poisson_HMM_research

March 27, 2025

1 $PHMM$ on (monthly, yearly) data agg

1.1 EDA

EDA of the time series to find the earthquakes

[1]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.stats import poisson
from hmmlearn import hmm
```

[2]:
```
df = pd.read_csv("All Earthquakes.csv")
df.head(5)
```

[2]:
```
          No.          Orgin date  Longitude(E)  Latitude(N)  Magnitude  Depth  \
0  Small area   2025-02-12 0:09       121.942      24.3840        3.8   24.3
1          64  2025-02-11 22:04       121.665      24.1742        4.0   13.3
2  Small area  2025-02-11 20:46       120.459      23.5483        3.2    5.6
3          63  2025-02-11 15:52       120.496      23.2458        4.1    7.7
4  Small area  2025-02-11 15:45       120.505      23.2862        3.6    7.5

          Location                                         Unnamed: 7  \
0  24.38N 121.94E    i.e. 42.5 km SSE of Yilan County(24.38N 121.94E
1  24.17N 121.66E   i.e. 20.8 km NNE of Hualien County(24.17N 121…
2  23.55N 120.46E   i.e. 19.6 km ENE of Chiayi County(23.55N 120.46E
3  23.25N 120.50E      i.e. 42.5 km NE of Tainan City(23.25N 120.50E
4  23.29N 120.50E      i.e. 46.2 km NE of Tainan City(23.29N 120.50E

                              Unnamed: 8 Unnamed: 9 Unnamed: 10
0     i.e. 42.5 km SSE of Yilan County)        NaN         NaN
1   i.e. 20.8 km NNE of Hualien County)        NaN         NaN
2    i.e. 19.6 km ENE of Chiayi County)        NaN         NaN
3       i.e. 42.5 km NE of Tainan City)        NaN         NaN
4       i.e. 46.2 km NE of Tainan City)        NaN         NaN
```

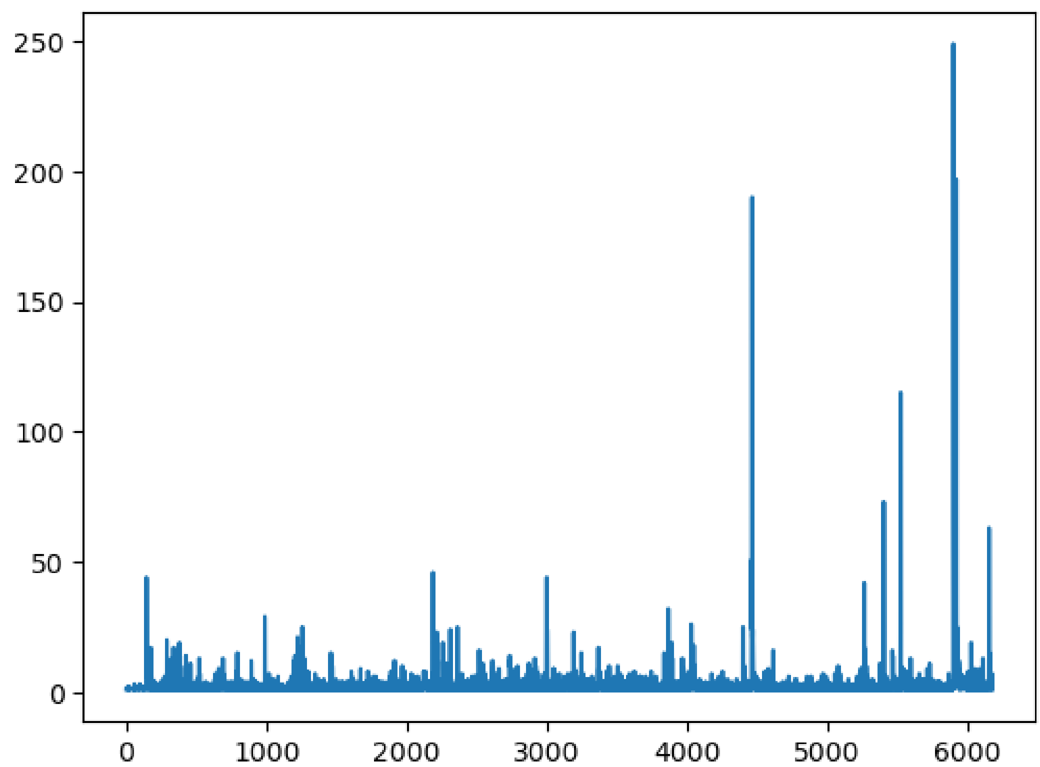
2 $PHMM$ on (daily, monthly, yearly) data agg

2.1 EDA

EDA of the time series to find the earthquakes

[16]:
```
years = pd.to_datetime(df['Orgin date']).dt.year
months = pd.to_datetime(df['Orgin date']).dt.month
days = pd.to_datetime(df['Orgin date']).dt.day

