Dataset_Z_Exploration_Matlab

April 4, 2021

0.1 Dataset Prueba 1 - Tesis Javier-Uriel

0.1.1 Importamos algunas librerías que nos serán útiles más adelante

[1]:
```
import os
import time
import random

import pandas as pd # for dataframe operations.
import numpy as np #for linear algebra operations.
import seaborn as sns # data visualization library
import matplotlib.pyplot as plt # for plotting

from scipy.fftpack import fft, fftfreq

from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
from statsmodels.tsa.stattools import pacf

pd.set_option('display.max_columns', None) #Para mostrar todas las columnas
random.seed(1)
```

0.1.2 Leemos el Dataset

[2]:
```
#Dataset solo movimientos en Z
#rpm_list = ['RPM0', 'RPM1', 'RPM2', 'RPM3']
#states_list_org = ["vz","az", "uvz",
#                   "p", "q",
#                   "wp", "wq",
#                   "ap", "aq"]
rpm_list = ['Motor1', 'Motor2', 'Motor3', 'Motor4']
states_list_org = ["Z","Dz", "Z_r", "Ac_Dz",
                   "Yaw", "Roll",
                   "P", "Q",
                   "Acceleracion P", "Acceleracion Q"]
#states_list_org = ["vz","az", "uvz"]
states_list_min = ["vz","az", "uvz"]
dataset_name = "Dataset_Z_Matlab"
directory = "../logs/Datasets/"+dataset_name
```

```
ORDER = 3
dfs = []
states_list=states_list_org.copy()
```

0.1.3 Corregir la salida

El estado que entrega Pybullet de RPMs es la salida anterior, en este dataset se tomará RPMs como la salida actual. Si el primer elemento de RPMs es 0, es necesario hacer el shift

[3]:
```
for filename in os.listdir(directory):
    if not filename.endswith(".csv"):
        continue
    df = pd.read_csv(os.path.join(directory, filename))
    #if any(df['z']<=1) or any(abs(df['vz'])>=10): #Eliminar si el dron se cae
    #    print(filename)
    #else:
    if any(df[rpm_list].loc[0]==0): #Desplazar los estados de RPM si es necesario
        df[rpm_list] = df[rpm_list].shift(periods=-1)
        df = df.dropna()
        df.to_csv(os.path.join(directory, filename), index=False)

    a = []
    ## Desplazamos estados anteriores
    for n in range(1,ORDER+1):
        for column in states_list:
            df[column+str(n)] = df[column].shift(periods=n, fill_value=0)
            a.append(column+str(n))
    dfs.append(df)
states_list+=a

dataset = pd.concat(dfs)
dataset.describe()
```

[3]:

	Time	X	Y	Z	Yaw	\
count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	
mean	4.281013e+01	-3.350768e-04	-3.359317e-04	-1.503027e+00	2.256389e-06	
std	2.896393e+01	1.074610e-02	1.136344e-02	2.700165e-01	2.768997e-04	
min	0.000000e+00	-3.573908e-01	-5.542104e-01	-3.318702e+00	-1.254526e-02	
25%	1.806000e+01	-1.364899e-03	-1.247569e-03	-1.624232e+00	-1.617708e-05	
50%	3.521000e+01	-3.312734e-04	-2.898734e-04	-1.499096e+00	1.685380e-07	
75%	6.760500e+01	7.783263e-04	6.850931e-04	-1.367094e+00	1.726007e-05	
max	1.000000e+02	3.491811e-01	5.142932e-01	-4.311047e-02	1.233279e-02	

	Roll	Pitch	Dx	Dy	Dz	\
count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	
mean	7.887180e-05	-8.071778e-05	3.052208e-06	2.332470e-06	-1.521121e-02	
std	3.506121e-03	5.052975e-03	4.558698e-02	2.659362e-02	4.544270e-01	

```
min   -1.588011e-01 -1.569786e-01 -1.510064e+00 -1.360795e+00 -4.524404e+00
25%   -2.072770e-04 -3.469328e-04 -8.009977e-04 -1.753193e-03 -9.322637e-03
50%    6.043164e-05 -7.090611e-05 -1.754226e-06  0.000000e+00  1.322787e-04
75%    3.423737e-04  1.998152e-04  7.909324e-04  1.652702e-03  8.660311e-03
max    1.636863e-01  1.538717e-01  1.486235e+00  1.353771e+00  3.034264e+00

                 P             Q             R        Motor1        Motor2  \
count  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06
mean   1.573519e-06  1.412977e-06 -3.197492e-07  2.365206e+02 -2.365207e+02
std    9.057596e-03  3.927625e-02  2.225740e-03  3.395921e+01  3.395556e+01
min   -5.037703e-01 -3.575321e+00 -1.820346e-01  1.000000e+01 -4.613083e+02
25%   -1.220251e-03 -1.284665e-03 -9.134351e-04  2.355287e+02 -2.375263e+02
50%    4.287249e-06 -4.722129e-06 -4.495727e-06  2.365282e+02 -2.365222e+02
75%    1.240739e-03  1.283613e-03  9.029967e-04  2.374787e+02 -2.354865e+02
max    4.727377e-01  3.632708e+00  1.794934e-01  4.609845e+02 -1.000000e+01

             Motor3        Motor4        X_r        Y_r           Z_r  \
count  1.295895e+06  1.295895e+06  1295895.0  1295895.0  1.295895e+06
mean   2.365206e+02 -2.365208e+02        0.0        0.0 -1.482117e+00
std    3.394866e+01  3.396455e+01        0.0        0.0  2.440522e-01
min    1.000000e+01 -4.609848e+02        0.0        0.0 -2.774623e+00
25%    2.355364e+02 -2.375314e+02        0.0        0.0 -1.620000e+00
50%    2.365288e+02 -2.365235e+02        0.0        0.0 -1.500000e+00
75%    2.374726e+02 -2.354862e+02        0.0        0.0 -1.351574e+00
max    4.611932e+02 -1.000000e+01        0.0        0.0  0.000000e+00

           Yaw_r    Pitch_r     Roll_r       Dx_r       Dy_r          Dz_r  \
count  1295895.0  1295895.0  1295895.0  1295895.0  1295895.0  1.295895e+06
mean         0.0        0.0        0.0        0.0        0.0 -2.193838e-02
std          0.0        0.0        0.0        0.0        0.0  8.223455e+00
min          0.0        0.0        0.0        0.0        0.0 -3.460435e+02
25%          0.0        0.0        0.0        0.0        0.0  0.000000e+00
50%          0.0        0.0        0.0        0.0        0.0  0.000000e+00
75%          0.0        0.0        0.0        0.0        0.0  0.000000e+00
max          0.0        0.0        0.0        0.0        0.0  3.807929e+02

             P_r        Q_r        R_r  Flag_Pitch_Roll         Ac_Dx  \
count  1295895.0  1295895.0  1295895.0        1295895.0  1.295895e+06
mean         0.0        0.0        0.0              1.0  9.007334e-02
std          0.0        0.0        0.0              0.0  2.089574e-01
min          0.0        0.0        0.0              1.0 -8.013137e-01
25%          0.0        0.0        0.0              1.0 -5.126491e-02
50%          0.0        0.0        0.0              1.0  9.049701e-02
75%          0.0        0.0        0.0              1.0  2.315978e-01
max          0.0        0.0        0.0              1.0  8.437319e-01

              Ac_Dy         Ac_Dz        Gyro P        Gyro Q        Gyro R  \
```

count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06
mean	-5.992936e-02	-9.419827e+00	-9.498428e-03	-7.498578e-03	1.499741e-03
std	1.930278e-01	1.427087e+00	9.045007e-03	3.952919e-02	2.383690e-03
min	-8.834900e-01	-1.963813e+01	-5.125701e-01	-3.605846e+00	-1.798834e-01
25%	-1.905823e-01	-9.646096e+00	-1.071855e-02	-8.792938e-03	4.273835e-04
50%	-5.959882e-02	-9.423019e+00	-9.495718e-03	-7.504752e-03	1.502034e-03
75%	7.084187e-02	-9.203916e+00	-8.260985e-03	-6.208120e-03	2.568620e-03
max	6.365708e-01	8.609541e-01	4.625807e-01	3.648603e+00	1.830248e-01

	Sonar Altitud	Pressure Altitud	Bat_V	Bat_Percentage	\
count	1.295895e+06	1.295895e+06	1295895.0	1295895.0	
mean	1.504551e+00	1.012529e+05	3.5	70.0	
std	2.614817e-01	3.211676e+00	0.0	0.0	
min	4.400000e-01	1.012314e+05	3.5	70.0	
25%	1.367890e+00	1.012514e+05	3.5	70.0	
50%	1.498847e+00	1.012529e+05	3.5	70.0	
75%	1.624728e+00	1.012545e+05	3.5	70.0	
max	3.290363e+00	1.012704e+05	3.5	70.0	

	Acceleracion X	Acceleracion Y	Acceleracion Z	Acceleracion P	\
count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	
mean	5.755633e-06	-1.250541e-04	-1.736796e-04	6.004077e-05	
std	5.950564e-01	8.118001e-02	1.435704e+00	4.211311e-01	
min	-8.899236e+01	-4.018375e+00	-1.017578e+01	-8.605778e+00	
25%	-8.635339e-03	-2.117448e-02	-1.253270e-01	-2.800144e-01	
50%	0.000000e+00	0.000000e+00	-1.526624e-03	-3.745025e-03	
75%	8.559134e-03	2.102111e-02	1.203972e-01	2.815473e-01	
max	9.037159e+01	4.432607e+00	1.060796e+01	7.373816e+00	

	Acceleracion Q	Acceleracion R	Z1	Dz1	\
count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	
mean	2.189152e-05	-8.116385e-06	-1.502918e+00	-1.521034e-02	
std	1.670874e+00	2.951463e-01	2.703173e-01	4.544223e-01	
min	-1.592394e+02	-8.434417e+00	-3.318702e+00	-4.524404e+00	
25%	-3.060012e-01	-1.960427e-01	-1.624222e+00	-9.322412e-03	
50%	-3.043190e-03	-7.657334e-04	-1.499095e+00	1.304944e-04	
75%	3.080426e-01	1.959933e-01	-1.367004e+00	8.658752e-03	
max	1.689137e+02	7.723484e+00	0.000000e+00	3.034264e+00	

	Z_r1	Ac_Dz1	Yaw1	Roll1	P1	\
count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	
mean	-1.482007e+00	-9.419130e+00	2.257514e-06	7.887457e-05	1.273315e-06	
std	2.443724e-01	1.429272e+00	2.768997e-04	3.505640e-03	9.056365e-03	
min	-2.774623e+00	-1.963813e+01	-1.254526e-02	-1.588011e-01	-5.037703e-01	
25%	-1.620000e+00	-9.646093e+00	-1.617320e-05	-2.072770e-04	-1.220251e-03	
50%	-1.500000e+00	-9.423018e+00	1.684218e-07	6.035169e-05	4.136165e-06	
75%	-1.351574e+00	-9.203855e+00	1.726007e-05	3.423065e-04	1.240343e-03	

```
max    0.000000e+00  8.609541e-01  1.233279e-02  1.636863e-01  4.727377e-01

                Q1  Acceleracion P1  Acceleracion Q1            Z2  \
count  1.295895e+06     1.295895e+06     1.295895e+06  1.295895e+06
mean   1.303519e-06     1.038755e-05    -3.086813e-05 -1.502809e+00
std    3.927625e-02     4.210900e-01     1.670862e+00  2.706177e-01
min   -3.575321e+00    -8.605778e+00    -1.592394e+02 -3.318702e+00
25%   -1.284665e-03    -2.800144e-01    -3.060012e-01 -1.624207e+00
50%   -4.722129e-06    -3.745025e-03    -3.043190e-03 -1.499094e+00
75%    1.283548e-03     2.814385e-01     3.079379e-01 -1.366925e+00
max    3.632708e+00     7.373816e+00     1.689137e+02  0.000000e+00

               Dz2          Z_r2        Ac_Dz2          Yaw2         Roll2  \
count  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06
mean  -1.520958e-02 -1.481896e+00 -9.418387e+00  2.258437e-06  7.887883e-05
std    4.544177e-01  2.446916e-01  1.431431e+00  2.768996e-04  3.505148e-03
min   -4.524404e+00 -2.774623e+00 -1.963813e+01 -1.254526e-02 -1.588011e-01
25%   -9.322241e-03 -1.620000e+00 -9.646035e+00 -1.617313e-05 -2.072770e-04
50%    1.281137e-04 -1.500000e+00 -9.422956e+00  1.683297e-07  6.028301e-05
75%    8.657166e-03 -1.351574e+00 -9.203737e+00  1.726007e-05  3.422434e-04
max    3.034264e+00  0.000000e+00  8.609541e-01  1.233279e-02  1.636863e-01

                P2            Q2  Acceleracion P2  Acceleracion Q2  \
count  1.295895e+06  1.295895e+06     1.295895e+06     1.295895e+06
mean   1.221378e-06  1.457860e-06     2.812219e-05    -7.125476e-06
std    9.055216e-03  3.927624e-02     4.210710e-01     1.670856e+00
min   -5.037703e-01 -3.575321e+00    -8.605778e+00    -1.592394e+02
25%   -1.219919e-03 -1.284440e-03    -2.799338e-01    -3.059567e-01
50%    4.130569e-06 -4.424624e-06    -3.700447e-03    -2.996484e-03
75%    1.240317e-03  1.283548e-03     2.814385e-01     3.079379e-01
max    4.727377e-01  3.632708e+00     7.373816e+00     1.689137e+02

                Z3           Dz3          Z_r3        Ac_Dz3          Yaw3  \
count  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06
mean  -1.502699e+00 -1.520887e-02 -1.481784e+00 -9.417694e+00  2.258529e-06
std    2.709177e-01  4.544130e-01  2.450097e-01  1.433600e+00  2.768996e-04
min   -3.318702e+00 -4.524404e+00 -2.774623e+00 -1.963813e+01 -1.254526e-02
25%   -1.624196e+00 -9.322085e-03 -1.620000e+00 -9.646004e+00 -1.617308e-05
50%   -1.499093e+00  1.261767e-04 -1.500000e+00 -9.422915e+00  1.660678e-07
75%   -1.366811e+00  8.655519e-03 -1.351574e+00 -9.203696e+00  1.726007e-05
max    0.000000e+00  3.034264e+00  0.000000e+00  8.609541e-01  1.233279e-02

              Roll3            P3            Q3  Acceleracion P3  \
count  1.295895e+06  1.295895e+06  1.295895e+06     1.295895e+06
mean   7.888335e-05  1.080767e-06  1.493488e-06     2.985777e-06
std    3.504645e-03  9.054026e-03  3.927624e-02     4.210606e-01
min   -1.588011e-01 -5.037703e-01 -3.575321e+00    -8.605778e+00
```

```
25%   -2.072770e-04 -1.219723e-03 -1.284153e-03    -2.799338e-01
50%    6.020387e-05  3.981350e-06 -4.307566e-06    -3.700447e-03
75%    3.421859e-04  1.240157e-03  1.283347e-03     2.813485e-01
max    1.636863e-01  4.727377e-01  3.632708e+00     7.373816e+00

       Acceleracion Q3
count     1.295895e+06
mean     -3.594663e-05
std       1.670853e+00
min      -1.592394e+02
25%      -3.059567e-01
50%      -2.996484e-03
75%       3.079038e-01
max       1.689137e+02
```

0.1.4 Estados repetidos

En este caso se eliminan estados repetidos y estados que se encuentren en estado transitorio mientras el dron despega o se estabiliza antes de introducir la señal de control.

