Template Matching

- Template matching (TM) is a basic technique for locating a template image within a larger target image. It involves sliding the template across the target image and calculating a similarity score at each position.
- Template matching has a variety of applications in computer vision, for example:
  - Object detection: Template matching can be used to identify objects within a larger image by searching for areas that closely match a predefined template.
  - Facial recognition: Template matching techniques can be employed in security systems to recognize faces by comparing facial features to stored templates.
  - Navigation of mobile robots: Template matching can be used to help robots navigate by recognizing landmarks and features in their environment.
  - Quality control: Template matching can be used to inspect products for defects by comparing them to a standard template.
  - Medical imaging Template matching is applicable in medical imaging for tasks such as image registration and identifying anatomical structures.
  - Activity recognition: Template matching can be used to recognize and classify human activities in videos by comparing the motion patterns to predefined templates.
  - Vehicle Counting: Template matching can be used to count vehicles in traffic monitoring applications.

Template Matching

- In essence, TM is relativelly basic method for object localization.
  - We need the **template** image and the **source** (input) image.
  - We need compare this template vs. overlapped image regions.

template

source

Template Matching

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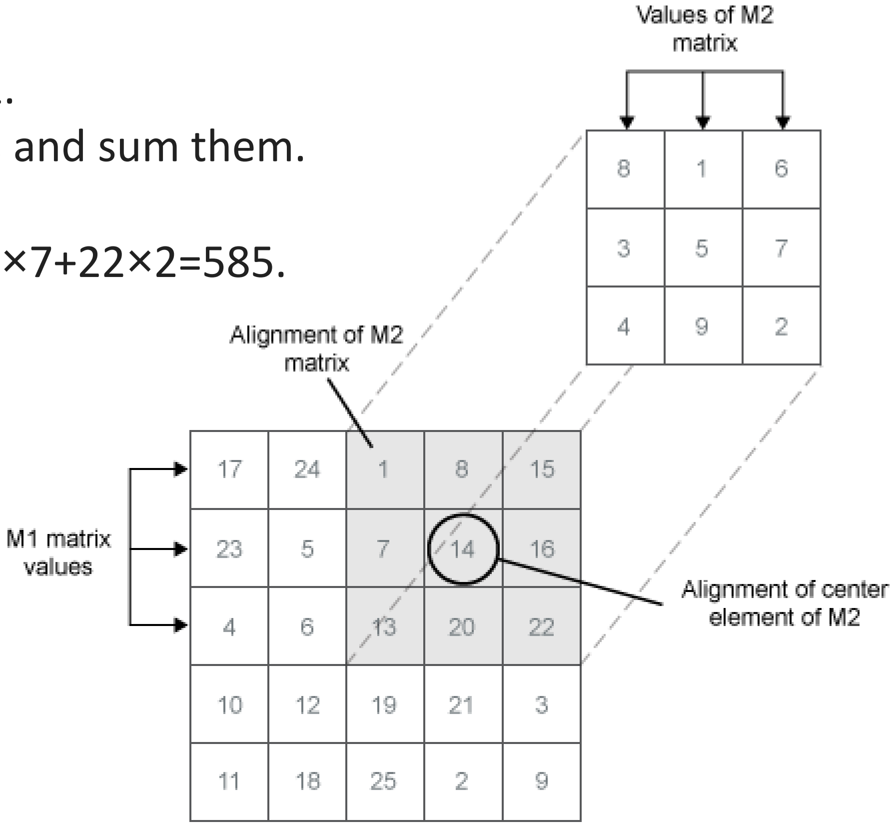
CC- Cross correlation

$$CC = \sum_{x,y} (I_1[x,y] \cdot I_2[x,y])$$

Template Matching

Example of cross correlation.
Suppose that M2 is on top of the matrix M1.
Compute the element-by-element products and sum them.
The answer should be:
1×8+7×3+13×4+8×1+14×5+20×9+15×6+16×7+22×2=585.



https://www.mathworks.com/help/signal/ref/xcorr2.html

Template Matching

- Template matching is a basic technique for locating a template image within a larger target image. It involves sliding the template across the target image and calculating a similarity score at each position. The location with the highest similarity score indicates the best match. OpenCV's **cv2.matchTemplate()** function can be used for this process, taking the template and target images as inputs and producing a result matrix.
- The **cv2.matchTemplate function in OpenCV** takes three parameters:
  - The input image that contains the object to be detected.
  - The template of the object.
  - The template matching method.
- The function returns a result matrix, where each element corresponds to a position in the target image and contains a value indicating the degree of similarity between the template and the content of the target image at that position.

Template Matching

Several comparison methods are implemented in OpenCV:

- TM_SQDIFF
- TM_CCORR
- TM_CCOEFF
- TM_SQDIFF_NORMED
- TM_CCORR_NORMED
- TM_CCOEFF_NORMED

Template Matching

- Several comparison methods are implemented in OpenCV:

- TM_SQDIFF $$R(x,y) = \sum_{x',y'} (T(x',y') - I(x+x',y+y'))^2$$

- TM_CCORR $$R(x,y) = \sum_{x',y'} (T(x',y') \cdot I(x+x',y+y'))$$

Cross-Correlation (TM_CCORR**) and its limitations:**

The result is highly dependent on the brightness and contrast of both the template and the image region. For example:

- A bright region in the image (e.g., a white patch) will produce a high correlation value, even if it doesn't match the template pattern.
- Variations in lighting or contrast between the template and image can lead to incorrect matches.

Template Matching

- There are also the **normalized** versions (that address some of the problems): https://docs.opencv.org/4.x/df/dfb/group__imgproc__object.html#ga586ebfb0a7fb604b35a23d85391329be
  - TM_SQDIFF_NORMED $$R(x,y) = \frac{\sum_{x',y'} (T(x',y') - I(x+x',y+y'))^2}{\sqrt{\sum_{x',y'} T(x',y')^2 \cdot \sum_{x',y'} I(x+x',y+y')^2}}$$
  - TM_CCORR_NORMED $$R(x,y) = \frac{\sum_{x',y'} (T(x',y') \cdot I(x+x',y+y'))}{\sqrt{\sum_{x',y'} T(x',y')^2 \cdot \sum_{x',y'} I(x+x',y+y')^2}}$$
- The results are scaled to a consistent range (e.g. 0 to 1), making it easier to compare different regions of an image or different templates.

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  - TM_SQDIFF_NORMED $$R(x,y)=\frac{\sum_{x',y'}(T(x',y')-I(x+x',y+y'))^2}{\sqrt{\sum_{x',y'}T(x',y')^2\cdot\sum_{x',y'}I(x+x',y+y')^2}}$$
  - TM_CCORR_NORMED $$R(x,y)=\frac{\sum_{x',y'}(T(x',y')\cdot I(x+x',y+y'))}{\sqrt{\sum_{x',y'}T(x',y')^2\cdot\sum_{x',y'}I(x+x',y+y')^2}}$$
- After the function finishes the comparison, the best matches can be found as global minimums (when **TM_SQDIFF** was used) or maximums (when **TM_CCORR** or **TM_CCOEFF** was used) using the **minMaxLoc** function.

Template Matching

- **The Correlation Coefficient (cv2.TM_CCOEFF / cv2.TM_CCOEFF_NORMED**) method calculates the correlation coefficient between the template and the target image.

- A higher value indicates a better match. This method matches a template relative to its mean against the image relative to its mean. Therefore, a perfect match will be 1, and a perfect mismatch will be -1.

TM_CCOEFF
Python: cv.TM_CCOEFF

$$R(x,y) = \sum_{x',y'} (T'(x',y') \cdot I'(x+x',y+y'))$$

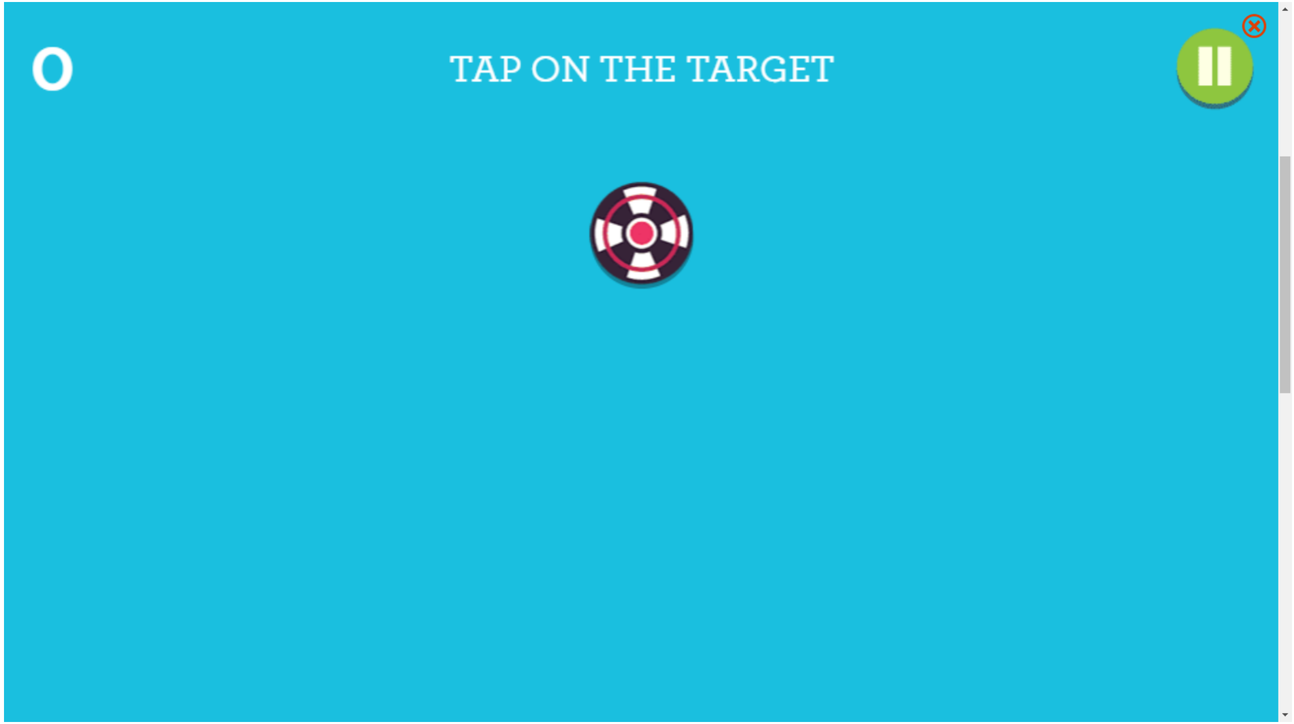
where

$$T'(x',y') = T(x',y') - 1/(w \cdot h) \cdot \sum_{x'',y''} T(x'',y'')$$
$$I'(x+x',y+y') = I(x+x',y+y') - 1/(w \cdot h) \cdot \sum_{x'',y''} I(x+x'',y+y'')$$

TM_CCOEFF_NORMED
Python: cv.TM_CCOEFF_NORMED

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

Template Matching



https://www.addictinggames.com/shooting/dart-master

Template Matching

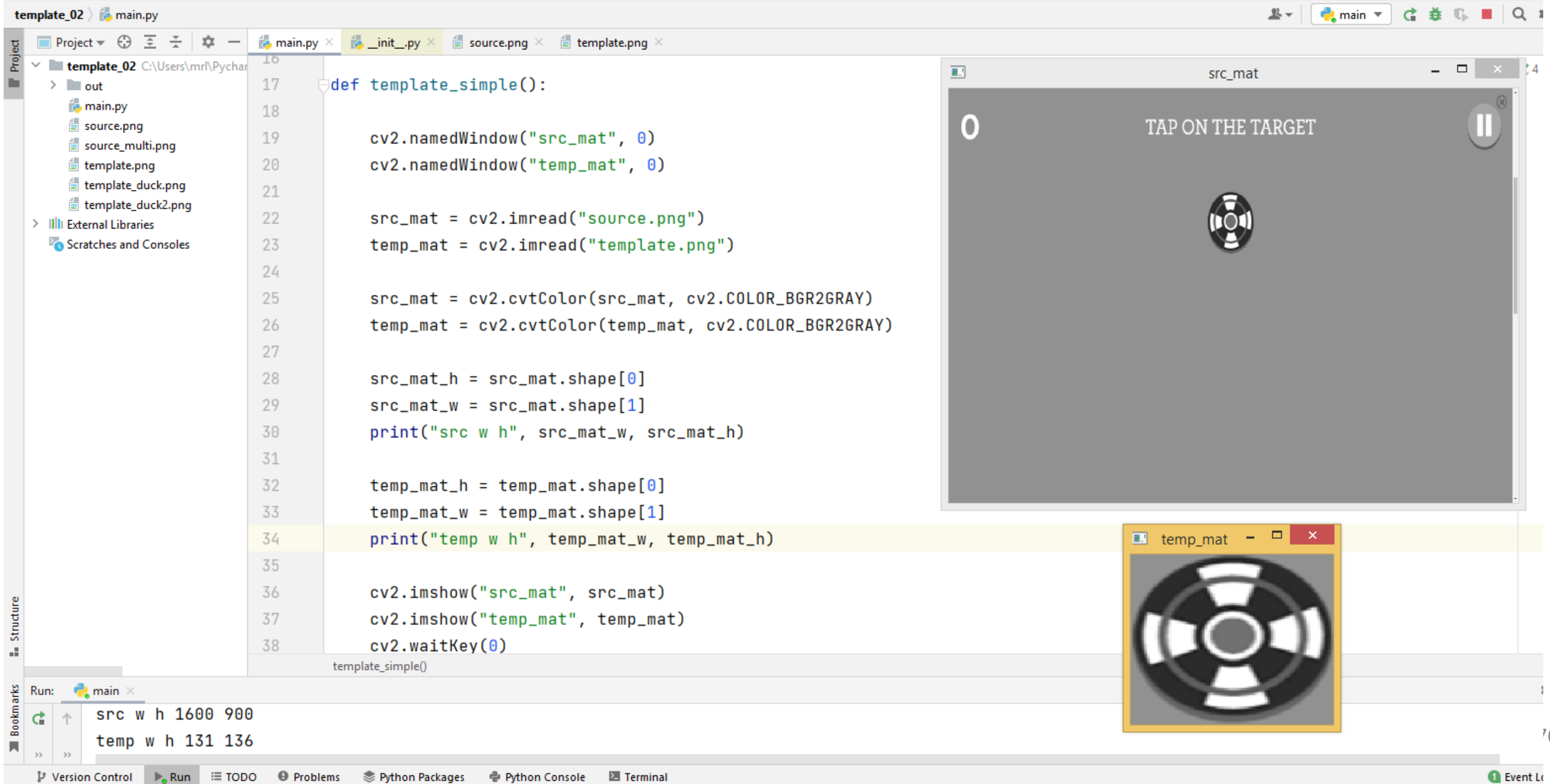
TM_SQDIFF_NORMED

Template Matching

TM_CCORR_NORMED

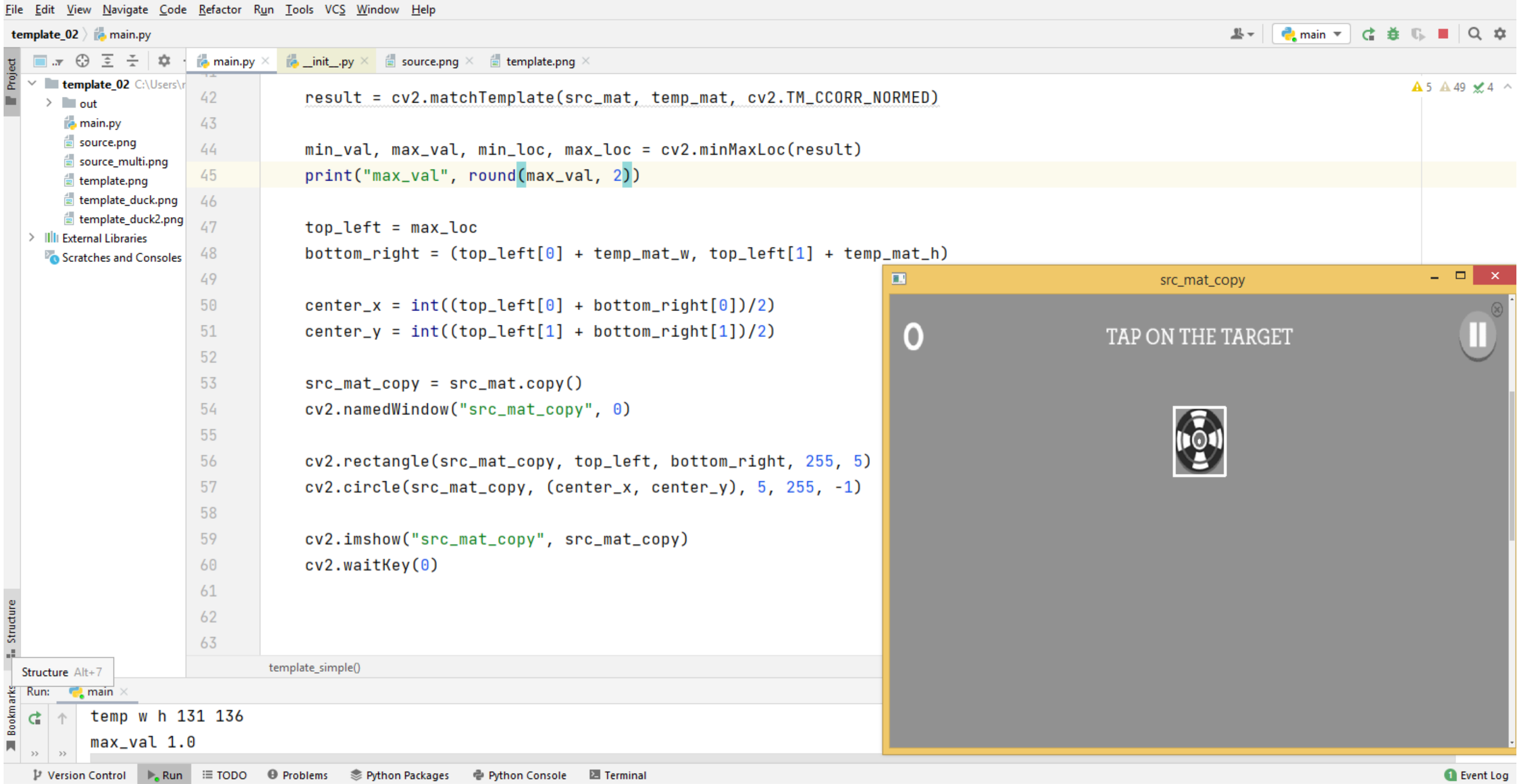
Template Matching

- Example – preparing phase:



Template Matching

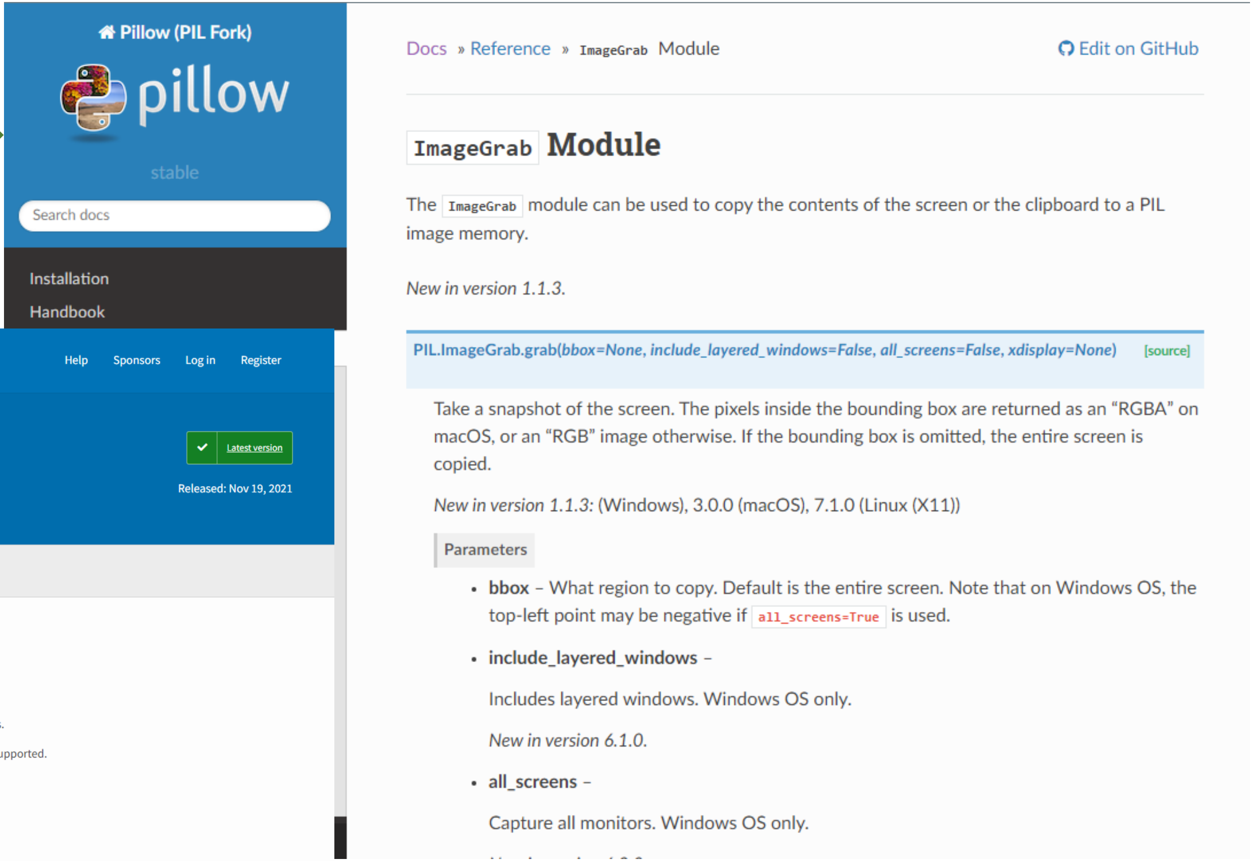
- Example – localization phase:

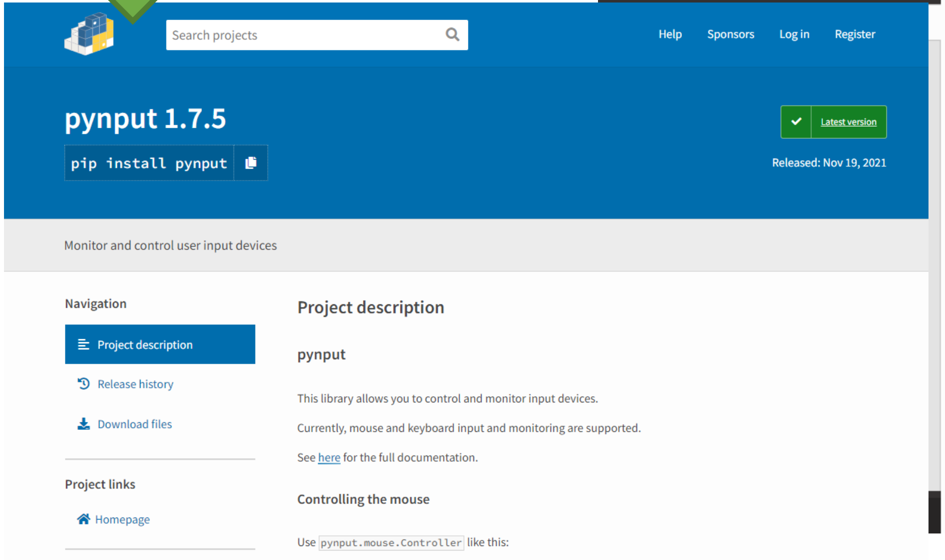


Template Matching

- taking screenshots :

```
import cv2
from PIL import ImageGrab
import numpy as np
from pynput.mouse import Button, Controller
```





Template Matching

- Save screenshot for creating the template :

```
def simple_capture():

    image_grab = ImageGrab.grab(bbox=None)  # x, y, w, h
    screen_mat = np.array(image_grab)

    screen_mat_h = screen_mat.shape[0]
    screen_mat_w = screen_mat.shape[1]
    print("screen_mat w h", screen_mat_w, screen_mat_h)

    screen_mat = cv2.cvtColor(screen_mat, cv2.COLOR_BGR2GRAY)
    cv2.imwrite("screen.jpg", screen_mat)
```

Template Matching

- pynput example :

```python
import cv2 as cv
import numpy as np
from PIL import ImageGrab
from pynput.mouse import Button, Controller
import time

mouse = Controller()
n_frame = 0
x=21
y=648
while(True):
    image_grab = ImageGrab.grab(bbox=None)
    image_grab_np = np.array(image_grab)
    cv.imwrite(f"out/{n_frame}.jpg", image_grab_np)
    print('The current pointer position is {0}'.format(mouse.position))
    mouse.position = (x, y)
    mouse.press(Button.left)
    mouse.release(Button.left)
    n_frame += 1
    time.sleep(5)
```