dates = pd.DataFrame({'years': years, 'months': months, 'days': days})

counts = dates.groupby(['years', 'months', 'days']).size()
plt.plot(np.array(counts))
```

[16]:
```
[<matplotlib.lines.Line2D at 0x19999f62a50>]
```



[35]:
```
scores = list()
models = list()

earthquakes = np.array(counts).reshape(-1,1)

for n_components in range(1, 5):
```

```
    for idx in range(5):  # ten different random starting states
        # define our hidden Markov model
        model = hmm.PoissonHMM(n_components=n_components, random_state=idx,
                               n_iter=10)
        model.fit(earthquakes)
        models.append(model)
        scores.append(model.score(earthquakes))
        # print(f'Converged: {model.monitor_.converged}\t\t'
        #       f'Score: {scores[-1]}')

# get the best model
model1 = models[np.argmax(scores)]
print(f'The best model had a score of {max(scores)} and '
      f'{model.n_components} components')

# use the Viterbi algorithm to predict the most likely sequence of states
# given the model
states = model1.predict(earthquakes)
```

```
The best model had a score of -11078.408118260739 and 4 components
```

[34]:

```
scores = list()
models = list()

earthquakes = np.array(counts).reshape(-1,1)

for n_components in range(1, 10):
    for idx in range(10):  # ten different random starting states
        # define our hidden Markov model
        model = hmm.PoissonHMM(n_components=n_components, random_state=idx,
                               n_iter=10)
        model.fit(earthquakes)
        models.append(model)
        scores.append(model.score(earthquakes))
        # print(f'Converged: {model.monitor_.converged}\t\t'
        #       f'Score: {scores[-1]}')

# get the best model
model2 = models[np.argmax(scores)]
print(f'The best model had a score of {max(scores)} and '
      f'{model.n_components} components')

# use the Viterbi algorithm to predict the most likely sequence of states
# given the model
states = model2.predict(earthquakes)
```

```
The best model had a score of -10766.56809738259 and 9 components
```

[38]:

```python
scores = list()
models = list()

earthquakes = np.array(counts).reshape(-1,1)

for n_components in range(1, 20):
    for idx in range(10):  # ten different random starting states
        # define our hidden Markov model
        model = hmm.PoissonHMM(n_components=n_components, random_state=idx,
                               n_iter=10)
        model.fit(earthquakes)
        models.append(model)
        scores.append(model.score(earthquakes))
        # print(f'Converged: {model.monitor_.converged}\t\t'
        #       f'Score: {scores[-1]}')

# get the best model
model3 = models[np.argmax(scores)]
print(f'The best model had a score of {max(scores)} and '
      f'{model.n_components} components')