[4]:
```
shape_b4 = dataset.drop(["Time"], axis=1).shape
shape_drop= dataset.drop(["Time"], axis=1).drop_duplicates().shape
print(f'shape (b4 drop) = {shape_b4}')
print(f'shape = {shape_drop}')
print(f'len (b4 drop) - len = {shape_b4[0]-shape_drop[0]}')
```

```
shape (b4 drop) = (1295895, 75)
shape = (1136656, 75)
len (b4 drop) - len = 159239
```

[5]:
```
states = dataset.drop(["Time"], axis=1).drop_duplicates()[states_list]
print(f'columns = {states.columns}')
print(f'shape = {states.shape}')
states.head()
```

```
columns = Index(['Z', 'Dz', 'Z_r', 'Ac_Dz', 'Yaw', 'Roll', 'P', 'Q',
'Acceleracion P',
       'Acceleracion Q', 'Z1', 'Dz1', 'Z_r1', 'Ac_Dz1', 'Yaw1', 'Roll1', 'P1',
       'Q1', 'Acceleracion P1', 'Acceleracion Q1', 'Z2', 'Dz2', 'Z_r2',
       'Ac_Dz2', 'Yaw2', 'Roll2', 'P2', 'Q2', 'Acceleracion P2',
       'Acceleracion Q2', 'Z3', 'Dz3', 'Z_r3', 'Ac_Dz3', 'Yaw3', 'Roll3', 'P3',
       'Q3', 'Acceleracion P3', 'Acceleracion Q3'],
      dtype='object')
shape = (1136656, 40)
```

[5]:

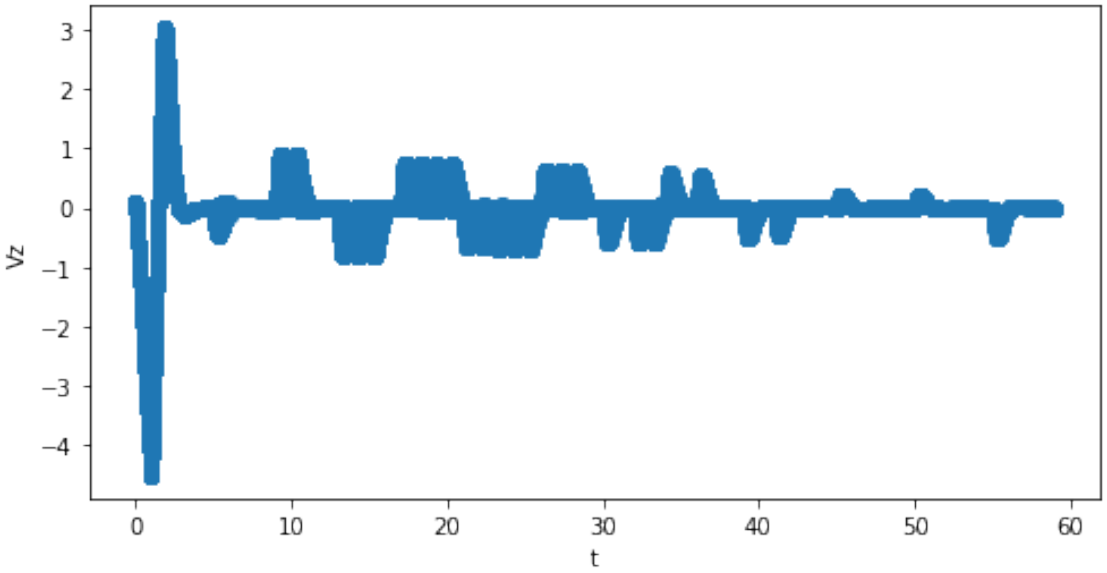
	Z	Dz	Z_r	Ac_Dz	Yaw	Roll	P	\
0	-0.046000	0.000000	0.0	-9.492839	-5.859605e-07	-1.965233e-06	-0.000393	
1	-0.046000	0.047745	0.0	-13.635429	-5.307764e-07	2.704250e-06	0.000934	

```
2 -0.045761  0.087995  0.0 -14.080304 -7.171090e-08 -4.059651e-06 -0.001353
3 -0.045321  0.108800  0.0 -13.597730 -1.382231e-06  9.645310e-07  0.001005
4 -0.044777  0.105958  0.0 -13.629545  5.927828e-07  6.776180e-06  0.001162

          Q  Acceleracion P  Acceleracion Q        Z1       Dz1  Z_r1  \
0 -0.000431       -0.078609       -0.086239  0.000000  0.000000   0.0
1  0.001025        0.265389        0.291147 -0.046000  0.000000   0.0
2 -0.001527       -0.457335       -0.510345 -0.046000  0.047745   0.0
3  0.001162        0.471523        0.537868 -0.045761  0.087995   0.0
4  0.001192        0.031499        0.006026 -0.045321  0.108800   0.0

      Ac_Dz1          Yaw1         Roll1        P1        Q1  Acceleracion P1  \
0   0.000000  0.000000e+00  0.000000e+00  0.000000  0.000000         0.000000
1  -9.492839 -5.859605e-07 -1.965233e-06 -0.000393 -0.000431        -0.078609
2 -13.635429 -5.307764e-07  2.704250e-06  0.000934  0.001025         0.265389
3 -14.080304 -7.171090e-08 -4.059651e-06 -0.001353 -0.001527        -0.457335
4 -13.597730 -1.382231e-06  9.645310e-07  0.001005  0.001162         0.471523

   Acceleracion Q1        Z2       Dz2  Z_r2     Ac_Dz2          Yaw2  \
0         0.000000  0.000000  0.000000   0.0   0.000000  0.000000e+00
1        -0.086239  0.000000  0.000000   0.0   0.000000  0.000000e+00
2         0.291147 -0.046000  0.000000   0.0  -9.492839 -5.859605e-07
3        -0.510345 -0.046000  0.047745   0.0 -13.635429 -5.307764e-07
4         0.537868 -0.045761  0.087995   0.0 -14.080304 -7.171090e-08

      Roll2        P2        Q2  Acceleracion P2  Acceleracion Q2     Z3  \
0  0.000000  0.000000  0.000000         0.000000         0.000000  0.000
1  0.000000  0.000000  0.000000         0.000000         0.000000  0.000
2 -0.000002 -0.000393 -0.000431        -0.078609        -0.086239  0.000
3  0.000003  0.000934  0.001025         0.265389         0.291147 -0.046
4 -0.000004 -0.001353 -0.001527        -0.457335        -0.510345 -0.046

        Dz3  Z_r3     Ac_Dz3          Yaw3     Roll3        P3        Q3  \
0  0.000000   0.0   0.000000  0.000000e+00  0.000000  0.000000  0.000000
1  0.000000   0.0   0.000000  0.000000e+00  0.000000  0.000000  0.000000
2  0.000000   0.0   0.000000  0.000000e+00  0.000000  0.000000  0.000000
3  0.000000   0.0  -9.492839 -5.859605e-07 -0.000002 -0.000393 -0.000431
4  0.047745   0.0 -13.635429 -5.307764e-07  0.000003  0.000934  0.001025

   Acceleracion P3  Acceleracion Q3
0         0.000000         0.000000
1         0.000000         0.000000
2         0.000000         0.000000
3        -0.078609        -0.086239
4         0.265389         0.291147
```

[6]:
```
states_duplicates = dataset[dataset.duplicated(keep='last')]
states_duplicates = states_duplicates.dropna()
```

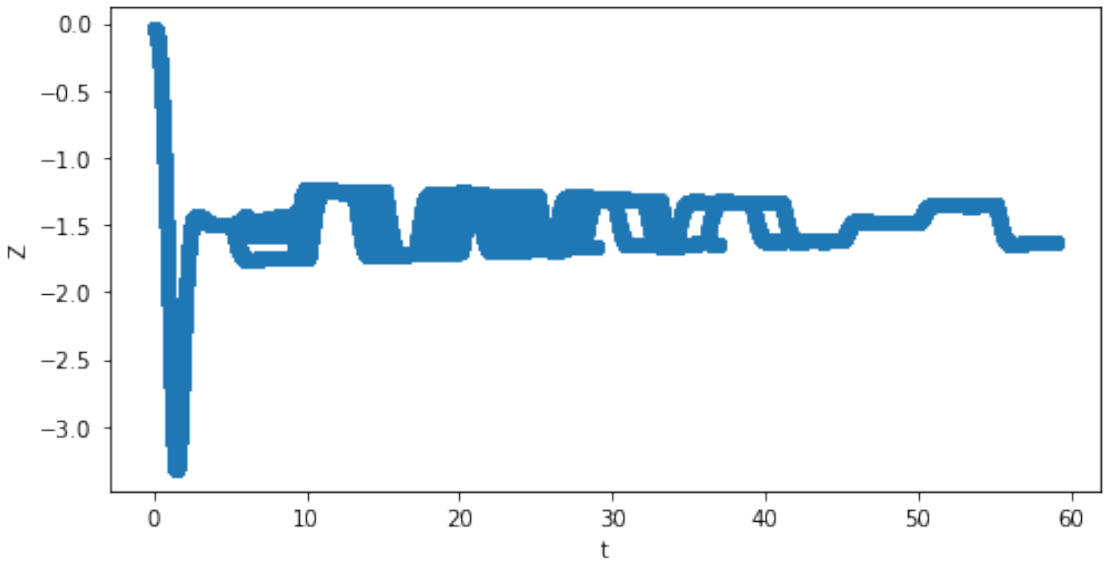
[7]:
```
fig = plt.figure(figsize=(8, 4))
t = states_duplicates['Time']
y = states_duplicates['Dz']
#y_ref = states_duplicates['uvz']
plt.scatter(t, y)
#plt.scatter(t, y_ref)
plt.ylabel('Vz')
plt.xlabel('t')
```

[7]:
```
Text(0.5, 0, 't')
```



[8]:
```
fig = plt.figure(figsize=(8, 4))
t = states_duplicates['Time']
y = states_duplicates['Z']
#y_ref = states_duplicates['uvz']
plt.scatter(t, y)
#plt.scatter(t, y_ref)
plt.ylabel('Z')
plt.xlabel('t')
```

[8]:
```
Text(0.5, 0, 't')
```



0.1.5 Se grafican los datos

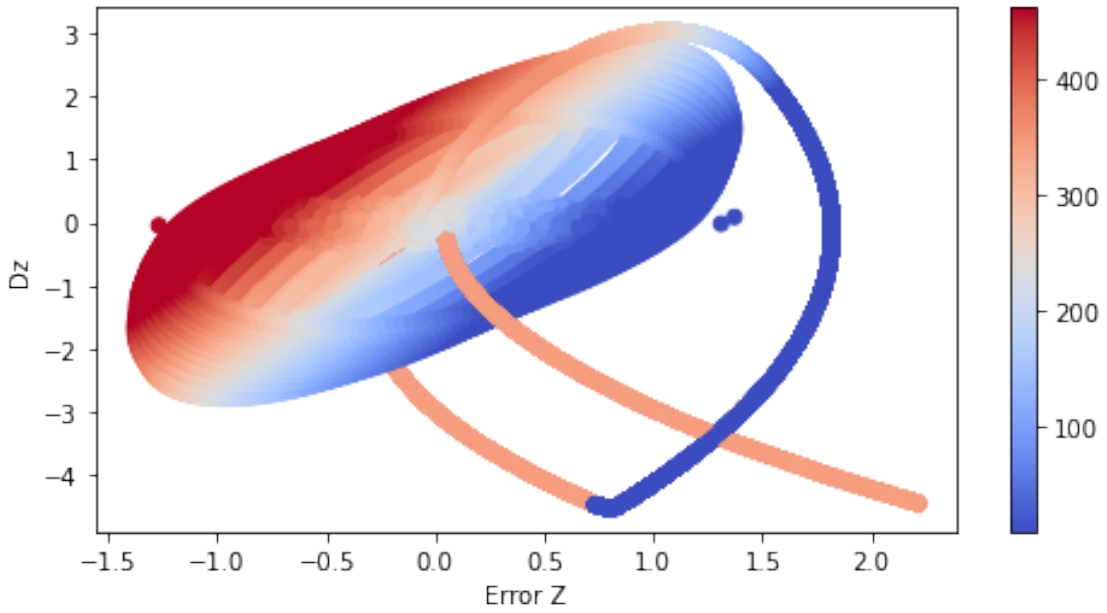
Se grafica un histograma de cada una de las propiedades los datos analizados individualmente por columnas, en el cual se observa que todos tienen distribuciones altamente apuntadas (curosis) y en algunos casos bimodales, pero de cualquier manera, no son uniformes

[9]:
```
n_bins = 50
#_ = dataset.hist(bins=n_bins, figsize=(30,30))
```

0.1.6 Análisis de estados

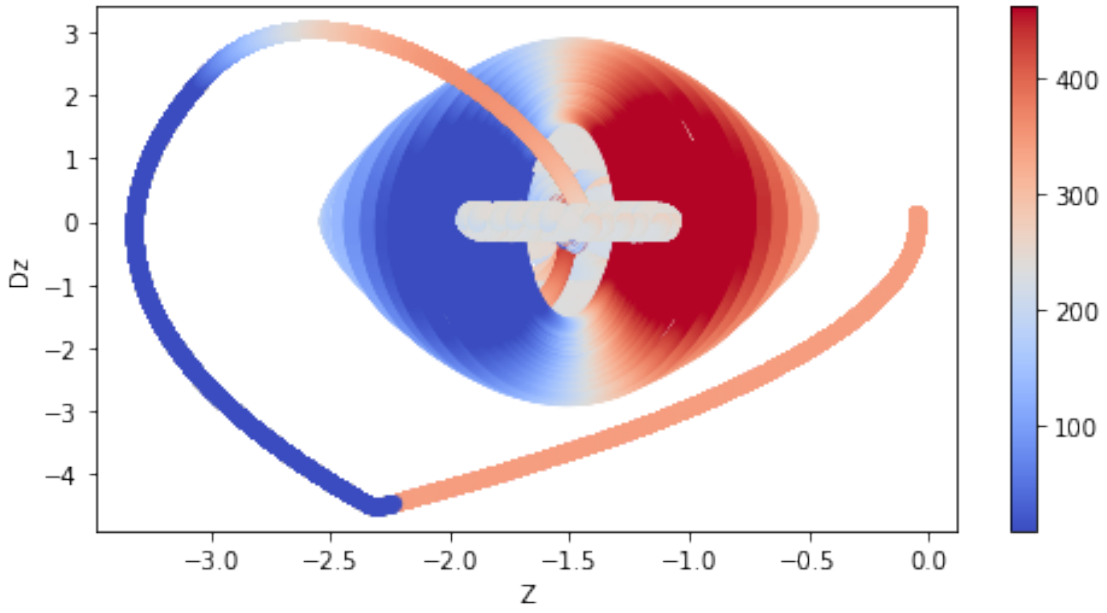
[10]:
```
fig = plt.figure(figsize=(8, 4))
x = dataset['Z_r']-dataset['Z']
y = dataset['Dz']
c = dataset['Motor1']
plt.scatter(x, y, c=c, cmap='coolwarm')
plt.colorbar()
plt.ylabel('Dz')
plt.xlabel('Error Z')
```

[10]:
```
Text(0.5, 0, 'Error Z')
```



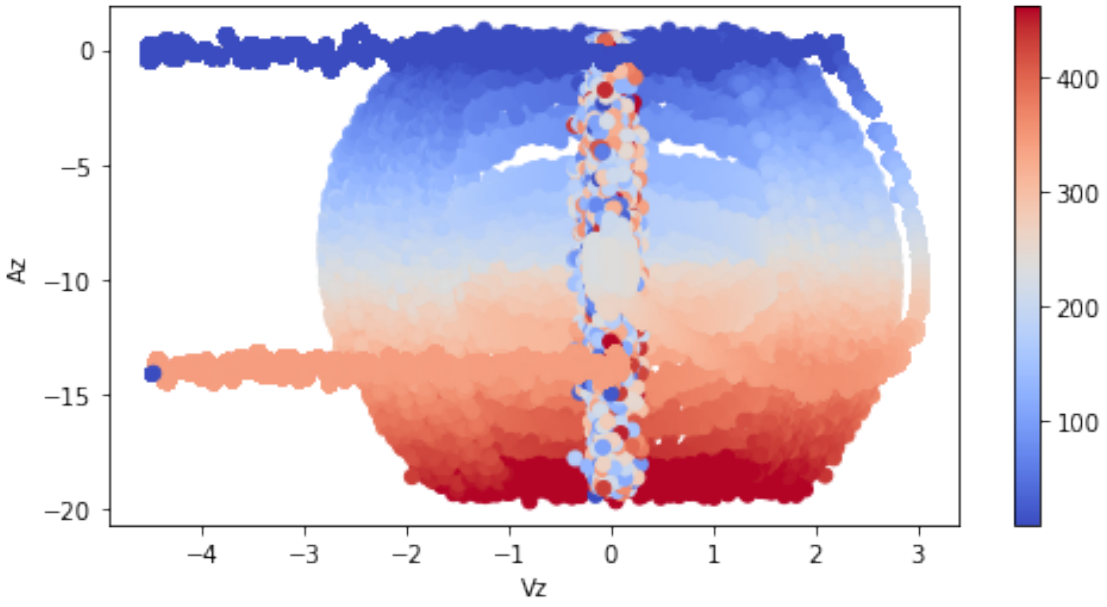
[11]:
```
fig = plt.figure(figsize=(8, 4))
x = dataset['Z']
plt.scatter(x, y, c=c, cmap='coolwarm')
plt.colorbar()
plt.ylabel('Dz')
plt.xlabel('Z')
```

[11]: `Text(0.5, 0, 'Z')`



[12]:
```
fig = plt.figure(figsize=(8, 4))
x = dataset['Dz']
y = dataset['Ac_Dz']
plt.scatter(x, y, c=c, cmap='coolwarm')
plt.colorbar()
plt.ylabel('Az')
plt.xlabel('Vz')
```

[12]:
```
Text(0.5, 0, 'Vz')
```



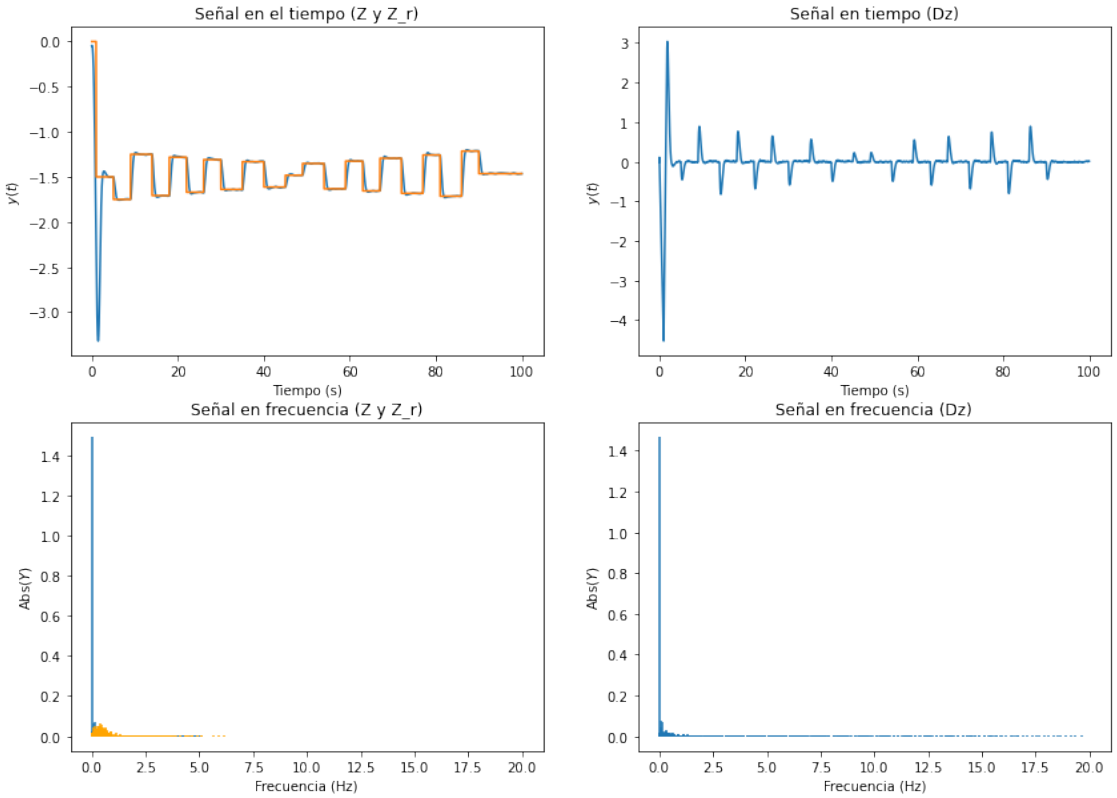
0.1.7 Análisis de Fourier

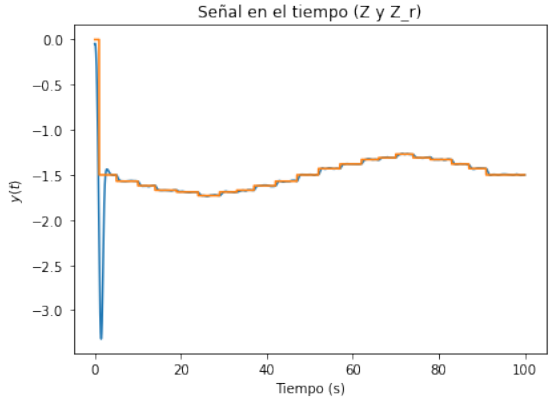
Gráfica de algunas señales

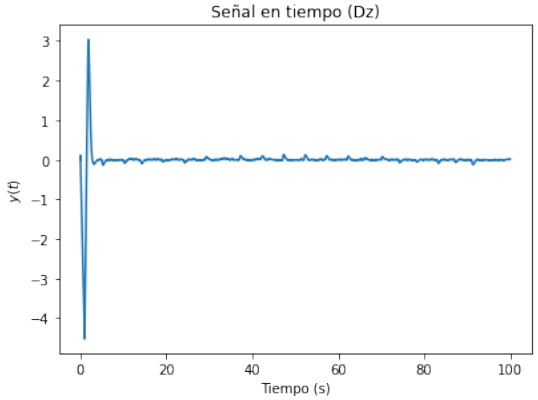
[13]:
```
def plot_fourier(df, states=['Z', 'Dz', 'Z_r']):
    dt = df['Time'][1]-df['Time'][0]
    n = len(df['Time'])
    Y = fft(df[states[0]].to_numpy()) / n # Transformada normalizada
    Y_ref = fft(df[states[1]].to_numpy()) / n
    frq = fftfreq(n, dt)
    fig = plt.figure(figsize=(14, 10))
    ax1 = fig.add_subplot(221)
    ax1.plot(df['Time'], df[states[0]], df['Time'], df[states[2]])
    ax1.set_xlabel('Tiempo (s)')
    ax1.set_ylabel('$y(t)$')
```

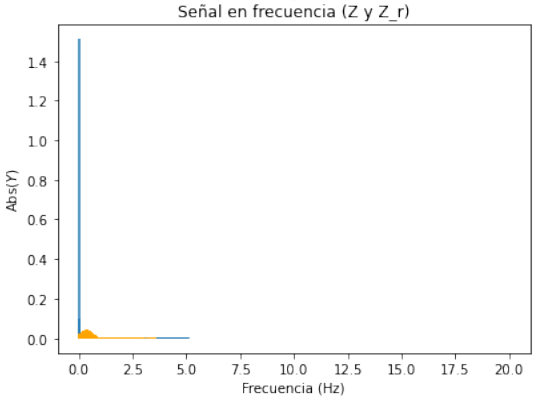
```
    ax1.set_title(f'Señal en el tiempo ({states[0]} y {states[2]})')
    ax2 = fig.add_subplot(223)
    ax2.set_title(f'Señal en frecuencia ({states[0]} y {states[2]})')
    ax2.vlines(frq[0:int(n/10)], 0, abs(Y[0:int(n/10)]))
    ax2.vlines(frq[0:int(n/10)], 0, abs(Y_ref[0:int(n/10)]),  color='orange')
    plt.xlabel('Frecuencia (Hz)')
    plt.ylabel('Abs($Y$)')

    Y = fft(df[states[2]].to_numpy()) / n # Transformada normalizada
    ax1 = fig.add_subplot(222)
    ax1.plot(df['Time'], df[states[1]])
    ax1.set_xlabel('Tiempo (s)')
    ax1.set_ylabel('$y(t)$')
    ax1.set_title(f'Señal en tiempo ({states[1]})')
    ax2 = fig.add_subplot(224)
    ax2.set_title(f'Señal en frecuencia ({states[1]})')
    ax2.vlines(frq[0:int(n/10)], 0, abs(Y[0:int(n/10)]))
    plt.xlabel('Frecuencia (Hz)')
    plt.ylabel('Abs($Y$)')
```

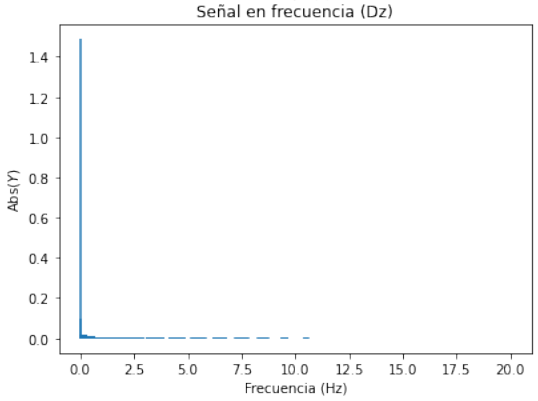
[14]:
```
for df in random.choices(dfs, k = 8):
    plot_fourier(df)
```

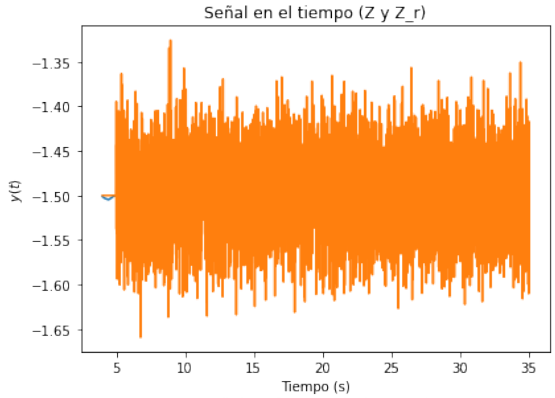


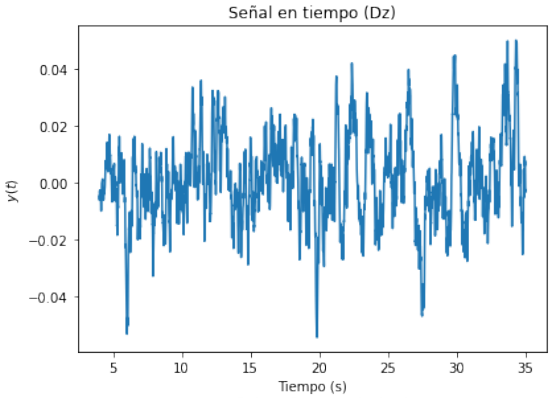

Señal en el tiempo (Z y Z_r)
y(t)
Tiempo (s)

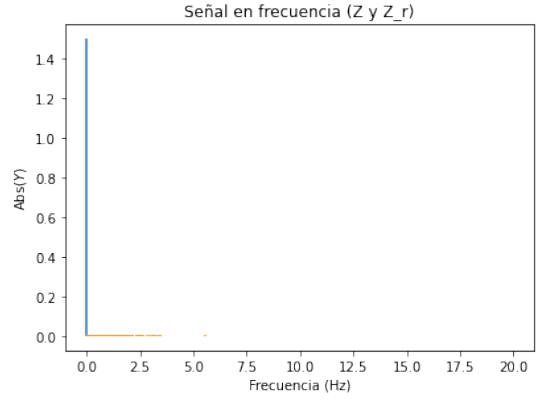

Señal en tiempo (Dz)
y(t)
Tiempo (s)

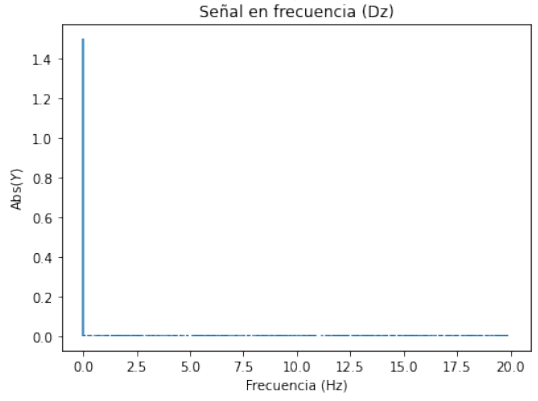

Señal en frecuencia (Z y Z_r)
Abs(Y)
Frecuencia (Hz)

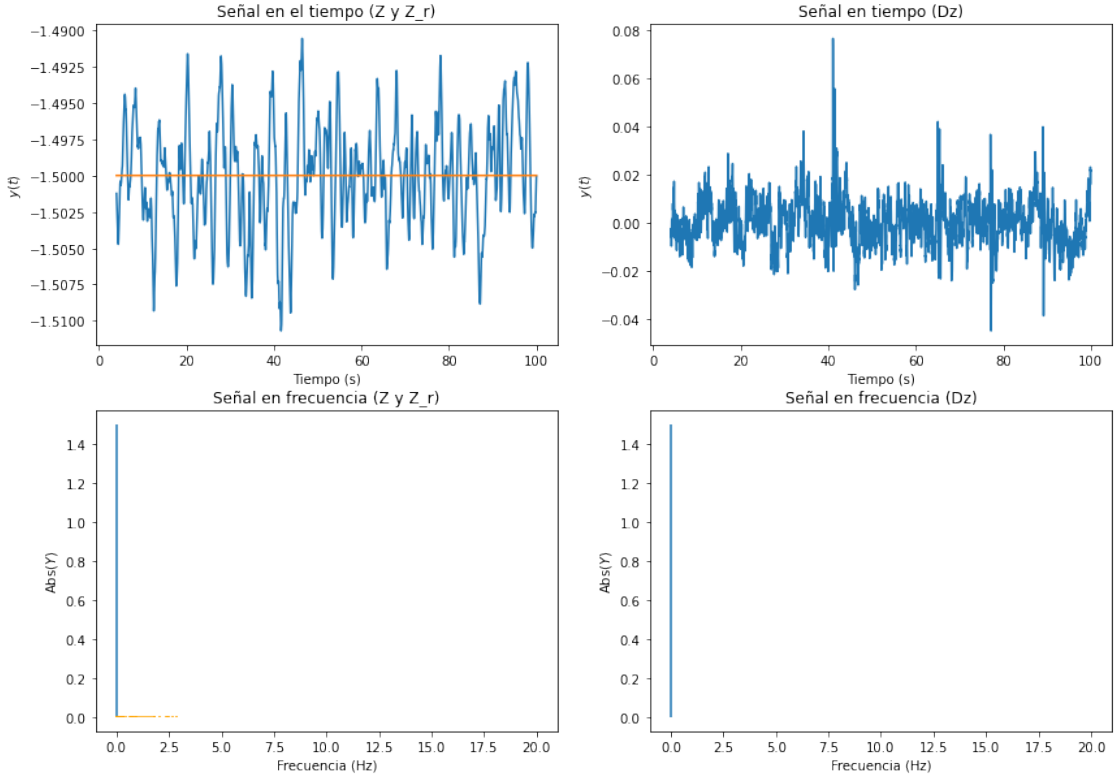

Señal en frecuencia (Dz)
Abs(Y)
Frecuencia (Hz)

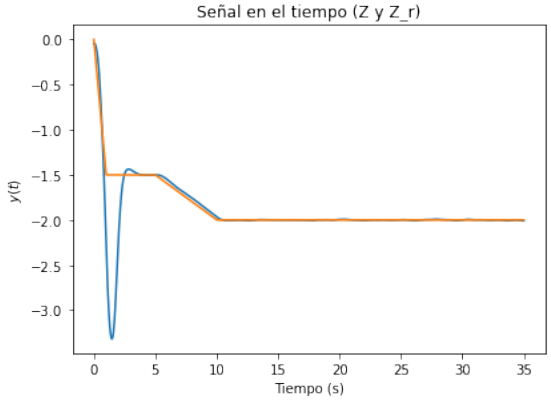

Señal en el tiempo (Z y Z_r)
y(t)
Tiempo (s)

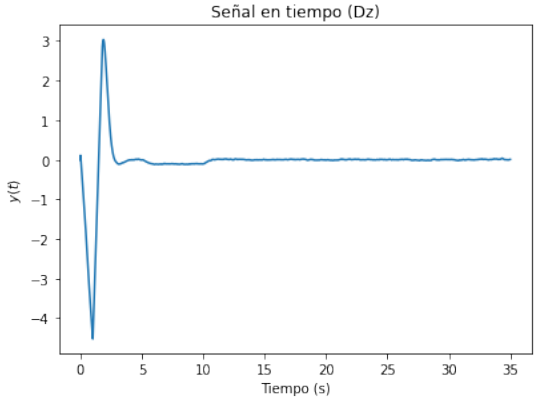

Señal en tiempo (Dz)
y(t)
Tiempo (s)

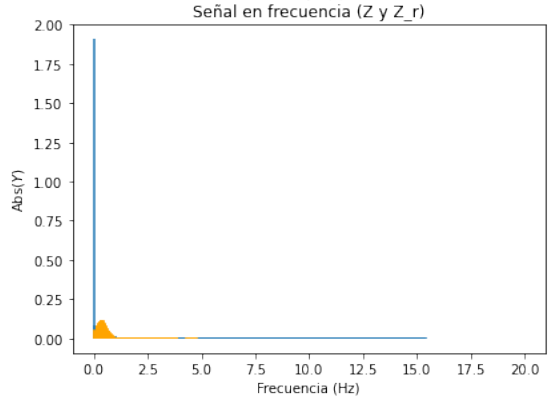

Señal en frecuencia (Z y Z_r)
Abs(Y)
Frecuencia (Hz)

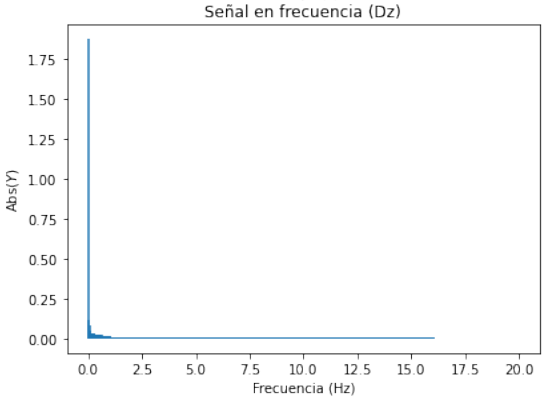

Señal en frecuencia (Dz)
Abs(Y)
Frecuencia (Hz)

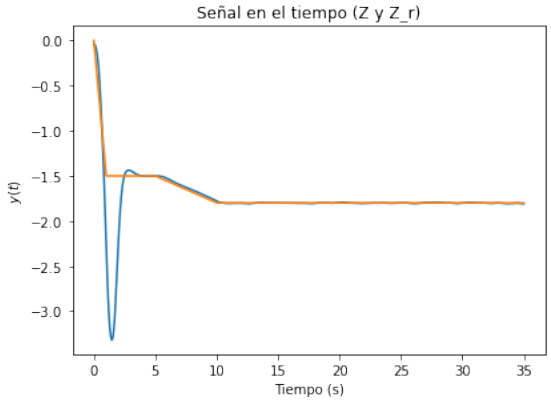

Señal en el tiempo (Z y Z_r)
y(t)
Tiempo (s)
Señal en tiempo (Dz)
y(t)
Tiempo (s)
Señal en frecuencia (Z y Z_r)
Abs(Y)
Frecuencia (Hz)
Señal en frecuencia (Dz)
Abs(Y)
Frecuencia (Hz)

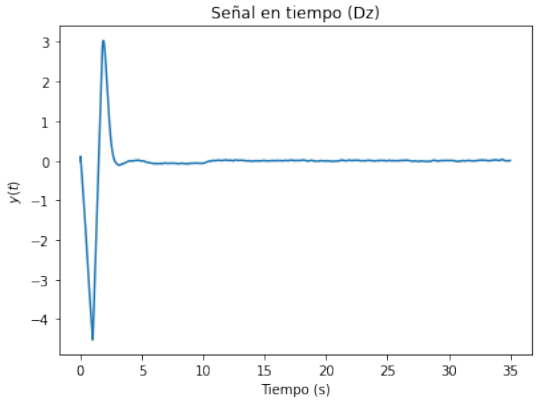

Señal en el tiempo (Z y Z_r)
y(t)
Tiempo (s)

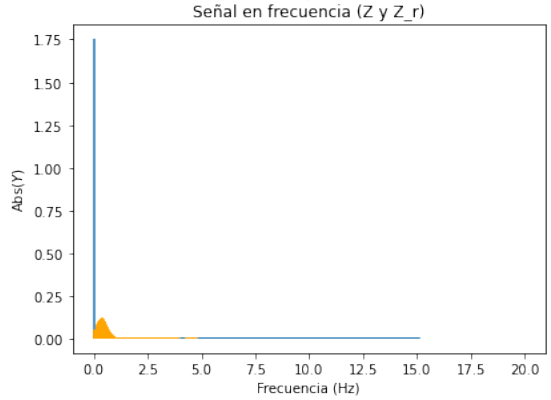

Señal en tiempo (Dz)
y(t)
Tiempo (s)

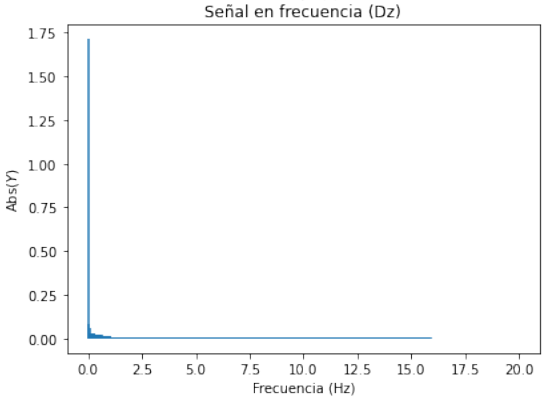

Señal en frecuencia (Z y Z_r)
Abs(Y)
Frecuencia (Hz)

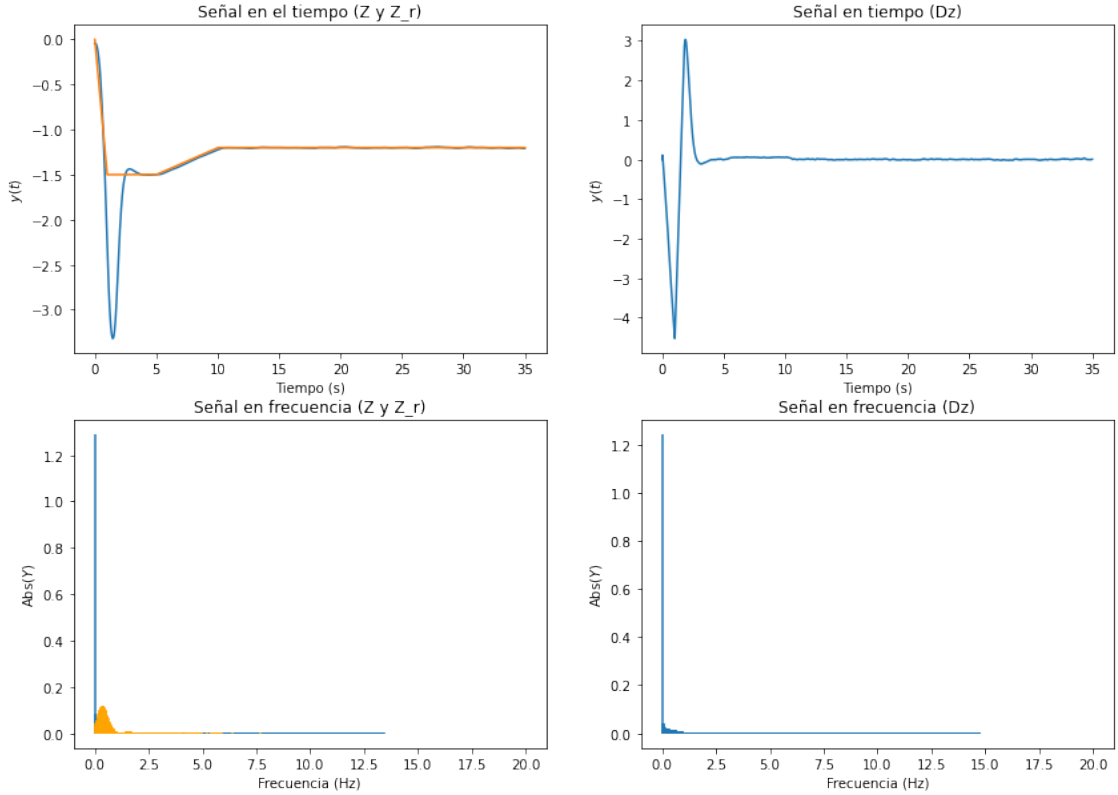

Señal en frecuencia (Dz)
Abs(Y)
Frecuencia (Hz)

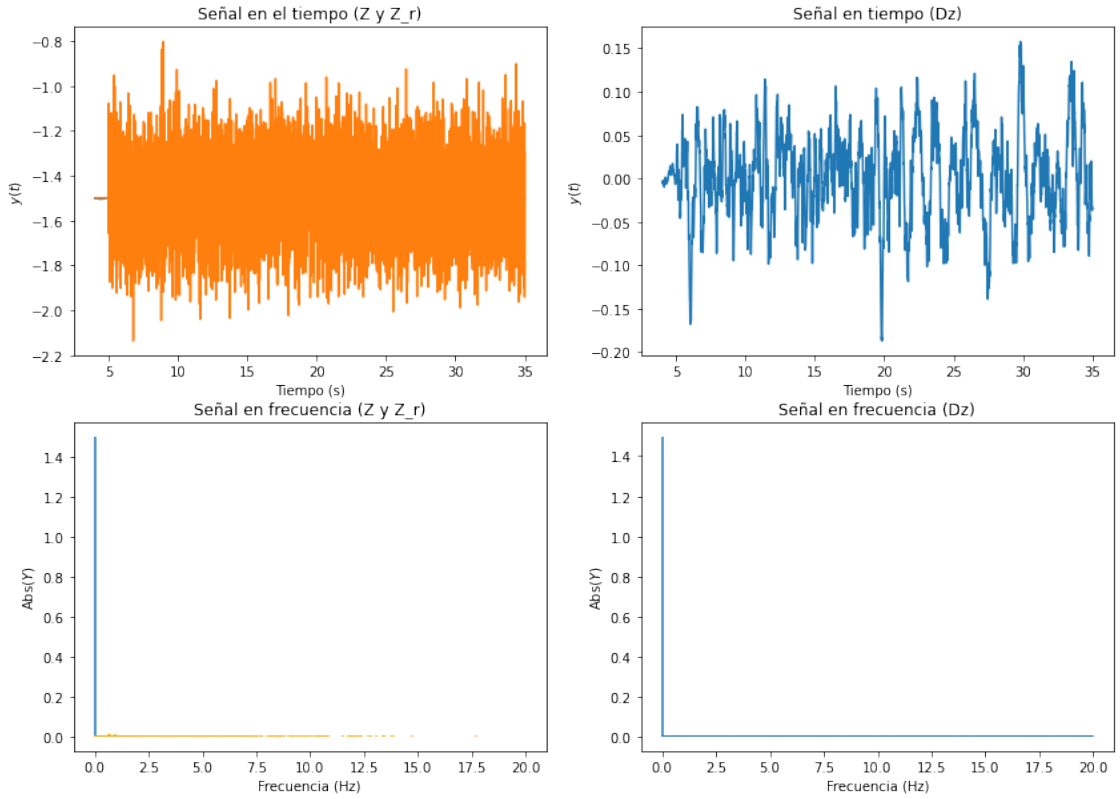

Señal en el tiempo (Z y Z_r)
y(t)
Tiempo (s)


Señal en tiempo (Dz)
y(t)
Tiempo (s)

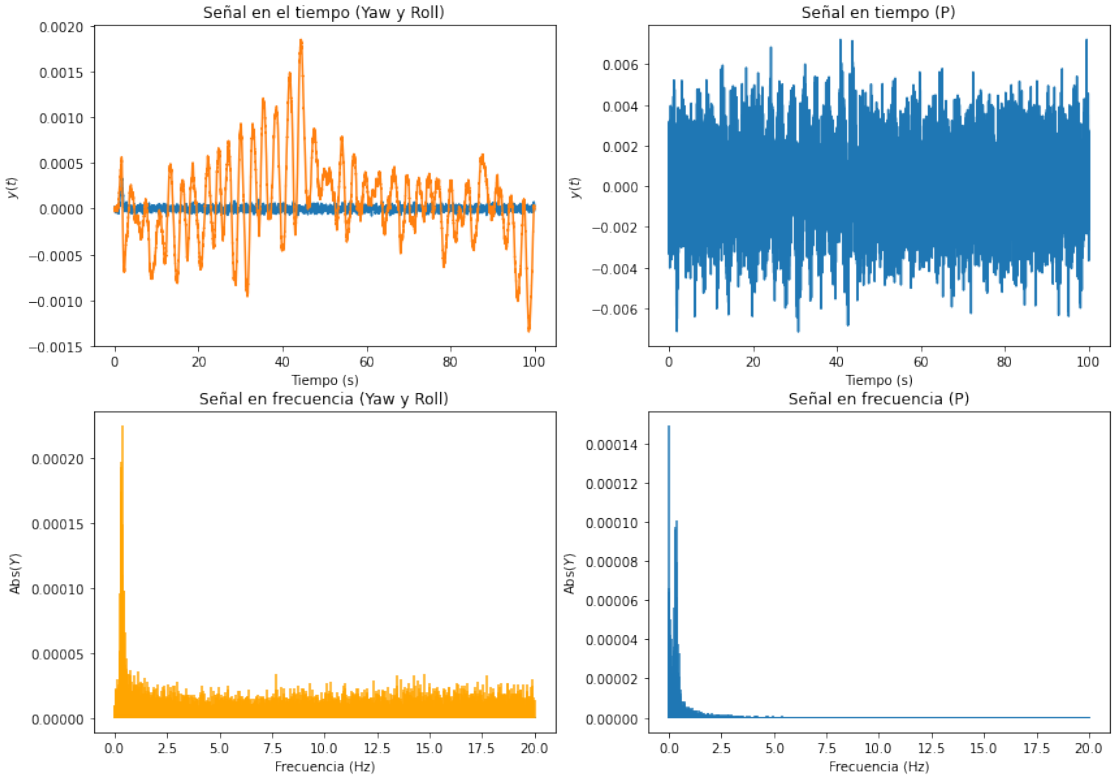

Señal en frecuencia (Z y Z_r)
Abs(Y)
Frecuencia (Hz)

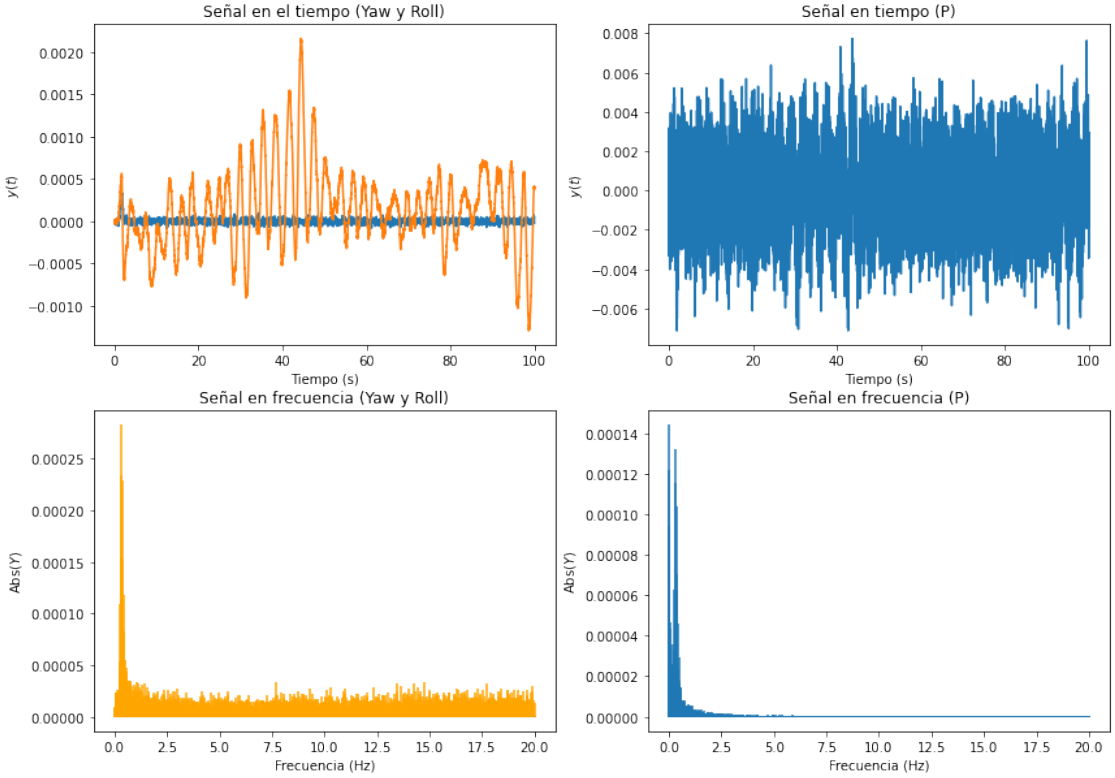

Señal en frecuencia (Dz)
Abs(Y)
Frecuencia (Hz)

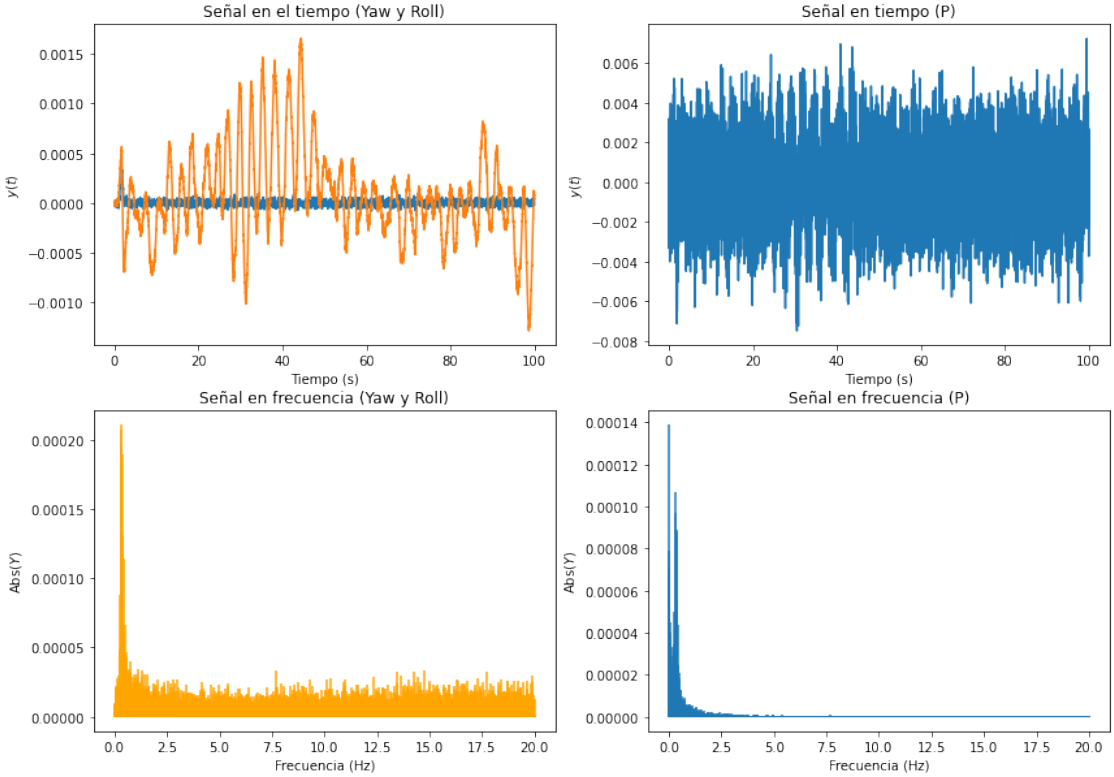

Señal en el tiempo (Z y Z_r)
y(t)
Tiempo (s)
Señal en tiempo (Dz)
y(t)
Tiempo (s)
Señal en frecuencia (Z y Z_r)
Abs(Y)
Frecuencia (Hz)
Señal en frecuencia (Dz)
Abs(Y)
Frecuencia (Hz)

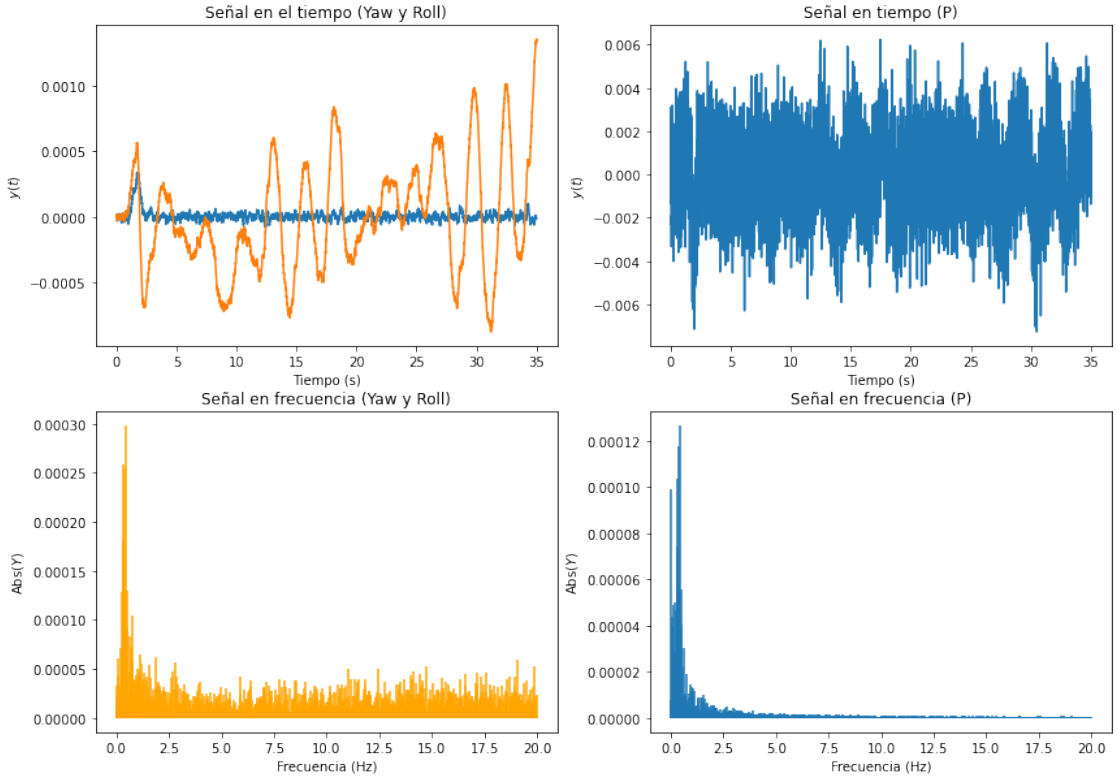


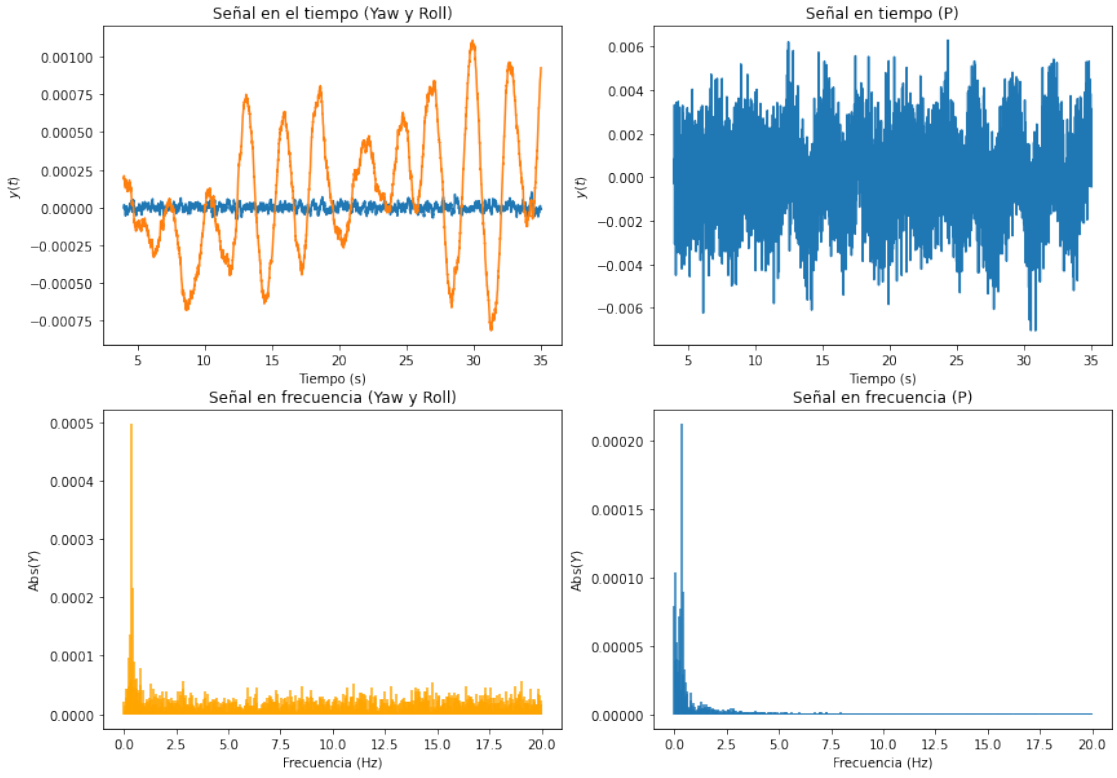
[15]:
```
for df in random.choices(dfs, k = 8):
    plot_fourier(df, states=['Yaw', 'P', 'Roll'])
```

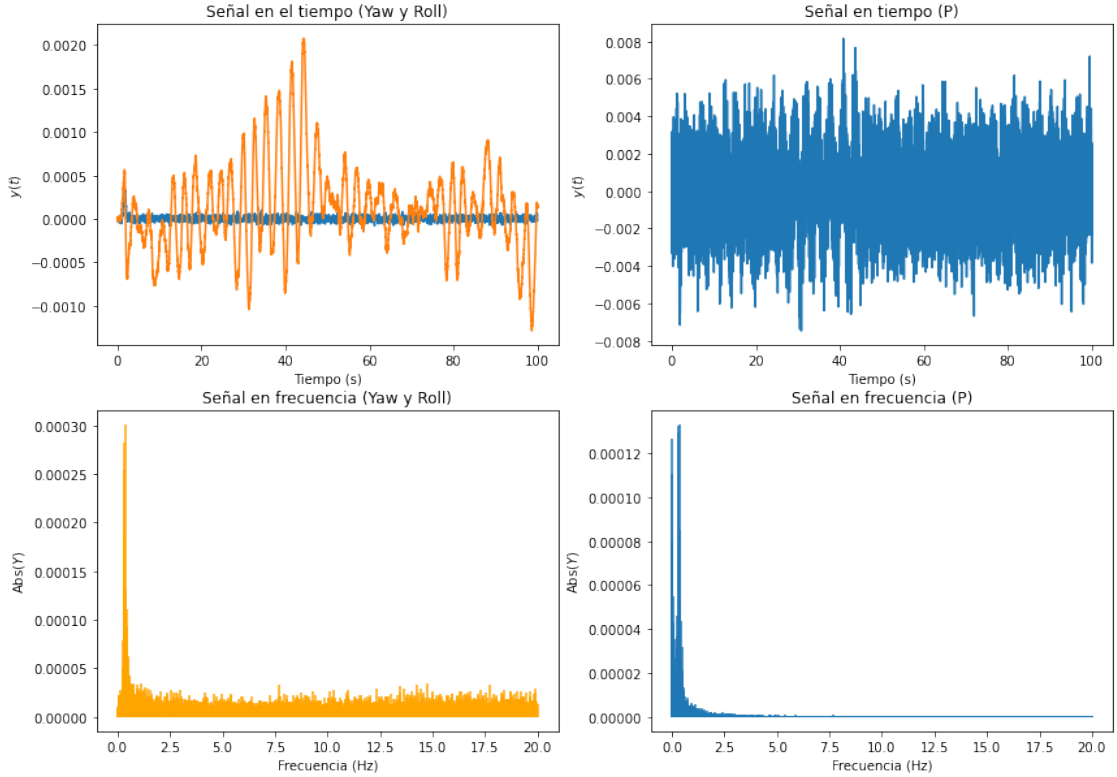

Señal en el tiempo (Yaw y Roll)
Señal en tiempo (P)
Señal en frecuencia (Yaw y Roll)
Señal en frecuencia (P)
y(t)
Tiempo (s)
Abs(Y)
Frecuencia (Hz)

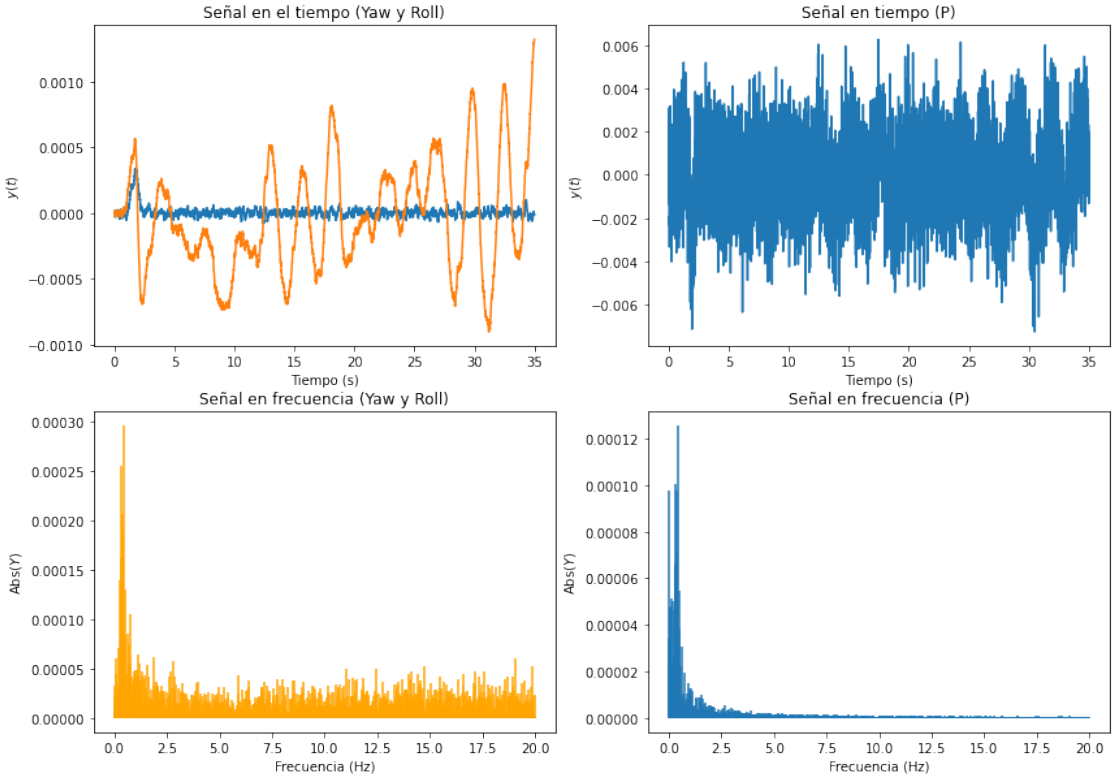

Señal en el tiempo (Yaw y Roll)
Señal en tiempo (P)
Señal en frecuencia (Yaw y Roll)
Señal en frecuencia (P)
y(t)
Tiempo (s)
Abs(Y)
Frecuencia (Hz)

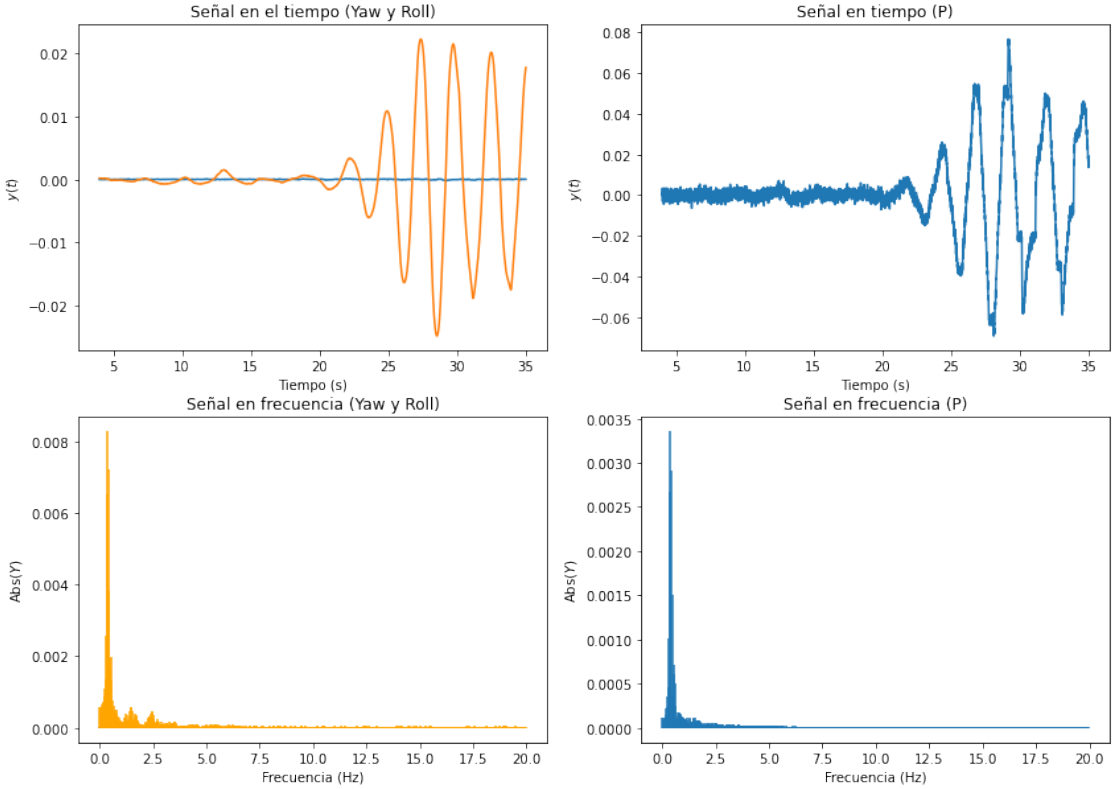

Señal en el tiempo (Yaw y Roll)
y(t)
Tiempo (s)
Señal en tiempo (P)
y(t)
Tiempo (s)
Señal en frecuencia (Yaw y Roll)
Abs(Y)
Frecuencia (Hz)
Señal en frecuencia (P)
Abs(Y)
Frecuencia (Hz)


Señal en el tiempo (Yaw y Roll)
Señal en tiempo (P)
Señal en frecuencia (Yaw y Roll)
Señal en frecuencia (P)
y(t)
Abs(Y)
Tiempo (s)
Frecuencia (Hz)


Señal en el tiempo (Yaw y Roll)
Señal en tiempo (P)
Señal en frecuencia (Yaw y Roll)
Señal en frecuencia (P)
y(t)
Abs(Y)
Tiempo (s)
Frecuencia (Hz)


Señal en el tiempo (Yaw y Roll)
y(t)
Tiempo (s)
Señal en tiempo (P)
y(t)
Tiempo (s)
Señal en frecuencia (Yaw y Roll)
Abs(Y)
Frecuencia (Hz)
Señal en frecuencia (P)
Abs(Y)
Frecuencia (Hz)


Señal en el tiempo (Yaw y Roll)
y(t)
Tiempo (s)
Señal en tiempo (P)
y(t)
Tiempo (s)
Señal en frecuencia (Yaw y Roll)
Abs(Y)
Frecuencia (Hz)
Señal en frecuencia (P)
Abs(Y)
Frecuencia (Hz)


Señal en el tiempo (Yaw y Roll)
y(t)
Tiempo (s)
Señal en tiempo (P)
y(t)
Tiempo (s)
Señal en frecuencia (Yaw y Roll)
Abs(Y)
Frecuencia (Hz)
Señal en frecuencia (P)
Abs(Y)
Frecuencia (Hz)

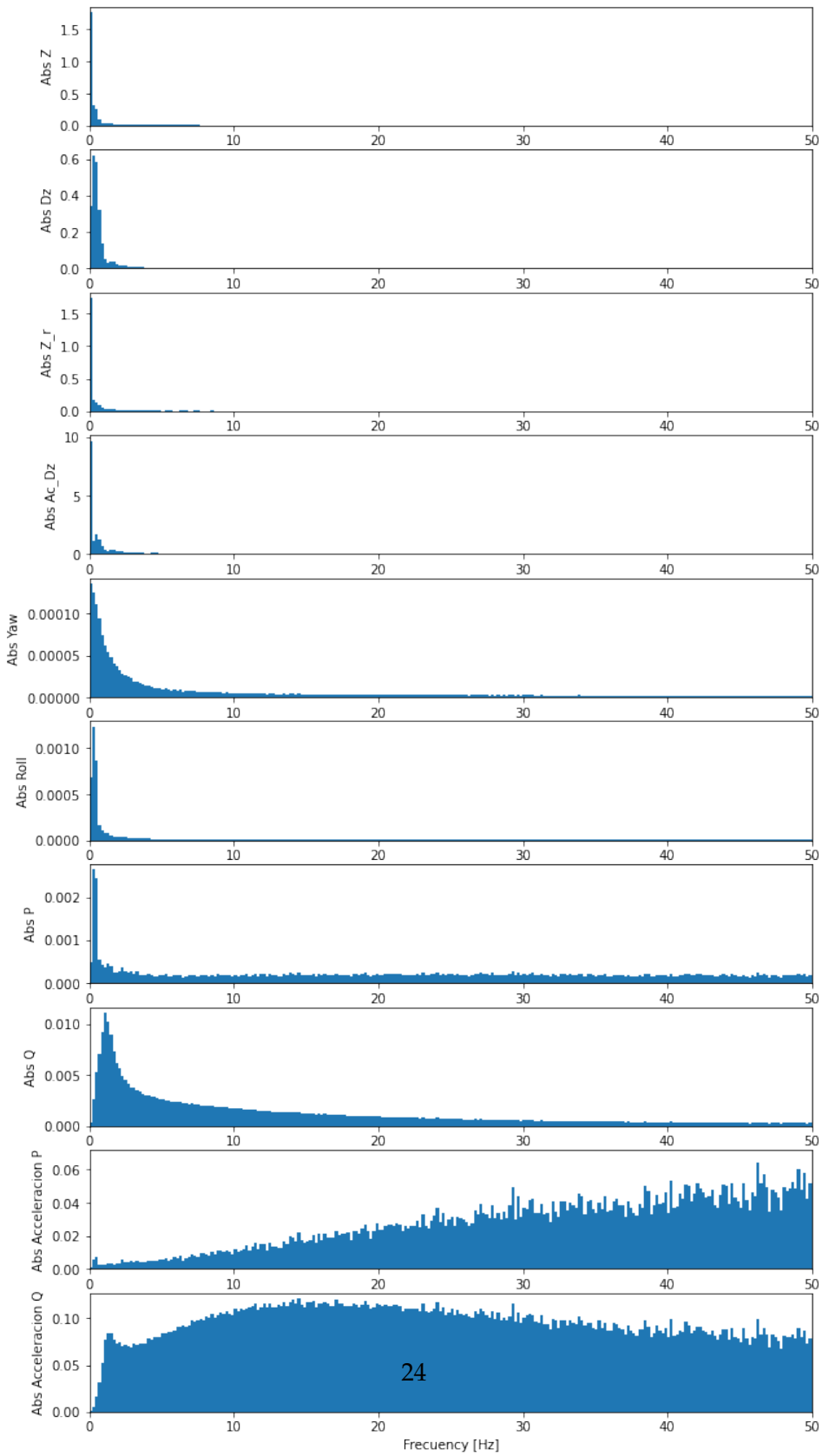
Histograma

[16]:
```
Fourier = []
for i, df in enumerate(dfs):
    dt = df['Time'][1]-df['Time'][0]
    n = len(df['Time'])
    Fourier.append({})
    for state in states_list_org:
        Fourier[i][state]={}
        Fourier[i][state]['Y'] = abs(fft(df[state].to_numpy())/n)[0:int(n/2)] #␣
 ↪Transformada normalizada
        Fourier[i][state]['X'] = fftfreq(n, dt)[0:int(n/2)]
```

[17]:
```
F = {}
for state in states_list_org:
    F[state]={}
    F[state]['X'] = []
    F[state]['Y'] = []
    for f in Fourier:
        F[state]['X'] = np.concatenate([F[state]['X'], f[state]['X']])
        F[state]['Y'] = np.concatenate([F[state]['Y'], f[state]['Y']])
```

[22]:
```
fig, axs = plt.subplots(len(states_list_org), 1, figsize=(10, 20))
fig.suptitle('Fourier Transform Histogram per State')
for i, state in enumerate(states_list_org):
    axs[i].hist(F[state]['X'], bins=10*n_bins, weights=((F[state]['Y']+1e-7)/
 ↪len(Fourier)))
    axs[i].set_ylabel(f'Abs {state}')
    axs[i].set_xlim(0, 50)
axs[i].set_xlabel('Frecuency [Hz]')
```

[22]:
```
Text(0.5, 0, 'Frecuency [Hz]')
```


Fourier Transform Histogram per State
Abs Z
Abs Dz
Abs Z_r
Abs Ac_Dz
Abs Yaw
Abs Roll
Abs P
Abs Q
Abs Acceleracion P
Abs Acceleracion Q
Frecuency [Hz]

0.1.8 Análisis de Características - Método Estático

[19]:
```
dataset.describe()
```

[19]:

	Time	X	Y	Z	Yaw
count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06
mean	4.281013e+01	-3.350768e-04	-3.359317e-04	-1.503027e+00	2.256389e-06
std	2.896393e+01	1.074610e-02	1.136344e-02	2.700165e-01	2.768997e-04
min	0.000000e+00	-3.573908e-01	-5.542104e-01	-3.318702e+00	-1.254526e-02
25%	1.806000e+01	-1.364899e-03	-1.247569e-03	-1.624232e+00	-1.617708e-05
50%	3.521000e+01	-3.312734e-04	-2.898734e-04	-1.499096e+00	1.685380e-07
75%	6.760500e+01	7.783263e-04	6.850931e-04	-1.367094e+00	1.726007e-05
max	1.000000e+02	3.491811e-01	5.142932e-01	-4.311047e-02	1.233279e-02

	Roll	Pitch	Dx	Dy	Dz
count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06
mean	7.887180e-05	-8.071778e-05	3.052208e-06	2.332470e-06	-1.521121e-02
std	3.506121e-03	5.052975e-03	4.558698e-02	2.659362e-02	4.544270e-01
min	-1.588011e-01	-1.569786e-01	-1.510064e+00	-1.360795e+00	-4.524404e+00
25%	-2.072770e-04	-3.469328e-04	-8.009977e-04	-1.753193e-03	-9.322637e-03
50%	6.043164e-05	-7.090611e-05	-1.754226e-06	0.000000e+00	1.322787e-04
75%	3.423737e-04	1.998152e-04	7.909324e-04	1.652702e-03	8.660311e-03
max	1.636863e-01	1.538717e-01	1.486235e+00	1.353771e+00	3.034264e+00

	P	Q	R	Motor1	Motor2
count	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06	1.295895e+06
mean	1.573519e-06	1.412977e-06	-3.197492e-07	2.365206e+02	-2.365207e+02
std	9.057596e-03	3.927625e-02	2.225740e-03	3.395921e+01	3.395556e+01
min	-5.037703e-01	-3.575321e+00	-1.820346e-01	1.000000e+01	-4.613083e+02
25%	-1.220251e-03	-1.284665e-03	-9.134351e-04	2.355287e+02	-2.375263e+02
50%	4.287249e-06	-4.722129e-06	-4.495727e-06	2.365282e+02	-2.365222e+02
75%	1.240739e-03	1.283613e-03	9.029967e-04	2.374787e+02	-2.354865e+02
max	4.727377e-01	3.632708e+00	1.794934e-01	4.609845e+02	-1.000000e+01

	Motor3	Motor4	X_r	Y_r	Z_r
count	1.295895e+06	1.295895e+06	1295895.0	1295895.0	1.295895e+06
mean	2.365206e+02	-2.365208e+02	0.0	0.0	-1.482117e+00
std	3.394866e+01	3.396455e+01	0.0	0.0	2.440522e-01
min	1.000000e+01	-4.609848e+02	0.0	0.0	-2.774623e+00
25%	2.355364e+02	-2.375314e+02	0.0	0.0	-1.620000e+00
50%	2.365288e+02	-2.365235e+02	0.0	0.0	-1.500000e+00
75%	2.374726e+02	-2.354862e+02	0.0	0.0	-1.351574e+00
max	4.611932e+02	-1.000000e+01	0.0	0.0	0.000000e+00

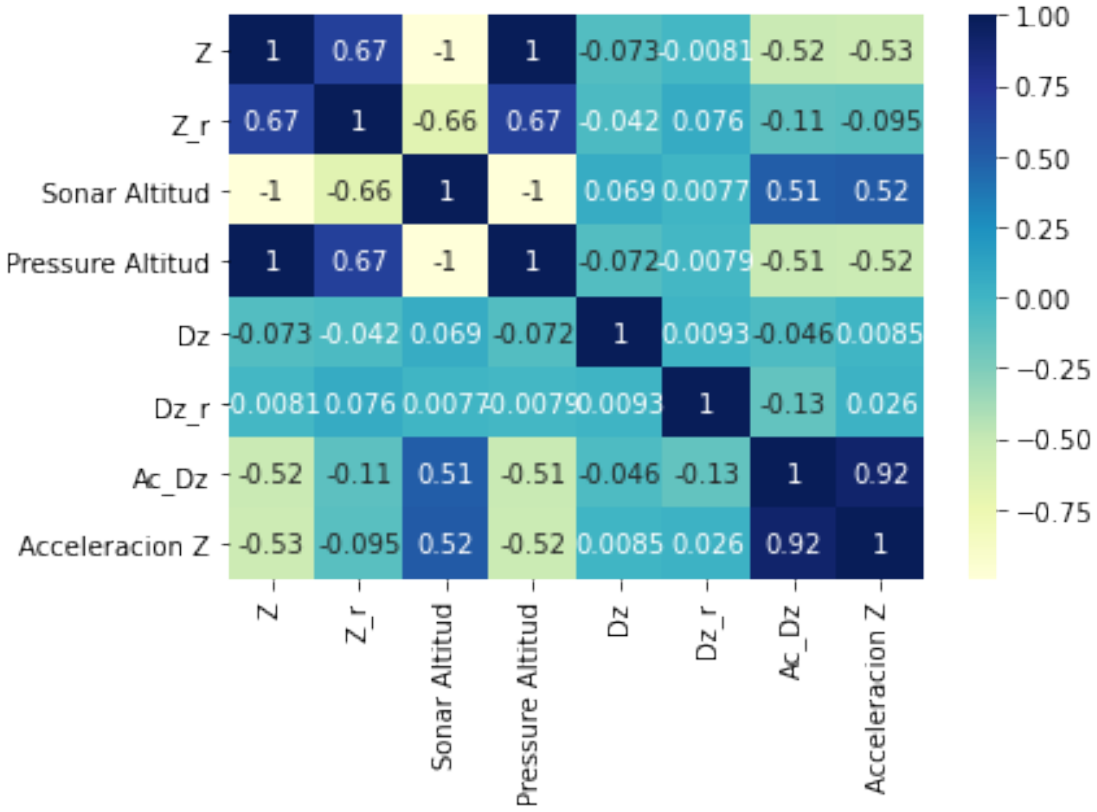
```
           Yaw_r    Pitch_r     Roll_r       Dx_r       Dy_r          Dz_r  \
count  1295895.0  1295895.0  1295895.0  1295895.0  1295895.0  1.295895e+06
mean         0.0        0.0        0.0        0.0        0.0 -2.193838e-02
std          0.0        0.0        0.0        0.0        0.0  8.223455e+00
min          0.0        0.0        0.0        0.0        0.0 -3.460435e+02
25%          0.0        0.0        0.0        0.0        0.0  0.000000e+00
50%          0.0        0.0        0.0        0.0        0.0  0.000000e+00
75%          0.0        0.0        0.0        0.0        0.0  0.000000e+00
max          0.0        0.0        0.0        0.0        0.0  3.807929e+02

           P_r        Q_r        R_r  Flag_Pitch_Roll         Ac_Dx  \
count  1295895.0  1295895.0  1295895.0        1295895.0  1.295895e+06
mean         0.0        0.0        0.0              1.0  9.007334e-02
std          0.0        0.0        0.0              0.0  2.089574e-01
min          0.0        0.0        0.0              1.0 -8.013137e-01
25%          0.0        0.0        0.0              1.0 -5.126491e-02
50%          0.0        0.0        0.0              1.0  9.049701e-02
75%          0.0        0.0        0.0              1.0  2.315978e-01
max          0.0        0.0        0.0              1.0  8.437319e-01

            Ac_Dy         Ac_Dz        Gyro P        Gyro Q        Gyro R  \
count  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06
mean  -5.992936e-02 -9.419827e+00 -9.498428e-03 -7.498578e-03  1.499741e-03
std    1.930278e-01  1.427087e+00  9.045007e-03  3.952919e-02  2.383690e-03
min   -8.834900e-01 -1.963813e+01 -5.125701e-01 -3.605846e+00 -1.798834e-01
25%   -1.905823e-01 -9.646096e+00 -1.071855e-02 -8.792938e-03  4.273835e-04
50%   -5.959882e-02 -9.423019e+00 -9.495718e-03 -7.504752e-03  1.502034e-03
75%    7.084187e-02 -9.203916e+00 -8.260985e-03 -6.208120e-03  2.568620e-03
max    6.365708e-01  8.609541e-01  4.625807e-01  3.648603e+00  1.830248e-01

       Sonar Altitud  Pressure Altitud      Bat_V  Bat_Percentage  \
count   1.295895e+06      1.295895e+06  1295895.0       1295895.0
mean    1.504551e+00      1.012529e+05        3.5            70.0
std     2.614817e-01      3.211676e+00        0.0             0.0
min     4.400000e-01      1.012314e+05        3.5            70.0
25%     1.367890e+00      1.012514e+05        3.5            70.0
50%     1.498847e+00      1.012529e+05        3.5            70.0
75%     1.624728e+00      1.012545e+05        3.5            70.0
max     3.290363e+00      1.012704e+05        3.5            70.0

       Acceleracion X  Acceleracion Y  Acceleracion Z  Acceleracion P  \
count    1.295895e+06    1.295895e+06    1.295895e+06    1.295895e+06
mean     5.755633e-06   -1.250541e-04   -1.736796e-04    6.004077e-05
std      5.950564e-01    8.118001e-02    1.435704e+00    4.211311e-01
min     -8.899236e+01   -4.018375e+00   -1.017578e+01   -8.605778e+00
25%     -8.635339e-03   -2.117448e-02   -1.253270e-01   -2.800144e-01
50%      0.000000e+00    0.000000e+00   -1.526624e-03   -3.745025e-03
```

```
75%      8.559134e-03    2.102111e-02    1.203972e-01    2.815473e-01
max      9.037159e+01    4.432607e+00    1.060796e+01    7.373816e+00

       Acceleracion Q  Acceleracion R            Z1           Dz1  \
count    1.295895e+06    1.295895e+06  1.295895e+06  1.295895e+06
mean     2.189152e-05   -8.116385e-06 -1.502918e+00 -1.521034e-02
std      1.670874e+00    2.951463e-01  2.703173e-01  4.544223e-01
min     -1.592394e+02   -8.434417e+00 -3.318702e+00 -4.524404e+00
25%     -3.060012e-01   -1.960427e-01 -1.624222e+00 -9.322412e-03
50%     -3.043190e-03   -7.657334e-04 -1.499095e+00  1.304944e-04
75%      3.080426e-01    1.959933e-01 -1.367004e+00  8.658752e-03
max      1.689137e+02    7.723484e+00  0.000000e+00  3.034264e+00

              Z_r1        Ac_Dz1          Yaw1         Roll1            P1  \
count  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06
mean  -1.482007e+00 -9.419130e+00  2.257514e-06  7.887457e-05  1.273315e-06
std    2.443724e-01  1.429272e+00  2.768997e-04  3.505640e-03  9.056365e-03
min   -2.774623e+00 -1.963813e+01 -1.254526e-02 -1.588011e-01 -5.037703e-01
25%   -1.620000e+00 -9.646093e+00 -1.617320e-05 -2.072770e-04 -1.220251e-03
50%   -1.500000e+00 -9.423018e+00  1.684218e-07  6.035169e-05  4.136165e-06
75%   -1.351574e+00 -9.203855e+00  1.726007e-05  3.423065e-04  1.240343e-03
max    0.000000e+00  8.609541e-01  1.233279e-02  1.636863e-01  4.727377e-01

                Q1  Acceleracion P1  Acceleracion Q1            Z2  \
count  1.295895e+06     1.295895e+06     1.295895e+06  1.295895e+06
mean   1.303519e-06     1.038755e-05    -3.086813e-05 -1.502809e+00
std    3.927625e-02     4.210900e-01     1.670862e+00  2.706177e-01
min   -3.575321e+00    -8.605778e+00    -1.592394e+02 -3.318702e+00
25%   -1.284665e-03    -2.800144e-01    -3.060012e-01 -1.624207e+00
50%   -4.722129e-06    -3.745025e-03    -3.043190e-03 -1.499094e+00
75%    1.283548e-03     2.814385e-01     3.079379e-01 -1.366925e+00
max    3.632708e+00     7.373816e+00     1.689137e+02  0.000000e+00

              Dz2          Z_r2        Ac_Dz2          Yaw2         Roll2  \
count  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06
mean  -1.520958e-02 -1.481896e+00 -9.418387e+00  2.258437e-06  7.887883e-05
std    4.544177e-01  2.446916e-01  1.431431e+00  2.768996e-04  3.505148e-03
min   -4.524404e+00 -2.774623e+00 -1.963813e+01 -1.254526e-02 -1.588011e-01
25%   -9.322241e-03 -1.620000e+00 -9.646035e+00 -1.617313e-05 -2.072770e-04
50%    1.281137e-04 -1.500000e+00 -9.422956e+00  1.683297e-07  6.028301e-05
75%    8.657166e-03 -1.351574e+00 -9.203737e+00  1.726007e-05  3.422434e-04
max    3.034264e+00  0.000000e+00  8.609541e-01  1.233279e-02  1.636863e-01

                P2            Q2  Acceleracion P2  Acceleracion Q2  \
count  1.295895e+06  1.295895e+06     1.295895e+06     1.295895e+06
mean   1.221378e-06  1.457860e-06     2.812219e-05    -7.125476e-06
std    9.055216e-03  3.927624e-02     4.210710e-01     1.670856e+00
```

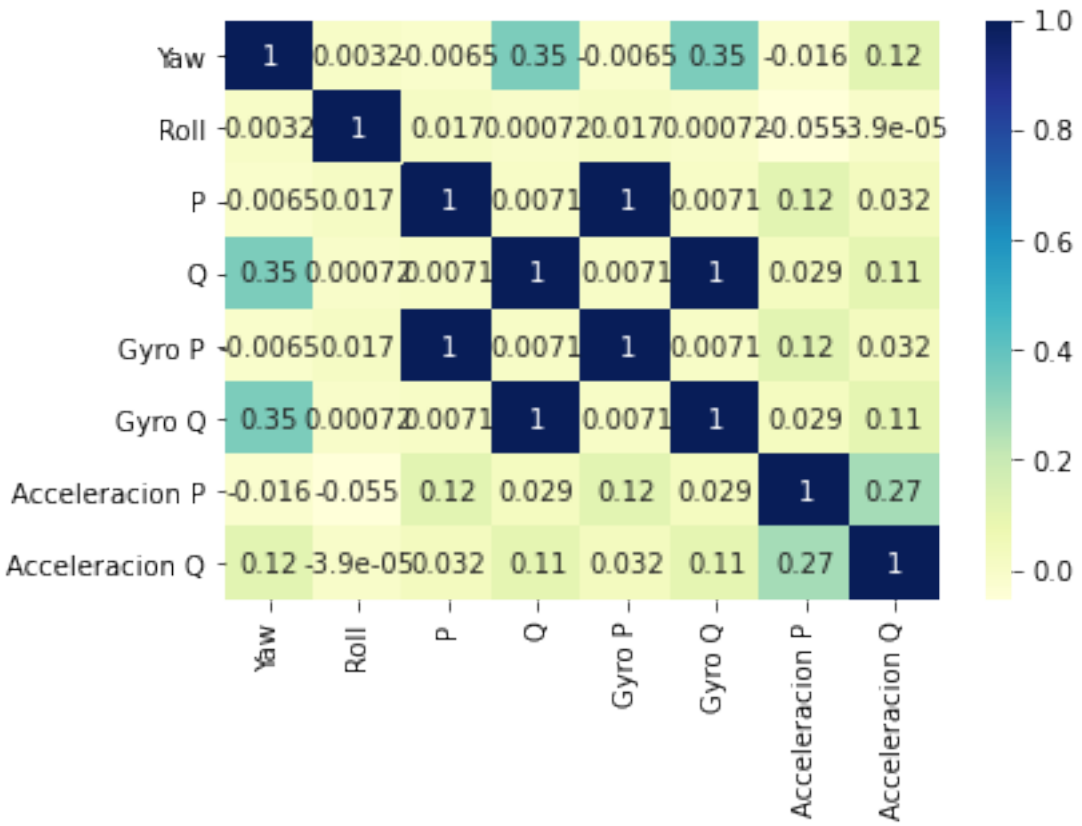
```
min   -5.037703e-01 -3.575321e+00    -8.605778e+00    -1.592394e+02
25%   -1.219919e-03 -1.284440e-03    -2.799338e-01    -3.059567e-01
50%    4.130569e-06 -4.424624e-06    -3.700447e-03    -2.996484e-03
75%    1.240317e-03  1.283548e-03     2.814385e-01     3.079379e-01
max    4.727377e-01  3.632708e+00     7.373816e+00     1.689137e+02

                Z3           Dz3          Z_r3        Ac_Dz3          Yaw3  \
count  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06  1.295895e+06
mean  -1.502699e+00 -1.520887e-02 -1.481784e+00 -9.417694e+00  2.258529e-06
std    2.709177e-01  4.544130e-01  2.450097e-01  1.433600e+00  2.768996e-04
min   -3.318702e+00 -4.524404e+00 -2.774623e+00 -1.963813e+01 -1.254526e-02
25%   -1.624196e+00 -9.322085e-03 -1.620000e+00 -9.646004e+00 -1.617308e-05
50%   -1.499093e+00  1.261767e-04 -1.500000e+00 -9.422915e+00  1.660678e-07
75%   -1.366811e+00  8.655519e-03 -1.351574e+00 -9.203696e+00  1.726007e-05
max    0.000000e+00  3.034264e+00  0.000000e+00  8.609541e-01  1.233279e-02

              Roll3            P3            Q3  Acceleracion P3  \
count  1.295895e+06  1.295895e+06  1.295895e+06     1.295895e+06
mean   7.888335e-05  1.080767e-06  1.493488e-06     2.985777e-06
std    3.504645e-03  9.054026e-03  3.927624e-02     4.210606e-01
min   -1.588011e-01 -5.037703e-01 -3.575321e+00    -8.605778e+00
25%   -2.072770e-04 -1.219723e-03 -1.284153e-03    -2.799338e-01
50%    6.020387e-05  3.981350e-06 -4.307566e-06    -3.700447e-03
75%    3.421859e-04  1.240157e-03  1.283347e-03     2.813485e-01
max    1.636863e-01  4.727377e-01  3.632708e+00     7.373816e+00

       Acceleracion Q3
count     1.295895e+06
mean     -3.594663e-05
std       1.670853e+00
min      -1.592394e+02
25%      -3.059567e-01
50%      -2.996484e-03
75%       3.079038e-01
max       1.689137e+02
```

Mapa de Correlación

[27]:
```
corr_states = ["Z", "Z_r", "Sonar Altitud", "Pressure Altitud",
               "Dz", "Dz_r", "Ac_Dz", "Acceleracion Z"]
correlation = dataset[corr_states].corr() #corr() method of pandas library␣
 ↪calculates correlation between columns of dataframe
sns.heatmap(correlation,cmap="YlGnBu",annot=True)
plt.show()
```



[29]:
```
corr_states = ["Yaw", "Roll", "P", "Q",
               "Gyro P", "Gyro Q",
              "Acceleracion P", "Acceleracion Q"]
correlation = dataset[corr_states].corr() #corr() method of pandas library␣
 ↪calculates correlation between columns of dataframe
sns.heatmap(correlation,cmap="YlGnBu",annot=True)
plt.show()
```


Yaw 1 0.0032 -0.0065 0.35 -0.0065 0.35 -0.016 0.12
Roll -0.0032 1 0.017 0.00072 0.017 0.00072 -0.055 3.9e-05
P -0.0065 0.017 1 0.0071 1 0.0071 0.12 0.032
Q 0.35 0.00072 0.0071 1 0.0071 1 0.029 0.11
Gyro P -0.0065 0.017 1 0.0071 1 0.0071 0.12 0.032
Gyro Q 0.35 0.00072 0.0071 1 0.0071 1 0.029 0.11
Acceleracion P -0.016 -0.055 0.12 0.029 0.12 0.029 1 0.27
Acceleracion Q 0.12 -3.9e-05 0.032 0.11 0.032 0.11 0.27 1
Yaw
Roll
P
Q
Gyro P
Gyro Q
Acceleracion P
Acceleracion Q
1.0
0.8
0.6
0.4
0.2
0.0

[ ]: