Exogenous Variables

Exogenous variables or external factors are crucial in time series forecasting as they provide additional information that might influence the prediction. These variables could include holiday markers, marketing spending, weather data, or any other external data that correlate with the time series data you are forecasting.

For example, if you're forecasting ice cream sales, temperature data could serve as a useful exogenous variable. On hotter days, ice cream sales may increase.

To incorporate exogenous variables in TimeGPT, you'll need to pair each point in your time series data with the corresponding external data.

In [ ]:
```
# | hide
from dotenv import load_dotenv
```

In [ ]:
```
# | hide
load_dotenv()
```

Out[ ]:
```
True
```

In [ ]:
```
import pandas as pd
from nixtlats import TimeGPT
import os
```

In [ ]:
```
timegpt = TimeGPT(token=os.getenv("TIMEGPT_TOKEN"))
```

In [ ]:
```
# | hide
timegpt = TimeGPT()
```

You can test the validate of your token calling the `validate_token` method:

In [ ]:
```
timegpt.validate_token()
```

```
INFO:nixtlats.timegpt:Happy Forecasting! :), If you have questions or need support, please email ops@nixtla.io
```

Out[ ]:
```
True
```

Let's see an example on predicting day-ahead electricity prices. The following dataset contains the hourly electricity price (`y` column) for five markets in Europe and US, identified by the `unique_id` column. The columns from `Exogenous1` to `day_6` are exogenous variables that TimeGPT will use to predict the prices.

In [ ]:
```
df = pd.read_csv(
    "https://raw.githubusercontent.com/Nixtla/transfer-learning-time-series/main/da
```

```
)
df.head()
```

Out[ ]:

	unique_id	ds	y	Exogenous1	Exogenous2	day_0	day_1	day_2	day_3	day_
0	BE	2016-12-01 00:00:00	72.00	61507.0	71066.0	0.0	0.0	0.0	1.0	0.
1	BE	2016-12-01 01:00:00	65.80	59528.0	67311.0	0.0	0.0	0.0	1.0	0.
2	BE	2016-12-01 02:00:00	59.99	58812.0	67470.0	0.0	0.0	0.0	1.0	0.
3	BE	2016-12-01 03:00:00	50.69	57676.0	64529.0	0.0	0.0	0.0	1.0	0.
4	BE	2016-12-01 04:00:00	52.58	56804.0	62773.0	0.0	0.0	0.0	1.0	0.

To produce forecasts we also have to add the future values of the exogenous variables. Let's read this dataset. In this case, we want to predict 24 steps ahead, therefore each `unique_id` will have 24 observations.

In [ ]:
```
future_ex_vars_df = pd.read_csv(
    "https://raw.githubusercontent.com/Nixtla/transfer-learning-time-series/main/da
)
future_ex_vars_df.head()
```

Out[ ]:

	unique_id	ds	Exogenous1	Exogenous2	day_0	day_1	day_2	day_3	day_4	day_
0	BE	2016-12-31 00:00:00	64108.0	70318.0	0.0	0.0	0.0	0.0	0.0	1
1	BE	2016-12-31 01:00:00	62492.0	67898.0	0.0	0.0	0.0	0.0	0.0	1
2	BE	2016-12-31 02:00:00	61571.0	68379.0	0.0	0.0	0.0	0.0	0.0	1
3	BE	2016-12-31 03:00:00	60381.0	64972.0	0.0	0.0	0.0	0.0	0.0	1
4	BE	2016-12-31 04:00:00	60298.0	62900.0	0.0	0.0	0.0	0.0	0.0	1

Let's call the `forecast` method, adding this information:

In [ ]:
```
timegpt_fcst_ex_vars_df = timegpt.forecast(
    df=df, X_df=future_ex_vars_df, h=24, level=[80, 90]
)
timegpt_fcst_ex_vars_df.head()
```

```
INFO:nixtlats.timegpt:Validating inputs...
INFO:nixtlats.timegpt:Preprocessing dataframes...
INFO:nixtlats.timegpt:Inferred freq: h
INFO:nixtlats.timegpt:Attempt 1 failed...
WARNING:nixtlats.timegpt:The specified horizon "h" exceeds the model horizon. This m
ay lead to less accurate forecasts. Please consider using a smaller horizon.
INFO:nixtlats.timegpt:Using the following exogenous variables: Exogenous1, Exogenous
2, day_0, day_1, day_2, day_3, day_4, day_5, day_6
INFO:nixtlats.timegpt:Calling Forecast Endpoint...
```

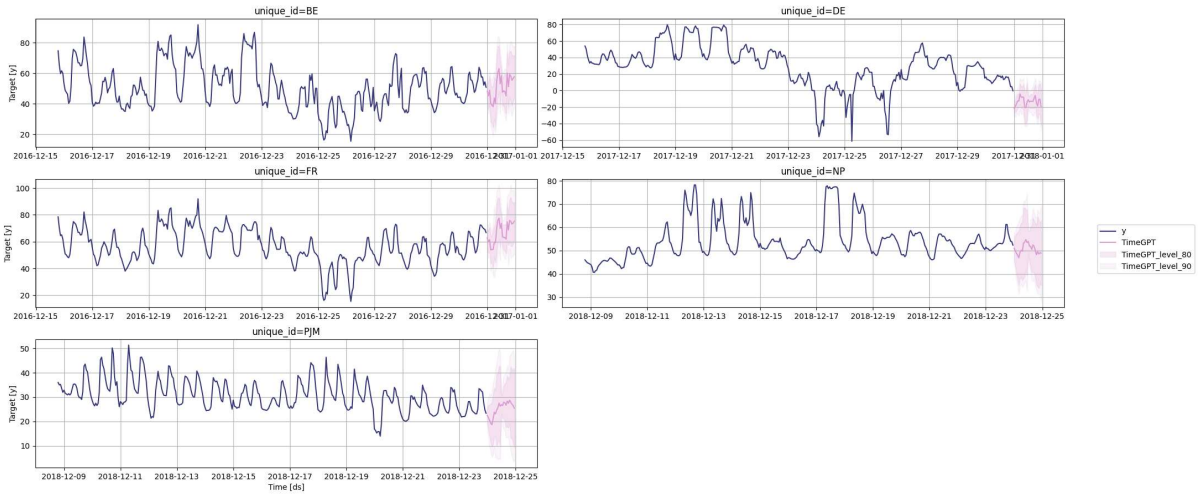
Out[ ]:

	unique_id	ds	TimeGPT	TimeGPT-lo-90	TimeGPT-lo-80	TimeGPT-hi-80	TimeGPT-hi-90
0	BE	2016-12-31 00:00:00	48.235492	38.564627	43.525878	52.945107	57.906358
1	BE	2016-12-31 01:00:00	45.188141	33.659668	36.171925	54.204357	56.716614
2	BE	2016-12-31 02:00:00	48.867367	36.208286	39.510485	58.224250	61.526448
3	BE	2016-12-31 03:00:00	39.980112	24.760213	27.955178	52.005046	55.200011
4	BE	2016-12-31 04:00:00	38.964503	22.335701	27.180510	50.748496	55.593304

> BEFORE: *4 API Calls | 253200 Tokens | 443.04 Spent*
> AFTER: *5 API Calls | 290880 Tokens | 489.46 Spent*
> **USAGE: 1 API Call | 37680 Tokens | 46.42 Spent**

In [ ]:
```
timegpt.plot(
    df[["unique_id", "ds", "y"]],
    timegpt_fcst_ex_vars_df,
    max_insample_length=365,
    level=[80, 90],
)
```

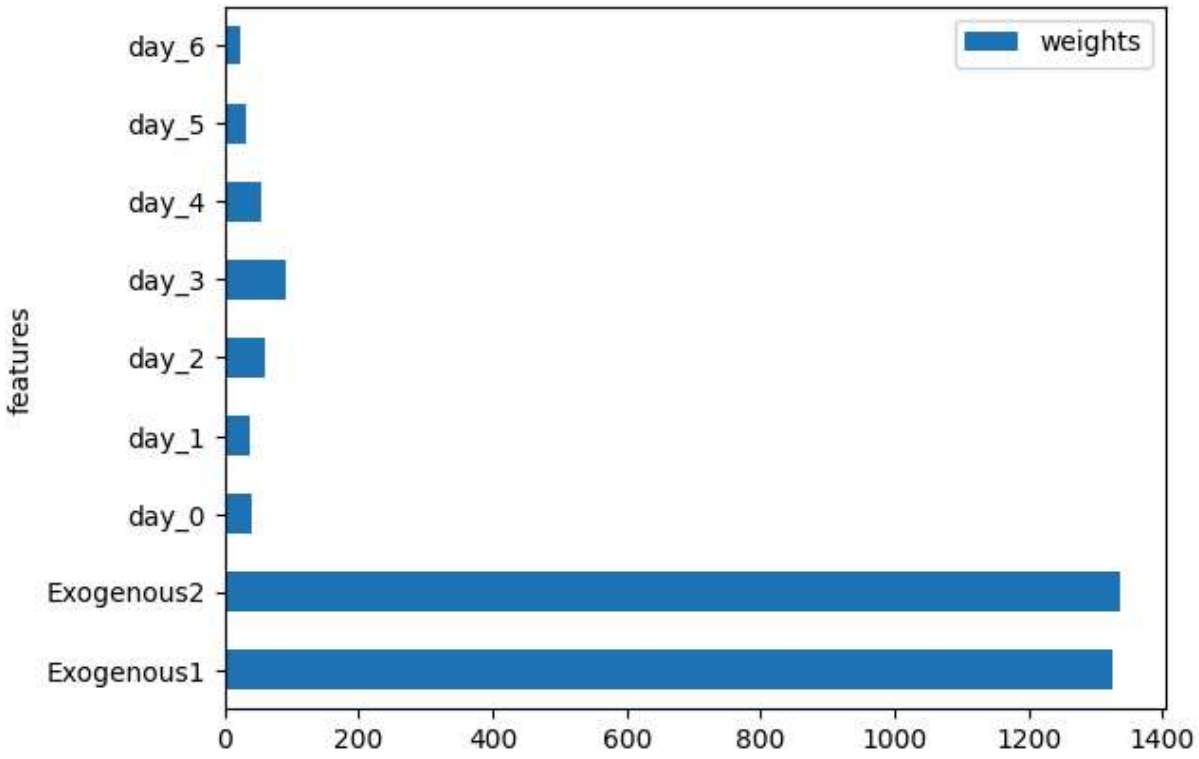
Out[ ]:



We also can get the importance of the features.

In [ ]:
```
timegpt.weights_x.plot.barh(x="features", y="weights")
```

Out[ ]:
```
<Axes: ylabel='features'>
```



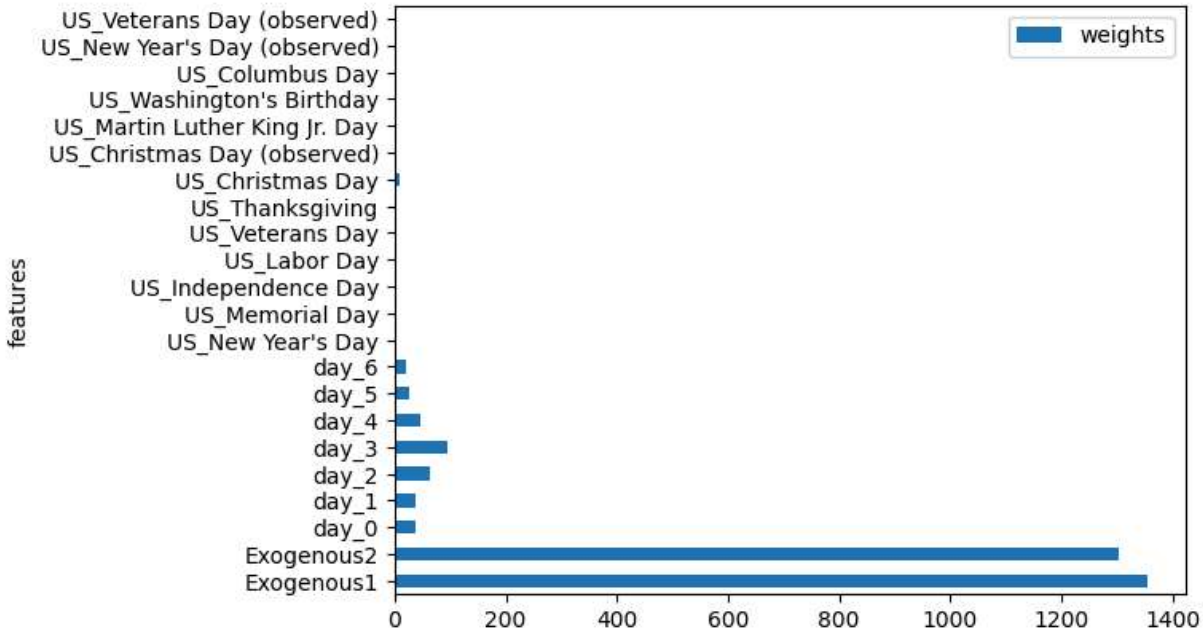
You can also add country holidays using the `CountryHolidays` class.

In [ ]:
```
from nixtlats.date_features import CountryHolidays
```

In [ ]:
```
timegpt_fcst_ex_vars_df = timegpt.forecast(
    df=df,
    X_df=future_ex_vars_df,
    h=24,
    level=[80, 90],
    date_features=[CountryHolidays(["US"])],
)
timegpt.weights_x.plot.barh(x="features", y="weights")
```

```
INFO:nixtlats.timegpt:Validating inputs...
INFO:nixtlats.timegpt:Preprocessing dataframes...
INFO:nixtlats.timegpt:Inferred freq: h
WARNING:nixtlats.timegpt:The specified horizon "h" exceeds the model horizon. This m
ay lead to less accurate forecasts. Please consider using a smaller horizon.
INFO:nixtlats.timegpt:Using the following exogenous variables: Exogenous1, Exogenous
2, day_0, day_1, day_2, day_3, day_4, day_5, day_6, US_New Year's Day, US_Memorial D
ay, US_Independence Day, US_Labor Day, US_Veterans Day, US_Thanksgiving, US_Christma
s Day, US_Christmas Day (observed), US_Martin Luther King Jr. Day, US_Washington's B
irthday, US_Columbus Day, US_New Year's Day (observed), US_Veterans Day (observed)
INFO:nixtlats.timegpt:Calling Forecast Endpoint...
```

Out[ ]:
```
<Axes: ylabel='features'>
```



> BEFORE: *5 API Calls | 290880 Tokens | 489.46 Spent*
> AFTER: *6 API Calls | 376920 Tokens | 593.91 Spent*
> **USAGE: 1 API Call | 86040 Tokens | 104.45 Spent**