# use the Viterbi algorithm to predict the most likely sequence of states
# given the model
states = model3.predict(earthquakes)
```

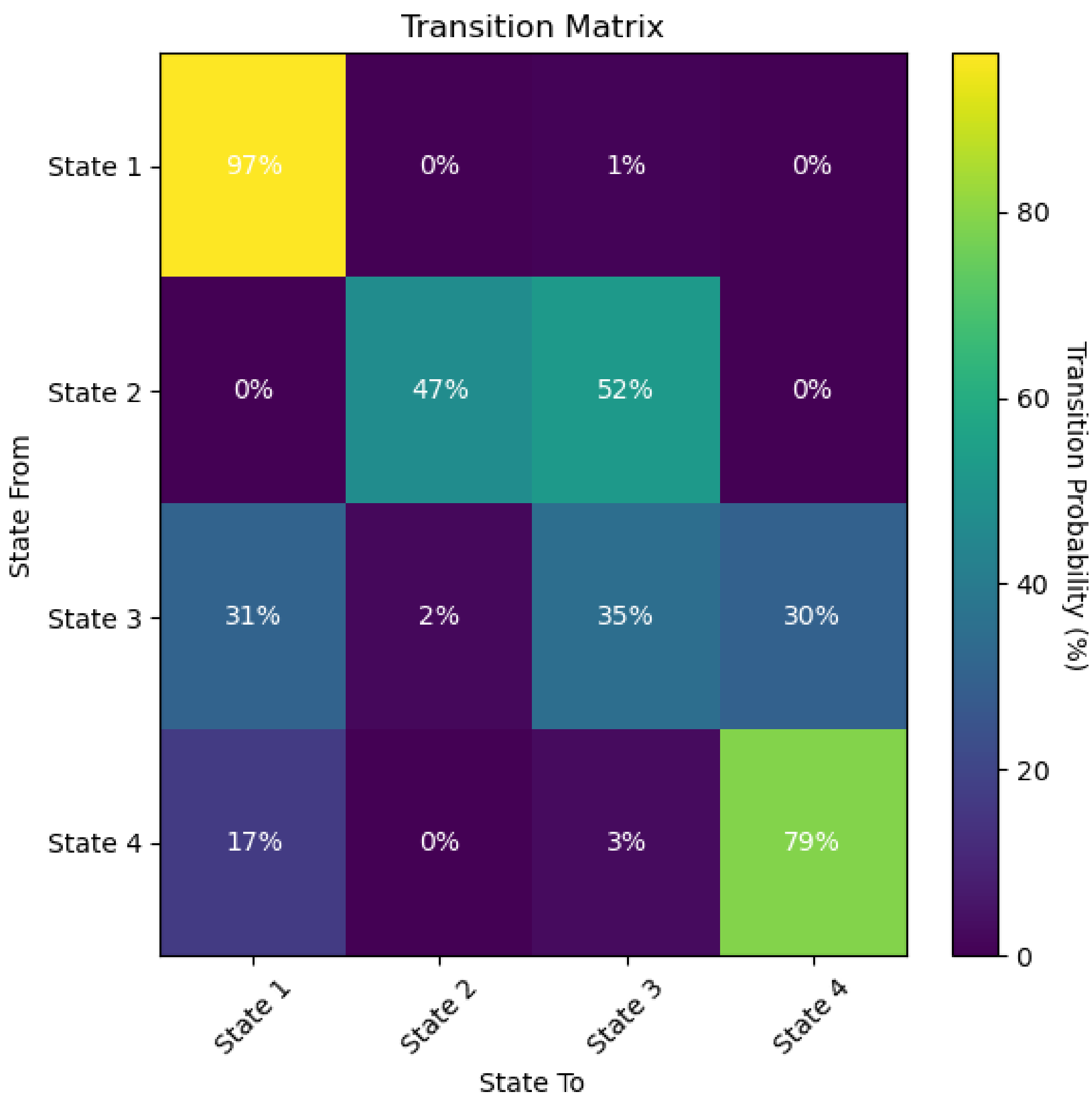
```
The best model had a score of -10672.304913912656 and 19 components
```

[39]:

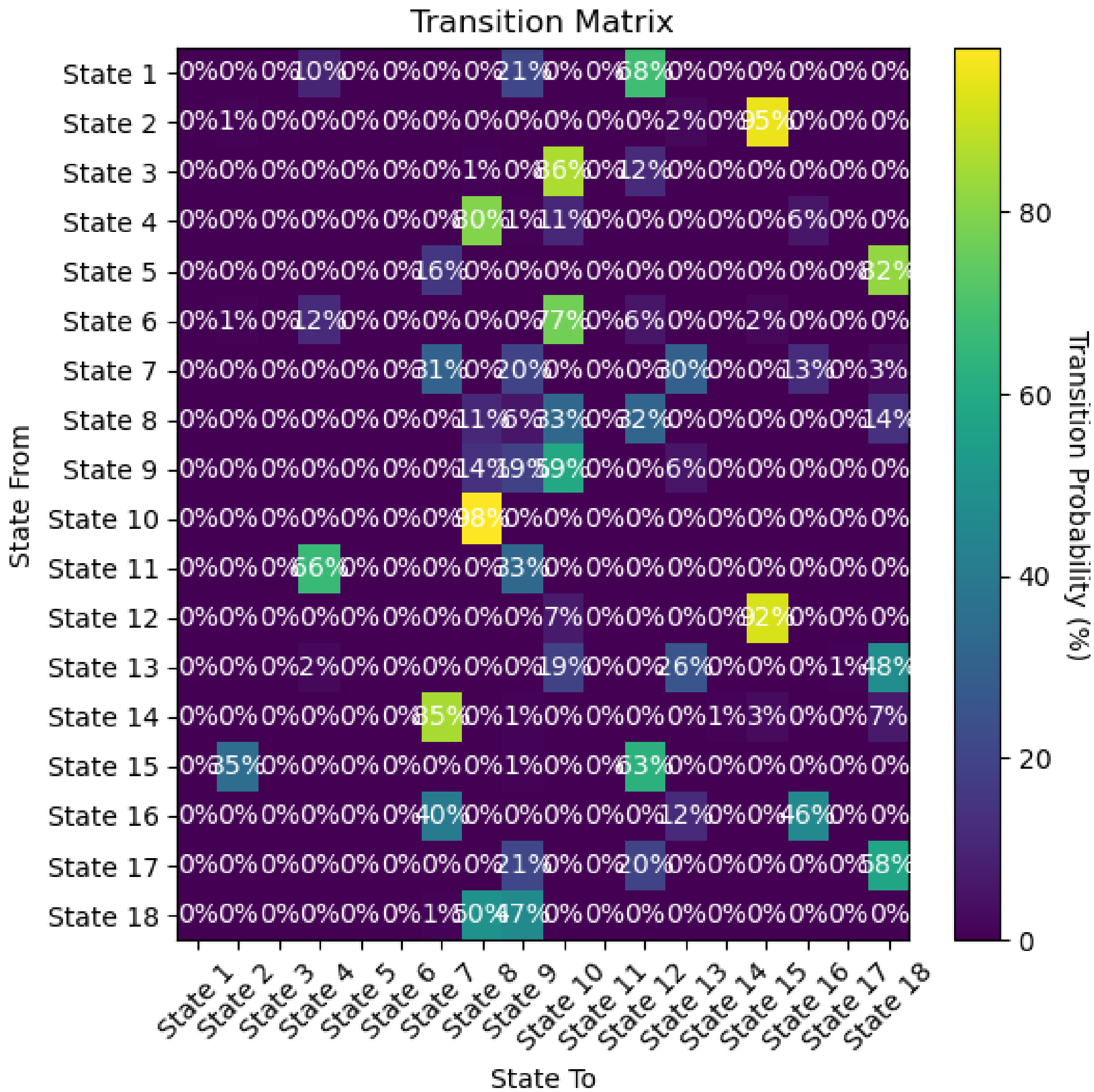
```python
# use the Viterbi algorithm to predict the most likely sequence of states
# given the model
# states = model1.predict(earthquakes)
# fig, ax = plt.subplots()
# ax.plot(model.lambdas_[states], ".-", ms=6, mfc="orange")
# ax.plot(earthquakes)
# ax.set_title('States compared to generated')
# ax.set_xlabel('State')


