Analyse vidéo

March 16, 2024

[ ]:

```
import cv2
from matplotlib import pyplot as plt
import numpy as np
import ipywidgets as widgets
import scienceplots
import scipy as sp
import pandas as pd

plt.style.use(['science','notebook','grid'])
```

[ ]:

```
m40 = 40e-3
m60 = 60e-3
m70 = 70e-3
m80 = 80e-3
m100 = 100e-3

r_p = 1.5e-2
r_m = 3e-2
r_g = 4.5e-2
```

[ ]:

```
quad = lambda x, a, b, c: a*x**2 + b*x + c
lin = lambda x, a, b: a*x + b
```

1 Analyse vidéos

1.1 Vidéo m40

[ ]:

```
video_path = "m40.mp4"
cap = cv2.VideoCapture(video_path)
```

[ ]:

```
frame_rate = cap.get(cv2.CAP_PROP_FPS)
print("Frame rate: ", frame_rate)
```

```
Frame rate:  59.78801512879166
```

[ ]:

```
frames = []
while True:
    ret, frame = cap.read()
    if not ret:
        break
    frames.append(frame)
```

[ ]:
```
frame_rate = cap.get(cv2.CAP_PROP_FPS)
print("Frame rate: ", frame_rate)
```

```
Frame rate:  59.78801512879166
```

[ ]:
```
def disp_f(num):
    plt.imshow(frames[num])

widgets.interact(disp_f, num=widgets.IntSlider(min=0, max=len(frames)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=1183),␣
 ↪Output()), _dom_classes=('widget-intera…
```

[ ]:
```
<function __main__.disp_f(num)>
```

[ ]:
```
analyse = frames[363:1098]
```

[ ]:
```
def pos_track(x,y):
    image = analyse[0].copy()
    w, h = 50, 50
    cv2.rectangle(image, (x, y), (x + w, y + h), (255, 0, 0), 4)
    plt.imshow(image)

widgets.interact(pos_track, x=widgets.IntSlider(min=0, max=len(analyse[0]),␣
 ↪step=1), y=widgets.IntSlider(min=0, max=len(analyse[0][0]), step=1))
```

```
interactive(children=(IntSlider(value=0, description='x', max=1080),␣
 ↪IntSlider(value=0, description='y', max=1…
```

[ ]:
```
<function __main__.pos_track(x, y)>
```

[ ]:
```
tracker = cv2.TrackerCSRT_create()

track_frames = analyse.copy()

init_trac_f = track_frames[0]
roi = (357, 372, 50, 50)

tracker.init(init_trac_f, roi)

results = []
frame_tracked = []
```

```
for i in range(1, len(track_frames)):
    # Read the next frame
    frame = track_frames[i]

    # Update the tracker
    success, roi = tracker.update(frame)

    if success:
        # Draw a bounding box around the tracked object
        (x, y, w, h) = tuple(map(int, roi))
        results += [(x,y,w,h)]
        cv2.rectangle(frame, (x, y), (x + w, y + h), (255, 0, 0), 4)
        frame_tracked.append(frame)
```

[ ]:

```
def disp_t(num):
    plt.imshow(frame_tracked[num])

widgets.interact(disp_t, num=widgets.IntSlider(min=0, max=len(frame_tracked)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=733), Output()),␣
 ↪_dom_classes=('widget-interac…
```

[ ]: `<function __main__.disp_t(num)>`

[ ]:

```
good_results = results
```

[ ]:

```
center_of_rot = (705, 535, 50, 50)
```

[ ]:

```
def pos_from_case(case):
    x,y,w,h = case
    return (x + (x+w))/2, (y + (y+h))/2
```

[ ]:

```
pos_c = pos_from_case(center_of_rot)
pos_r = [pos_from_case(i) for i in good_results]
```

[ ]:

```
theta = []
cur_theta = 0

prev_dir = [pos_r[0][0]-pos_c[0], pos_r[0][1]-pos_c[1]]
for i in range(len(pos_r)):
    next_dir = [pos_r[i][0]-pos_c[0], pos_r[i][1]-pos_c[1]]
    cur_theta += (np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    if np.abs(np.arctan2(next_dir[1], next_dir[0]) - np.arctan2(prev_dir[1],␣
 ↪prev_dir[0])) > np.pi:
        cur_theta -= 2*np.pi*np.sign(np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    theta.append(cur_theta)
    prev_dir = next_dir

print(theta)
```

```
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10.6344159718033, 10.723185026094486, 10.810373276723555, 10.893027832448217,
10.974918831954882, 11.062584727471469]
```
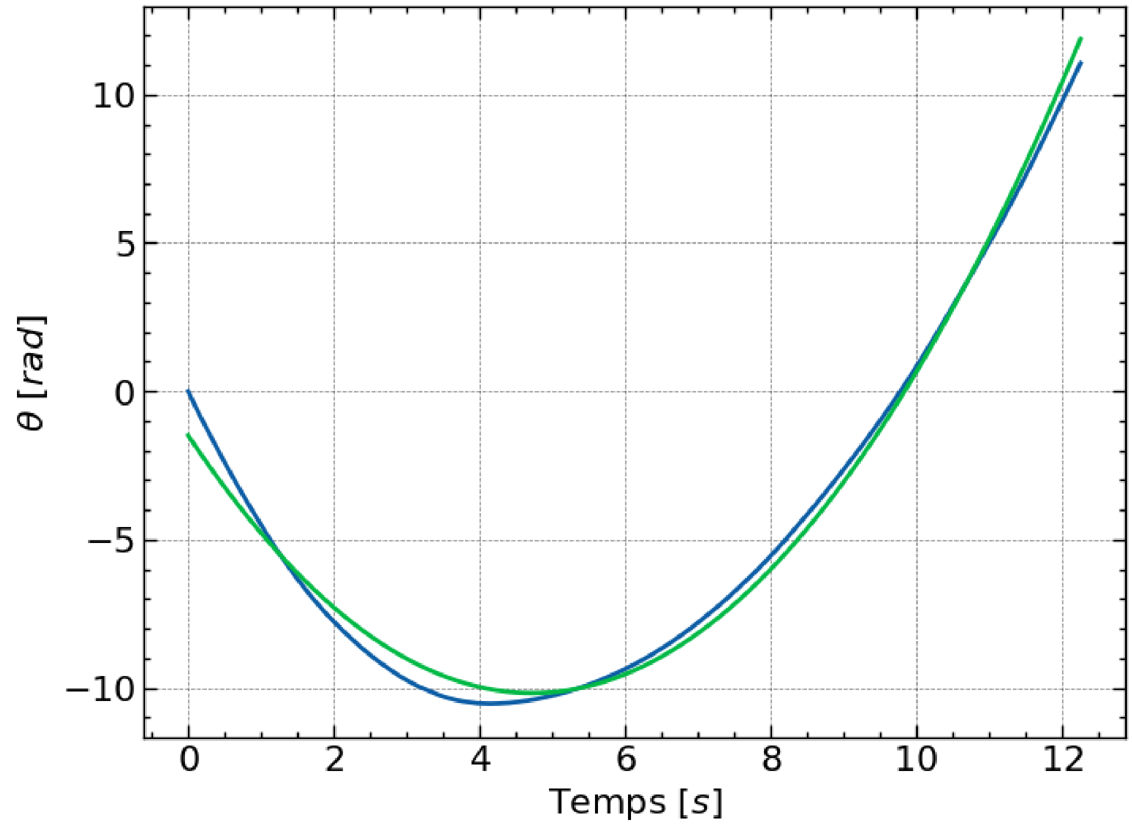

[ ]:
```
time_1 = np.arange(len(theta))/frame_rate
popt_1, _ = sp.optimize.curve_fit(quad, time_1, theta)
popt_1
```

[ ]:
```
array([ 0.38865188, -3.67438253, -1.49138986])
```

[ ]:
```
plt.plot(time_1, theta)
plt.plot(time_1, quad(time_1, *popt_1))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\theta$ $[rad]$")
plt.savefig("m40_t.png")
```

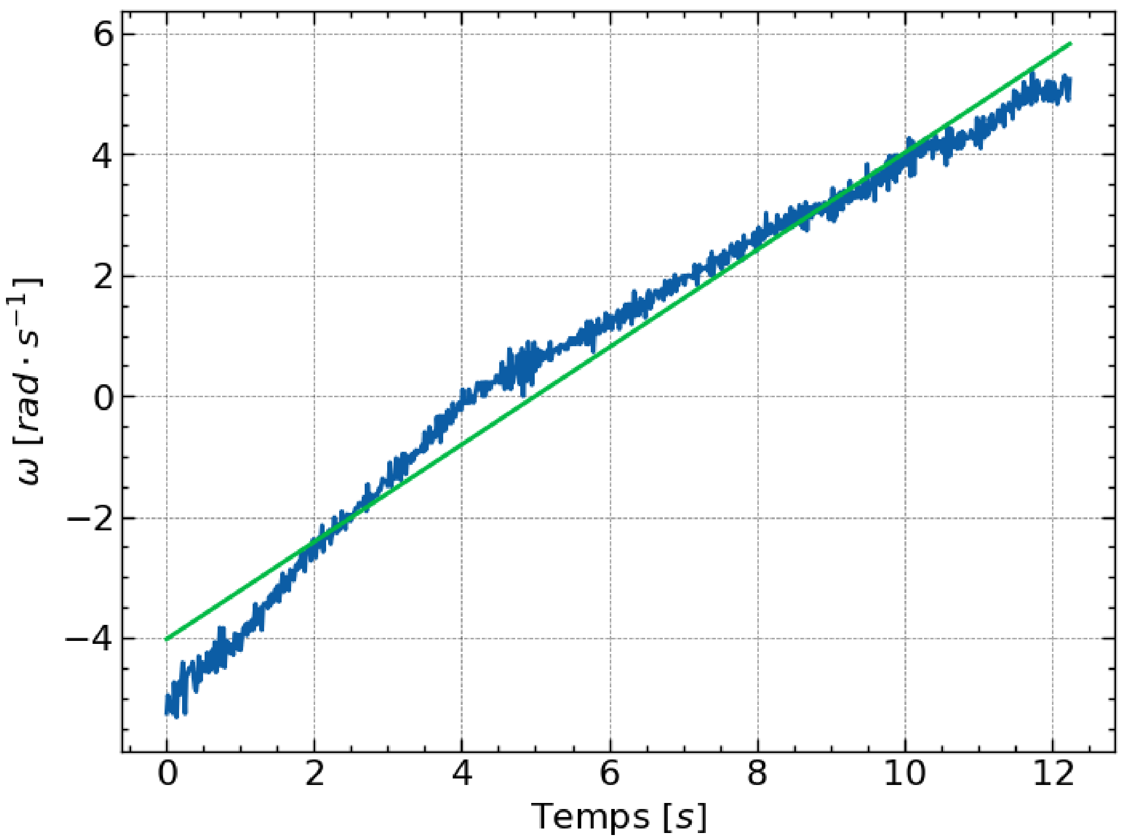


```
[ ]: omega = []

     for i in range(len(theta)-1):
         omega.append((theta[i+1]-theta[i])/(1/frame_rate))
```

```
[ ]: time_2 = np.arange(len(omega))/frame_rate
     popt_2, _ = sp.optimize.curve_fit(lin, time_2, omega)
     popt_2
```

```
[ ]: array([ 0.80432804, -4.02146438])
```

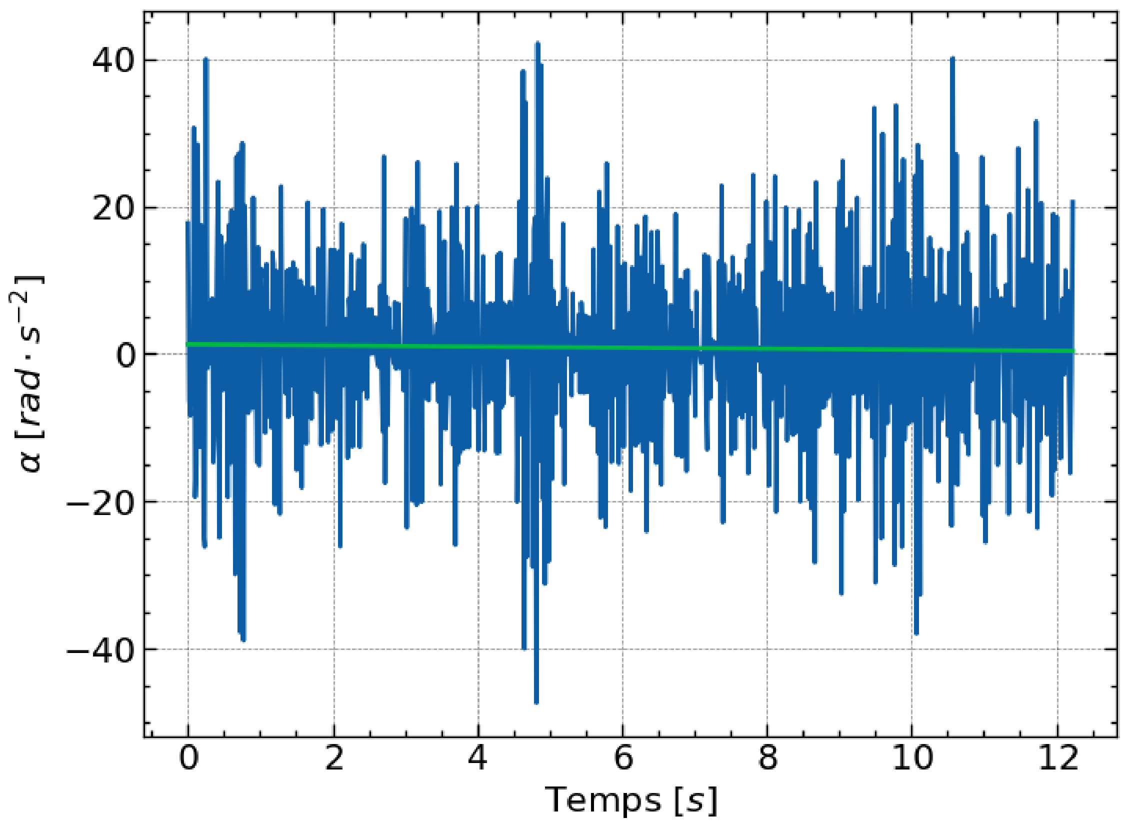
```
[ ]: plt.plot(time_2, omega)
     plt.plot(time_2, lin(time_2, *popt_2))
     plt.xlabel(r"Temps $[s]$")
     plt.ylabel(r"$\omega$ $[rad \cdot s^{-1}]$")
     plt.savefig("m40_o.png")
```



[ ]:

```
alpha = []

for i in range(len(omega)-1):
    alpha.append((omega[i+1]-omega[i])/(1/frame_rate))

time_3 = np.arange(len(alpha))/frame_rate
popt_3, _ = sp.optimize.curve_fit(lin, time_3, alpha)
print(popt_3)

plt.plot(np.arange(len(alpha))/frame_rate, alpha)
plt.plot(np.arange(len(alpha))/frame_rate, lin(time_3, *popt_3))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\alpha$ $[rad \cdot s^{-2}]$")
plt.savefig("m40_a.png")
```

```
[-0.07261683  1.30070567]
```



```
[ ]: acc_quad = popt_1[0]*2
     acc_lin = popt_2[0]
     print(acc_quad, acc_lin)
     acc = (acc_quad + acc_lin)/2
     Mom = 9.81 * m40 * r_m
     I_m40 = Mom/acc
     print(I_m40)
```

```
0.7773037662037253 0.8043280421534522
0.014885891821090 07
```

1.2 Vidéo m60

```
[ ]: video_path = "m60.mp4"
     cap = cv2.VideoCapture(video_path)
```

```
[ ]: frame_rate = cap.get(cv2.CAP_PROP_FPS)
     print("Frame rate: ", frame_rate)
```

```
Frame rate:  59.78680582027616
```

[ ]:

```
frames = []
while True:
    ret, frame = cap.read()
    if not ret:
        break
    frames.append(frame)
```

[ ]:

```
frame_rate = cap.get(cv2.CAP_PROP_FPS)
print("Frame rate: ", frame_rate)
```

```
Frame rate:  59.78680582027616
```

[ ]:

```
def disp_f(num):
    plt.imshow(frames[num])

widgets.interact(disp_f, num=widgets.IntSlider(min=0, max=len(frames)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=1008),␣
 ↪Output()), _dom_classes=('widget-intera…
```

[ ]:

```
<function __main__.disp_f(num)>
```

[ ]:

```
analyse = frames[480:886]
```

[ ]:

```
def pos_track(x,y):
    image = analyse[0].copy()
    w, h = 50, 50
    cv2.rectangle(image, (x, y), (x + w, y + h), (255, 0, 0), 4)
    plt.imshow(image)

widgets.interact(pos_track, x=widgets.IntSlider(min=0, max=len(analyse[0]),␣
 ↪step=1), y=widgets.IntSlider(min=0, max=len(analyse[0][0]), step=1))
```

```
interactive(children=(IntSlider(value=0, description='x', max=1080),␣
 ↪IntSlider(value=0, description='y', max=1…
```

[ ]:

```
<function __main__.pos_track(x, y)>
```

[ ]:

```
tracker = cv2.TrackerCSRT_create()

track_frames = analyse.copy()

init_trac_f = track_frames[0]
roi = (331, 573, 50, 50)

tracker.init(init_trac_f, roi)
```

```
results = []
frame_tracked = []
for i in range(1, len(track_frames)):
    # Read the next frame
    frame = track_frames[i]

    # Update the tracker
    success, roi = tracker.update(frame)

    if success:
        # Draw a bounding box around the tracked object
        (x, y, w, h) = tuple(map(int, roi))
        results += [(x,y,w,h)]
        cv2.rectangle(frame, (x, y), (x + w, y + h), (255, 0, 0), 4)
        frame_tracked.append(frame)
```

[ ]:

```
def disp_t(num):
    plt.imshow(frame_tracked[num])

widgets.interact(disp_t, num=widgets.IntSlider(min=0, max=len(frame_tracked)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=404), Output()),␣
 ↪_dom_classes=('widget-interac…
```

[ ]: `<function __main__.disp_t(num)>`

[ ]:

```
good_results = results
```

[ ]:

```
center_of_rot = (705, 535, 50, 50)
```

[ ]:

```
def pos_from_case(case):
    x,y,w,h = case
    return (x + (x+w))/2, (y + (y+h))/2
```

[ ]:

```
pos_c = pos_from_case(center_of_rot)
pos_r = [pos_from_case(i) for i in good_results]
```

[ ]:

```
theta = []
cur_theta = 0

prev_dir = [pos_r[0][0]-pos_c[0], pos_r[0][1]-pos_c[1]]
for i in range(len(pos_r)):
    next_dir = [pos_r[i][0]-pos_c[0], pos_r[i][1]-pos_c[1]]
    cur_theta += (np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
```

```
    if np.abs(np.arctan2(next_dir[1], next_dir[0]) - np.arctan2(prev_dir[1],␣
 ↪prev_dir[0])) > np.pi:
        cur_theta -= 2*np.pi*np.sign(np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    theta.append(cur_theta)
    prev_dir = next_dir

print(theta)
```

```
[0.0, -0.046383276811095, -0.08874740571573225, -0.13015454387925285,
-0.1689842042016183, -0.20942116835834357, -0.2499888461535571,
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16.92764228525224, 17.029812642037047, 17.12845631219424]
```
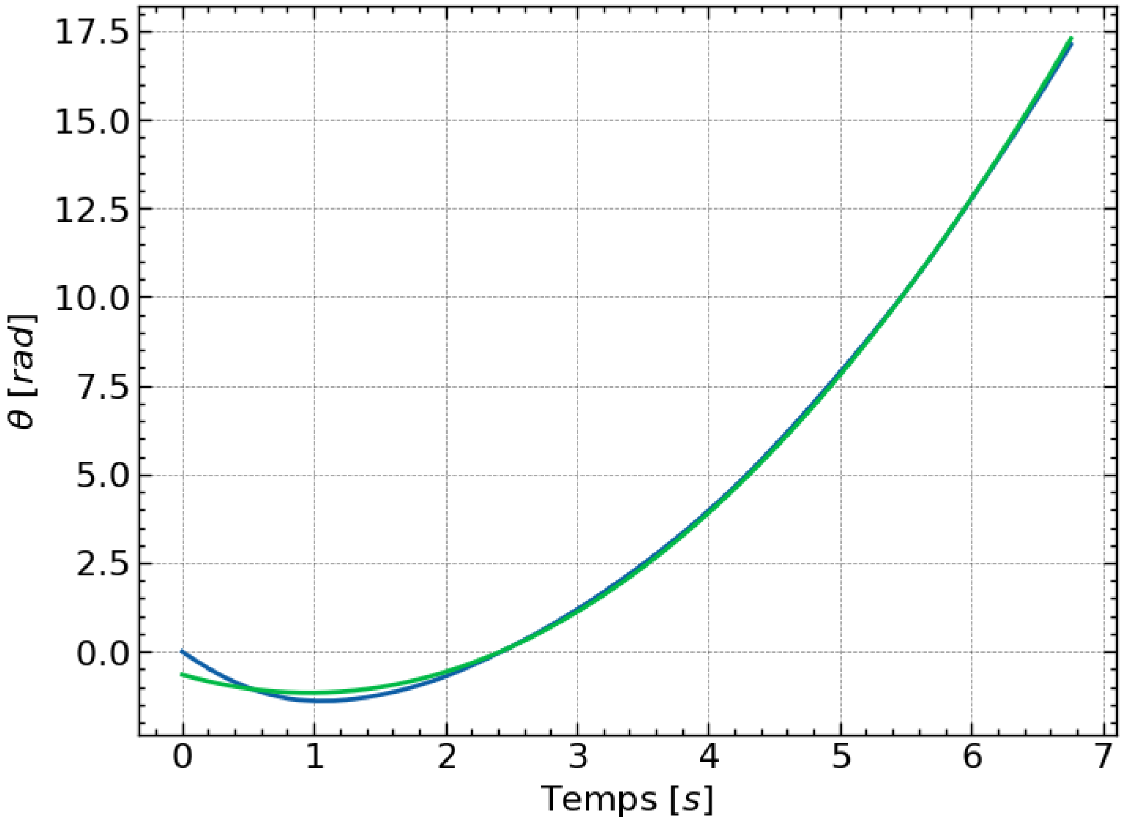

[ ]:
```
time_1 = np.arange(len(theta))/frame_rate
popt_1, _ = sp.optimize.curve_fit(quad, time_1, theta)
popt_1
```

[ ]:
```
array([ 0.55067263, -1.06492991, -0.65186379])
```

[ ]:
```
plt.plot(time_1, theta)
plt.plot(time_1, quad(time_1, *popt_1))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\theta$ $[rad]$")
plt.savefig("m60_t.png")
```



[ ]:

```
omega = []

for i in range(len(theta)-1):
    omega.append((theta[i+1]-theta[i])/(1/frame_rate))
```

[ ]:

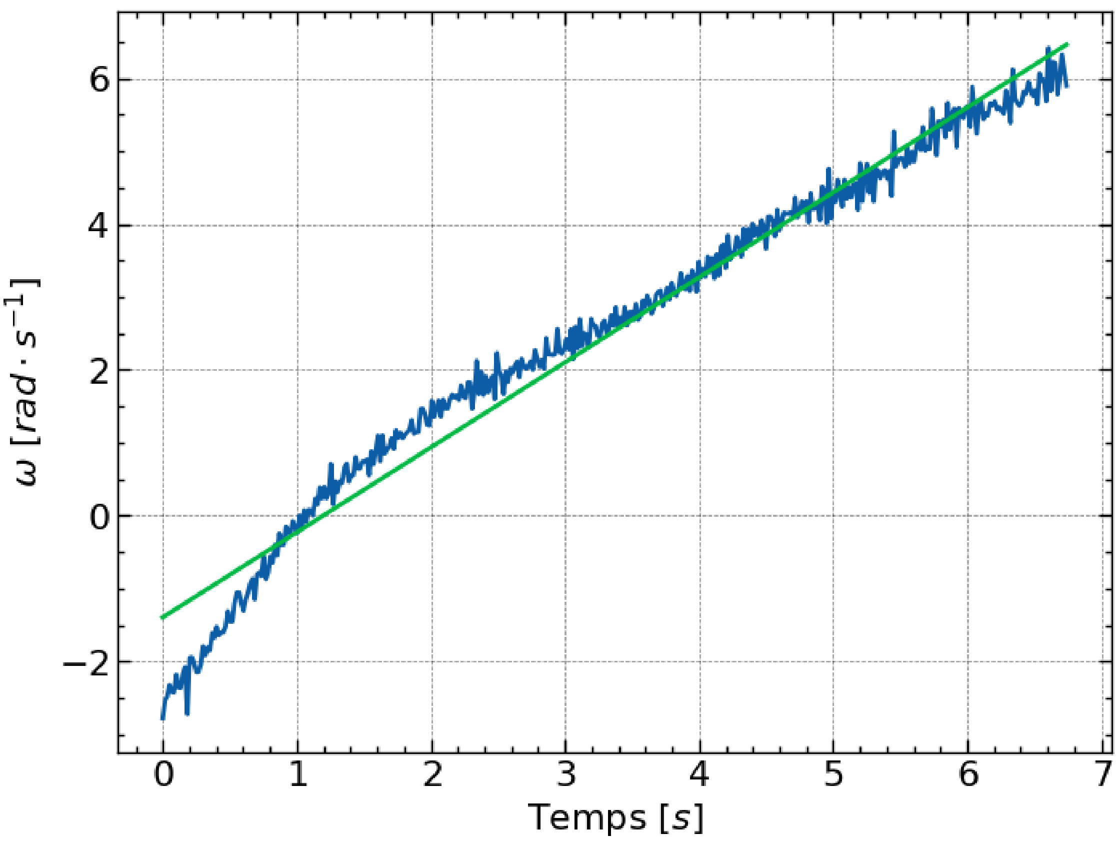
```
time_2 = np.arange(len(omega))/frame_rate
popt_2, _ = sp.optimize.curve_fit(lin, time_2, omega)
popt_2
```

[ ]:

```
array([ 1.16505327, -1.39179803])
```

[ ]:

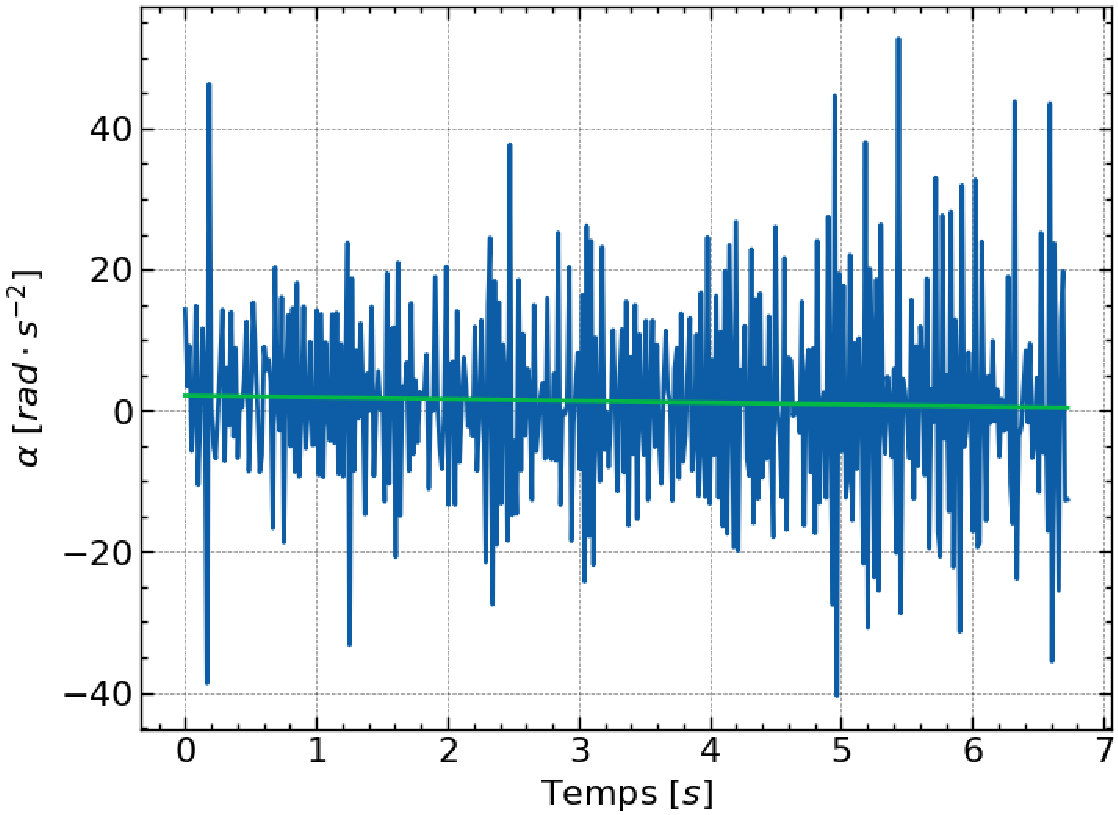
```
plt.plot(time_2, omega)
plt.plot(time_2, lin(time_2, *popt_2))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\omega$ $[rad \cdot s^{-1}]$")
plt.savefig("m60_o.png")
```



[ ]:

```
alpha = []

for i in range(len(omega)-1):
    alpha.append((omega[i+1]-omega[i])/(1/frame_rate))

time_3 = np.arange(len(alpha))/frame_rate
popt_3, _ = sp.optimize.curve_fit(lin, time_3, alpha)
print(popt_3)

plt.plot(np.arange(len(alpha))/frame_rate, alpha)
plt.plot(np.arange(len(alpha))/frame_rate, lin(time_3, *popt_3))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\alpha$ $[rad \cdot s^{-2}]$")
plt.savefig("m60_a.png")
```

```
[-0.25749748  2.15202835]
```



```
[ ]: acc_quad = popt_1[0]*2
     acc_lin = popt_2[0]
     print(acc_quad, acc_lin)
     acc = (acc_quad + acc_lin)/2
     Mom = 9.81 * m60 * r_m
     I_m60 = Mom/acc
     print(I_m60)
```

```
1.1013452537778434 1.1650532741707633
0.015582431582306796
```

1.3 Vidéo p70

```
[ ]: video_path = "p70.mp4"
     cap = cv2.VideoCapture(video_path)
```

```
[ ]: frame_rate = cap.get(cv2.CAP_PROP_FPS)
     print("Frame rate: ", frame_rate)
```

```
Frame rate:  30.0
```

[ ]:

```
frames = []
while True:
    ret, frame = cap.read()
    if not ret:
        break
    frames.append(frame)
```

[ ]:

```
frame_rate = 120
print("Frame rate: ", frame_rate)
```

```
Frame rate:  120
```

