TRANSLATION STAGE CONTROL

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TOPICS

01
About Internship project

Translation stage control project is a mini project that part of EvWaCo project from NARIT.

Evanescent Wave Coronagraph or EvWaCo is project that study optical instruments for study about binary star system or exoplanetary system . EvWaCo aim to develop optical instruments for separate light from bright star to observe the companion star

The main idea of translation stage control project is control translation stage moving light source along horizontal axis to make the light source closest align to imaging system for get high quality image by using PID closed loop control .

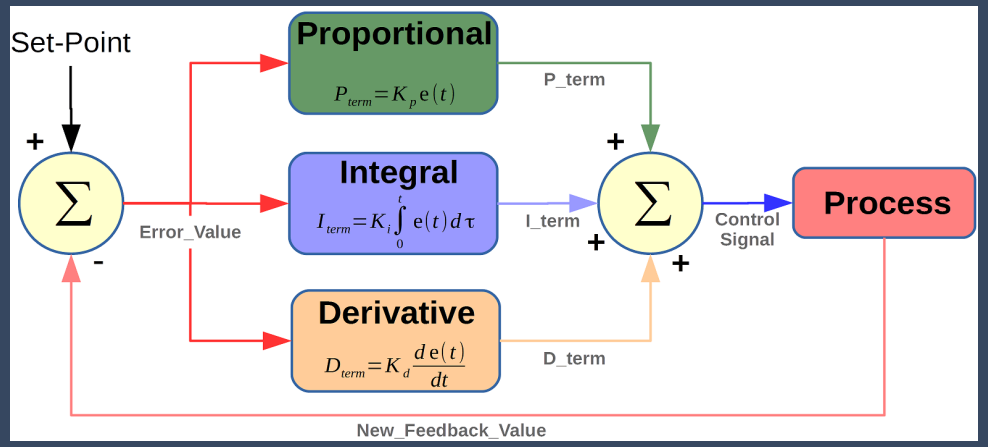
Why we use PID Control ?

- Stability and Responsiveness : The D term dampens oscillations, while the I term corrects steady-state errors, leading to a more stable system.
- Improved Accuracy : The I term ensures the system output matches the desired setpoint more precisely.
- Flexibility : PID provides three tunable parameters (Kp, Ki, Kd) to optimize performance for different systems and dynamic behaviors.

In summary, PID control offers balanced error management, enhancing stability, accuracy, and responsiveness over pure error control.

PID CONTROLLER

- Stands for "Proportional, Integral, Derivative" .
- It is closed-loop feedback control .
- instrument used by control engineers to regulate temperature, flow, pressure, speed, and other process variables in industrial control systems.



https://microcontrollerslab.com/pid-controller-implementation-using-arduino/

PID CONTROLLER

P : Proportional

- tuning -> correcting a target proportional to the difference
- based on the current error (setpoint - measured output of the system)

I : Integral

- tuning -> cumulating the error result from the "P" action to increase the correction factor
- Increase -> increases the contribution of the accumulated error over time to the control signal

D : Derivative

- tuning -> minimize overshoot by slowing the correction factor
- reduce the rate of change of the error
- helps improve the stability and responsiveness of the control loop

PID CONTROLLER

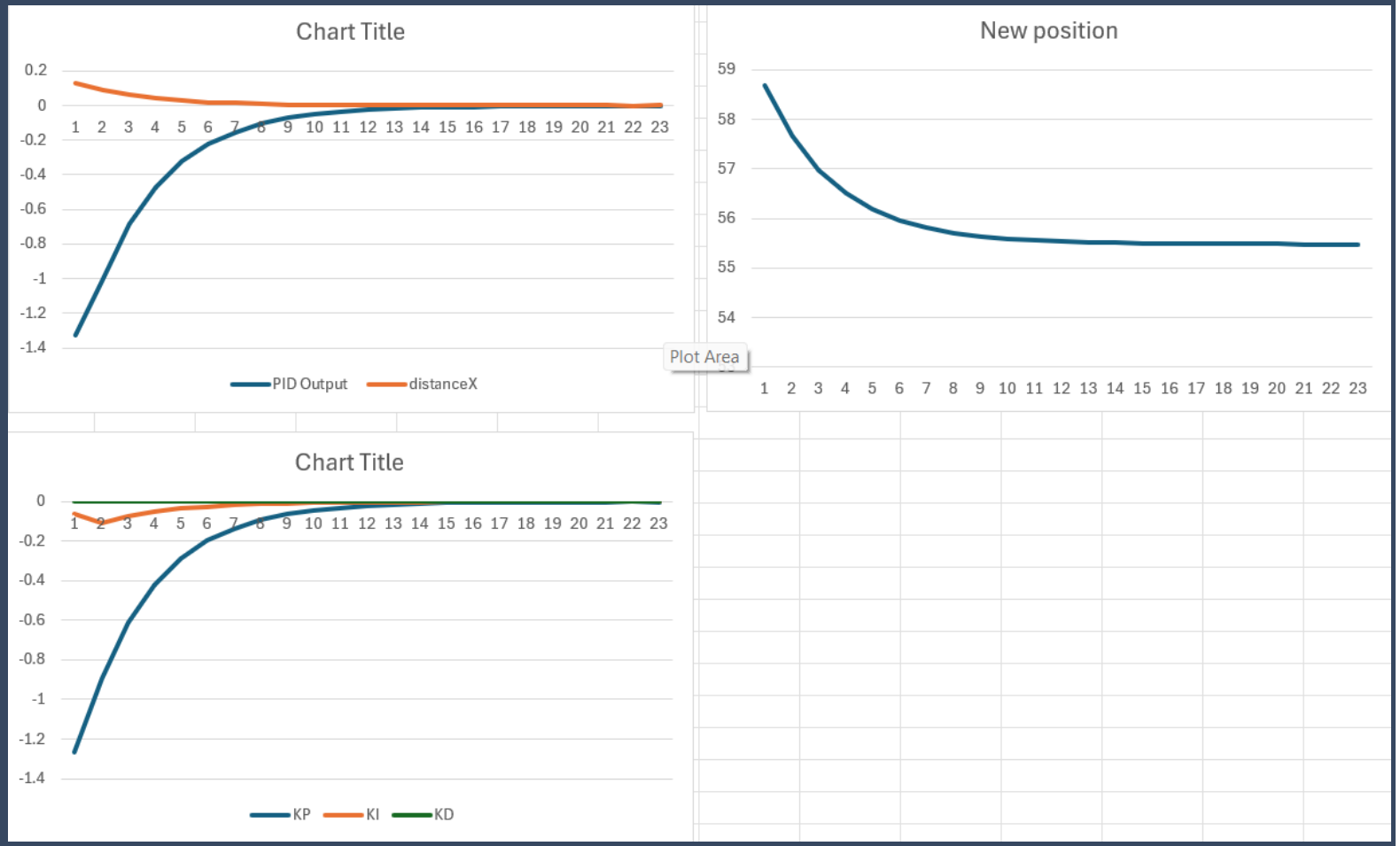
P Controller

- Use only error term to affect the output
- simply multiply e(t) * Kp
- provides a linear relationship between the error of a system and the controller output of the system

PID CONTROLLER

PI Controller

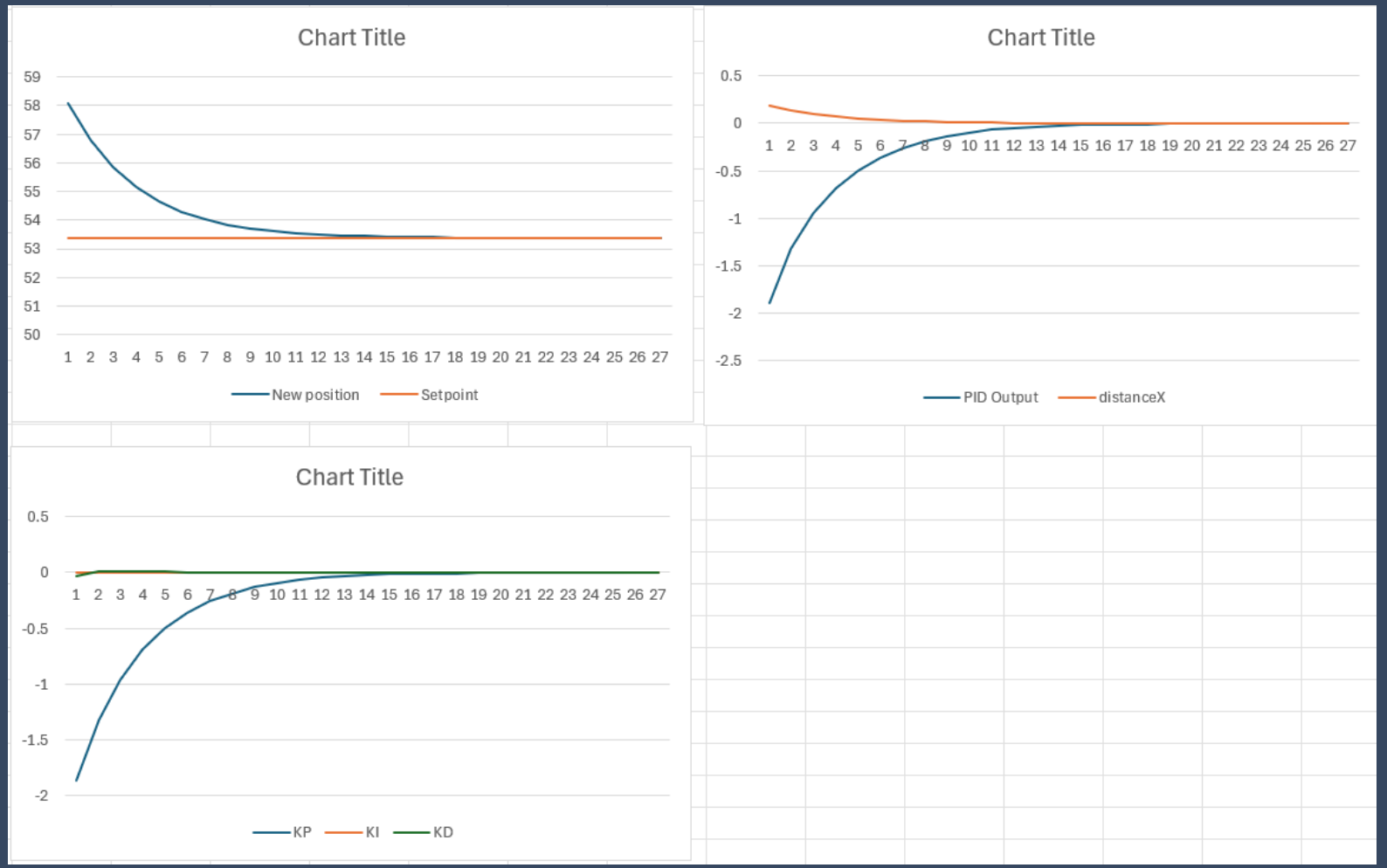
- a combination of Proportional controller action and Integral controller action
- correlates the controller output to the error and the integral of the error.
  provides a faster response time than I-only control
- Eliminates steady state error



PID CONTROLLER

PD Controller

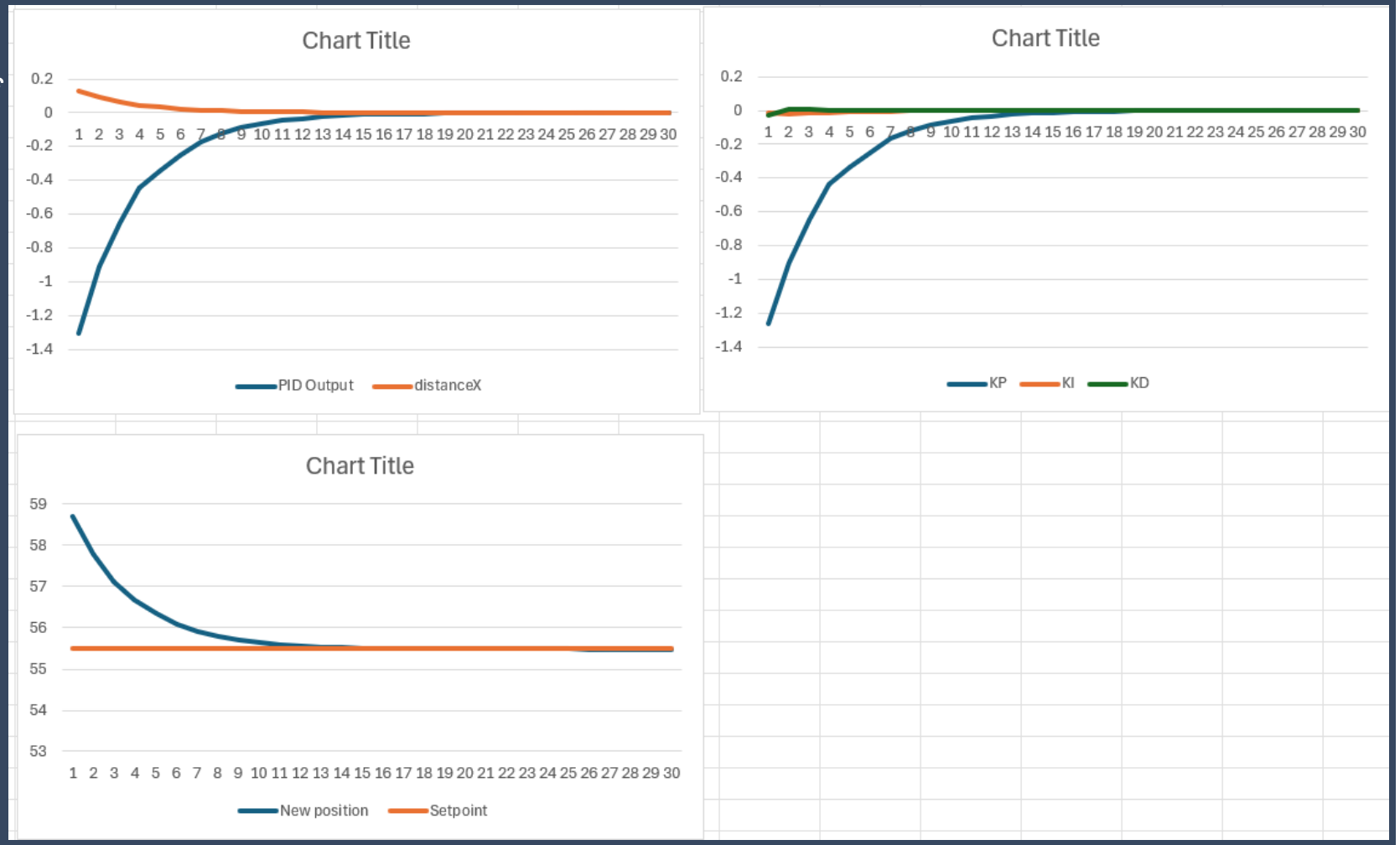
- combination of feedforward and feedback control
- contains – proportional control's damping of the fluctuation
  – derivative control's prediction of process error output
- Improves transient response, reduces overshoot



PID CONTROLLER

PID Controller

- a combination of all three types of control methods
- most commonly used
- balances steady state and transient response



02
Get to know instruments

INSTRUMENTS

Mainly focus on

- KDC101 -> Controller for control DDS100/M
- DDS100/m -> One axis translation Stage
- ASI1600mm PRO -> Camera for capture images

KDC101

chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://optomechs.com/pdf/manuals/KDC101/KDC101_ManualforKinesis.pdf

DDS100/M

https://www.thorlabs.com/thorproduct.cfm?partnumber=DDS100/M

ASI1600mm PRO

https://telescopes.net/zwo-asi1600mm-pro-monochrome-cmos-camera.html

Optical components

- Light source
- Mirrors
- lens

1. Find error of translation stage

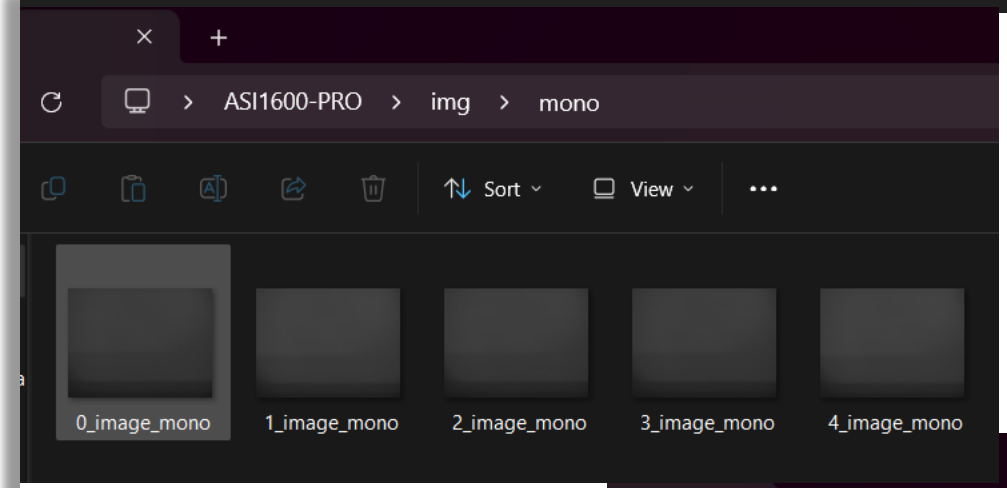
```
print("Homing Device...")
kcube.Home(60000)  # 60 second timeout
print("Device Homed")

for i in range (10) :
    kcube.MoveTo(Decimal(10.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(20.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(30.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(40.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(50.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(60.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(70.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(80.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(90.0), 60000)
    print(f'{kcube.Position}')
    kcube.MoveTo(Decimal(0.0), 60000)
    print(f'{kcube.Position}')
kcube.Home(60000)
print("Finished")
```

	10mm	20mm	30mm	40 mm	50mm	60mm	70mm	60mm	90mm	
	10.0085	20.001	30.011	40.0015	50.008	60.001	70.008	80.001	90.006	
#1	9.999	20.0095	30.001	40.0055	50.001	60.007	70.001	80.0045	90.001	
#2	9.994	20.001	30.0085	40.0015	50.009	60.0005	70.0085	80.001	90.009	
#3	9.999	20.008	30.0015	40.0085	50.001	60.0105	70.001	80.0075	90.001	error = 0.01 - 0.05
#4	9.9935	20.001	30.005	40.001	50.0075	60.001	70.006	80.001	90.0065	
#5	9.999	20.0055	30.001	40.004	50.001	60.0085	70.001	80.0055	90.001	
#6	9.9945	20.001	30.008	40.0015	50.001	60.004	70.001	80.007	90.001	
#7	9.999	20.0095	30.001	40.0045	50.001	60.0085	70.001	80.001	90.005	
#8	9.999	20.001	30.0095	40.001	50.007	60.001	70.006	80.001	90.004	
#9	9.999	20.0075	30.001	40.0055	50.001	60.005	70.001	80.0075	90.001	
Total	99.9845	200.045	300.0475	400.0345	500.0375	600.047	700.0345	800.037	900.0355	
Calculated	0.0155	-0.0450	-0.0475	-0.0345	-0.0375	-0.0470	-0.0345	-0.0370	-0.0355	

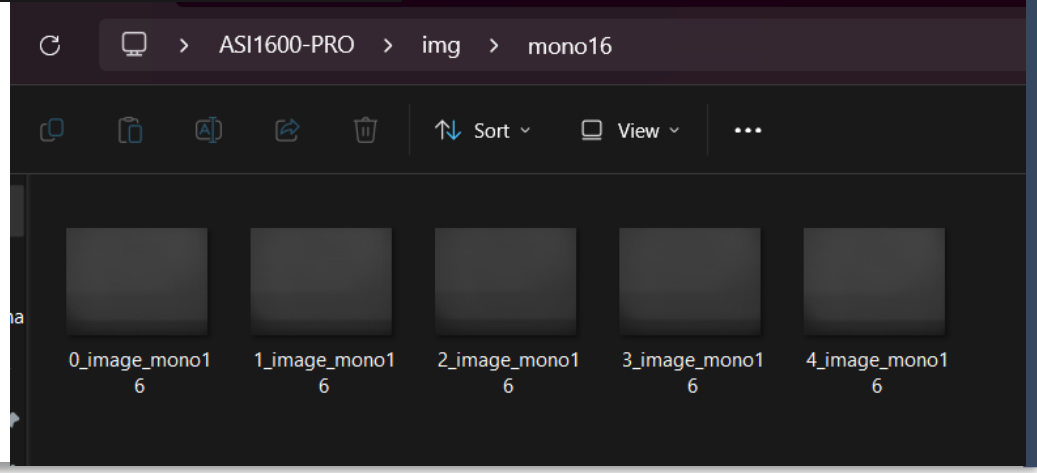
- Moving translation stage into steps for find error of stage .
- Home position can't change.
- Home position is 0.0000 .
- Error of translation stage is ***0.0100 – 0.0500*** .

2. Capture image from camera

```
save_path_mono = r"C:\Users\Asus\Desktop\ASI1600-PRO\img\mono\\"
save_path_mono16 = r"C:\Users\Asus\Desktop\ASI1600-PRO\img\mono16\\"
asi.init('C:\\Users\\Asus\\AppData\\Local\\Programs\\Python\\Python310\\Lib\\ASI SDK\\lib\\x64\\ASICamera2.lib')
```

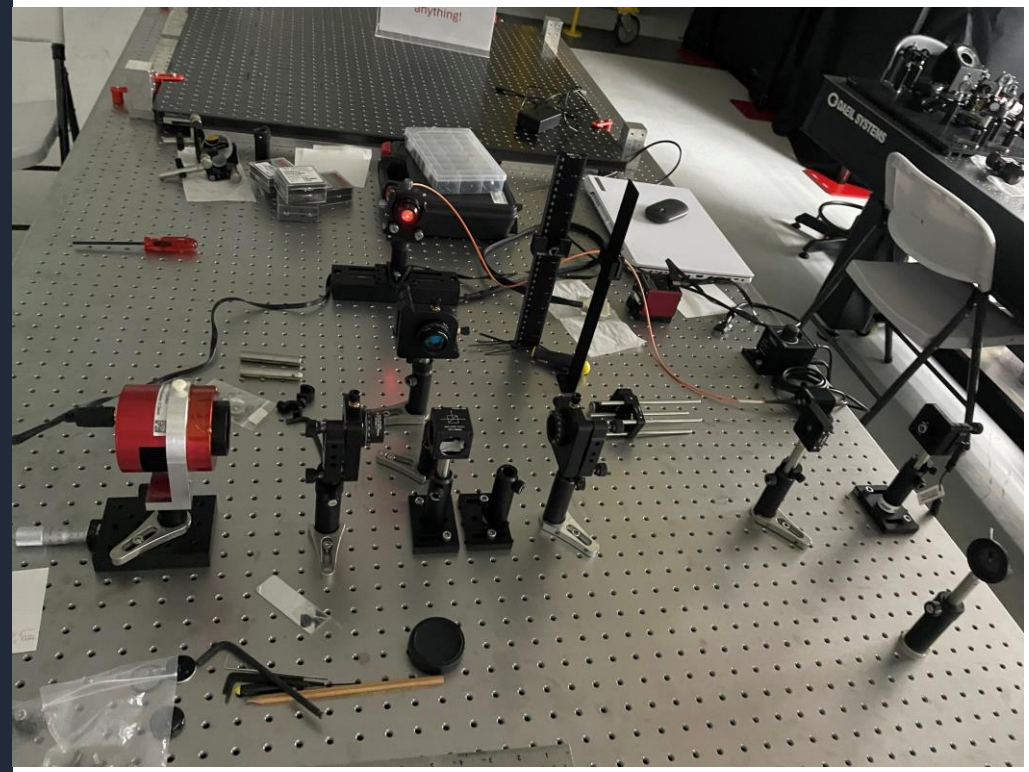


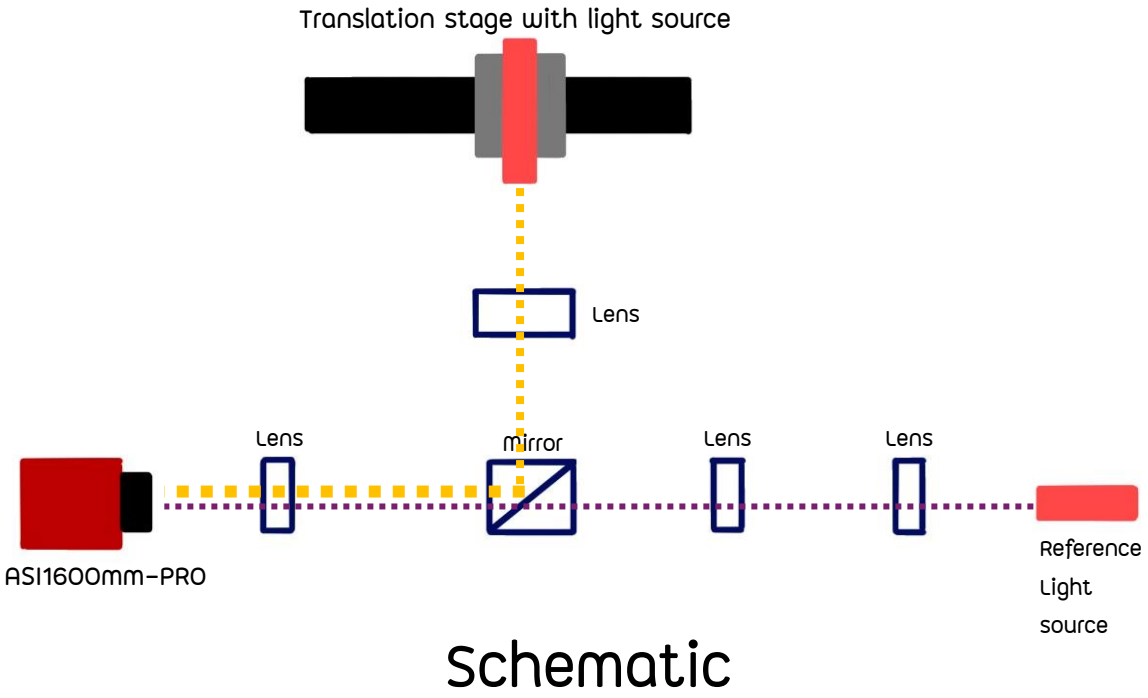
https://www.tecnosky.eu/index.php/zwo-asi-1600mm-pro-usb-3-0-cooled-mono.html



Try capture some image from ASI1600-PRO Camera and save images into .jpg for MONO8 and .tiff file. For MONO16

SETUP



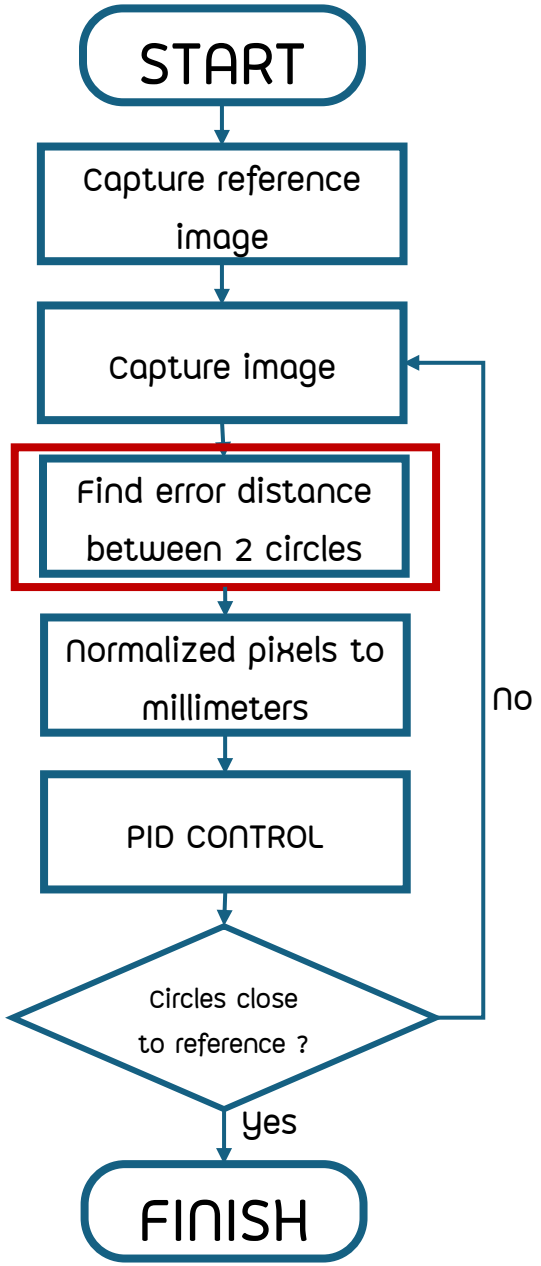


Schematic

03
Find Solution

WORKFLOW

Focus on



Mainly focus on

- Find distance between 2 circles
- Find solution of overlapped circles condition

3. Find center coordinates and distance of circle

METHOD 1

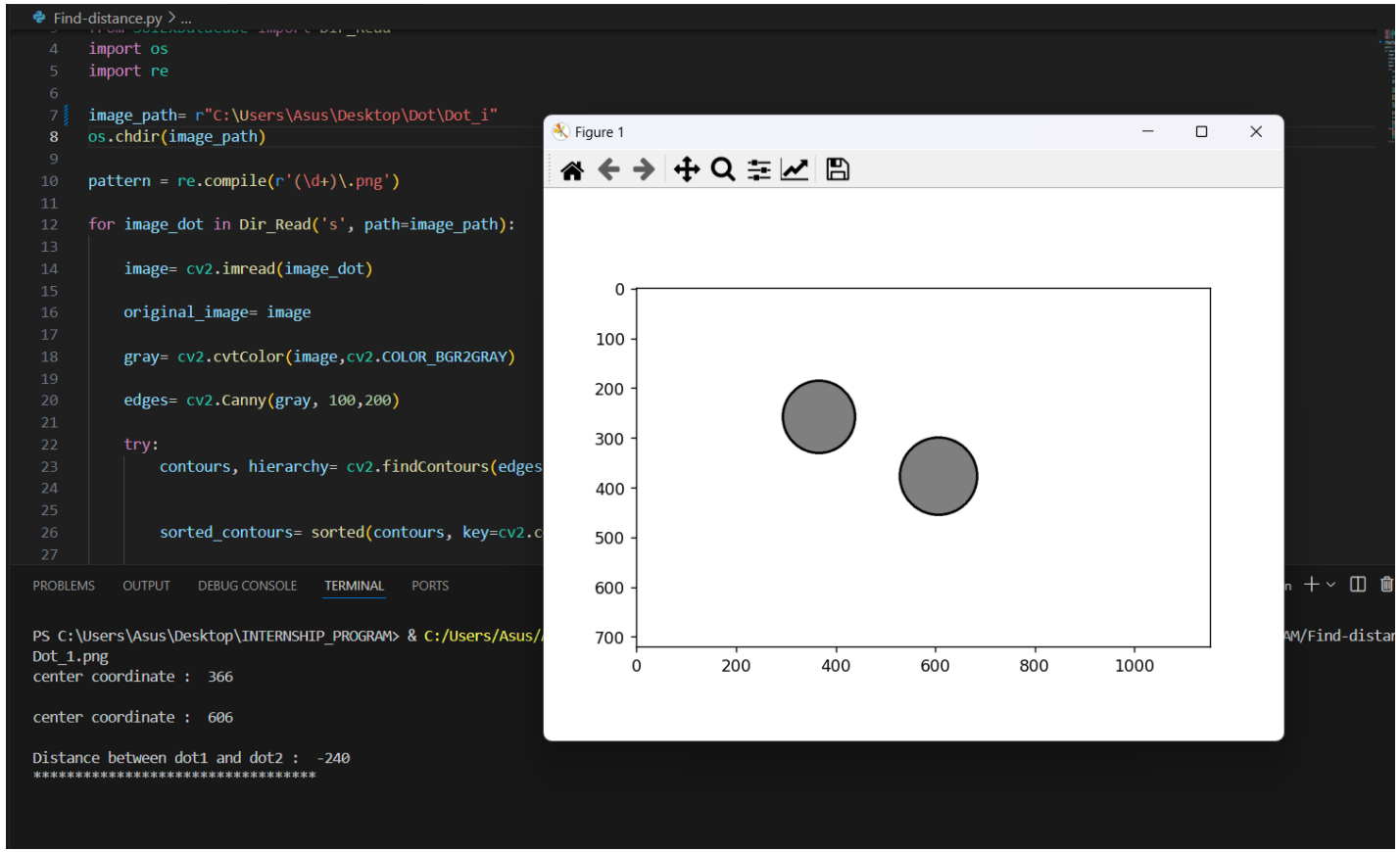
1. Find center coordinates of circle by

- Using OpenCV for find edge , contour area and coordinate of center point.
- Use Matplotlib for plot circle.

2. Find distance between 2 circle by

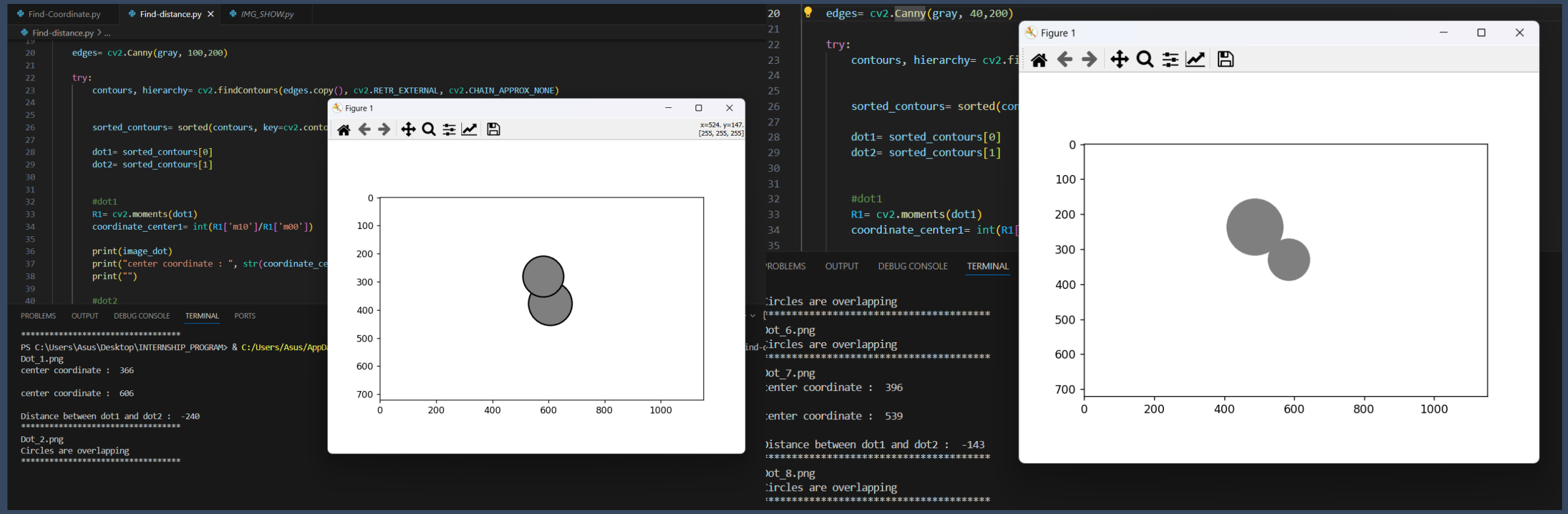
1.Find coordinate of center of 2 circles

2.Subtrac coordinate of center of 2 circles



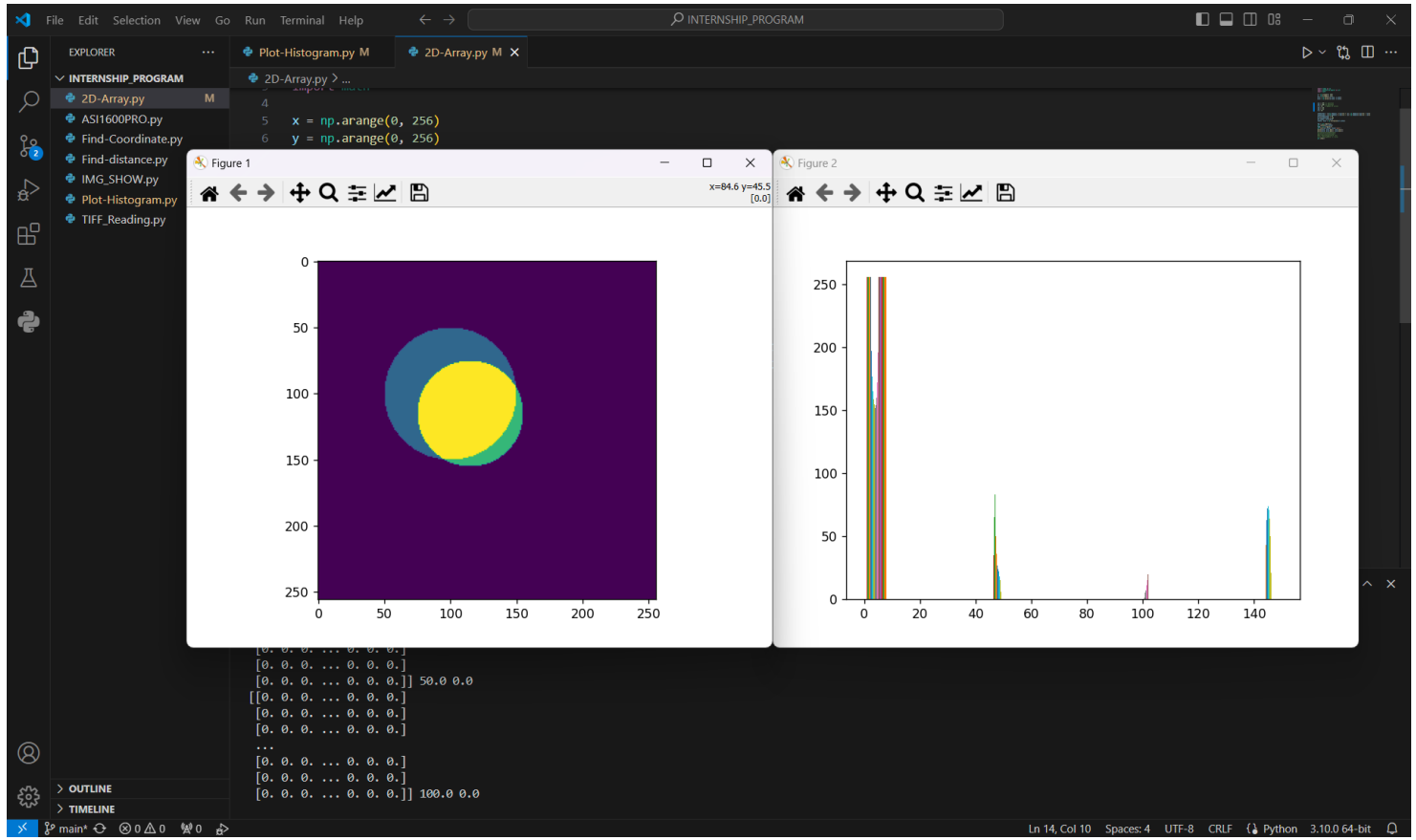
3. Find center coordinates and distance of circle

METHOD 1



Can't use this condition with image that has 2 circles that are overlapping

3. Find center coordinates and distance of circle

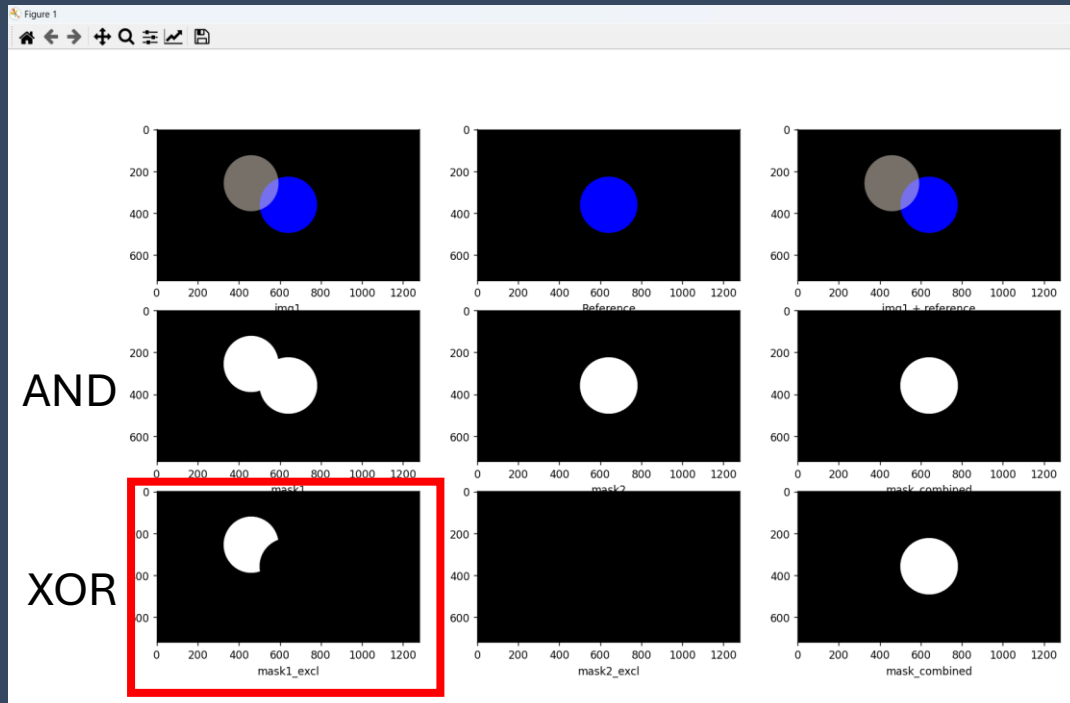


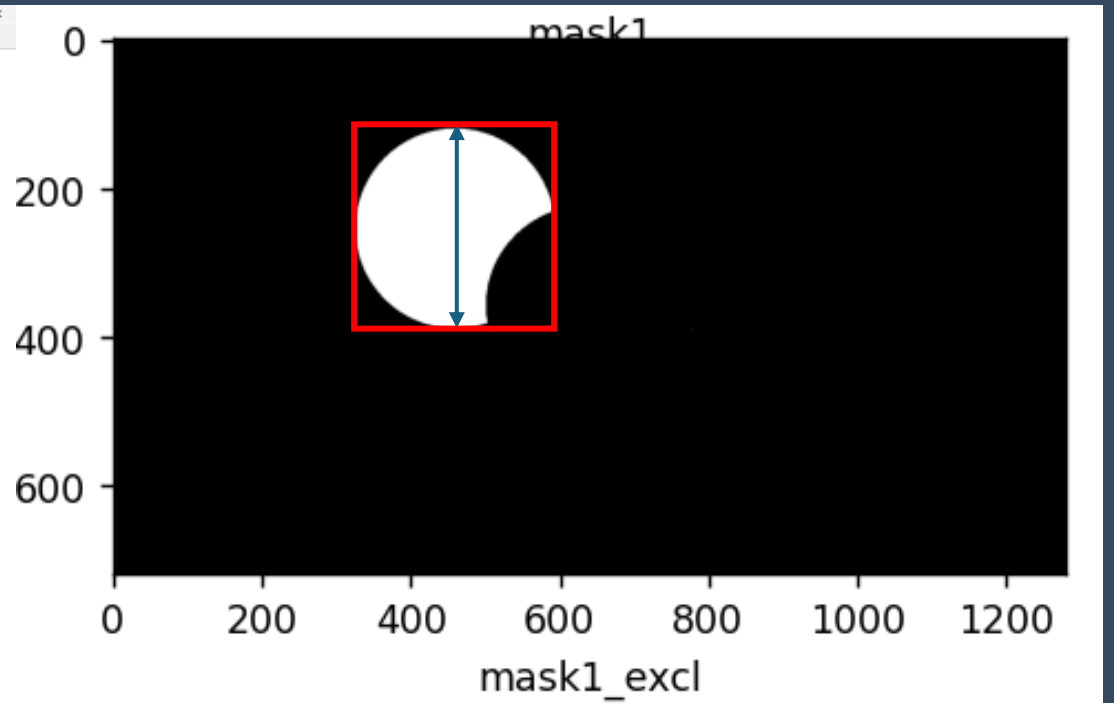
- Coding program for draw and plot circles from circle formula .
- Initialize as 2D array .
- Plot histogram for see intensity of circle

This code works for overlapped circle condition .

METHOD 3

3. Find center coordinates and distance of circle



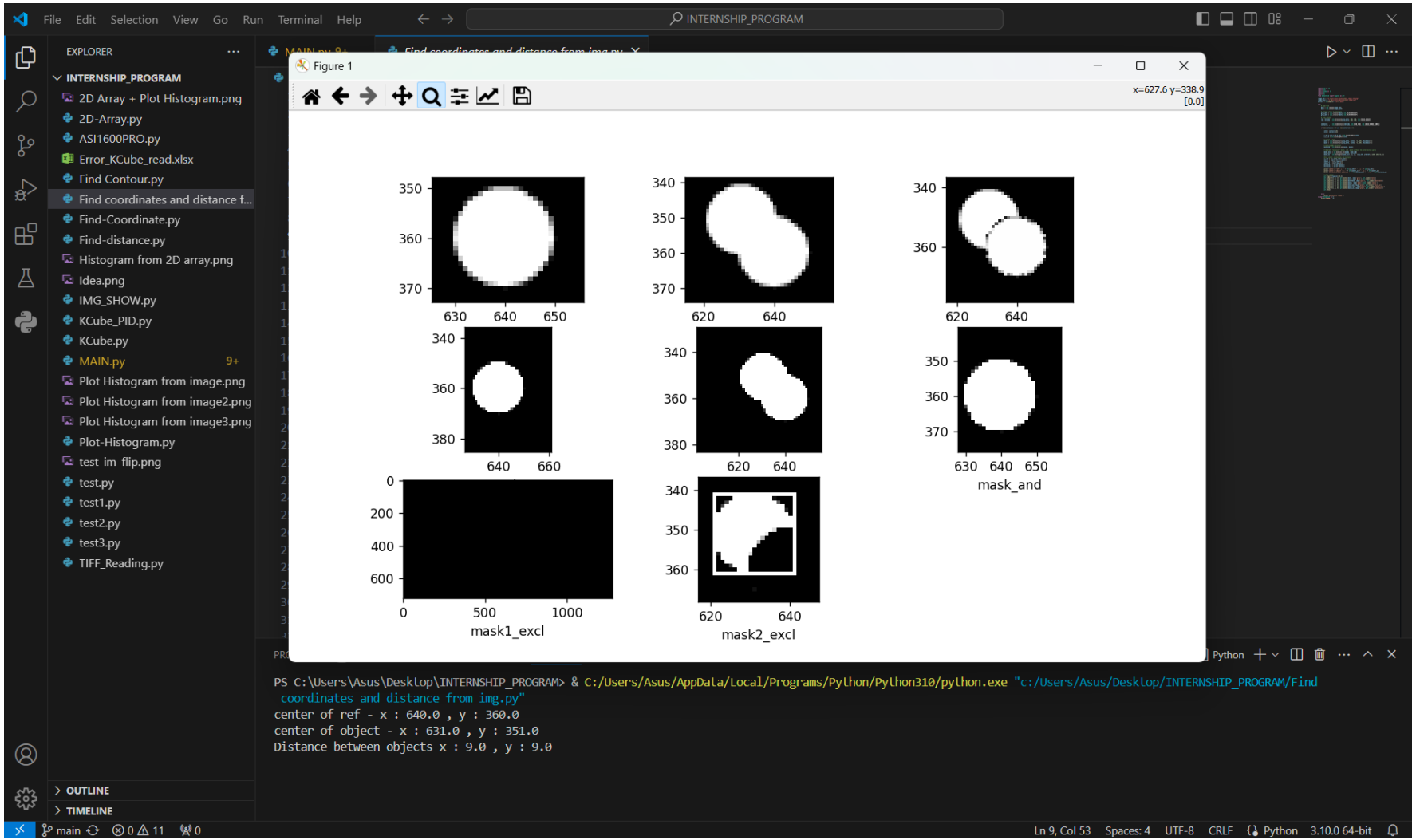


Main idea of this concept is

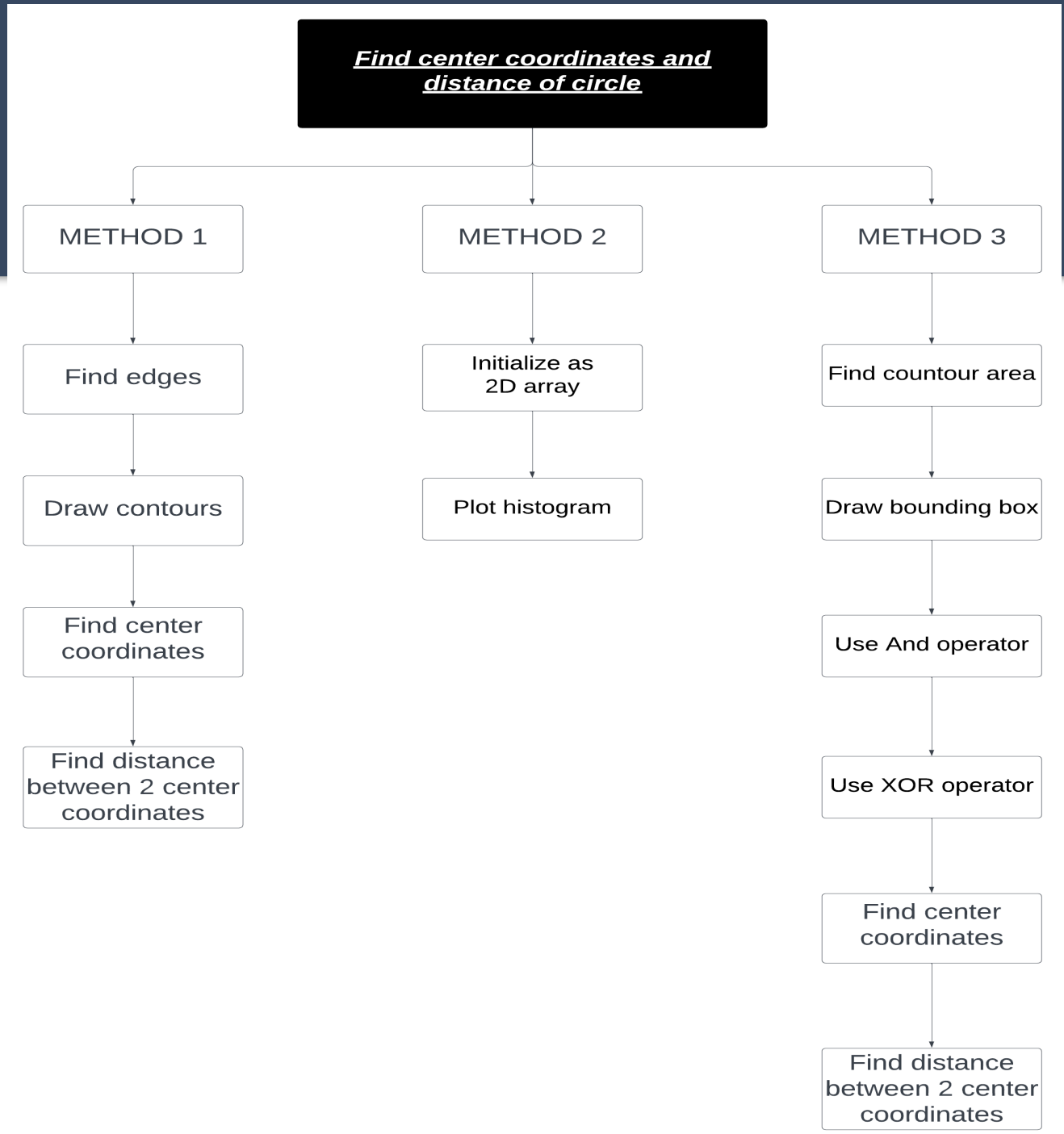
Use bitwise operation (AND , XOR) for find contour area that not overlapping. Then draw bounding box around the area then find height and width then calculate center of the area from height and width. Then find distance between 2 center point.

METHOD 3

3. Find center coordinates and distance of circle



OVERVIEW MAP



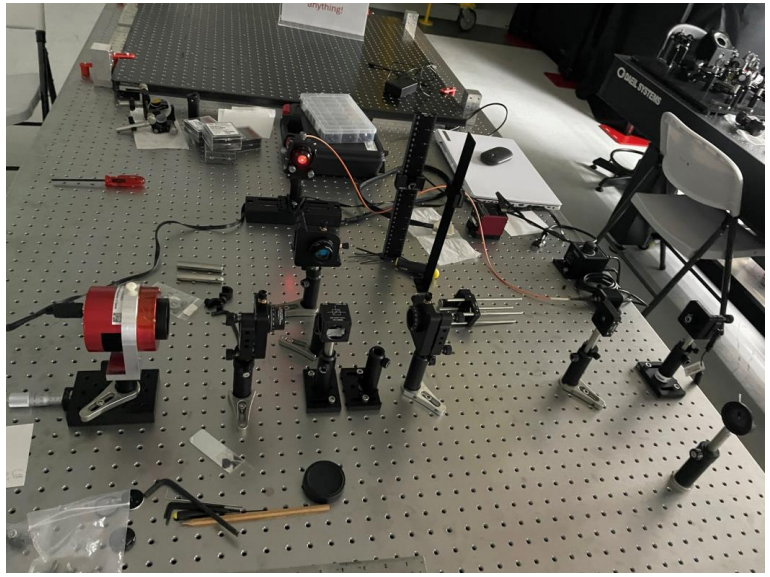
METHODS	ADVENTAGES	DISVENTAGES
METHOD 1	Easy for operate	Can't use this method with overlapped images
METHOD 2	Can use this method with overlapped images	Can't find distance between 2 images.
METHOD 3	Can use this method with overlapped images	Take more time to process

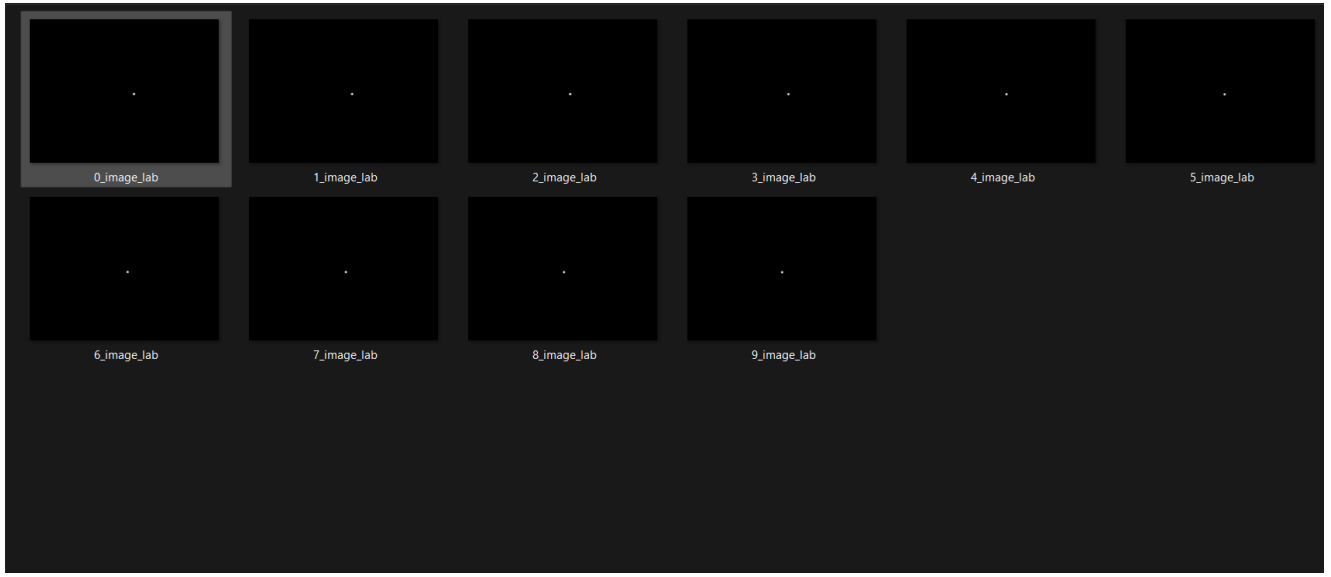
```
-------------------------------------------------
center of ref - x : 2253.0 , y : 1672.5
center of object - x : 2341.0 , y : 1861.5
Distance between objects - x : -88.0 , y : -189.0
--------------------Normalize--------------------
CX_ref =  8.5614
CY_ref =  6.3555
center_x =  8.8958
center_Y =  7.0737
disX =  -0.3344
disY =  -0.7182
-------------------------------------------------
```

Normalized data from pixel to mm.

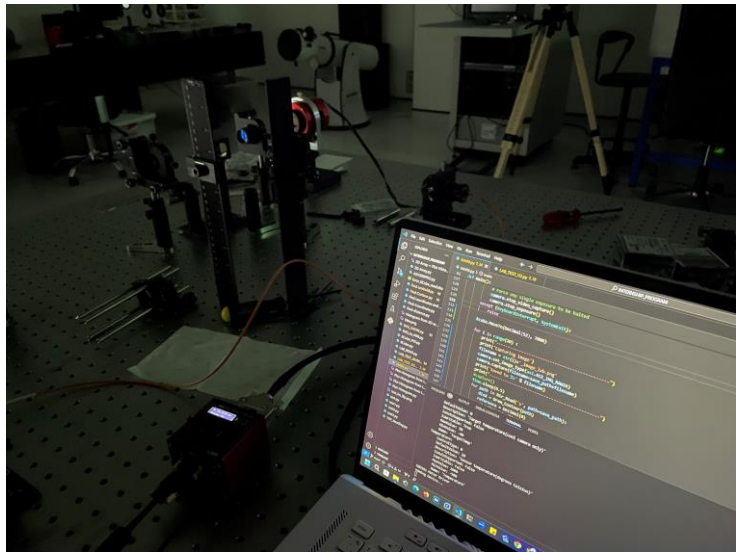
04
Experiment & Application

EXPERIMENT





Test code in lab with method 3 as solution for collect real data and find error of process of code when run in real situation.



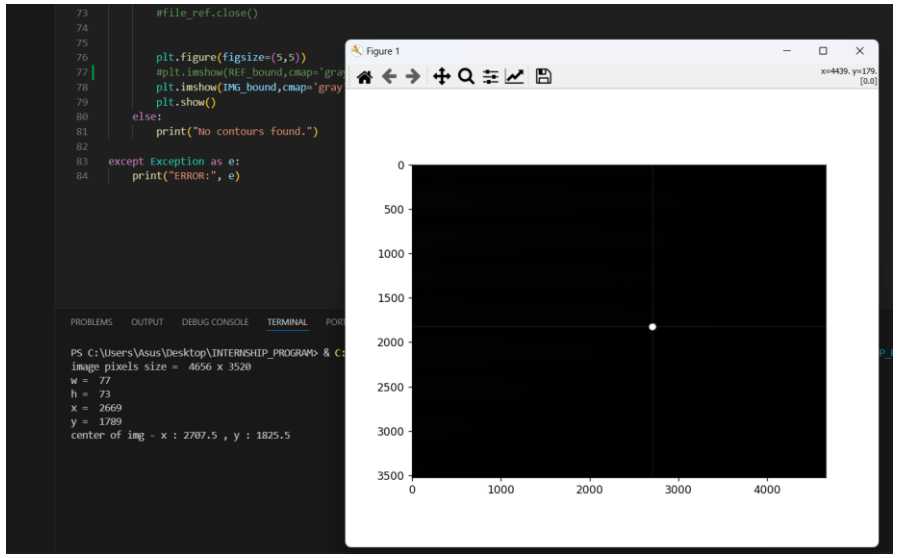
EXPERIMENT

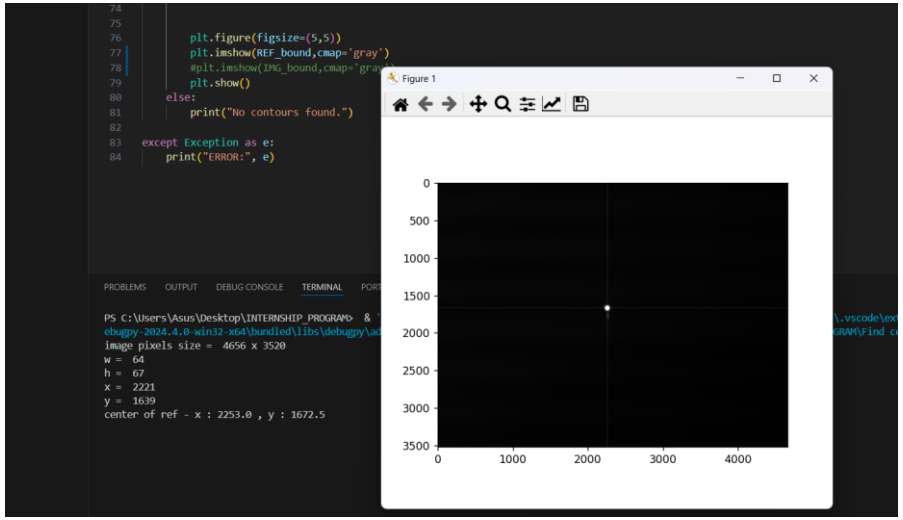
PROBLEM : Have only one light source so it can't see 2 dot in one image at the same time.

Solution

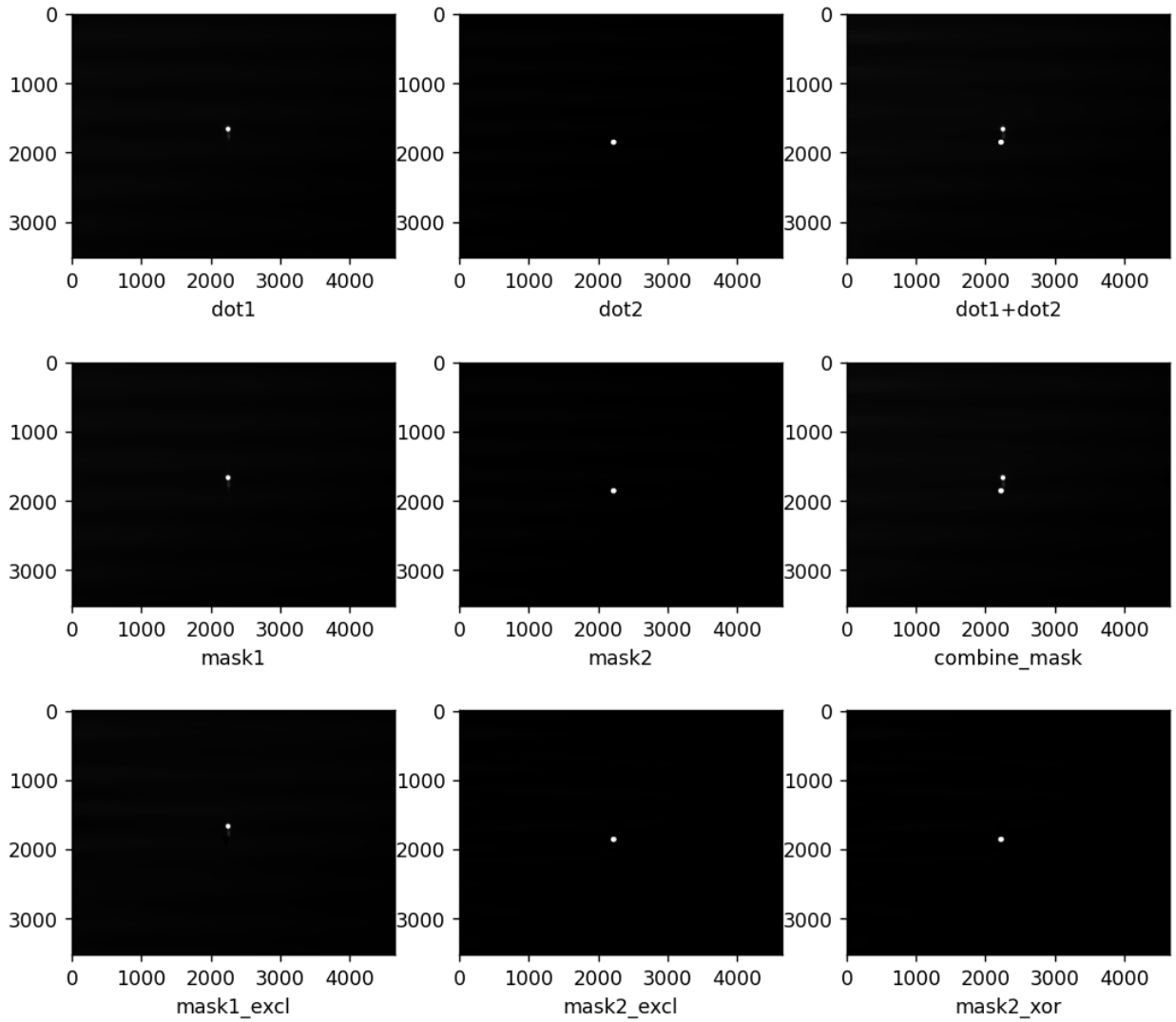
- Find centroid and position of dot both in reference image and collected image.
- Compare position of current image with reference image.

(Still use bitwise operation method in code for overlapped condition)





EXPERIMENT


dot1
dot2
dot1+dot2
mask1
mask2
combine_mask
mask1_excl
mask2_excl
mask2_xor

PROBLEM : Program doesn't read current images that had capture . It's read and overwrite old images in directory instead .

Solution : Coding new program that has infinity loop and can read images from current images .

```
reference = Decimal(0)
for path in Dir_Read('s'):
    print("-------------------------------------------")
    print('Capturing image')

    if i < 10:
        filename = '00'+ str(i)+'_image_lab.png'
    else:
        filename = '0'+ str(i)+'_image_lab.png'
    camera.set_image_type(asi.ASI_IMG_RAW16)
    camera.capture(filename=save_path+filename)
    print('Saved to %s' % filename)
    print("-------------------------------------------")
    #capture()
    time.sleep(0.5)
    disX = Draw_Contour(path)

    err = PID(Decimal(1) , Decimal(0.08), Decimal(0.01) , reference , Decimal(disX))

    print("Error : " + str(err))
    if err > reference :
        new_position = pos-err
        kcube.MoveTo(new_position, 7000)
        print("New_position : " + str(new_position)   )
    elif err < reference:
        new_position = pos+err
        kcube.MoveTo(new_position, 7000)
        print("New_position : " + str(new_position)    )
    elif  err == reference:
        break
    time.sleep(0.5)
    error.append(disX)

    plt.plot(error)
    plt.gca().invert_yaxis()
    plt.show()
    i = i+1
```

Problem and solution 3

PROBLEM : Program read and draw wrong contour area . It's read the random tiny pixels instead of the real reference pixels . So, it's effect to calculate distance between current pixels and reference pixels.

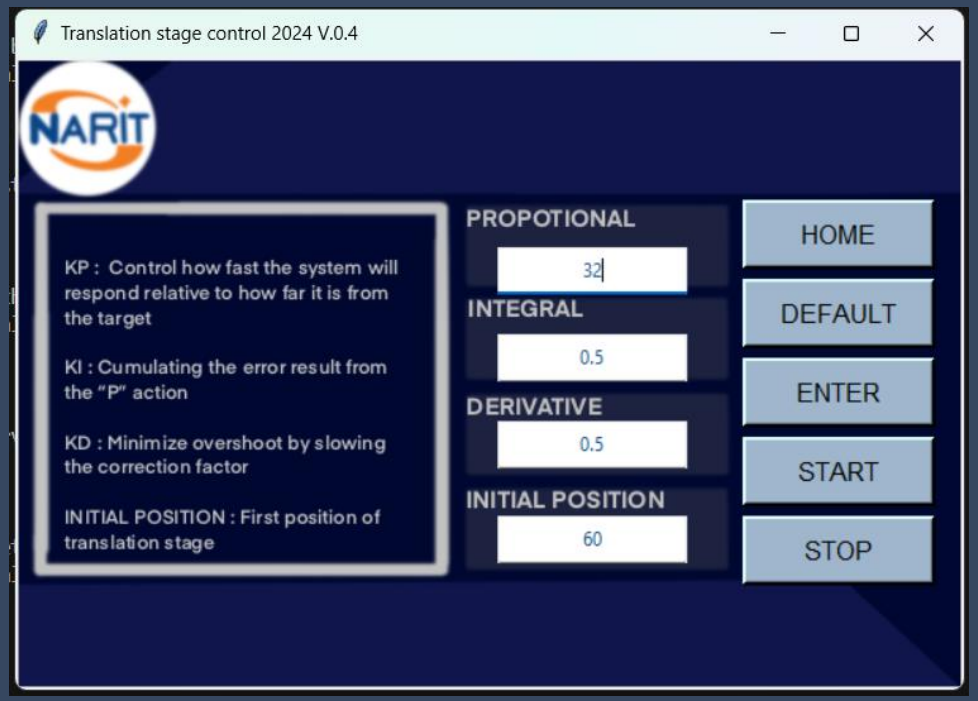
```
image pixels size =  4656 x 3520
w_ref =  1
h_ref =  1
x_ref =  894
y_ref =  3519
w =  1
h =  1
x =  2524
y =  1937
-----------------------------------------------
center of ref - x : 894.5 , y : 3519.5
center of object - x : 2524.5 , y : 1937.5
Distance between objects - x : -1630.0 , y : 1582.0
```

Solution : Add max(contours1, key=cv2.contourArea) to find and draw the biggest contour as reference pixels .

```
if len(contours1) > 0 and len(contours2) > 0:
    cnt1 = max(contours1, key=cv2.contourArea)
    cnt2 = contours2[0]

    x_ref,y_ref,w_ref,h_ref = cv2.boundingRect(cnt1)
    x,y,w,h = cv2.boundingRect(cnt2)
```

```
w_ref =  87
h_ref =  76
x_ref =  2495
y_ref =  1622
w =  60
h =  65
x =  1628
y =  1869
-----------------------------------------------
center of ref - x : 2538.5
center of object - x : 1671.5
Distance between objects - x : 867.0
```

Application have 2 versions



UI Version

```
        DefaultValue: 20
        Description: 'Sensor temperature(degrees Celsius)'
        IsAutoSupported: False
        IsWritable: False
        MaxValue: 1000
        MinValue: -500
        Name: 'Temperature'
Do you want to change paramter ? (Y/N) : Y
Please enter kp value : 34
Please enter ki value : 2
Please enter kd value : 0.2
Please enter first position : 70
```

Command line Version

Application

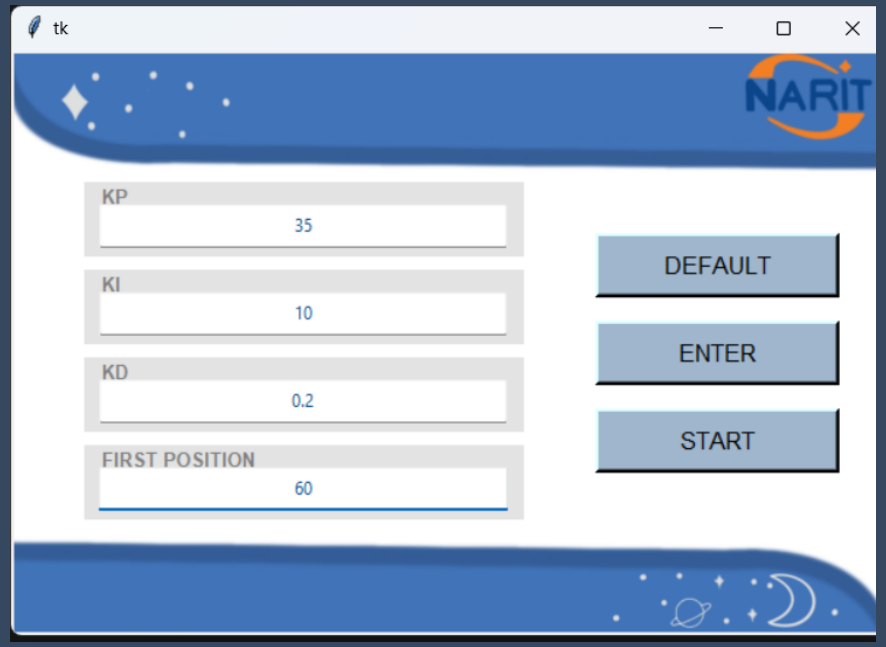
- Command line version for users.

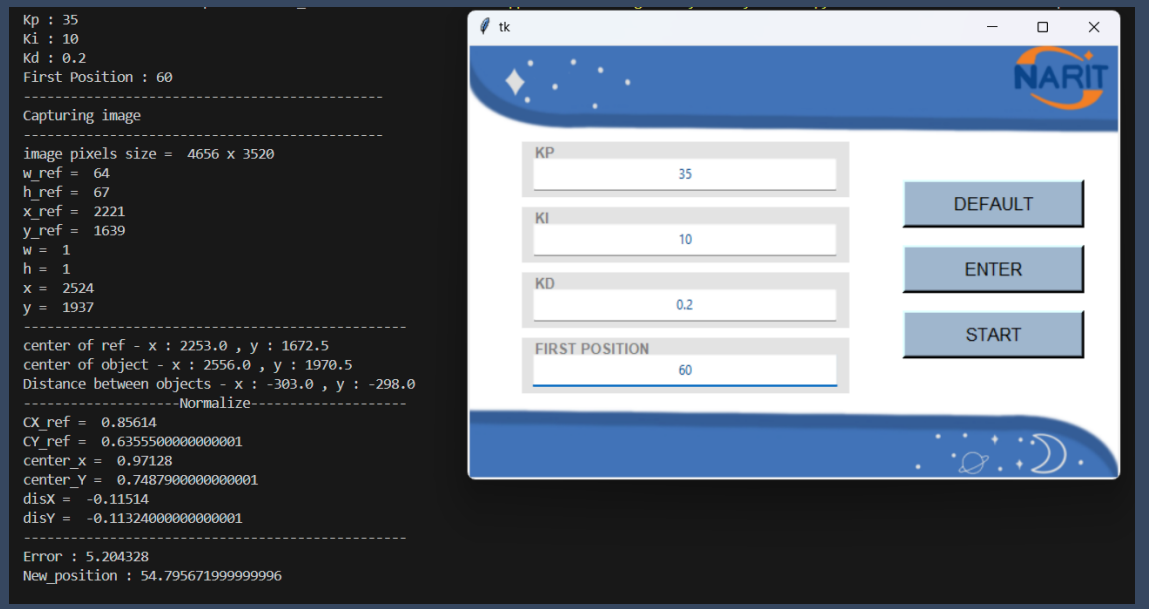
```
135  def main() :
136      try :
137          answer = input("Do you want to change paramter ? (Y/N) : ")
138          if answer == "Y" :
139              kp = float(input("Please enter kp value : "))
140              ki = float(input("Please enter ki value : "))
141              kd = float(input("Please enter kd value : "))
142              pos = float(input("Please enter first position : "))
143              new_position = pos
144              new_pos = []
145          elif answer == "N" :
146              kp = 35
147              kd = 2.5
148              ki = 0.1
149              pos = 60
150              new_position = pos
151              new_pos = []
152          else :
153              print("Please enter the answer (Y/N)")
154
155          for path in Dir_Read('s', path=save_path):
156              print("-----------------------------------------------")
157              print('Capturing image')
```

```
PROBLEMS  OUTPUT  DEBUG CONSOLE  TERMINAL  PORTS

exe c:/Users/Asus/Desktop/INTERNSHIP_PROGRAM/test_ui.py
PS C:\Users\Asus\Desktop\INTERNSHIP_PROGRAM> & C:/Users/Asus/AppData/Local/Programs/Python/Python310/python.exe c:
.py
PS C:\Users\Asus\Desktop\INTERNSHIP_PROGRAM> & C:/Users/Asus/AppData/Local/Programs/Python/Python310/python.exe "c
ead img_pid.py"
Do you want to change paramter ? (Y/N) : Y
Please enter kp value :
```

Application

- First version of UI version of application





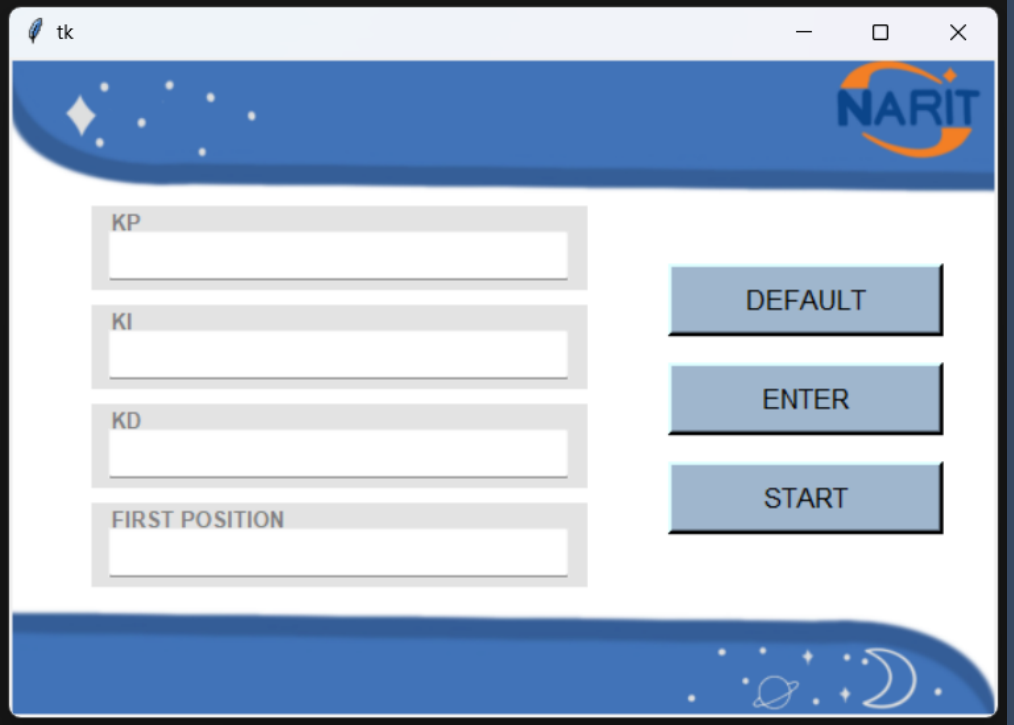
Application

- Have 2 options .

  Option 1 : Enter values with default values.

  - Click "DEFAULT" button then program will start immediately .

```
-------------------------------------------
Capturing image
-------------------------------------------
image pixels size =  4656 x 3520
w_ref =  64
h_ref =  67
x_ref =  2221
y_ref =  1639
w =  1
h =  1
x =  2524
y =  1937
-------------------------------------------------
center of ref - x : 2253.0 , y : 1672.5
center of object - x : 2556.0 , y : 1970.5
Distance between objects - x : -303.0 , y : -298.0
-------------------Normalize--------------------
CX_ref =  0.85614
CY_ref =  0.6355500000000001
center_x =  0.97128
center_Y =  0.7487900000000001
disX =  -0.11514
disY =  -0.11324000000000001
-------------------------------------------------
Error : 4.3315668
New_position : 50.6684332
```

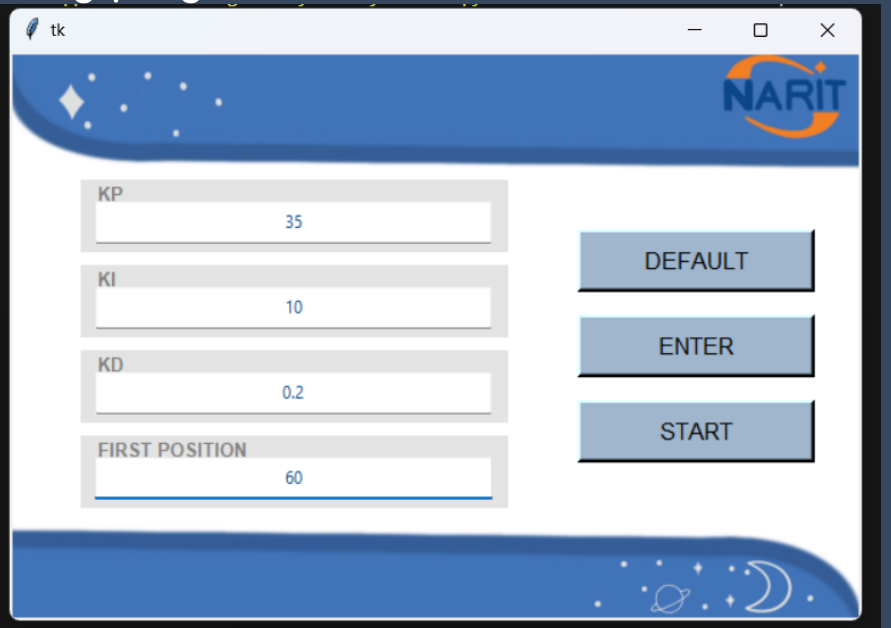


Application

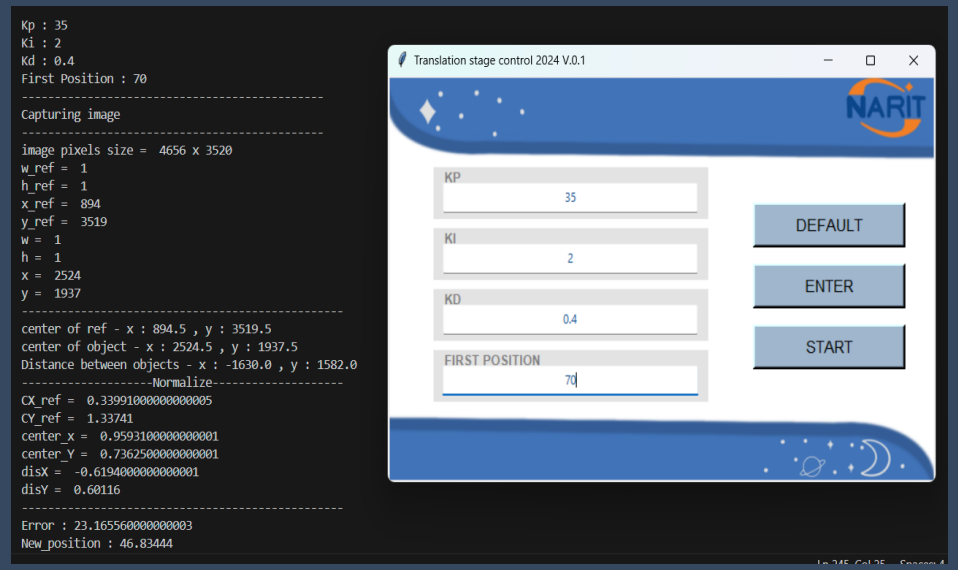
Option 2 : Enter values with other values.

- Enter each value in each entry box the click "ENTER" button then click "START" for starting program.

```
Kp : 35
Ki : 10
Kd : 0.2
First Position : 60
-----------------------------------------------
Capturing image
-----------------------------------------------
image pixels size =  4656 x 3520
w_ref =  64
h_ref =  67
x_ref =  2221
y_ref =  1639
w =  1
h =  1
x =  2524
y =  1937
-------------------------------------------------
center of ref - x : 2253.0 , y : 1672.5
center of object - x : 2556.0 , y : 1970.5
Distance between objects - x : -303.0 , y : -298.0
--------------------Normalize--------------------
CX_ref =  0.85614
CY_ref =  0.6355500000000001
center_x =  0.97128
center_Y =  0.7487900000000001
disX =  -0.11514
disY =  -0.11324000000000001
-------------------------------------------------
Error : 5.204328
New_position : 54.795671999999996
```



Collected feedback from user (researcher)

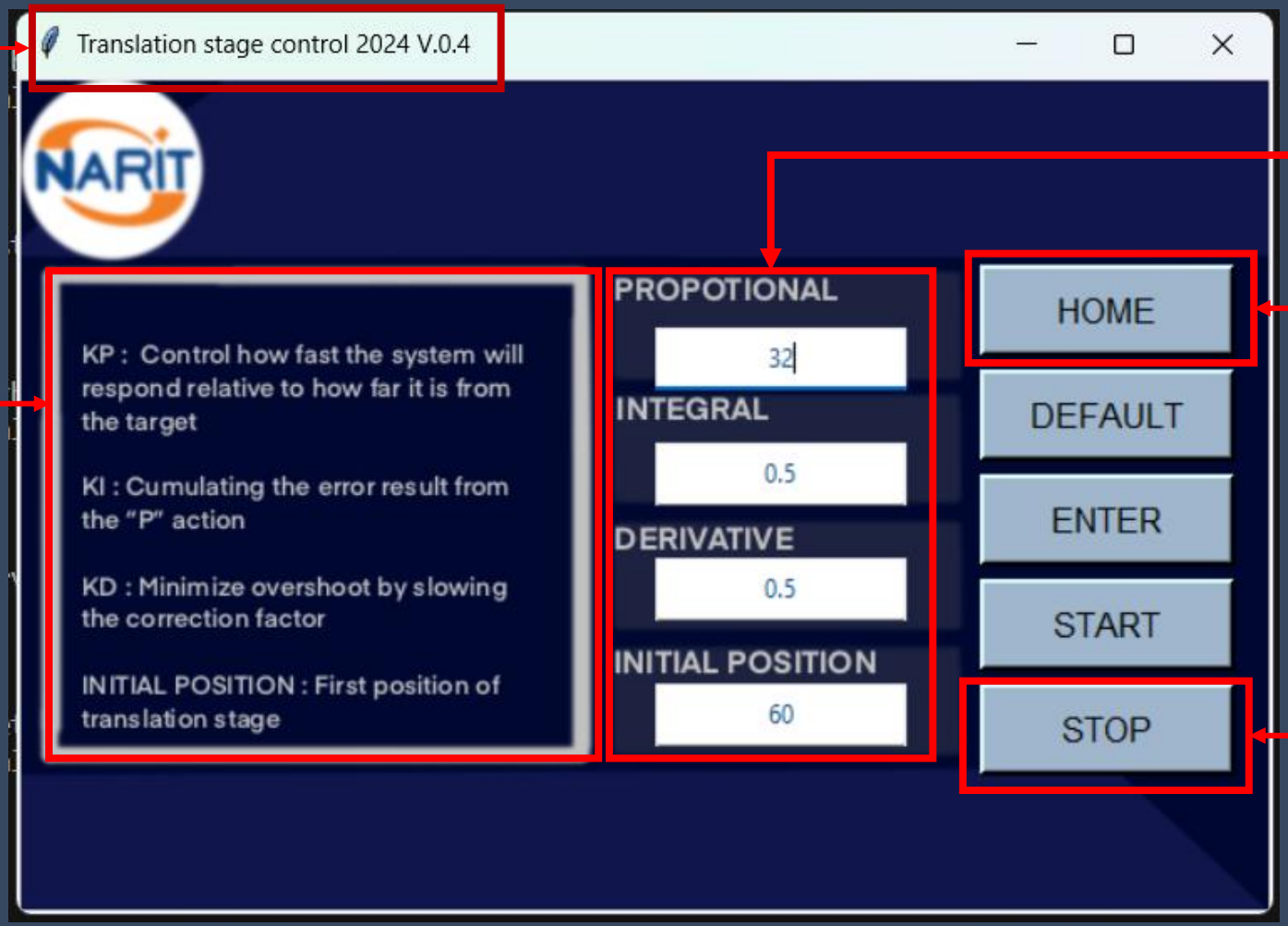


- Add the title of application
- Display properly dynamic range of PID parameters
- Create Stop and Home button
- Initialize the PID parameters in entry boxes
- Short describe for effect of each PID parameters

Current Version of application for users

Title of application

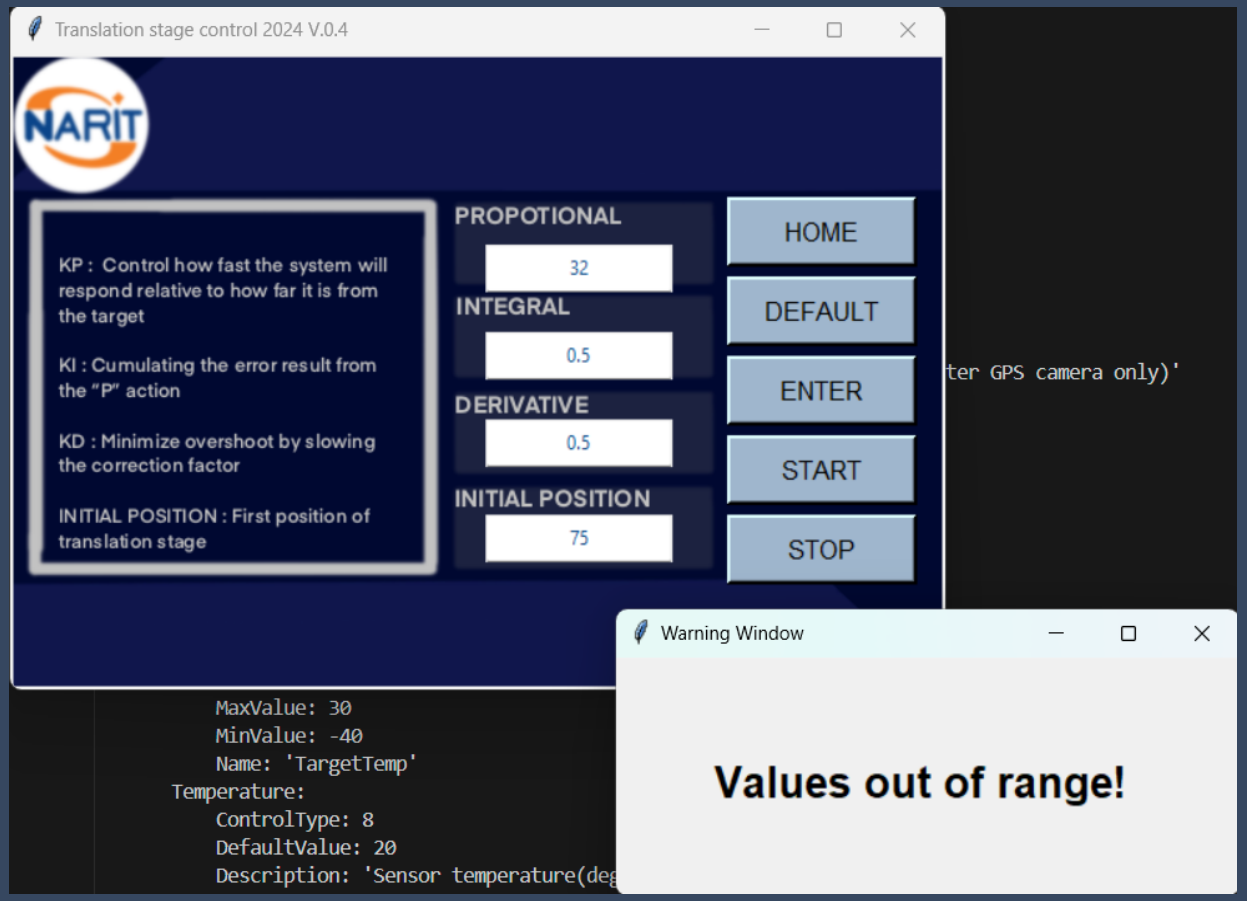
Short description about PID parameters



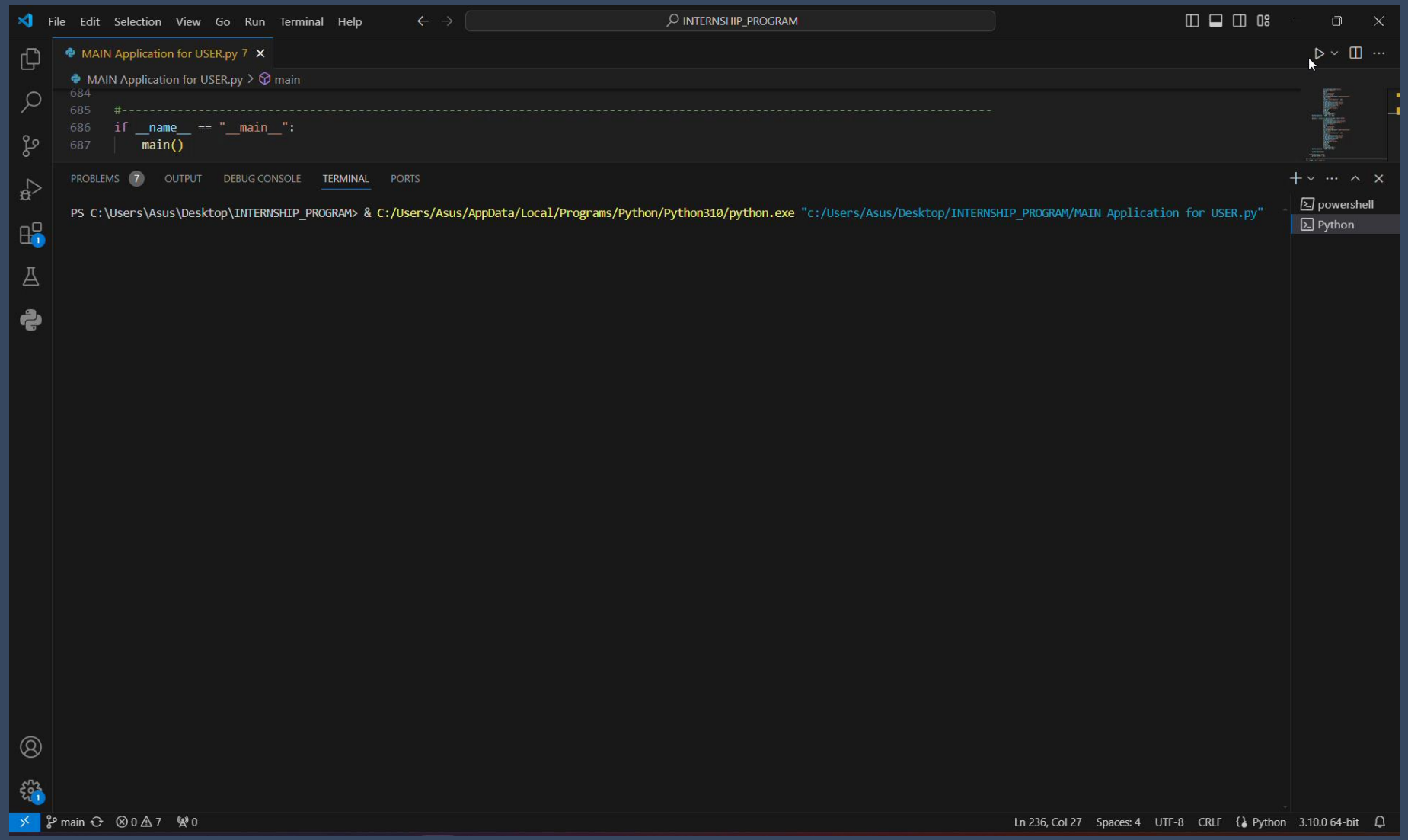
Initialized (Default) PID parameters

Add Home button

Add stop button



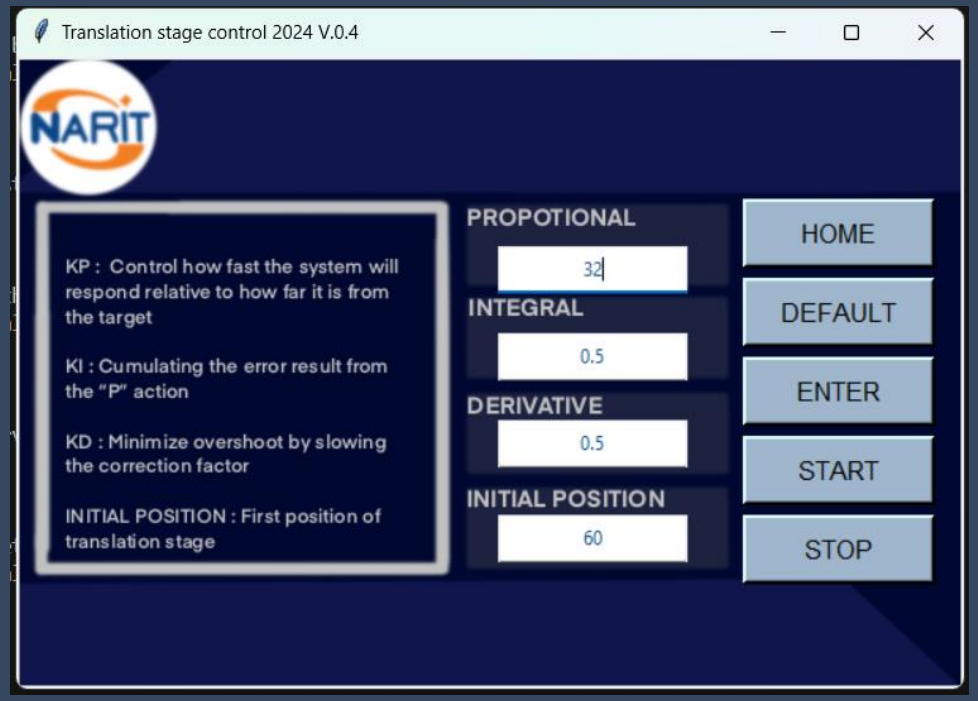
Add "Warning Window" for warning when put some values that out of range.


File Edit Selection View Go Run Terminal Help
INTERNSHIP_PROGRAM
MAIN Application for USER.py 7
MAIN Application for USER.py > main
684
685 #----------
686 if __name__ == "__main__":
687 main()
PROBLEMS 7 OUTPUT DEBUG CONSOLE TERMINAL PORTS
PS C:\Users\Asus\Desktop\INTERNSHIP_PROGRAM> & C:/Users/Asus/AppData/Local/Programs/Python/Python310/python.exe "c:/Users/Asus/Desktop/INTERNSHIP_PROGRAM/MAIN Application for USER.py"
powershell
Python
main
0 7
0
Ln 236, Col 27 Spaces: 4 UTF-8 CRLF Python 3.10.0 64-bit

05
Conclusion

Both UI version and input command in terminal version work successfully.

Can control translation stage with PID closed loop control and collect images.



UI Version

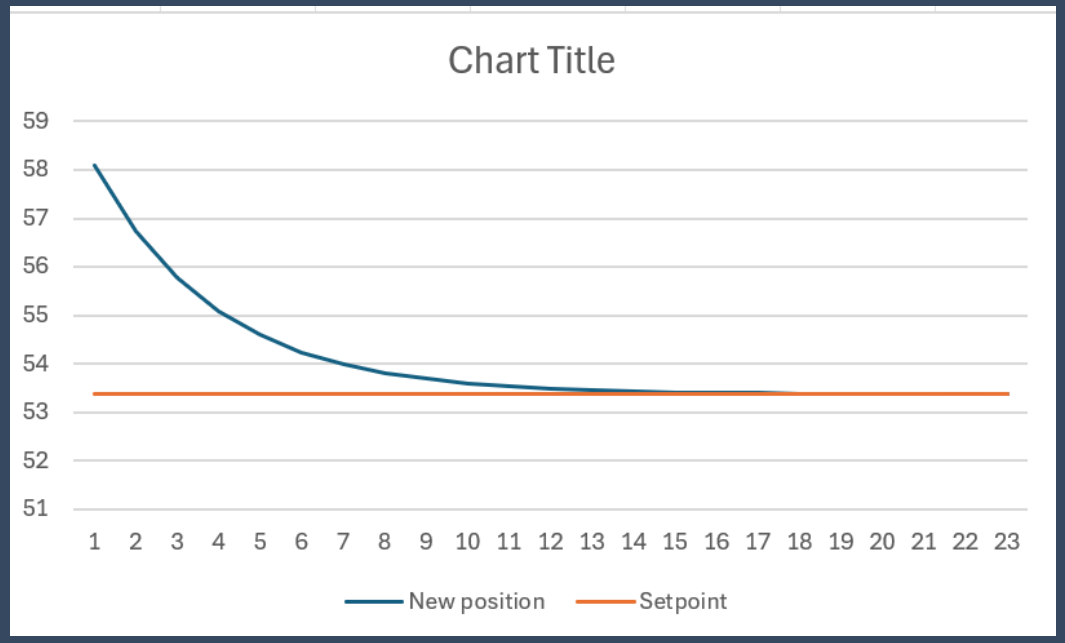
```
        DefaultValue: 20
        Description: 'Sensor temperature(degrees Celsius)'
        IsAutoSupported: False
        IsWritable: False
        MaxValue: 1000
        MinValue: -500
        Name: 'Temperature'
Do you want to change paramter ? (Y/N) : Y
Please enter kp value : 34
Please enter ki value : 2
Please enter kd value : 0.2
Please enter first position : 70
```

Command line Version

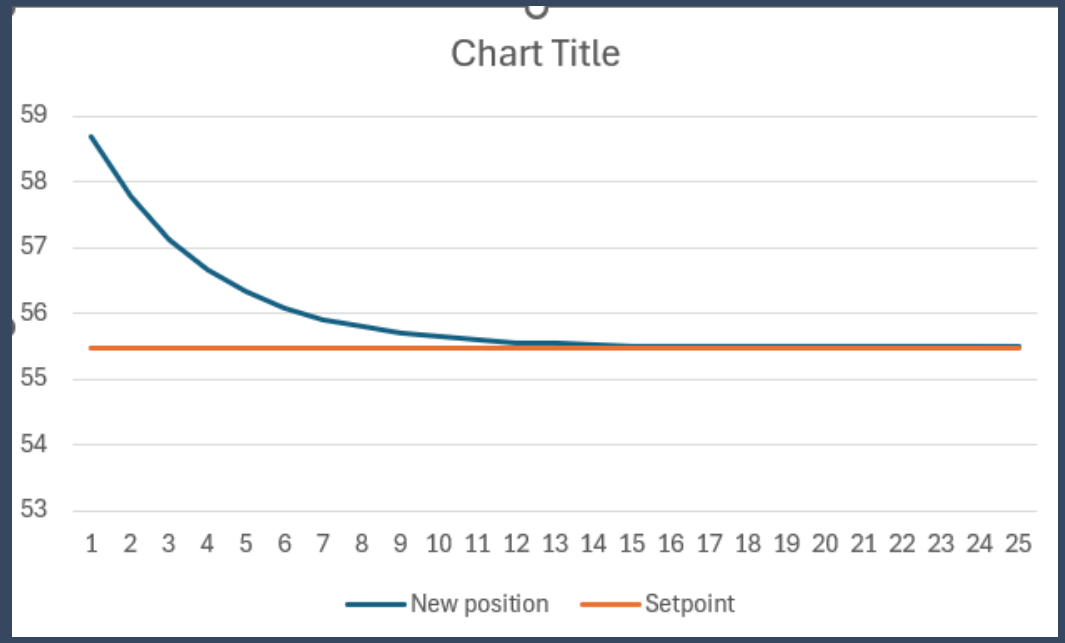
Default values of PID are :

P : Proportional : 10
I : Integral : 0.1
D : Derivative : 0.2
Initial position : 60

Application can run with the same values and the results still the same. The result is the position of current image is in the same place of reference image with 0.00 error even though change the reference position .



Reference position = 53.37



Reference position = 55.48