transmat_int1 = (model1.transmat_ * 100).astype(int)
transmat_int2 = (model2.transmat_ * 100).astype(int)
transmat_int3 = (model3.transmat_ * 100).astype(int)

# Create the heatmap
fig, ax = plt.subplots(figsize=(6, 6))
im = ax.imshow(transmat_int1, aspect='auto', cmap='viridis')
cbar = ax.figure.colorbar(im, ax=ax)
cbar.ax.set_ylabel('Transition Probability (%)', rotation=-90, va="bottom")
for i in range(transmat_int1.shape[0]):
    for j in range(transmat_int1.shape[1]):
```

```
        ax.text(j, i, f'{transmat_int1[i, j]}%', ha='center', va='center',␣
 ↪color='white')
ax.set_title('Transition Matrix')
ax.set_xlabel('State To')
ax.set_ylabel('State From')
ax.set_xticks(np.arange(transmat_int1.shape[1]))
ax.set_yticks(np.arange(transmat_int1.shape[0]))
ax.set_xticklabels([f'State {i+1}' for i in range(transmat_int1.shape[1])])
ax.set_yticklabels([f'State {i+1}' for i in range(transmat_int1.shape[0])])
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
plt.savefig("trans_mat_daily_prob_5.png")


fig, ax = plt.subplots(figsize=(6, 6))
im = ax.imshow(transmat_int2, aspect='auto', cmap='viridis')
cbar = ax.figure.colorbar(im, ax=ax)
cbar.ax.set_ylabel('Transition Probability (%)', rotation=-90, va="bottom")
for i in range(transmat_int2.shape[0]):
    for j in range(transmat_int2.shape[1]):
        ax.text(j, i, f'{transmat_int2[i, j]}%', ha='center', va='center',␣
 ↪color='white')
ax.set_title('Transition Matrix')
ax.set_xlabel('State To')
ax.set_ylabel('State From')
ax.set_xticks(np.arange(transmat_int2.shape[1]))
ax.set_yticks(np.arange(transmat_int2.shape[0]))
ax.set_xticklabels([f'State {i+1}' for i in range(transmat_int2.shape[1])])
ax.set_yticklabels([f'State {i+1}' for i in range(transmat_int2.shape[0])])
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
plt.savefig("trans_mat_daily_prob_10.png")


