LQR - State Analysis

LQR is an optimal control algorithm that calculates the best effective control input given the Q and R matrices to the controller for estimating the best K control matrix to apply to the state input.

For the simulation our findings are:

- HIGH Q, LOW R FINISHED AND GET THE GOALS VERY FAST
- HIGH R, LOW Q ONLY STAYS ON GOAL 3
- HIGH R, HIGH Q ACHIEVES ALL GOALS VERY CONSERVATIVE
- LOW R, LOW Q ONLY STAYS ON GOAL 1
- MID Q, MID R A WELL BALANCE BETWEEN GOAL AND RESPONSE INPUT

Import libraries

In [1]:
```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import numpy as np
import glob
import os
```

Load the log file and calculcate position and goals

In [2]:
```
fpaths = glob.glob('*.csv', recursive=True)
fpath = fpaths[1]
fpaths
```

Out[2]:
```
['log_task4.csv',
 'log_task4_best.csv',
 'log_task4_high_q_high_r.csv',
 'log_task4_high_q_low_r.csv',
 'log_task4_high_r_low_q.csv',
 'log_task4_low_q_low_r.csv',
 'log_task4_mid_q_mid_r.csv']
```

This are the parameters of the simulation that corresponds to this task

In [3]:
```python
df = pd.read_csv(fpath, nrows=1)
df.head(2)
```

Out[3]:

	q_diag	r_diag	horizon	tolerance	dt_
0	0.85	0.2	100	0.2	0.2

In [4]:
```python
df = pd.read_csv('log_task4.csv', skiprows=2)

df['Goal'] = np.sqrt(df.X_Goal**2+df.Y_Goal**2)
df['Pos'] = np.sqrt(df.X_Pos**2+df.Y_Pos**2)
df['error_x'] = df.X_Goal - df.X_Pos
df['error_y'] = df.Y_Goal - df.Y_Pos
df['error'] = df.Goal - df.Pos
df['error_theta'] = df.Theta_Goal - df.Theta

df.head()
```

Out[4]:

	X_Goal	Y_Goal	X_Pos	Y_Pos	Theta_Goal	Theta	Goal	Pos	error_x	error_y	error	error_theta
0	1	1.0	0.001182	2.042230e-07	0.785398	7.549530e-07	1.414214	0.001182	0.998818	1.0	1.413032	0.785397
1	1	1.0	0.011637	2.114010e-07	0.785398	6.888020e-07	1.414214	0.011637	0.988363	1.0	1.402577	0.785397
2	1	1.0	0.017428	1.706140e-07	0.785398	1.007170e-06	1.414214	0.017428	0.982572	1.0	1.396785	0.785397
3	1	1.0	0.041714	-2.976340e-08	0.785398	1.138330e-06	1.414214	0.041714	0.958286	1.0	1.372500	0.785397
4	1	1.0	0.076365	-2.923880e-07	0.785398	1.322700e-06	1.414214	0.076365	0.923635	1.0	1.337849	0.785397

In [5]:
```
def plot_pair(var1, var2, var3, palette, color_var1, color_var2, color_var3, title, xlabel, ylabel):
    fig, ax = plt.subplots(1, figsize=(12,6))

    ax = sns.lineplot(
        data=df,
        x=df.index, y=var1,
        palette=palette,
        label=var1,
        color = color_var1,
        ax=ax
    )

    ax = sns.lineplot(
        data=df,
        x=df.index, y=var2,
        palette=palette,
        label=var2,
        color=color_var2,
        ax=ax
    )

    ax = sns.lineplot(
        data=df,
        x=df.index, y=var3,
        palette=palette,
        label=var3,
        color=color_var3,
        ax=ax
    )

    fig.suptitle(title)
    ax.set_xlabel(xlabel)
    ax.set_ylabel(ylabel)


    ax.legend(title="Legend", loc="upper left", fontsize=12, title_fontsize='13')

    ax.grid(True)


def plot_distributions(var1, var2, var1_color, var2_color):
    fig, ax = plt.subplots(figsize=(12,6))
    sns.histplot(df.X_Goal, color=var1_color, ax=ax, label=var1)
    sns.histplot(df.X_Pos, color=var2_color, ax=ax, label=var2)
    ax.legend();
    ax.set_xlabel(f'{var1} | {var2}')
```

```
    fig.suptitle(f'{var1} | {var2} Distributions')
```

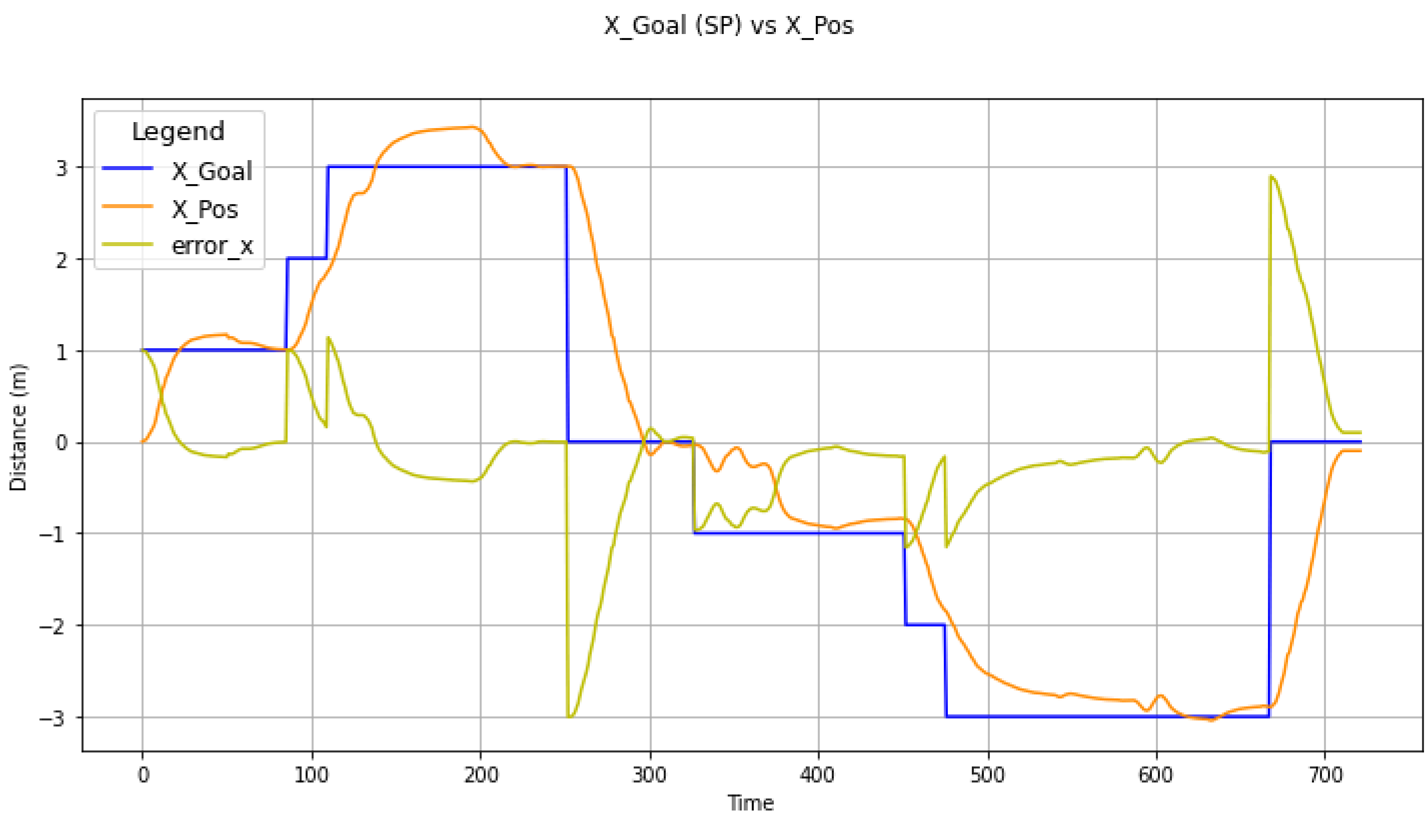
X (Goal vs Pos) Analysis

We can show here the effects of trajectories of X, Y and Theta over time and also the errors.

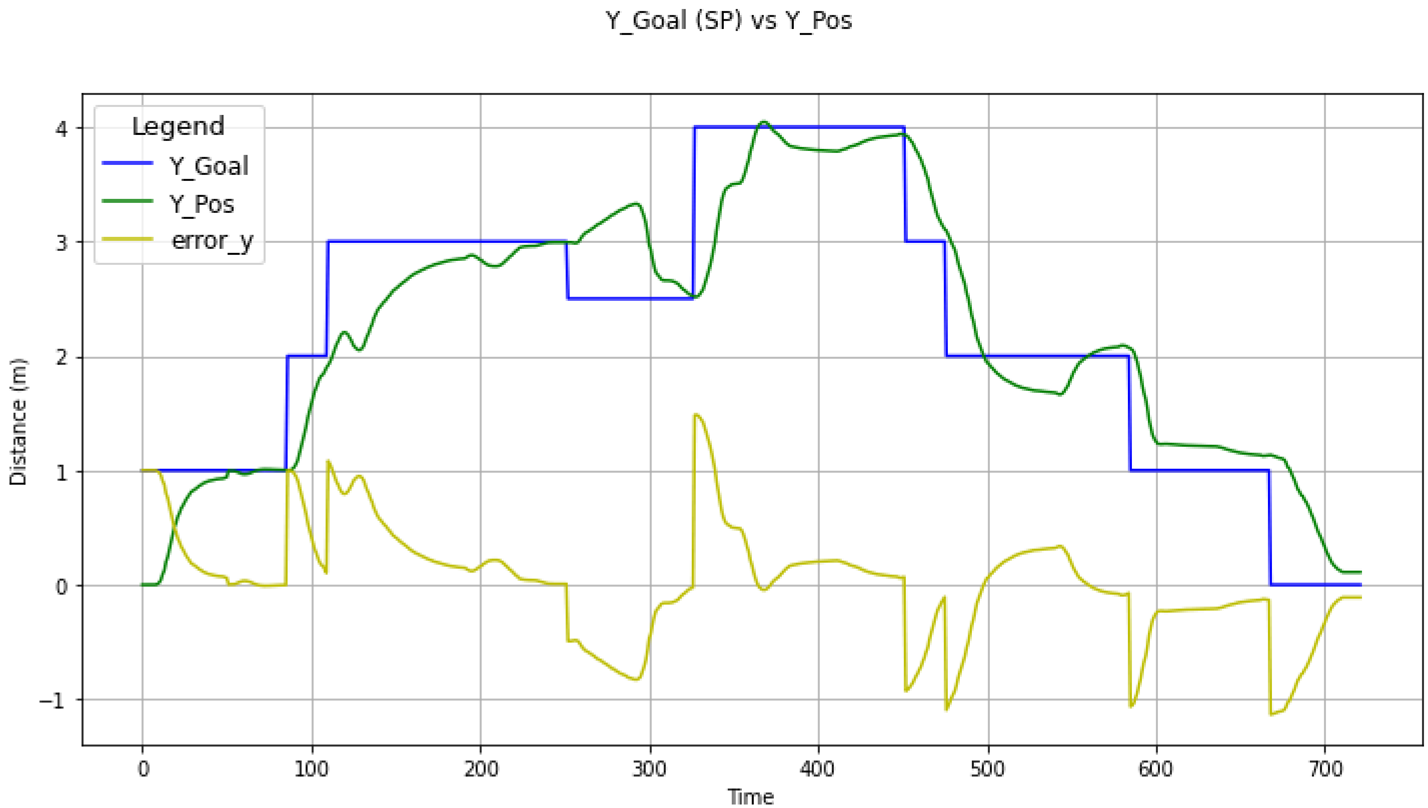
For this qualification we can se how good is the controller performing over time the control actions.

In [6]:

```
plot_pair(
    var1='X_Goal',
    var2='X_Pos',
    var3='error_x',
    palette='magma',
    color_var1='blue',
    color_var2='darkorange',
    color_var3='y',
    title='X_Goal (SP) vs X_Pos',
    xlabel='Time',
    ylabel='Distance (m)'
)
```

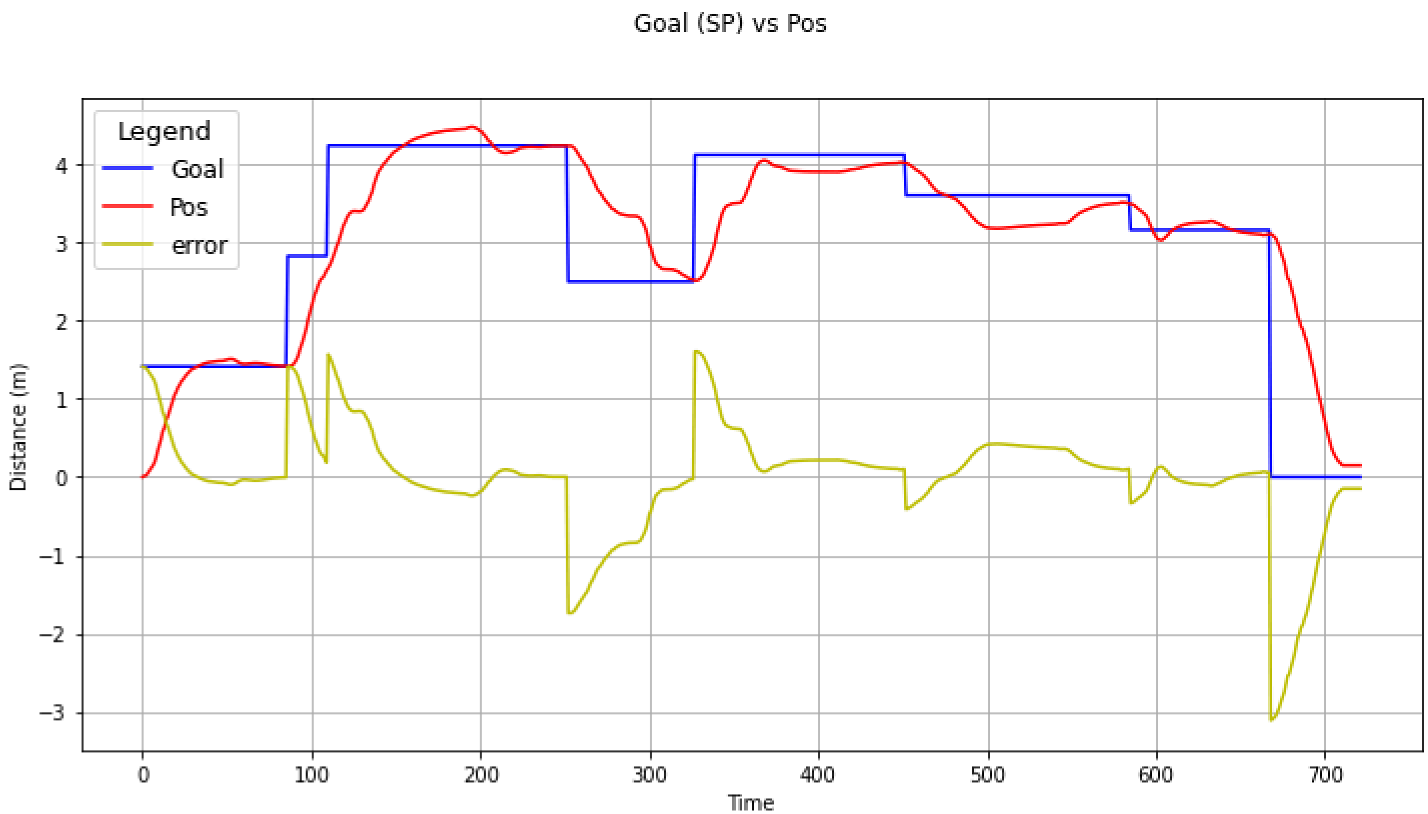


In [7]:
```
plot_pair(
    var1='Y_Goal',
    var2='Y_Pos',
    var3='error_y',
    palette='viridis',
    color_var1='blue',
    color_var2='green',
    color_var3='y',
    title='Y_Goal (SP) vs Y_Pos',
    xlabel='Time',
    ylabel='Distance (m)'
)
```

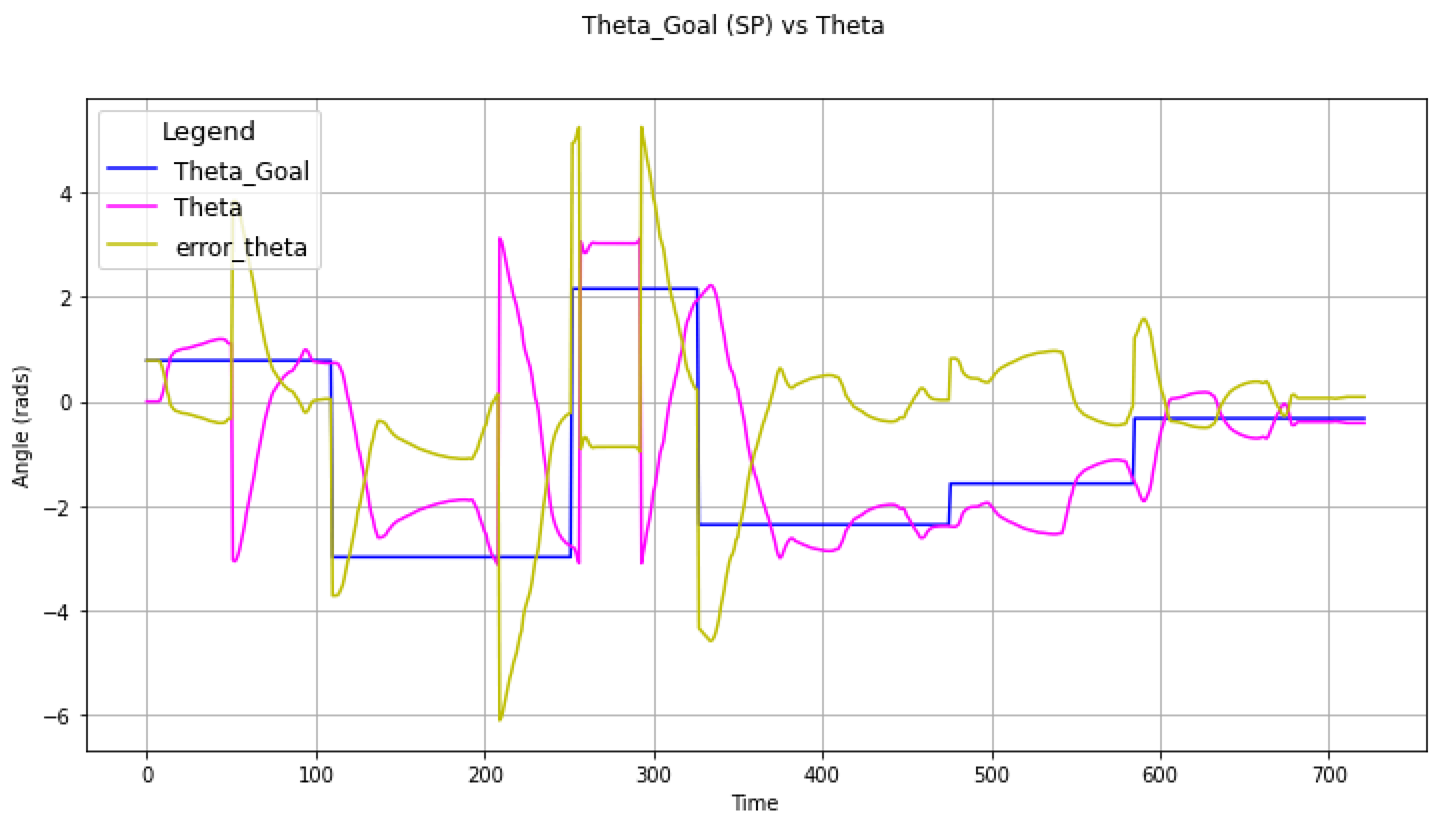


In [8]:

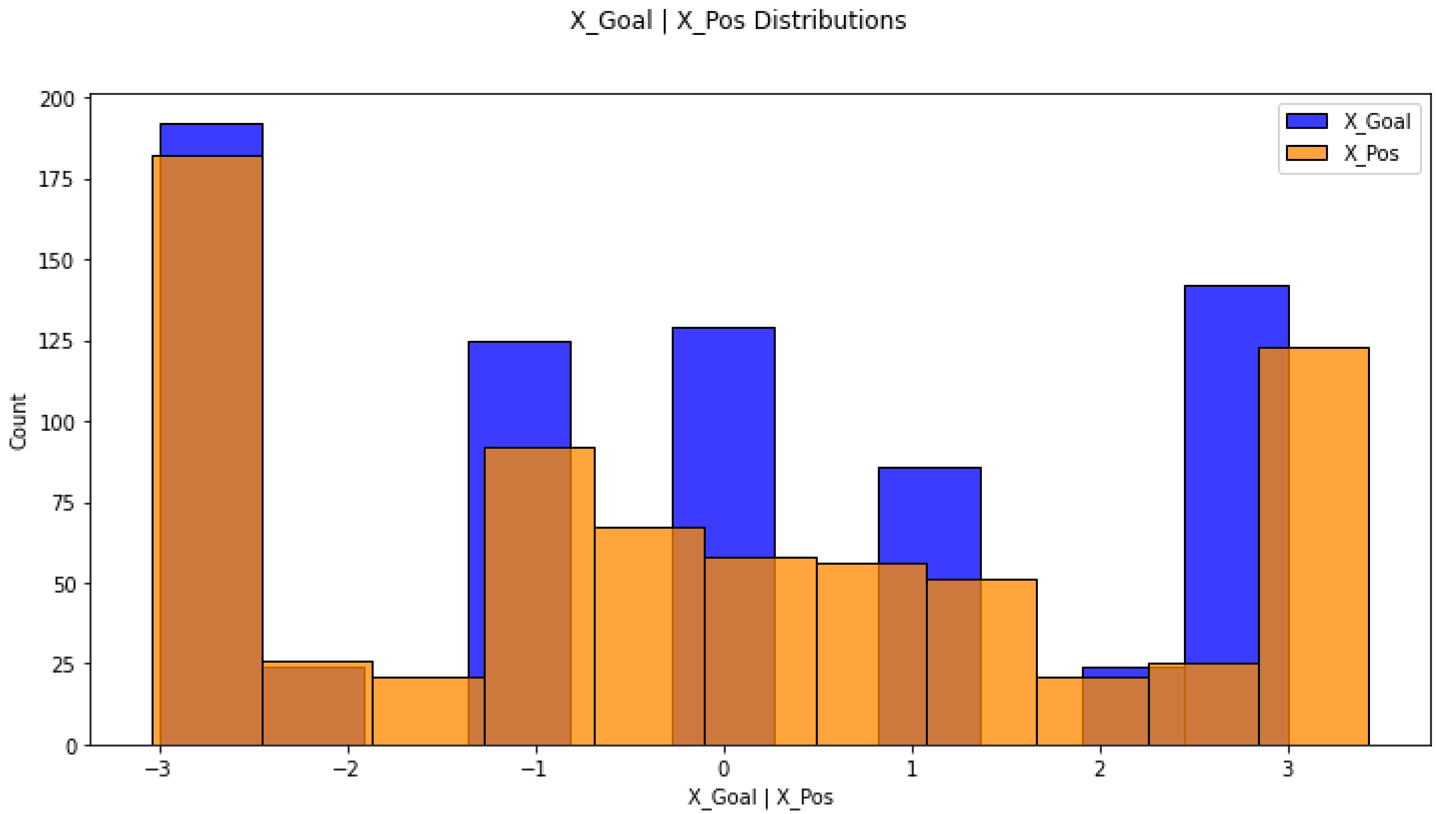
```
plot_pair(
    var1='Goal',
    var2='Pos',
    var3='error',
    palette='viridis',
    color_var1='blue',
    color_var2='red',
    color_var3='y',
    title='Goal (SP) vs Pos',
    xlabel='Time',
    ylabel='Distance (m)'
)
```



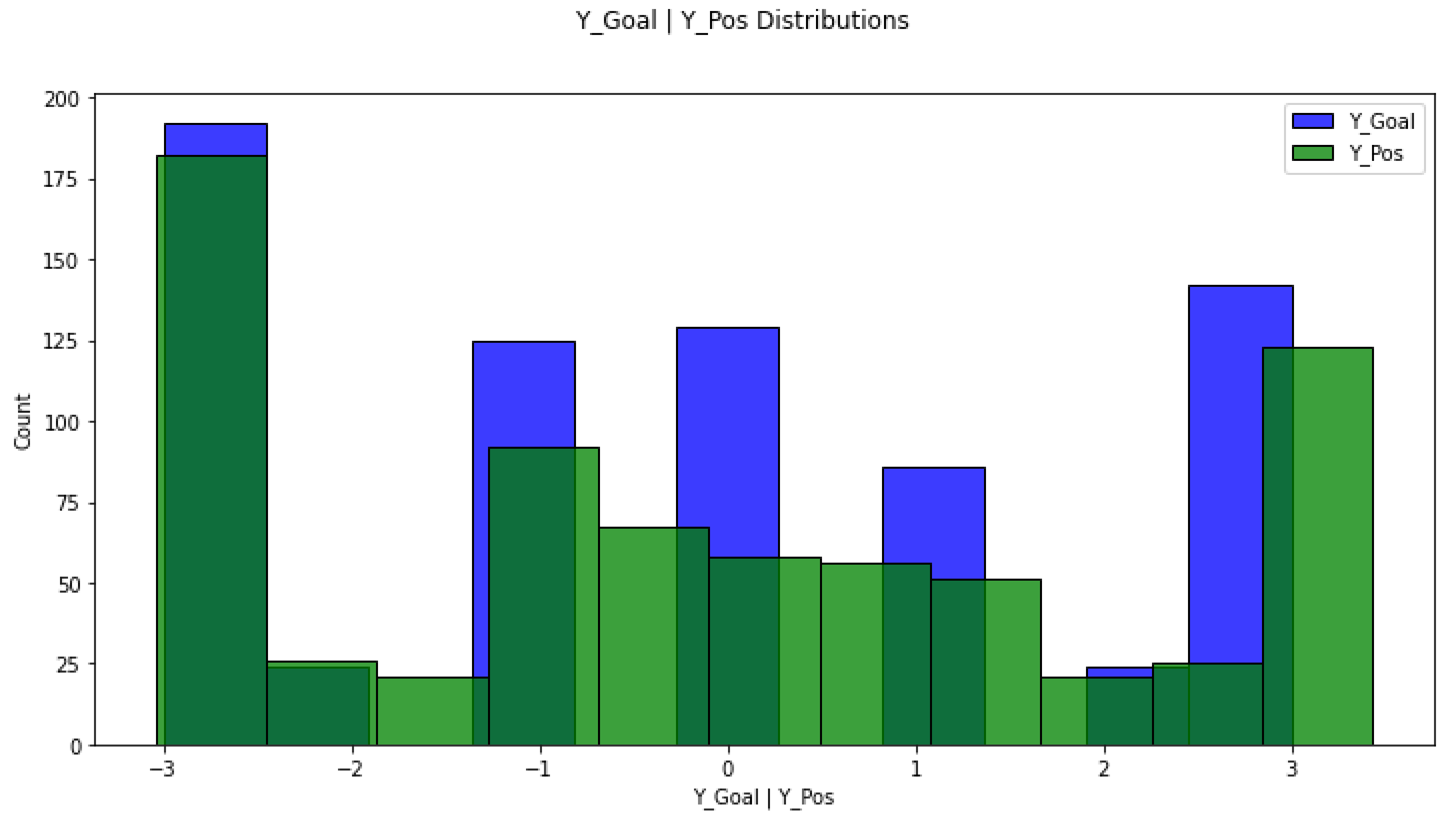
In [9]:
```
plot_pair(
    var1='Theta_Goal',
    var2='Theta',
    var3='error_theta',
    palette='viridis',
    color_var1='blue',
    color_var2='magenta',
    color_var3='y',
    title='Theta_Goal (SP) vs Theta',
    xlabel='Time',
    ylabel='Angle (rads)'
)
```



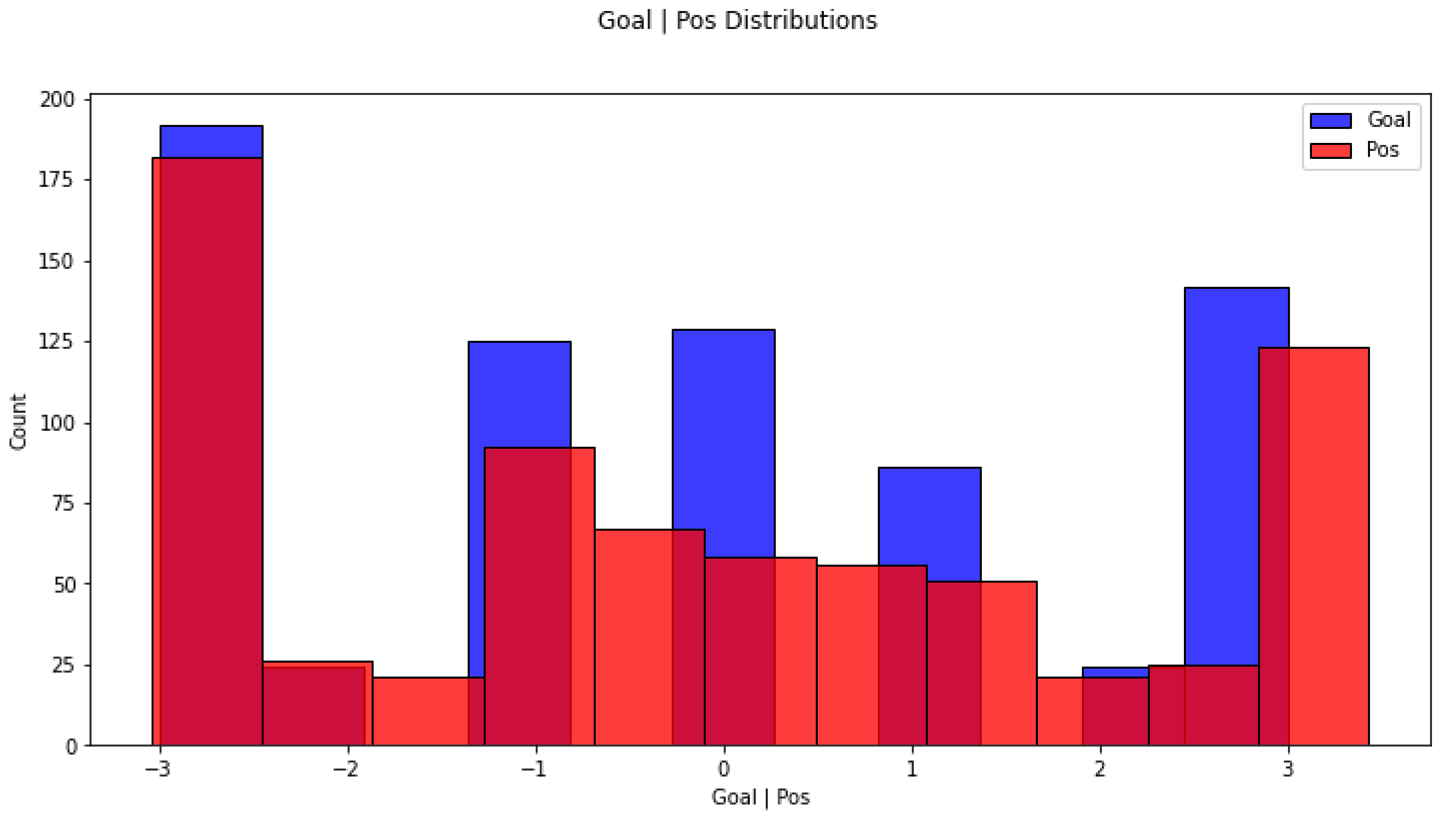
```python
In [10]: plot_distributions(var1='X_Goal', var2='X_Pos', var1_color='blue', var2_color='darkorange')
```



In [11]:
```
plot_distributions(var1='Y_Goal', var2='Y_Pos', var1_color='blue', var2_color='green')
```



```
In [12]: plot_distributions(var1='Goal', var2='Pos', var1_color='blue', var2_color='red')
```



In [13]:
```
plot_distributions(var1='Theta_Goal', var2='Theta', var1_color='blue', var2_color='magenta')
```