[ ]:

```
def disp_f(num):
    plt.imshow(frames[num])

widgets.interact(disp_f, num=widgets.IntSlider(min=0, max=len(frames)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=2197),␣
 ↪Output()), _dom_classes=('widget-intera…
```

[ ]:

```
<function __main__.disp_f(num)>
```

[ ]:

```
analyse = frames[532:1879]
```

[ ]:

```
def pos_track(x,y):
    image = analyse[0].copy()
    w, h = 50, 50
    cv2.rectangle(image, (x, y), (x + w, y + h), (255, 0, 0), 4)
    plt.imshow(image)

widgets.interact(pos_track, x=widgets.IntSlider(min=0, max=len(analyse[0]),␣
 ↪step=1), y=widgets.IntSlider(min=0, max=len(analyse[0][0]), step=1))
```

```
interactive(children=(IntSlider(value=0, description='x', max=1080),␣
 ↪IntSlider(value=0, description='y', max=1…
```

[ ]:

```
<function __main__.pos_track(x, y)>
```

[ ]:

```
tracker = cv2.TrackerCSRT_create()

track_frames = analyse.copy()

init_trac_f = track_frames[0]
roi = (1054, 666, 50, 50)

tracker.init(init_trac_f, roi)
```

```
results = []
frame_tracked = []
for i in range(1, len(track_frames)):
    # Read the next frame
    frame = track_frames[i]

    # Update the tracker
    success, roi = tracker.update(frame)

    if success:
        # Draw a bounding box around the tracked object
        (x, y, w, h) = tuple(map(int, roi))
        results += [(x,y,w,h)]
        cv2.rectangle(frame, (x, y), (x + w, y + h), (255, 0, 0), 4)
        frame_tracked.append(frame)
```

[ ]:

```
def disp_t(num):
    plt.imshow(frame_tracked[num])

widgets.interact(disp_t, num=widgets.IntSlider(min=0, max=len(frame_tracked)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=1345),␣
 ↪Output()), _dom_classes=('widget-intera…
```

[ ]:

```
<function __main__.disp_t(num)>
```

[ ]:

```
good_results = results
```

[ ]:

```
center_of_rot = (722, 535, 50, 50)
```

[ ]:

```
def pos_from_case(case):
    x,y,w,h = case
    return (x + (x+w))/2, (y + (y+h))/2
```

[ ]:

```
pos_c = pos_from_case(center_of_rot)
pos_r = [pos_from_case(i) for i in good_results]
```

[ ]:

```
theta = []
cur_theta = 0

prev_dir = [pos_r[0][0]-pos_c[0], pos_r[0][1]-pos_c[1]]
for i in range(len(pos_r)):
    next_dir = [pos_r[i][0]-pos_c[0], pos_r[i][1]-pos_c[1]]
    cur_theta += (np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
```

```
    if np.abs(np.arctan2(next_dir[1], next_dir[0]) - np.arctan2(prev_dir[1],␣
 ↪prev_dir[0])) > np.pi:
        cur_theta -= 2*np.pi*np.sign(np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    theta.append(cur_theta)
    prev_dir = next_dir

print(theta)
```

```
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12.791802928189284, 12.820759861996757, 12.821112969326714, 12.882943293073772]
```
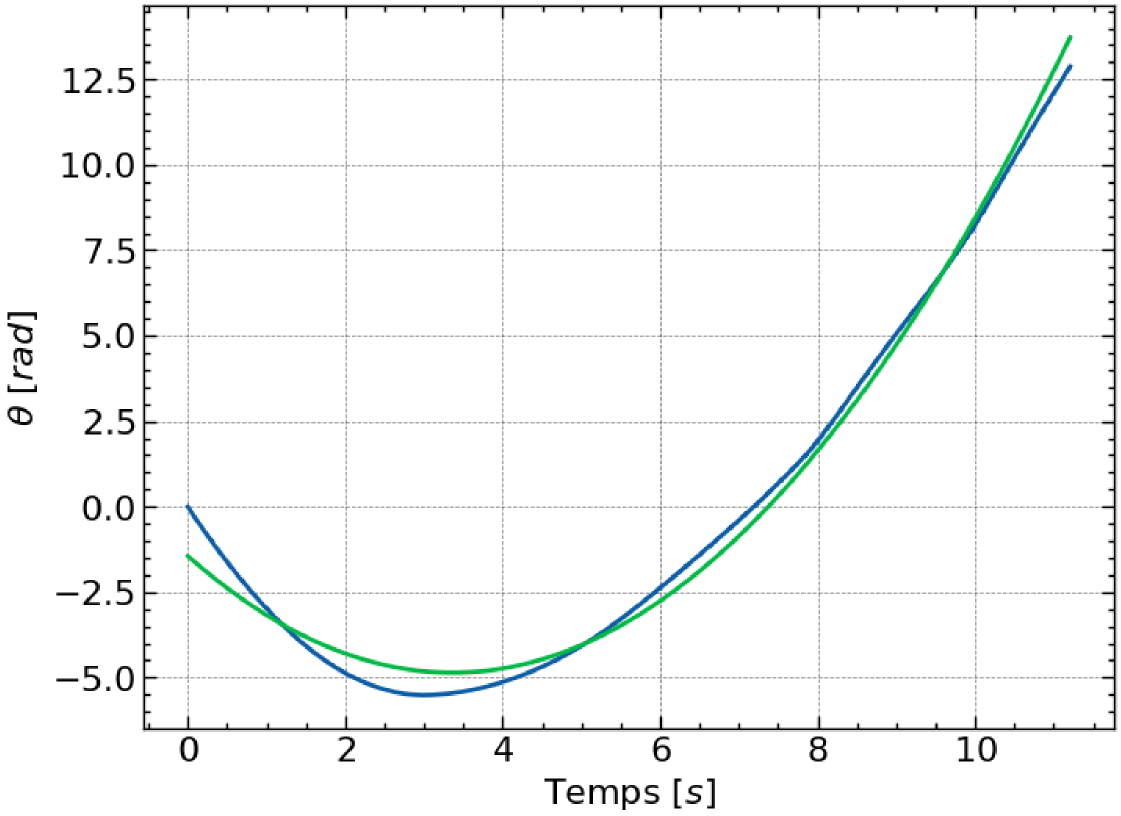

[ ]:

```
time_1 = np.arange(len(theta))/frame_rate
popt_1, _ = sp.optimize.curve_fit(quad, time_1, theta)
popt_1
```

[ ]:
```
array([ 0.30196946, -2.03139018, -1.44260368])
```

[ ]:
```
plt.plot(time_1, theta)
plt.plot(time_1, quad(time_1, *popt_1))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\theta$ $[rad]$")
plt.savefig("p70_t.png")
```

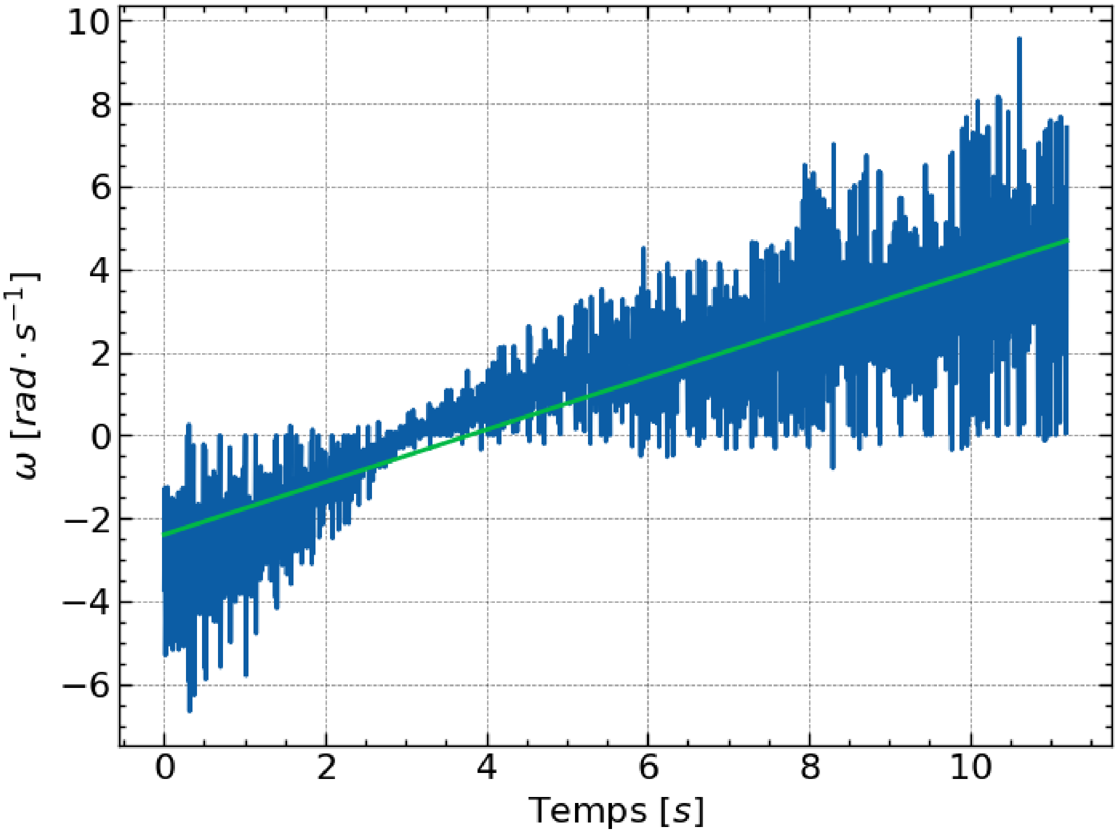


[ ]:
```
omega = []

for i in range(len(theta)-1):
    omega.append((theta[i+1]-theta[i])/(1/frame_rate))
```

[ ]:
```
time_2 = np.arange(len(omega))/frame_rate
popt_2, _ = sp.optimize.curve_fit(lin, time_2, omega)
popt_2
```

[ ]:
```
array([ 0.63267447, -2.39356945])
```

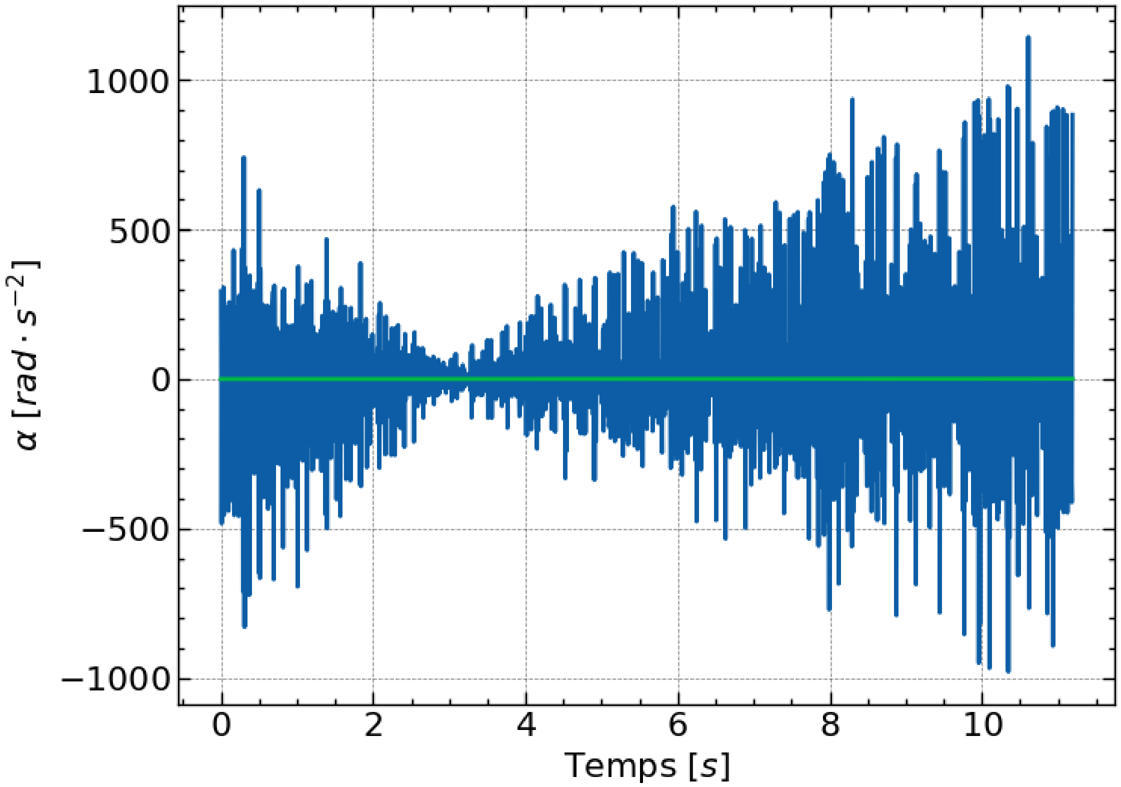
[ ]:
```
plt.plot(time_2, omega)
plt.plot(time_2, lin(time_2, *popt_2))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\omega$ $[rad \cdot s^{-1}]$")
plt.savefig("p70_o.png")
```



[ ]:

```
alpha = []

for i in range(len(omega)-1):
    alpha.append((omega[i+1]-omega[i])/(1/frame_rate))

time_3 = np.arange(len(alpha))/frame_rate
popt_3, _ = sp.optimize.curve_fit(lin, time_3, alpha)
print(popt_3)

plt.plot(np.arange(len(alpha))/frame_rate, alpha)
plt.plot(np.arange(len(alpha))/frame_rate, lin(time_3, *popt_3))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\alpha$ $[rad \cdot s^{-2}]$")
plt.savefig("p70_a.png")
```

```
[0.06707486 0.61923022]
```



[ ]:

```
acc_quad = popt_1[0]*2
acc_lin = popt_2[0]
print(acc_quad, acc_lin)
acc = (acc_quad + acc_lin)/2
Mom = 9.81 * m70 * r_p
I_p70 = Mom/acc
print(I_p70)
```

```
0.6039389114987118 0.6326744702267937
0.016659208370569663
```

1.4 Vidéo m70

[ ]:

```
video_path = "m70.mp4"
cap = cv2.VideoCapture(video_path)
```

[ ]:

```
frame_rate = cap.get(cv2.CAP_PROP_FPS)
print("Frame rate: ", frame_rate)
```

```
Frame rate:  30.0
```

[ ]:

```
frames = []
while True:
    ret, frame = cap.read()
    if not ret:
        break
    frames.append(frame)
```

[ ]:

```
frame_rate = 120
print("Frame rate: ", frame_rate)
```

```
Frame rate:  120
```

[ ]:

```
def disp_f(num):
    plt.imshow(frames[num])

widgets.interact(disp_f, num=widgets.IntSlider(min=0, max=len(frames)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=1587),␣
 ↪Output()), _dom_classes=('widget-intera…
```

[ ]:

```
<function __main__.disp_f(num)>
```

[ ]:

```
analyse = frames[755:1395]
```

[ ]:

```
def pos_track(x,y):
    image = analyse[0].copy()
    w, h = 50, 50
    cv2.rectangle(image, (x, y), (x + w, y + h), (255, 0, 0), 4)
    plt.imshow(image)

widgets.interact(pos_track, x=widgets.IntSlider(min=0, max=len(analyse[0]),␣
 ↪step=1), y=widgets.IntSlider(min=0, max=len(analyse[0][0]), step=1))
```

```
interactive(children=(IntSlider(value=0, description='x', max=1080),␣
 ↪IntSlider(value=0, description='y', max=1…
```

[ ]:

```
<function __main__.pos_track(x, y)>
```

[ ]:

```
tracker = cv2.TrackerCSRT_create()

track_frames = analyse.copy()

init_trac_f = track_frames[0]
roi = (1002, 310, 50, 50)

tracker.init(init_trac_f, roi)
```

```
results = []
frame_tracked = []
for i in range(1, len(track_frames)):
    # Read the next frame
    frame = track_frames[i]

    # Update the tracker
    success, roi = tracker.update(frame)

    if success:
        # Draw a bounding box around the tracked object
        (x, y, w, h) = tuple(map(int, roi))
        results += [(x,y,w,h)]
        cv2.rectangle(frame, (x, y), (x + w, y + h), (255, 0, 0), 4)
        frame_tracked.append(frame)
```

[ ]:

```
def disp_t(num):
    plt.imshow(frame_tracked[num])

widgets.interact(disp_t, num=widgets.IntSlider(min=0, max=len(frame_tracked)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=638), Output()),␣
 ↪_dom_classes=('widget-interac…
```

[ ]:

```
<function __main__.disp_t(num)>
```

[ ]:

```
good_results = results
```

[ ]:

```
center_of_rot = (725, 535, 50, 50)
```

[ ]:

```
def pos_from_case(case):
    x,y,w,h = case
    return (x + (x+w))/2, (y + (y+h))/2
```

[ ]:

```
pos_c = pos_from_case(center_of_rot)
pos_r = [pos_from_case(i) for i in good_results]
```

[ ]:

```
theta = []
cur_theta = 0

prev_dir = [pos_r[0][0]-pos_c[0], pos_r[0][1]-pos_c[1]]
for i in range(len(pos_r)):
    next_dir = [pos_r[i][0]-pos_c[0], pos_r[i][1]-pos_c[1]]
    cur_theta += (np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
```

```
    if np.abs(np.arctan2(next_dir[1], next_dir[0]) - np.arctan2(prev_dir[1],␣
 ↪prev_dir[0])) > np.pi:
        cur_theta -= 2*np.pi*np.sign(np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    theta.append(cur_theta)
    prev_dir = next_dir

print(theta)
```

```
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9.125887867663316, 9.212257611635987, 9.212257611635987, 9.301300250886836,
9.343744481497449, 9.386173427325184, 9.428812215510824, 9.473876621809461]
```
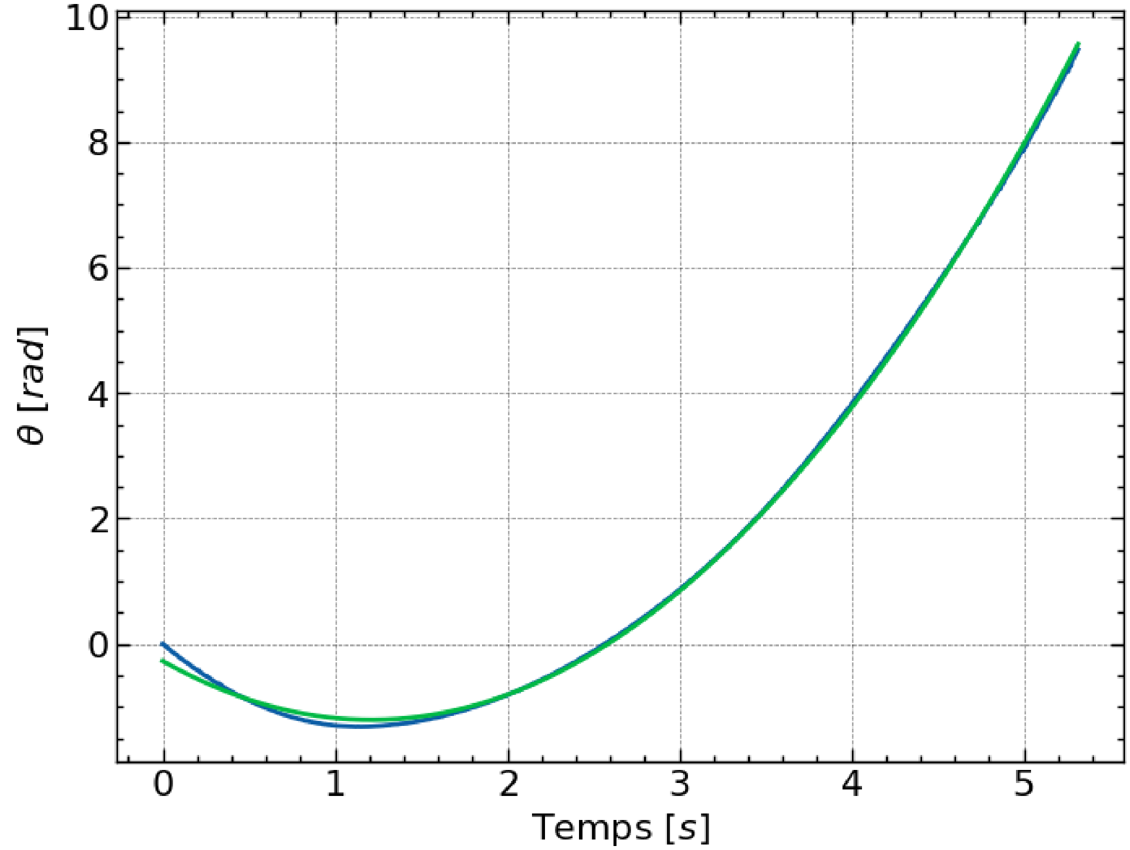

```
[ ]: time_1 = np.arange(len(theta))/frame_rate
     popt_1, _ = sp.optimize.curve_fit(quad, time_1, theta)
     popt_1
```

```
[ ]: array([ 0.63896602, -1.54767844, -0.27137422])
```

```
[ ]: plt.plot(time_1, theta)
     plt.plot(time_1, quad(time_1, *popt_1))
     plt.xlabel(r"Temps $[s]$")
     plt.ylabel(r"$\theta$ $[rad]$")
     plt.savefig("m70_t.png")
```



```
[ ]: omega = []

     for i in range(len(theta)-1):
```

```
    omega.append((theta[i+1]-theta[i])/(1/frame_rate))
```

[ ]:

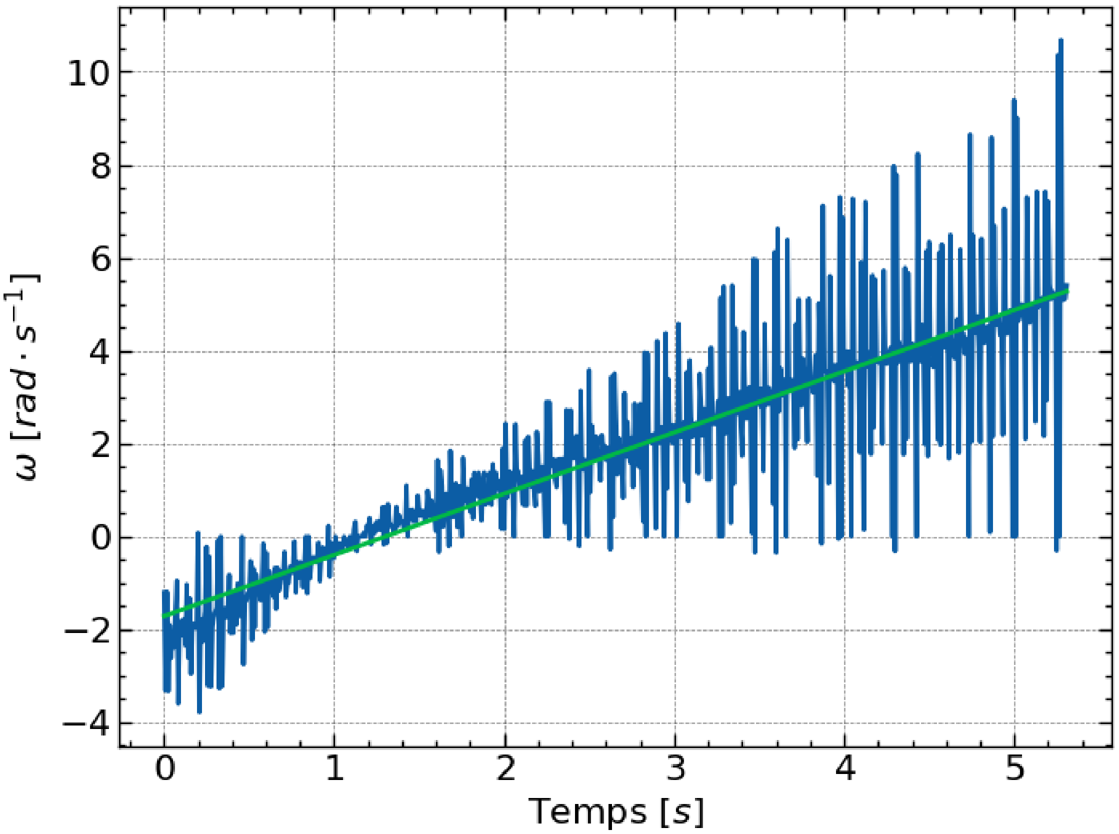
```
time_2 = np.arange(len(omega))/frame_rate
popt_2, _ = sp.optimize.curve_fit(lin, time_2, omega)
popt_2
```

[ ]:

```
array([ 1.31694293, -1.71346566])
```

[ ]:

```
plt.plot(time_2, omega)
plt.plot(time_2, lin(time_2, *popt_2))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\omega$ $[rad \cdot s^{-1}]$")
plt.savefig("m70_o.png")
```

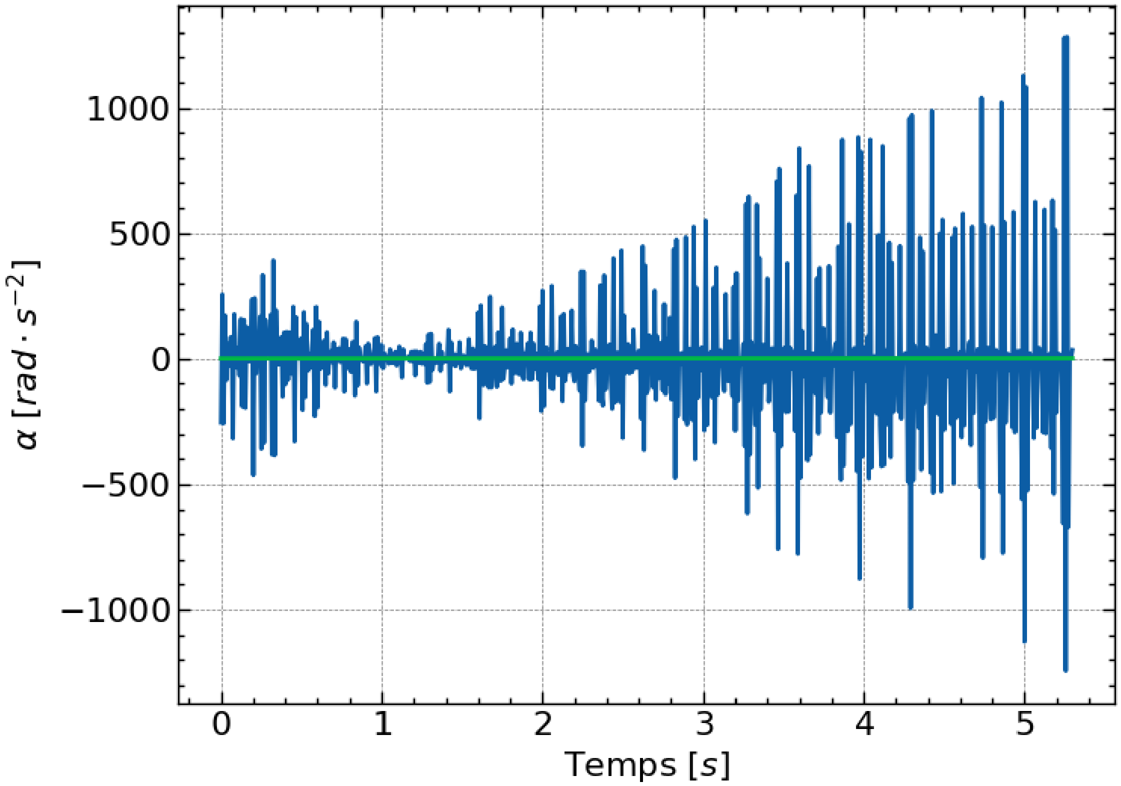


[ ]:

```
alpha = []

for i in range(len(omega)-1):
    alpha.append((omega[i+1]-omega[i])/(1/frame_rate))

time_3 = np.arange(len(alpha))/frame_rate
popt_3, _ = sp.optimize.curve_fit(lin, time_3, alpha)
```

```
print(popt_3)

plt.plot(np.arange(len(alpha))/frame_rate, alpha)
plt.plot(np.arange(len(alpha))/frame_rate, lin(time_3, *popt_3))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\alpha$ $[rad \cdot s^{-2}]$")
plt.savefig("m70_a.png")
```

```
[0.13666336 0.88319805]
```



[ ]:

```
acc_quad = popt_1[0]*2
acc_lin = popt_2[0]
print(acc_quad, acc_lin)
acc = (acc_quad + acc_lin)/2
Mom = 9.81 * m70 * r_m
I_m70 = Mom/acc
print(I_m70)
```

```
1.2779320473292384 1.3169429297856026
0.015878221634327522
```

1.5 Vidéo g70

```
[ ]: video_path = "g70.mp4"
     cap = cv2.VideoCapture(video_path)
```

```
[ ]: frame_rate = cap.get(cv2.CAP_PROP_FPS)
     print("Frame rate: ", frame_rate)
```

```
Frame rate:  30.0
```

```
[ ]: frames = []
     while True:
         ret, frame = cap.read()
         if not ret:
             break
         frames.append(frame)
```

```
[ ]: frame_rate = 120
     print("Frame rate: ", frame_rate)
```

```
Frame rate:  120
```

```
[ ]: def disp_f(num):
         plt.imshow(frames[num])

     widgets.interact(disp_f, num=widgets.IntSlider(min=0, max=len(frames)-1,␣
      ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=2152),␣
 ↪Output()), _dom_classes=('widget-intera…
```

```
[ ]: <function __main__.disp_f(num)>
```

```
[ ]: analyse = frames[903:2014]
```

```
[ ]: def pos_track(x,y):
         image = analyse[0].copy()
         w, h = 50, 50
         cv2.rectangle(image, (x, y), (x + w, y + h), (255, 0, 0), 4)
         plt.imshow(image)

     widgets.interact(pos_track, x=widgets.IntSlider(min=0, max=len(analyse[0]),␣
      ↪step=1), y=widgets.IntSlider(min=0, max=len(analyse[0][0]), step=1))
```

```
interactive(children=(IntSlider(value=0, description='x', max=1080),␣
 ↪IntSlider(value=0, description='y', max=1…
```

```
[ ]: <function __main__.pos_track(x, y)>
[ ]: tracker = cv2.TrackerCSRT_create()

     track_frames = analyse.copy()

     init_trac_f = track_frames[0]
     roi = (1054, 635, 50, 50)

     tracker.init(init_trac_f, roi)

     results = []
     frame_tracked = []
     for i in range(1, len(track_frames)):
         # Read the next frame
         frame = track_frames[i]

         # Update the tracker
         success, roi = tracker.update(frame)

         if success:
             # Draw a bounding box around the tracked object
             (x, y, w, h) = tuple(map(int, roi))
             results += [(x,y,w,h)]
             cv2.rectangle(frame, (x, y), (x + w, y + h), (255, 0, 0), 4)
             frame_tracked.append(frame)
```

```
[ ]: def disp_t(num):
         plt.imshow(frame_tracked[num])

     widgets.interact(disp_t, num=widgets.IntSlider(min=0, max=len(frame_tracked)-1,␣
      ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=1109),␣
 ↪Output()), _dom_classes=('widget-intera…
```

```
[ ]: <function __main__.disp_t(num)>
```

```
[ ]: good_results = results[698:895]
```

```
[ ]: center_of_rot = (725, 520, 50, 50)
```

```
[ ]: def pos_from_case(case):
         x,y,w,h = case
         return (x + (x+w))/2, (y + (y+h))/2
```

```
[ ]: pos_c = pos_from_case(center_of_rot)
     pos_r = [pos_from_case(i) for i in good_results]
```

[ ]:
```
theta = []
cur_theta = 0

prev_dir = [pos_r[0][0]-pos_c[0], pos_r[0][1]-pos_c[1]]
for i in range(len(pos_r)):
    next_dir = [pos_r[i][0]-pos_c[0], pos_r[i][1]-pos_c[1]]
    cur_theta += (np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    if np.abs(np.arctan2(next_dir[1], next_dir[0]) - np.arctan2(prev_dir[1],␣
 ↪prev_dir[0])) > np.pi:
        cur_theta -= 2*np.pi*np.sign(np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    theta.append(cur_theta)
    prev_dir = next_dir

print(theta)
```

```
[0.0, 0.04380327424584418, 0.0698416768609268, 0.0992867396492505,
0.1275495712062367, 0.15595449000322364, 0.18201905017031114,
0.18201905017031114, 0.2389515692831007, 0.2389515692831007, 0.2927828500948424,
0.3211879679773309, 0.34958392252349124, 0.37242472153889855,
0.4007690803770129, 0.4123452161977905, 0.45257238524667115,
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0.7727436513269781, 0.7727436513269781, 0.81897851086037, 0.81897851086037,
0.8667841195764162, 0.8899530260598265, 0.9123015535090342, 0.9330765338721232,
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1.9992525816152598, 2.0172848284758222, 2.026103159348146, 2.035339328217943,
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2.223117865758467, 2.2193308094664204, 2.208053092128025, 2.2014556383691986,
2.1977053899746055, 2.1948711814898996, 2.18830025232916, 2.184583224013301,
2.184583224013301, 2.172353979448701, 2.1629708768132776, 2.157249388069803]
```
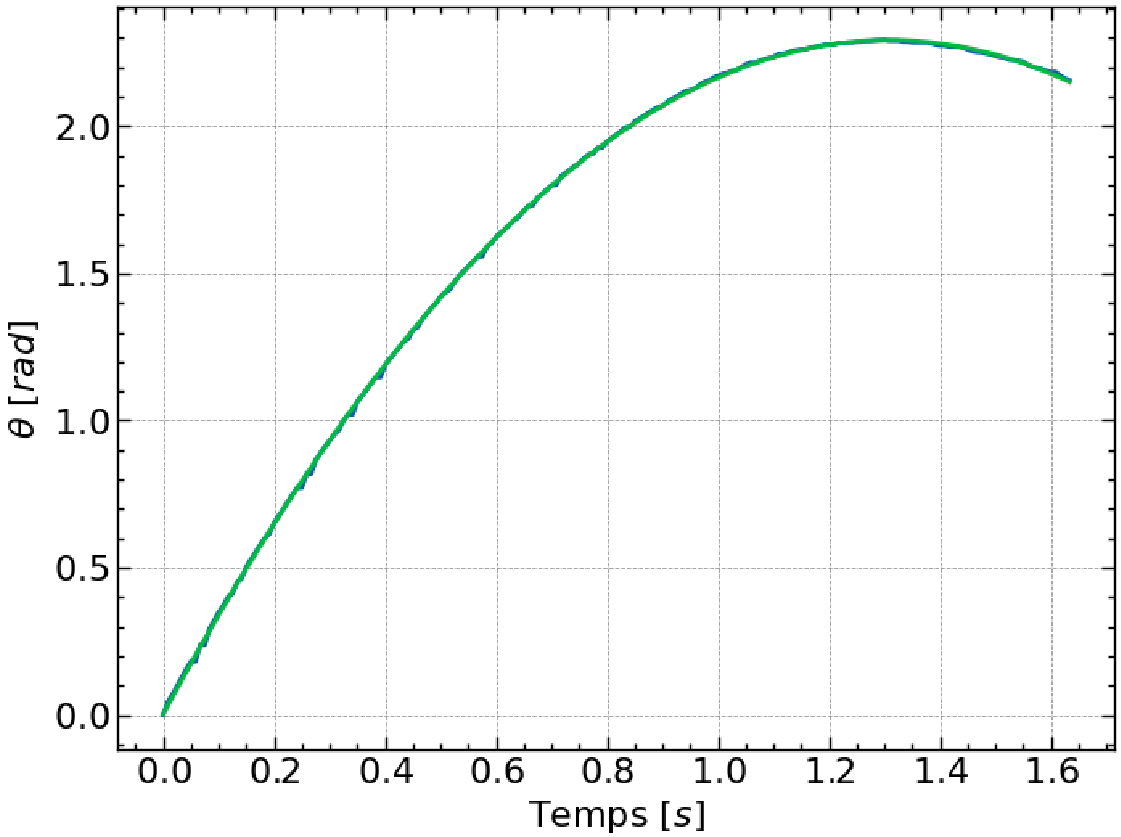

```
[ ]: time_1 = np.arange(len(theta))/frame_rate
     popt_1, _ = sp.optimize.curve_fit(quad, time_1, theta)
     popt_1
```

```
[ ]: array([-1.33778279e+00,  3.50021783e+00,  3.49643201e-03])
```

```
[ ]: plt.plot(time_1, theta)
     plt.plot(time_1, quad(time_1, *popt_1))
     plt.xlabel(r"Temps $[s]$")
     plt.ylabel(r"$\theta$ $[rad]$")
     plt.savefig("g70_t.png")
```

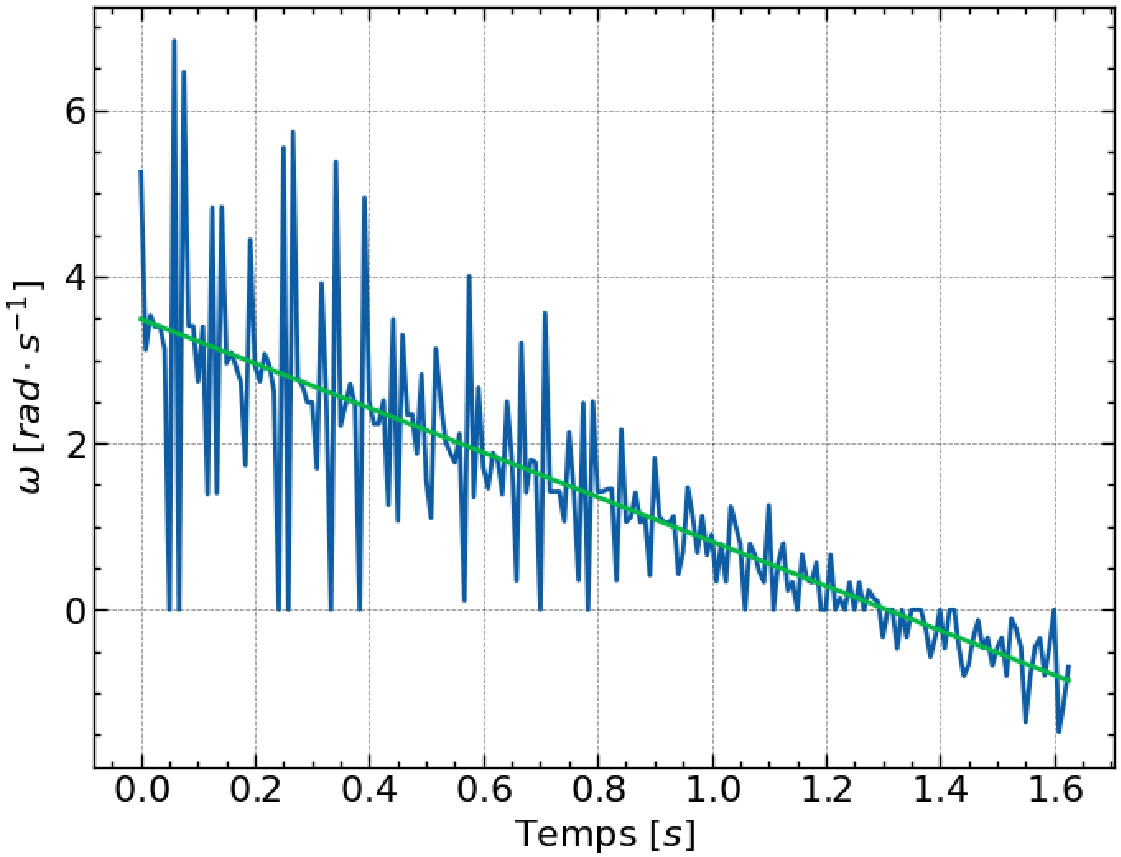


[ ]:
```
omega = []

for i in range(len(theta)-1):
    omega.append((theta[i+1]-theta[i])/(1/frame_rate))
```

[ ]:
```
time_2 = np.arange(len(omega))/frame_rate
popt_2, _ = sp.optimize.curve_fit(lin, time_2, omega)
popt_2
```

[ ]:
```
array([-2.67072506,  3.49072904])
```

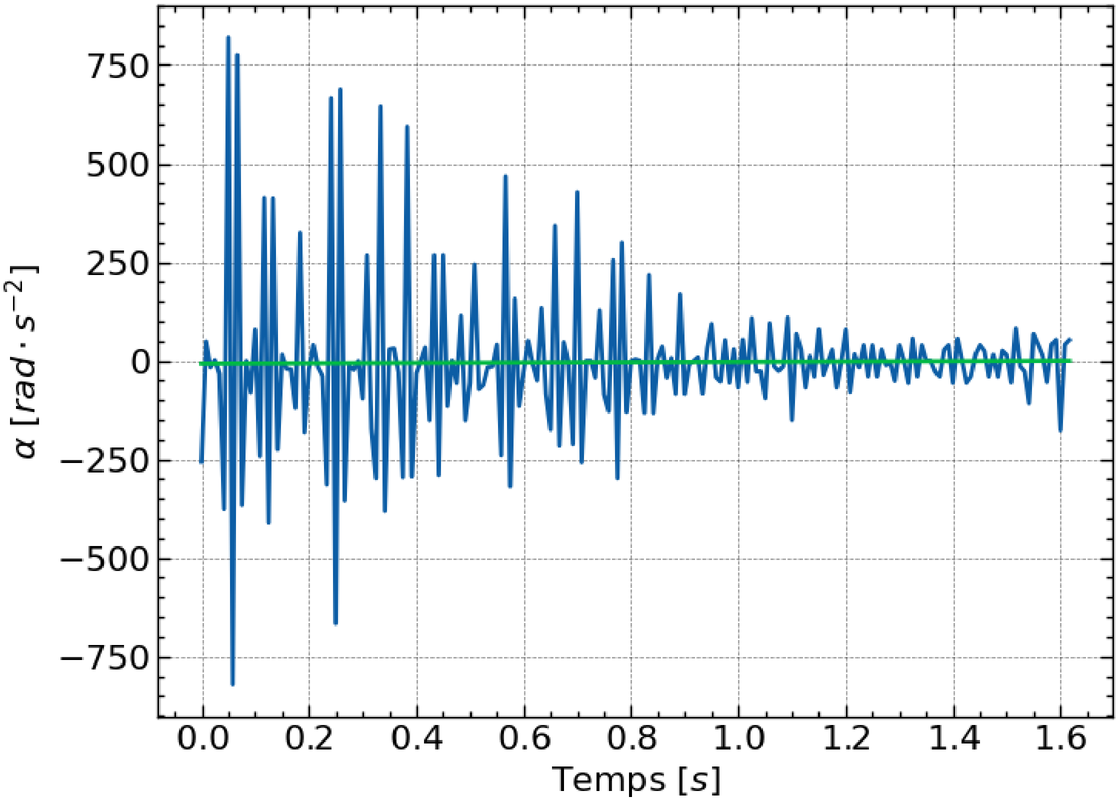
[ ]:
```
plt.plot(time_2, omega)
plt.plot(time_2, lin(time_2, *popt_2))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\omega$ $[rad \cdot s^{-1}]$")
plt.savefig("g70_o.png")
```



[ ]:

```
alpha = []

for i in range(len(omega)-1):
    alpha.append((omega[i+1]-omega[i])/(1/frame_rate))

time_3 = np.arange(len(alpha))/frame_rate
popt_3, _ = sp.optimize.curve_fit(lin, time_3, alpha)
print(popt_3)

plt.plot(np.arange(len(alpha))/frame_rate, alpha)
plt.plot(np.arange(len(alpha))/frame_rate, lin(time_3, *popt_3))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\alpha$ $[rad \cdot s^{-2}]$")
plt.savefig("g70_a.png")
```

```
[ 4.40400655 -7.21711223]
```



```
[ ]: acc_quad = popt_1[0]*2
     acc_lin = popt_2[0]
     print(acc_quad, acc_lin)
     acc = (acc_quad + acc_lin)/2
     Mom = 9.81 * m70 * r_g
     I_g70 = Mom/acc
     print(I_g70)
```

```
-2.675565570653598 -2.670725058482967
-0.011559977615728925
```

1.6 Vidéo m80

```
[ ]: video_path = "m80.mp4"
     cap = cv2.VideoCapture(video_path)
```

```
[ ]: frame_rate = cap.get(cv2.CAP_PROP_FPS)
     print("Frame rate: ", frame_rate)
```

```
Frame rate:  59.78746842677778
```

[ ]:
```
frames = []
while True:
    ret, frame = cap.read()
    if not ret:
        break
    frames.append(frame)
```

[ ]:
```
frame_rate = cap.get(cv2.CAP_PROP_FPS)
print("Frame rate: ", frame_rate)
```

```
Frame rate:  59.78746842677778
```

[ ]:
```
def disp_f(num):
    plt.imshow(frames[num])

widgets.interact(disp_f, num=widgets.IntSlider(min=0, max=len(frames)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=1152),␣
 ↪Output()), _dom_classes=('widget-intera…
```

[ ]:
```
<function __main__.disp_f(num)>
```

[ ]:
```
analyse = frames[678:957]
```

[ ]:
```
def pos_track(x,y):
    image = analyse[0].copy()
    w, h = 50, 50
    cv2.rectangle(image, (x, y), (x + w, y + h), (255, 0, 0), 4)
    plt.imshow(image)

widgets.interact(pos_track, x=widgets.IntSlider(min=0, max=len(analyse[0]),␣
 ↪step=1), y=widgets.IntSlider(min=0, max=len(analyse[0][0]), step=1))
```

```
interactive(children=(IntSlider(value=0, description='x', max=1080),␣
 ↪IntSlider(value=0, description='y', max=1…
```

[ ]:
```
<function __main__.pos_track(x, y)>
```

[ ]:
```
tracker = cv2.TrackerCSRT_create()

track_frames = analyse.copy()

init_trac_f = track_frames[0]
roi = (401, 294, 50, 50)

tracker.init(init_trac_f, roi)
```

```
results = []
frame_tracked = []
for i in range(1, len(track_frames)):
    # Read the next frame
    frame = track_frames[i]

    # Update the tracker
    success, roi = tracker.update(frame)

    if success:
        # Draw a bounding box around the tracked object
        (x, y, w, h) = tuple(map(int, roi))
        results += [(x,y,w,h)]
        cv2.rectangle(frame, (x, y), (x + w, y + h), (255, 0, 0), 4)
        frame_tracked.append(frame)
```

[ ]:

```
def disp_t(num):
    plt.imshow(frame_tracked[num])

widgets.interact(disp_t, num=widgets.IntSlider(min=0, max=len(frame_tracked)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=277), Output()),␣
 ↪_dom_classes=('widget-interac…
```

[ ]:

```
<function __main__.disp_t(num)>
```

[ ]:

```
good_results = results
```

[ ]:

```
center_of_rot = (705, 535, 50, 50)
```

[ ]:

```
def pos_from_case(case):
    x,y,w,h = case
    return (x + (x+w))/2, (y + (y+h))/2
```

[ ]:

```
pos_c = pos_from_case(center_of_rot)
pos_r = [pos_from_case(i) for i in good_results]
```

[ ]:

```
theta = []
cur_theta = 0

prev_dir = [pos_r[0][0]-pos_c[0], pos_r[0][1]-pos_c[1]]
for i in range(len(pos_r)):
    next_dir = [pos_r[i][0]-pos_c[0], pos_r[i][1]-pos_c[1]]
    cur_theta += (np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
```

```
    if np.abs(np.arctan2(next_dir[1], next_dir[0]) - np.arctan2(prev_dir[1],␣
 ↪prev_dir[0])) > np.pi:
        cur_theta -= 2*np.pi*np.sign(np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    theta.append(cur_theta)
    prev_dir = next_dir

print(theta)
```

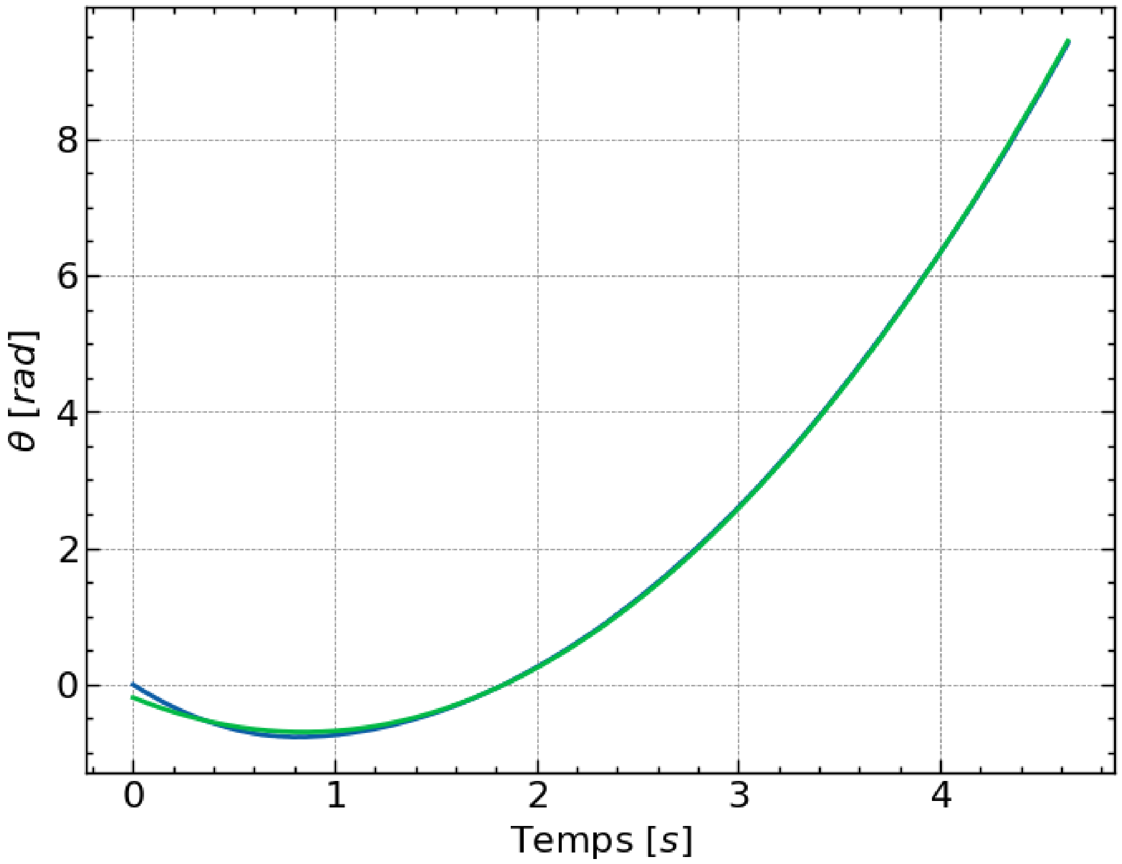
```
[0.0, -0.03351529685154597, -0.061766029641606934, -0.09542503022461757,
-0.12072140963968891, -0.14912421176569035, -0.1786368392925608,
-0.2063468739996459, -0.23483413978920975, -0.26032114218349056,
-0.2840963777029568, -0.3086339577490933, -0.3340273255975359,
-0.3569915570857578, -0.3781179566327788, -0.40132102303162354,
-0.42113884137910107, -0.4435170622073539, -0.4644126832071942,
-0.48426890882233753, -0.5029833012852252, -0.5221252777668921,
-0.5393300065382354, -0.5548421501731746, -0.5729908121751492,
-0.5847528264468131, -0.5992000290910728, -0.6173401912450336,
-0.6303070371103634, -0.6432870562466526, -0.6536892214798602,
-0.6692859648378877, -0.6784285556413399, -0.6900577068257081,
-0.6978368038801674, -0.7095828767580437, -0.7187494976922677,
-0.723929661199171, -0.7345226715542981, -0.73827896371031, -0.7446021725336851,
-0.7503308138486795, -0.7526248767176975, -0.7595392442860627,
-0.7606749101627779, -0.7647098921777196, -0.765837333220333,
-0.7698738123653417, -0.7709929890492679, -0.7687513642031663,
-0.7698738123653417, -0.7698738123653417, -0.7669615010141726,
-0.7618072900098274, -0.7621253927530556, -0.7606749101627779,
-0.7529191614956932, -0.7529191614956932, -0.7463064383017768,
-0.7437177368116359, -0.7371128130448916, -0.7345226715542981,
-0.7241496347987906, -0.7201497917183741, -0.7135650624385717,
-0.7057809991971964, -0.6992102671495459, -0.6914222204953893,
-0.6822724670518334, -0.6732271477673759, -0.6653540928977293,
-0.657565720759151, -0.6471779557737305, -0.6380855163021302,
-0.6250825898924859, -0.616013539094602, -0.6042897893621708,
-0.5939036396546249, -0.5809350074921786, -0.5665980570822482,
-0.5548421501731751, -0.5416589983274545, -0.5275825532089793,
-0.5132615708593313, -0.5000585957925896, -0.4831883958475043,
-0.46997286179655484, -0.45674754421391617, -0.43843164199807605,
-0.42367178447566767, -0.4054027152214963, -0.39157438894747143,
-0.3717696009014113, -0.3520198284422409, -0.33480455528665765,
-0.3184563691674538, -0.29887735591835707, -0.28076681946779747,
-0.2586390861644001, -0.2392366312709706, -0.21788547722609808,
-0.19885556506965996, -0.17689169871138155, -0.15611033268872365,
-0.13529792907779692, -0.11270667540387747, -0.08832379172541227,
-0.06533588503583321, -0.04459526777793954, -0.018537975729311373,
0.0036005351134389407, 0.02932859282125211, 0.056671195990560363,
0.08234614141125851, 0.10414238867039272, 0.12967977180296186,
0.1569209158939393, 0.18599094483456513, 0.21330575985119093,
0.2406194928310046, 0.2663077346392293, 0.29714455513679905,
0.32489141549314704, 0.352666812223279, 0.3826173836282978, 0.41258298116626335,
0.439560734688611, 0.47178809226504104, 0.5045701167486267, 0.5349416162169713,
0.5682873845041867, 0.6007315325322446, 0.6324386763190064, 0.6642548257839846,
0.6967149729404729, 0.7279573886552366, 0.762247398048965, 0.7960563483786403,
0.8323805828912116, 0.8682686616042086, 0.9005718717660649, 0.9391223504812416,
0.9738559549086832, 1.0155176288692986, 1.0488954166925235, 1.0897593733189992,
1.1232476753906522, 1.1607262047963893, 1.2017357674873899, 1.2425404598056449,
1.2784204755993396, 1.3193489318148541, 1.3569702229906586, 1.400269332093807,
1.4435189036241018, 1.4842516427012626, 1.5255083238558855, 1.5679186368966747,
1.6049387527706047, 1.6526764695047405, 1.6947937930691213, 1.7406136106912418,
1.7827678091293968, 1.8252377356380227, 1.867784507686145, 1.9124062318740256,
1.9600039236206983, 2.0044091316661583, 2.051922666410493, 2.1007244267572323,
2.1443471007639427, 2.190324294230517, 2.2389220490937696, 2.284946251802574,
2.3323552406875177, 2.38205340930373, 2.4318270987734163, 2.4813220564016016,
2.5309194814717464, 2.580579918829604, 2.6359678873518373, 2.683698056245706,
2.734495736874641, 2.78840570400252, 2.838017583303894, 2.893381973358346,
2.945950662465613, 2.9986295013085016, 3.0520599305802047, 3.1072552157173576,
3.1632499167543067, 3.218939797348542, 3.2728185583222453, 3.3283985941689336,
3.385801081882029, 3.4439177431037358, 3.5024532443554404, 3.5577581110124736,
3.6140447630958468, 3.6732729769146797, 3.733057671478127, 3.790204615740236,
3.8524872776781613, 3.9125896180263444, 3.9733344222073557, 4.033756222259003,
4.093942422209226, 4.156795913792738, 4.219698911218707, 4.283731177842544,
4.345207434504035, 4.410415992118265, 4.472411708258035, 4.535483823085386,
4.603141310063503, 4.666806918459837, 4.729016564883576, 4.799429105628047,
4.862077692120075, 4.928397400197243, 4.998736607348157, 5.060861877640604,
5.128854943193762, 5.197591884568309, 5.262810165896122, 5.33191694782031,
5.400079390942926, 5.468826179014435, 5.5397380123988675, 5.610133369831394,
5.6800529402848445, 5.750167258067182, 5.818321472894314, 5.889405417110121,
5.962276645158545, 6.03342260854437, 6.100526705743979, 6.176700246451693,
6.246086747628377, 6.321556622524583, 6.39466584256261, 6.463729287219111,
6.538055147935601, 6.611977409768528, 6.686059471452921, 6.761848433393836,
6.836715270182072, 6.913167578962673, 6.990492810541079, 7.065769535858834,
7.141367826906452, 7.223604493578726, 7.298702936048884, 7.379108408332678,
7.458634247536725, 7.536346282684952, 7.614058317833178, 7.695582639847269,
7.780331897478861, 7.860171522901564, 7.939517270496469, 8.02196837598242,
8.10862189486569, 8.190190151871837, 8.275266314731395, 8.356614027637187,
8.440619253206581, 8.525545775096333, 8.611473549028423, 8.6956726801845,
8.778873242599582, 8.872978665907704, 8.95976200232492, 9.048435313963582,
9.13449896728733, 9.22154513149358, 9.312807804065923, 9.39986652927939]
```

```
[ ]: time_1 = np.arange(len(theta))/frame_rate
     popt_1, _ = sp.optimize.curve_fit(quad, time_1, theta)
     popt_1
```

```
[ ]: array([ 0.70658563, -1.19618068, -0.1905181 ])
```

[ ]:

```
plt.plot(time_1, theta)
plt.plot(time_1, quad(time_1, *popt_1))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\theta$ $[rad]$")
plt.savefig("m80_t.png")
```



[ ]:

```
omega = []

for i in range(len(theta)-1):
    omega.append((theta[i+1]-theta[i])/(1/frame_rate))
```

[ ]:

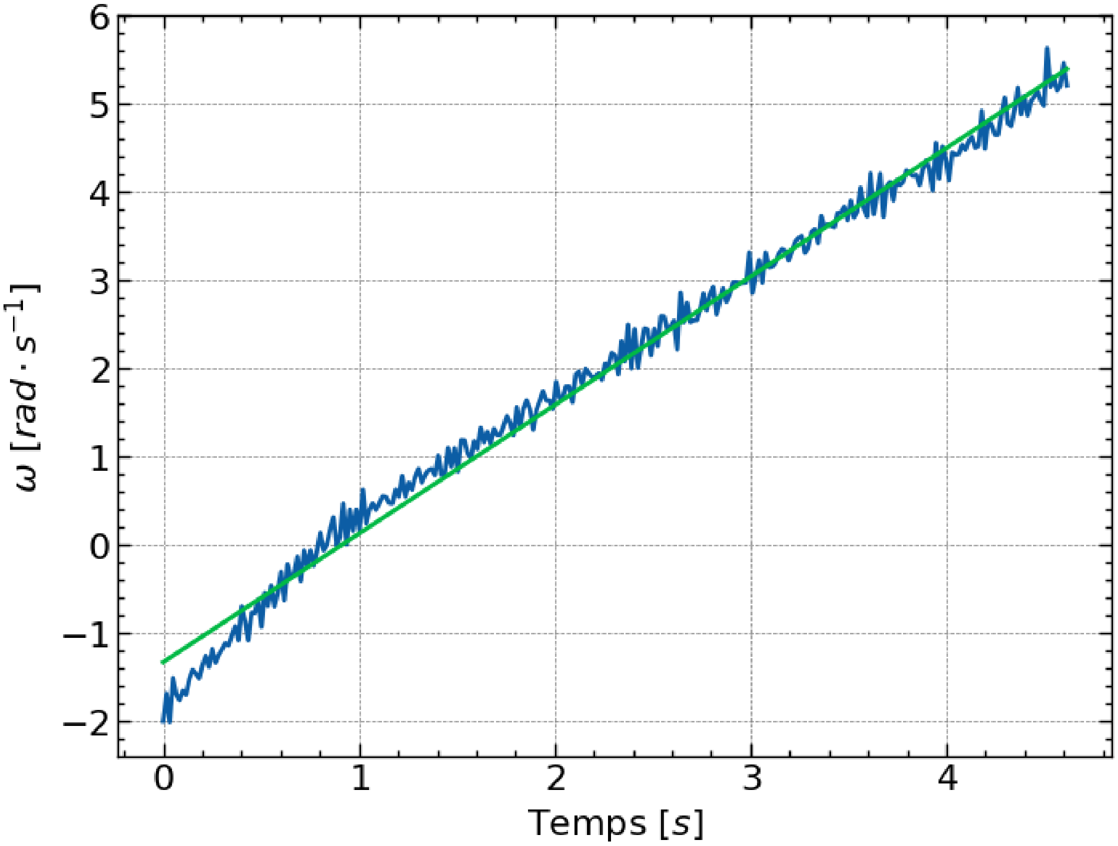
```
time_2 = np.arange(len(omega))/frame_rate
popt_2, _ = sp.optimize.curve_fit(lin, time_2, omega)
popt_2
```

[ ]:

```
array([ 1.45686417, -1.33383892])
```

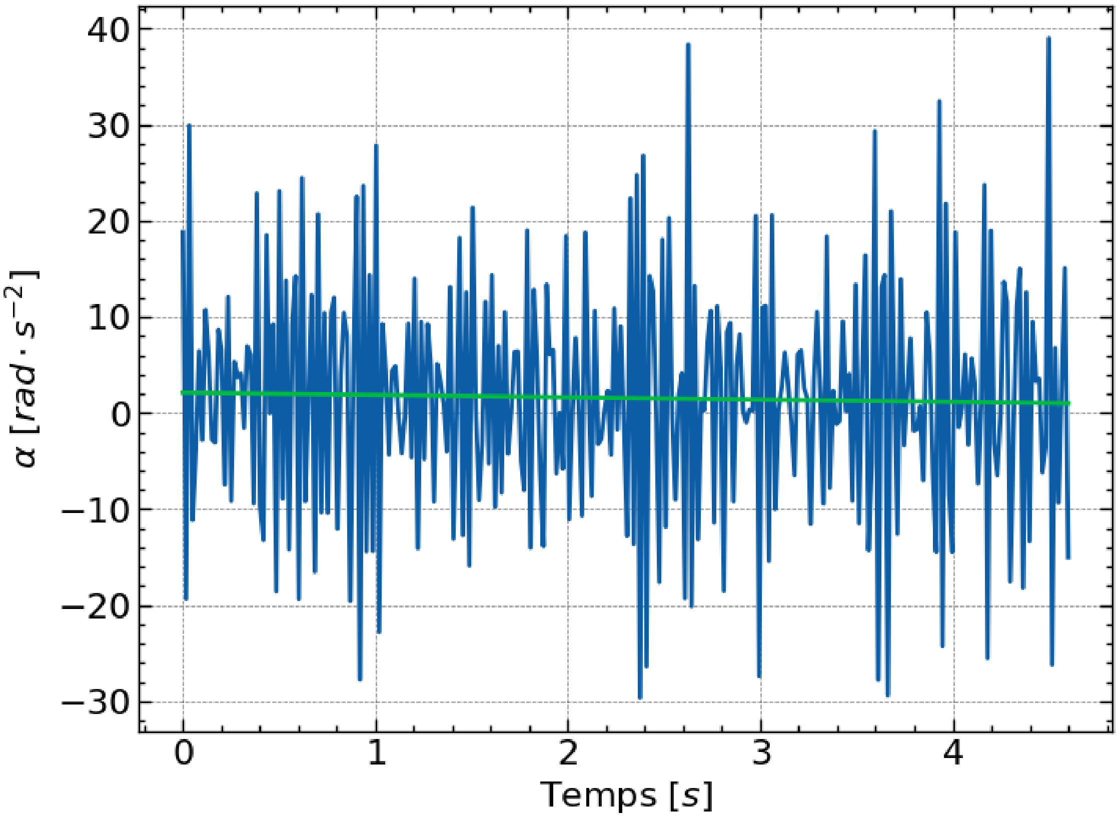
[ ]:

```
plt.plot(time_2, omega)
plt.plot(time_2, lin(time_2, *popt_2))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\omega$ $[rad \cdot s^{-1}]$")
plt.savefig("m80_o.png")
```



[ ]:
```
alpha = []

for i in range(len(omega)-1):
    alpha.append((omega[i+1]-omega[i])/(1/frame_rate))

time_3 = np.arange(len(alpha))/frame_rate
popt_3, _ = sp.optimize.curve_fit(lin, time_3, alpha)
print(popt_3)

plt.plot(np.arange(len(alpha))/frame_rate, alpha)
plt.plot(np.arange(len(alpha))/frame_rate, lin(time_3, *popt_3))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\alpha$ $[rad \cdot s^{-2}]$")
plt.savefig("m80_a.png")
```

```
[-0.24202158  2.11818713]
```



```
[ ]: acc_quad = popt_1[0]*2
     acc_lin = popt_2[0]
     print(acc_quad, acc_lin)
     acc = (acc_quad + acc_lin)/2
     Mom = 9.81 * m80 * r_m
     I_m80 = Mom/acc
     print(I_m80)
```

```
1.4131712550841267 1.4568641739241976
0.016406766106113954
```

1.7 Vidéo m100

```
[ ]: video_path = "m100.mp4"
     cap = cv2.VideoCapture(video_path)
```

```
[ ]: frame_rate = cap.get(cv2.CAP_PROP_FPS)
     print("Frame rate: ", frame_rate)
```

```
Frame rate:  59.78130509097191
```

[ ]:

```
frames = []
while True:
    ret, frame = cap.read()
    if not ret:
        break
    frames.append(frame)
```

[ ]:

```
frame_rate = cap.get(cv2.CAP_PROP_FPS)
print("Frame rate: ", frame_rate)
```

```
Frame rate:  59.78130509097191
```

[ ]:

```
def disp_f(num):
    plt.imshow(frames[num])

widgets.interact(disp_f, num=widgets.IntSlider(min=0, max=len(frames)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=791), Output()),␣
 ↪_dom_classes=('widget-interac…
```

[ ]:

```
<function __main__.disp_f(num)>
```

[ ]:

```
analyse = frames[356:662]
```

[ ]:

```
def pos_track(x,y):
    image = analyse[0].copy()
    w, h = 50, 50
    cv2.rectangle(image, (x, y), (x + w, y + h), (255, 0, 0), 4)
    plt.imshow(image)

widgets.interact(pos_track, x=widgets.IntSlider(min=0, max=len(analyse[0]),␣
 ↪step=1), y=widgets.IntSlider(min=0, max=len(analyse[0][0]), step=1))
```

```
interactive(children=(IntSlider(value=0, description='x', max=1080),␣
 ↪IntSlider(value=0, description='y', max=1…
```

[ ]:

```
<function __main__.pos_track(x, y)>
```

[ ]:

```
tracker = cv2.TrackerCSRT_create()

track_frames = analyse.copy()

init_trac_f = track_frames[0]
roi = (418, 279, 50, 50)

tracker.init(init_trac_f, roi)
```

```
results = []
frame_tracked = []
for i in range(1, len(track_frames)):
    # Read the next frame
    frame = track_frames[i]

    # Update the tracker
    success, roi = tracker.update(frame)

    if success:
        # Draw a bounding box around the tracked object
        (x, y, w, h) = tuple(map(int, roi))
        results += [(x,y,w,h)]
        cv2.rectangle(frame, (x, y), (x + w, y + h), (255, 0, 0), 4)
        frame_tracked.append(frame)
```

[ ]:

```
def disp_t(num):
    plt.imshow(frame_tracked[num])

widgets.interact(disp_t, num=widgets.IntSlider(min=0, max=len(frame_tracked)-1,␣
 ↪step=1))
```

```
interactive(children=(IntSlider(value=0, description='num', max=304), Output()),␣
 ↪_dom_classes=('widget-interac…
```

[ ]: `<function __main__.disp_t(num)>`

[ ]:

```
good_results = results[0:277]
```

[ ]:

```
center_of_rot = (705, 535, 50, 50)
```

[ ]:

```
def pos_from_case(case):
    x,y,w,h = case
    return (x + (x+w))/2, (y + (y+h))/2
```

[ ]:

```
pos_c = pos_from_case(center_of_rot)
pos_r = [pos_from_case(i) for i in good_results]
```

[ ]:

```
theta = []
cur_theta = 0

prev_dir = [pos_r[0][0]-pos_c[0], pos_r[0][1]-pos_c[1]]
for i in range(len(pos_r)):
    next_dir = [pos_r[i][0]-pos_c[0], pos_r[i][1]-pos_c[1]]
    cur_theta += (np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
```

```
    if np.abs(np.arctan2(next_dir[1], next_dir[0]) - np.arctan2(prev_dir[1],␣
 ↪prev_dir[0])) > np.pi:
        cur_theta -= 2*np.pi*np.sign(np.arctan2(next_dir[1], next_dir[0]) - np.
 ↪arctan2(prev_dir[1], prev_dir[0]))
    theta.append(cur_theta)
    prev_dir = next_dir

print(theta)
```

```
[0.0, -0.07118707274296376, -0.14414895625611068, -0.21949067471002426,
-0.28641815152193795, -0.35986876501066956, -0.43131650120932497,
-0.5034937685398377, -0.575541813344806, -0.6408766570481141,
-0.7060875973123704, -0.7740333815239029, -0.8450845470731321,
-0.9069616148433948, -0.9696355473074374, -1.0338017887510467,
-1.1007296210767783, -1.1623734616490187, -1.2212177431155604,
-1.2822995085797584, -1.3402878613562117, -1.4028677249995365,
-1.4615731774941763, -1.514962208937496, -1.5664169306634075,
-1.625407819080091, -1.6821973226303437, -1.7367742529236518,
-1.7877313730111988, -1.8411654063092386, -1.889558629680698,
-1.9412060628221415, -1.9921242364339742, -2.0398838107291057,
-2.0896915650714023, -2.1363644899388117, -2.180564378730214,
-2.227277586070473, -2.272633371539565, -2.3153153762374794,
-2.3621337704532603, -2.4042180450215325, -2.444361315428644,
-2.4864381972737144, -2.529011990199563, -2.5673941131072477,
-2.607444232533383, -2.644421986677937, -2.6825742920971734, -2.717821516037558,
-2.75149222183164, -2.7866330285017034, -2.820457241879943, -2.8560139376152027,
-2.8857654457631874, -2.9168965116969594, -2.9500140226305462,
-2.9811423618890394, -3.010378283091321, -3.039561535024689, -3.067094645053573,
-3.0925905403542004, -3.1220126297915645, -3.147833997312608,
-3.172157822686961, -3.194408647588779, -3.2174062094453624,
-3.2418756020298476, -3.2627879288633332, -3.2837075764451935,
-3.3058241195851257, -3.323182231353102, -3.3416648595177367,
-3.3589757434302783, -3.3769301399739384, -3.393222603397167,
-3.408835518180258, -3.422757019572278, -3.4366734987886978, -3.449716702914652,
-3.4636415500480773, -3.4710125228910815, -3.4841623870289204,
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4.4355114812512095, 4.5273271943531395, 4.615674703922185, 4.70874237949759,
4.799394911025825, 4.885961383117804, 4.973203543208877]
```
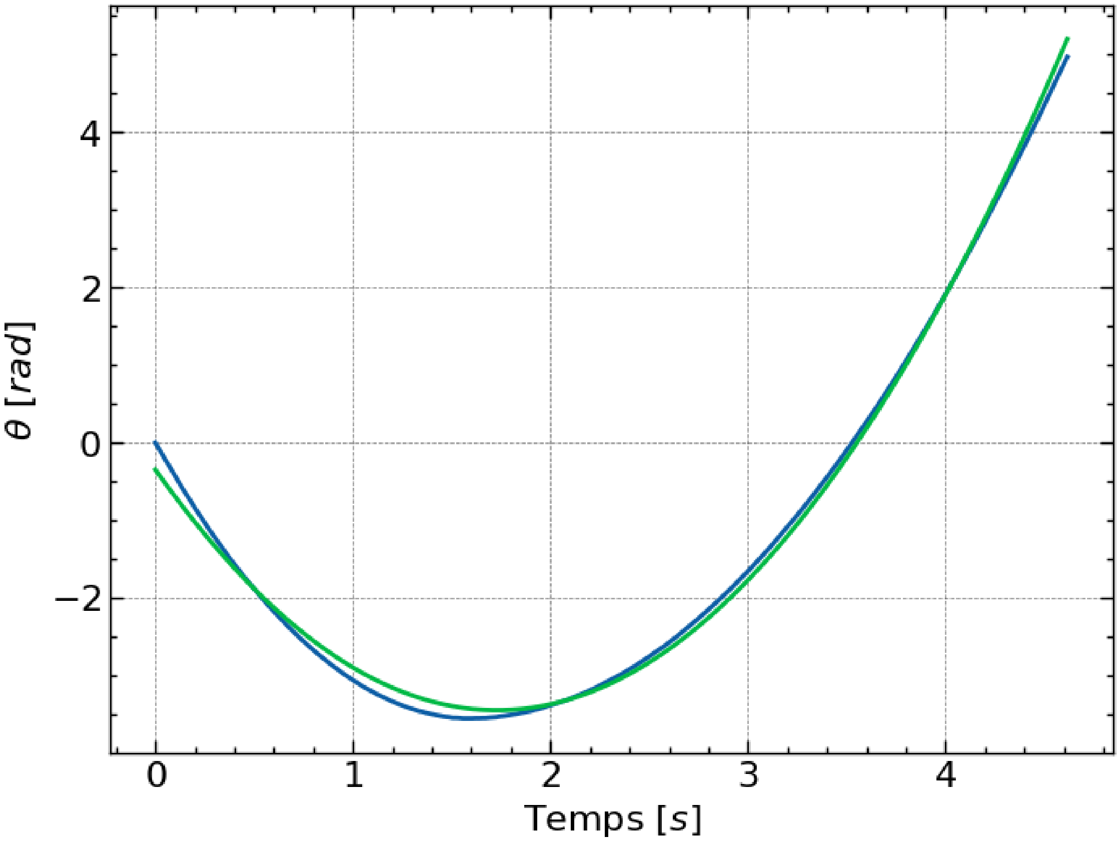

[ ]:
```
time_1 = np.arange(len(theta))/frame_rate
popt_1, _ = sp.optimize.curve_fit(quad, time_1, theta)
popt_1
```

```
[ ]: array([ 1.03777155, -3.58824855, -0.3479185 ])
```

```
[ ]: plt.plot(time_1, theta)
     plt.plot(time_1, quad(time_1, *popt_1))
     plt.xlabel(r"Temps $[s]$")
     plt.ylabel(r"$\theta$ $[rad]$")
     plt.savefig("m100_t.png")
```

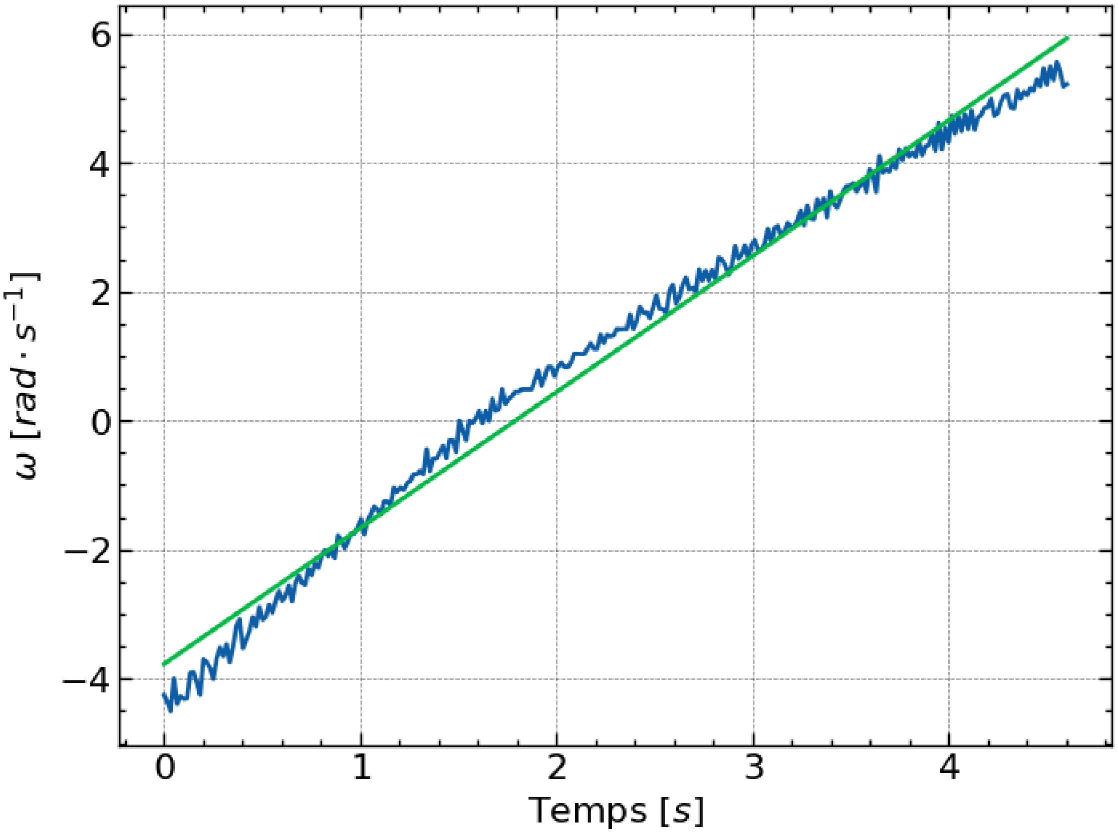


```
[ ]: omega = []

     for i in range(len(theta)-1):
         omega.append((theta[i+1]-theta[i])/(1/frame_rate))
```

```
[ ]: time_2 = np.arange(len(omega))/frame_rate
     popt_2, _ = sp.optimize.curve_fit(lin, time_2, omega)
     popt_2
```

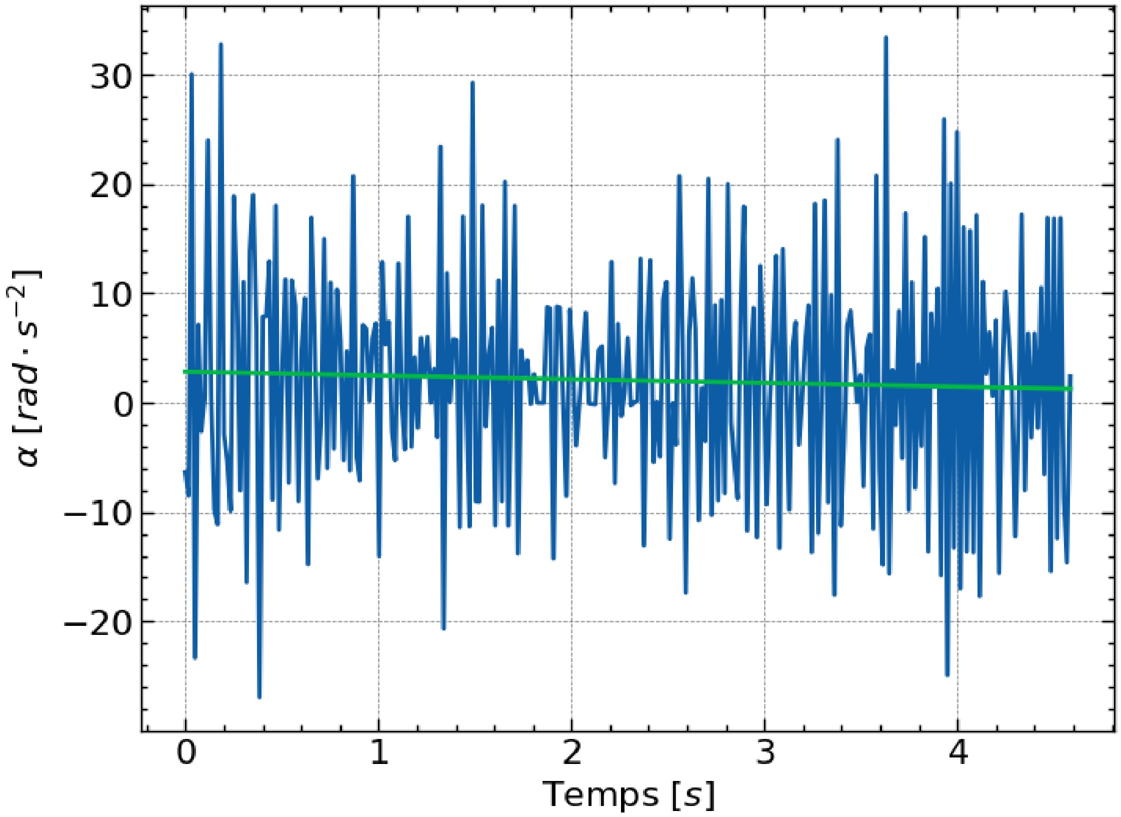
```
[ ]: array([ 2.10807802, -3.7714946 ])
```

[ ]:
```
plt.plot(time_2, omega)
plt.plot(time_2, lin(time_2, *popt_2))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\omega$ $[rad \cdot s^{-1}]$")
plt.savefig("m100_o.png")
```



[ ]:
```
alpha = []

for i in range(len(omega)-1):
    alpha.append((omega[i+1]-omega[i])/(1/frame_rate))

time_3 = np.arange(len(alpha))/frame_rate
popt_3, _ = sp.optimize.curve_fit(lin, time_3, alpha)
print(popt_3)

plt.plot(np.arange(len(alpha))/frame_rate, alpha)
plt.plot(np.arange(len(alpha))/frame_rate, lin(time_3, *popt_3))
plt.xlabel(r"Temps $[s]$")
plt.ylabel(r"$\alpha$ $[rad \cdot s^{-2}]$")
plt.savefig("m100_a.png")
```

```
[-0.33995123  2.83795285]
```



[ ]:
```
acc_quad = popt_1[0]*2
acc_lin = popt_2[0]
print(acc_quad, acc_lin)
acc = (acc_quad + acc_lin)/2
Mom = 9.81 * m100 * r_m
I_m100 = Mom/acc
print(I_m100)
```

```
2.0755430982955625 2.1080780173316844
0.014069151668667558
```

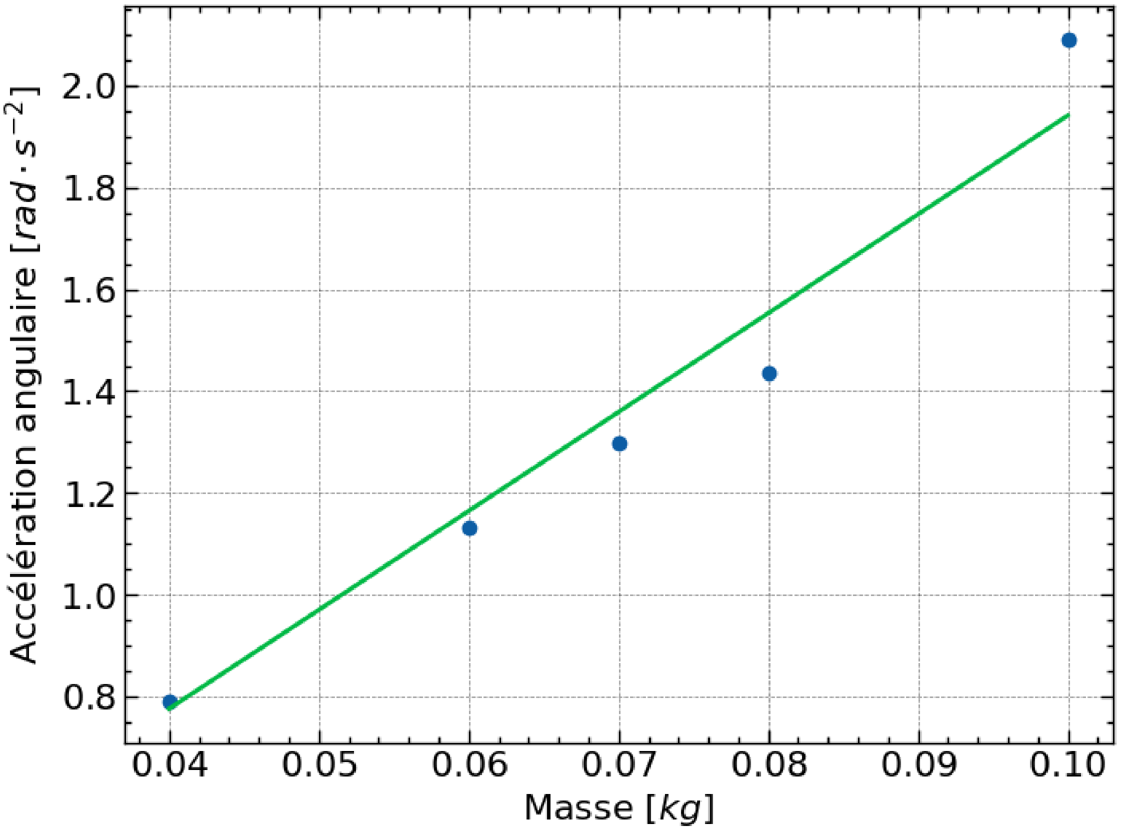
2 Analyse résultats

[ ]:
```
tabular = pd.DataFrame({
              "Mass": [40e-3, 60e-3, 70e-3, 70e-3, 70e-3, 80e-3, 100e-3],
              "Radius": [r_m, r_m, r_p, r_m, r_g, r_m, r_m],
              "Moment of Inertia": [I_m40, I_m60, I_p70, I_m70, np.abs(I_g70),␣
 ↪I_m80, I_m100]
              })
```

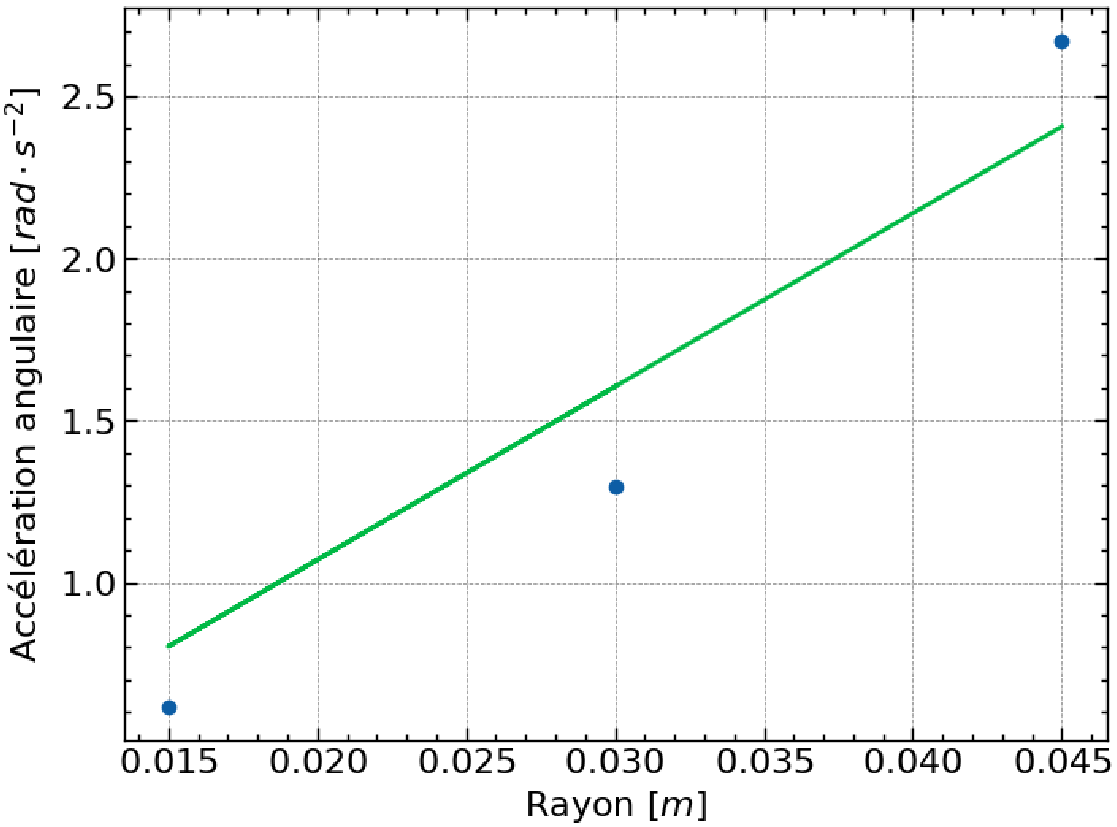
```
tabular["Angular Acceleration"] = tabular["Mass"]*9.81*tabular["Radius"]/
 ↪tabular["Moment of Inertia"]

tabular
```

```
[ ]:    Mass  Radius  Moment of Inertia  Angular Acceleration
     0  0.04   0.030           0.014886              0.790816
     1  0.06   0.030           0.015582              1.133199
     2  0.07   0.015           0.016659              0.618307
     3  0.07   0.030           0.015878              1.297437
     4  0.07   0.045           0.011560              2.673145
     5  0.08   0.030           0.016407              1.435018
     6  0.10   0.030           0.014069              2.091811
```

```
[ ]: # Plot a graph of the acceleration against the mass for all the measure with␣
      ↪radius r_m
     plt.plot(tabular["Mass"][tabular["Radius"] == r_m], tabular["Angular␣
      ↪Acceleration"][tabular["Radius"] == r_m], "o")
     popt_fr, _ = sp.optimize.curve_fit(prop:=lambda x,a: a*x,␣
      ↪tabular["Mass"][tabular["Radius"] == r_m], tabular["Angular␣
      ↪Acceleration"][tabular["Radius"] == r_m])
     plt.plot(np.array([40e-3, 100e-3]), prop(np.array([40e-3, 100e-3]), *popt_fr))
     plt.xlabel(r"Masse $[kg]$")
     plt.ylabel(r"Accélération angulaire $[rad \cdot s^{-2}]$")
     plt.savefig("prop_masse.png")
```



```
[ ]: # Plot a graph of the acceleration against the radius for all the measure with␣
      ↪mass 70g
     plt.plot(tabular["Radius"][tabular["Mass"] == 70e-3], tabular["Angular␣
      ↪Acceleration"][tabular["Mass"] == 70e-3], "o")
     popt_fr, _ = sp.optimize.curve_fit(prop:=lambda x,a: a*x,␣
      ↪tabular["Radius"][tabular["Mass"] == 70e-3], tabular["Angular␣
      ↪Acceleration"][tabular["Mass"] == 70e-3])
     plt.plot(np.array([r_m, r_p, r_g]), prop(np.array([r_m, r_p, r_g]), *popt_fr))
     plt.xlabel(r"Rayon $[m]$")
     plt.ylabel(r"Accélération angulaire $[rad \cdot s^{-2}]$")
     plt.savefig("prop_rayon.png")
```



[ ]:

```
# average and std for the moment of inertia
I_mean = np.mean(tabular["Moment of Inertia"])
I_std = np.std(tabular["Moment of Inertia"])
print(I_mean, I_std)
rel = I_std/I_mean
print(f"Relative uncertainty: {rel*100}%")
```

```
0.015005949828400644 0.0016281219932735526
Relative uncertainty: 10.849842974898712%
```

[ ]:

```
tab_report = pd.DataFrame()
tab_report["M [kg]"] = tabular["Mass"].round(2)
tab_report["r [m]"] = tabular["Radius"].round(3)
tab_report["I [kg m2]"] = tabular["Moment of Inertia"].round(3)
tab_report["alpha [rad s-2]"] = tabular["Angular Acceleration"].round(3)
print(tab_report.to_latex(index=False, float_format="%.3f"))
```

```
\begin{tabular}{rrrr}
\toprule
 M [kg] &  r [m] &  I [kg m2] &  alpha [rad s-2] \\
\midrule
```

```
  0.040 &  0.030 &      0.015 &            0.791 \\
  0.060 &  0.030 &      0.016 &            1.133 \\
  0.070 &  0.015 &      0.017 &            0.618 \\
  0.070 &  0.030 &      0.016 &            1.297 \\
  0.070 &  0.045 &      0.012 &            2.673 \\
  0.080 &  0.030 &      0.016 &            1.435 \\
  0.100 &  0.030 &      0.014 &            2.092 \\
\bottomrule
\end{tabular}

/tmp/ipykernel_25126/569439553.py:6: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(tab_report.to_latex(index=False, float_format="%.3f"))
```