fig, ax = plt.subplots(figsize=(6, 6))
im = ax.imshow(transmat_int3, aspect='auto', cmap='viridis')
cbar = ax.figure.colorbar(im, ax=ax)
cbar.ax.set_ylabel('Transition Probability (%)', rotation=-90, va="bottom")
for i in range(transmat_int3.shape[0]):
    for j in range(transmat_int3.shape[1]):
        ax.text(j, i, f'{transmat_int3[i, j]}%', ha='center', va='center',␣
 ↪color='white')
ax.set_title('Transition Matrix')
ax.set_xlabel('State To')
ax.set_ylabel('State From')
```

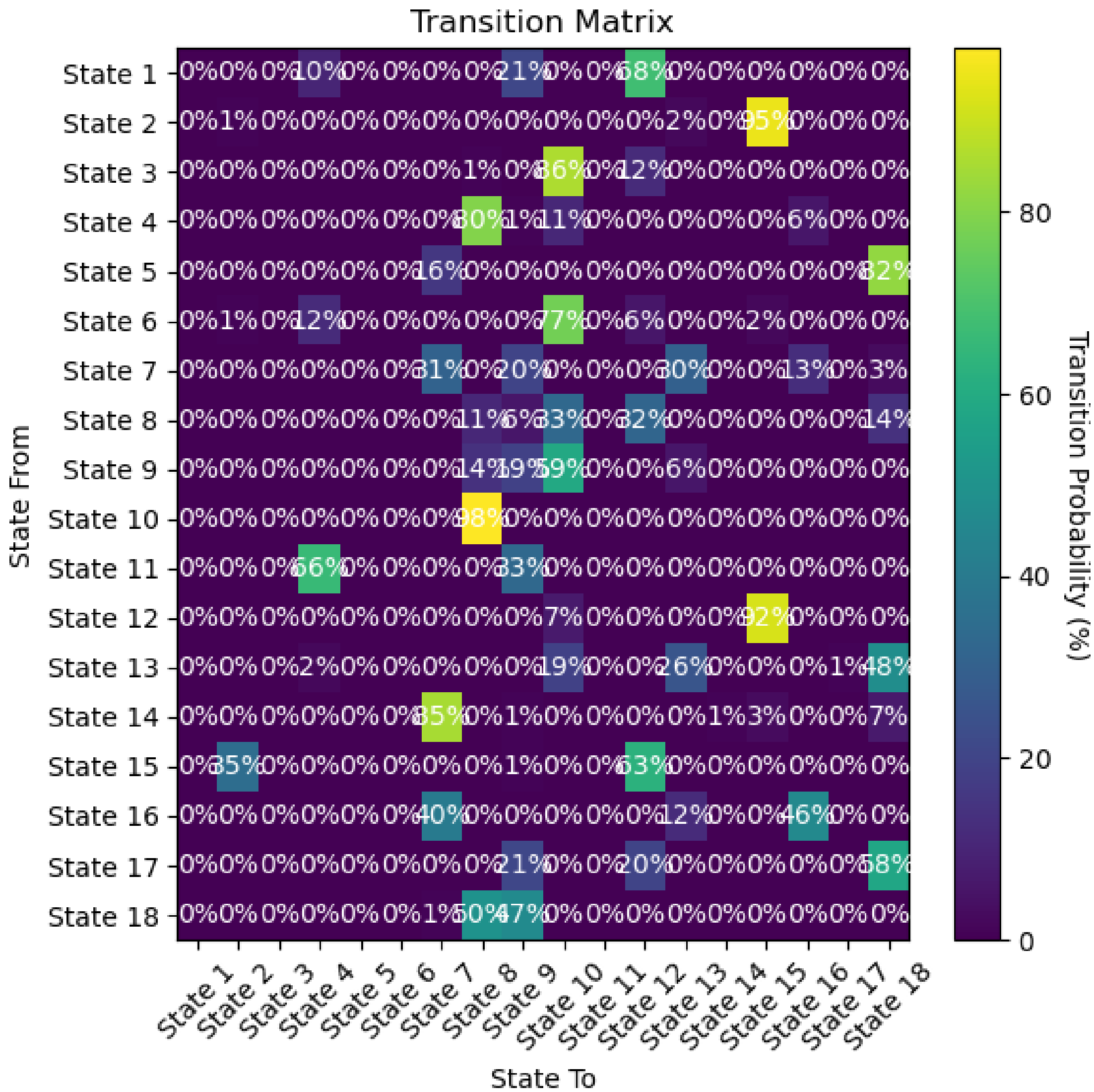
```
ax.set_xticks(np.arange(transmat_int3.shape[1]))
ax.set_yticks(np.arange(transmat_int3.shape[0]))
ax.set_xticklabels([f'State {i+1}' for i in range(transmat_int3.shape[1])])
ax.set_yticklabels([f'State {i+1}' for i in range(transmat_int3.shape[0])])
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
plt.savefig("trans_mat_daily_prob_20.png")

# prop_per_state = model.predict_proba(earthquakes).mean(axis=0)

# # earthquake counts to plot
# bins = sorted(np.unique(earthquakes))

# fig, ax = plt.subplots()
# ax.hist(earthquakes, bins=bins, density=True)
# ax.plot(bins, poisson.pmf(bins, model.lambdas_).T @ prop_per_state)
# ax.set_title('Histogram of Earthquakes with Fitted Poisson States')
# ax.set_xlabel('Number of Earthquakes')
# ax.set_ylabel('Proportion')

plt.show()
```




```
<Figure size 640x480 with 0 Axes>
```



<Figure size 640x480 with 0 Axes>




```
<Figure size 640x480 with 0 Axes>
```

[ ]: