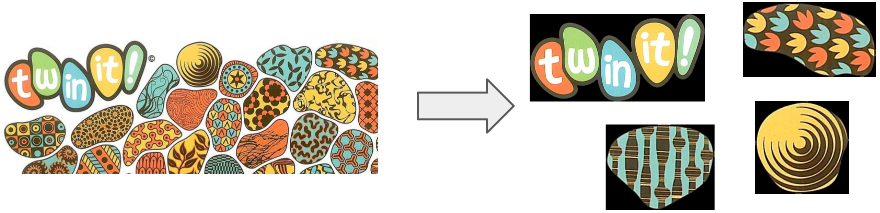
Not necessary for CCOEFF


twin it!

Twin it! underlying problems

1. Isolate each bubble ⇒ **Segmentation**

   We provide pre-computed results for this step.

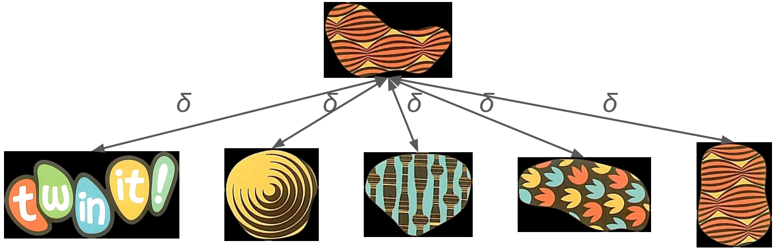


---

2. Compare image pairs ⇒ **Matching**

   We will focus on this one.

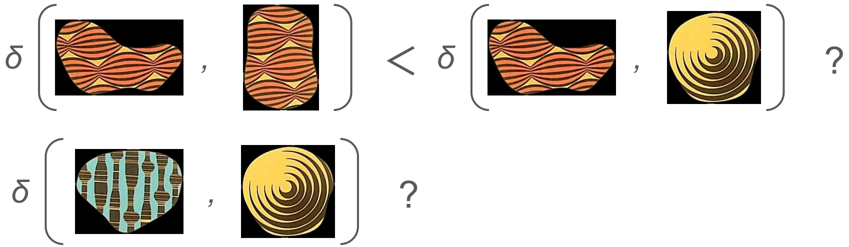
   *We will use **Template Matching.***



---

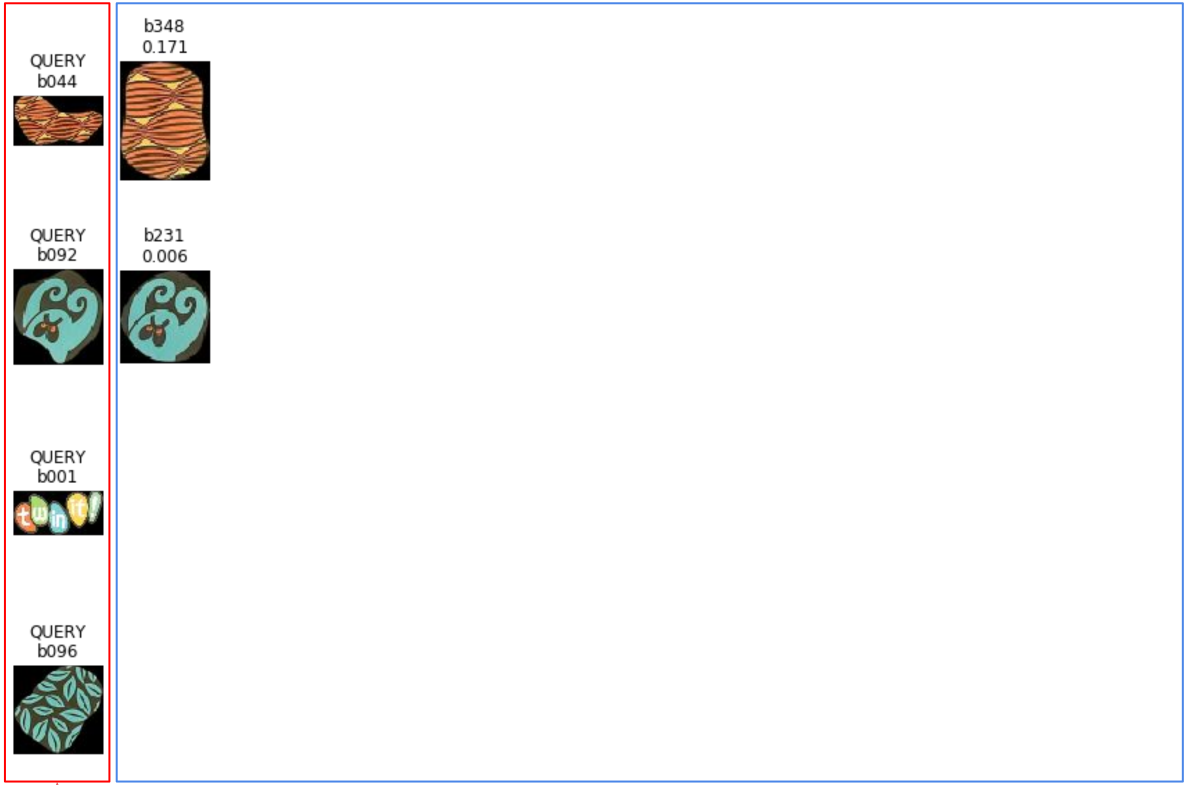
3. Identify pairs ⇒ **Calibration**

   We will understand the challenges of this one.



Ideal goal

For each bubble, return only a matching pair, if it exists.

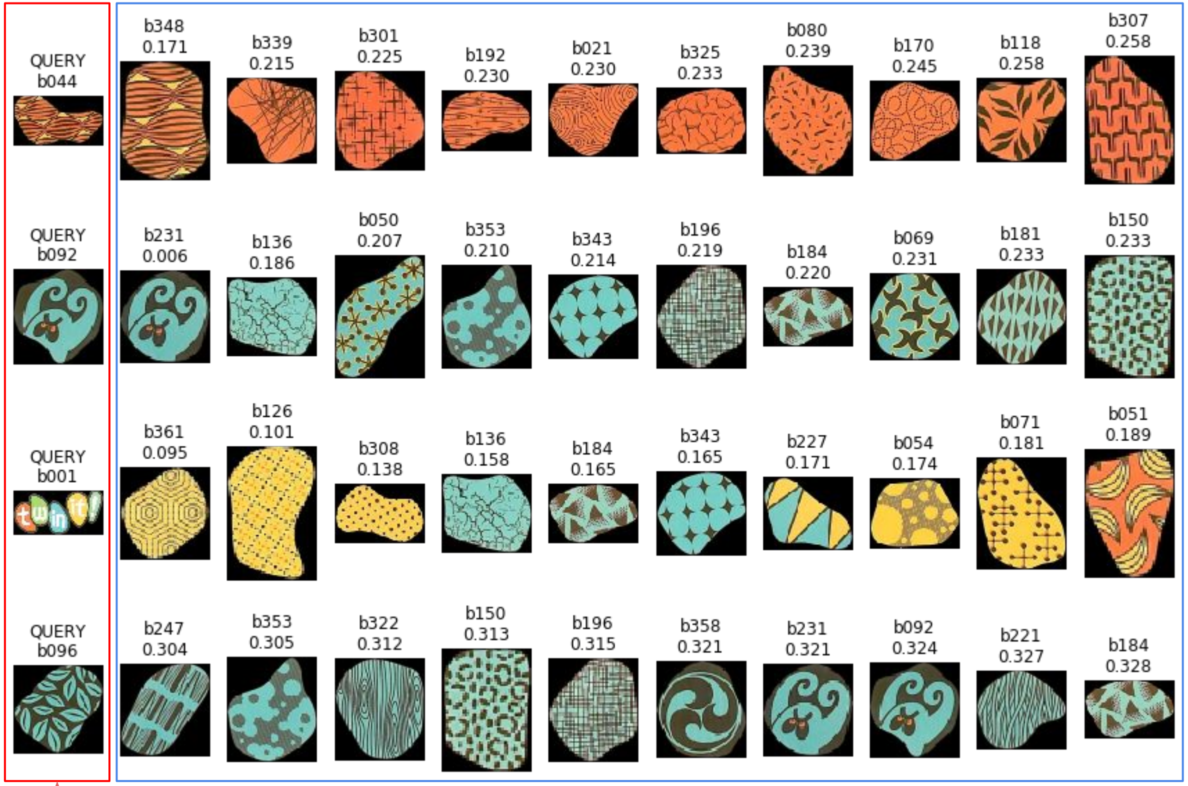


query images

result images (closest to query according to method)

Actual goal for practice session

For each bubble,
return **best matching**
bubbles



query images

result images (closest to query according to method)