coursework2

November 18, 2024

[19]:
```
"""
In order to run the code as is, you will need scipy, pandas and tqdm installed
(although tqdm is only needed for the progress bar, and pandas is only for the␣
 ↪autocorrelation function)
All of these can be installed (on linux) from the command interface using 'pip'
"""

import scipy.io as sio
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from gibbsrank import gibbs_sample
from eprank import eprank
import pandas
from cw2 import sorted_barplot


# Set a custom theme with the magma color palette
sns.set_theme(
    context="notebook",    # Options: paper, notebook, talk, poster
    style="darkgrid",      # Options: white, dark, whitegrid, darkgrid, ticks
    palette="magma",       # Set to the magma palette
    font="sans-serif",     # Set your desired font
    rc={"axes.spines.right": False, "axes.spines.top": False}  # Remove top/
 ↪right spines
)
```

[39]:
```
W
```

[39]:
```
array([['Rafael-Nadal'],
       ['Juan-Monaco'],
       ['Juan-Martin-Del-Potro'],
       ['Mardy-Fish'],
       ['Roger-Federer'],
       ['Jo-Wilfried-Tsonga'],
       ['Guillermo-Garcia-Lopez'],
       ['Florian-Mayer'],
```

```
['Milos-Raonic'],
['Santiago-Giraldo'],
['Andy-Murray'],
['Richard-Gasquet'],
['David-Nalbandian'],
['Gilles-Muller'],
['Andy-Roddick'],
['Novak-Djokovic'],
['Fernando-Verdasco'],
['Ivan-Dodig'],
['Ryan-Sweeting'],
['Radek-Stepanek'],
['John-Isner'],
['Pablo-Andujar'],
['Ivan-Ljubicic'],
['Robin-Soderling'],
['Feliciano-Lopez'],
['Marin-Cilic'],
['Marcos-Baghdatis'],
['Michael-Llodra'],
['Gael-Monfils'],
['David-Ferrer'],
['Jarkko-Nieminen'],
['Kei-Nishikori'],
['Alexandr-Dolgopolov'],
['Tomas-Berdych'],
['Somdev-K-Devvarman'],
['Ivo-Karlovic'],
['Olivier-Rochus'],
['Bernard-Tomic'],
['Karol-Beck'],
['Ernests-Gulbis'],
['Nikolay-Davydenko'],
['Gilles-Simon'],
['Nicolas-Almagro'],
['Fabio-Fognini'],
['Juan-Carlos-Ferrero'],
['Marcel-Granollers'],
['Stanislas-Wawrinka'],
['Janko-Tipsarevic'],
['Andreas-Seppi'],
['Simone-Bolelli'],
['Carlos-Berlocq'],
['Mikhail-Kukushkin'],
['Mikhail-Youzhny'],
['Grigor-Dimitrov'],
['Sergiy-Stakhovsky'],
```

```
['Victor-Hanescu'],
['Horacio-Zeballos'],
['Pablo-Cuevas'],
['Eduardo-Schwank'],
['Robin-Haase'],
['Adrian-Mannarino'],
['Dmitry-Tursunov'],
['Kevin-Anderson'],
['Sam-Querrey'],
['Philipp-Petzschner'],
['James-Blake'],
['Denis-Istomin'],
['Igor-Kunitsyn'],
['Philipp-Kohlschreiber'],
['Tommy-Robredo'],
['Lleyton-Hewitt'],
['Ryan-Harrison'],
['Albert-Ramos'],
['Potito-Starace'],
['Rui-Machado'],
['Xavier-Malisse'],
['Jurgen-Melzer'],
['Igor-Andreev'],
['Juan-Ignacio-Chela'],
['Viktor-Troicki'],
['Yen-Hsun-Lu'],
['Alex-Bogomolov-Jr'],
['Fernando-Gonzalez'],
['Michael-Berrer'],
['Pere-Riba'],
['Ruben-Ramirez-Hidalgo'],
['Lukasz-Kubot'],
['Robert-Kendrick'],
['Dustin-Brown'],
['Thomaz-Bellucci'],
['Albert-Montanes'],
['Andreas-Haider-Maurer'],
['Jeremy-Chardy'],
['Arnaud-Clement'],
['Lukas-Rosol'],
['Rajeev-Ram'],
['Alexander-Peya'],
['Juan-Sebastian-Cabal'],
['Colin-Fleming'],
['Santiago-Gonzalez'],
['Marc-Lopez'],
['Rohan-Bopanna'],
```

```
['Michael-Kohlmann'],
['Simon-Aspelin'],
['Mikhail-Elgin'],
['Robert-Lindstedt'],
['Jean-Julien-Rojer']], dtype=object)
```

We first need to load the data, stored in "tennis_data.mat". The data consists of an array, W containing the names of each player, and an array, G, containing the results of all of the matches in the season.

[199]:
```
# set seed for reproducibility
np.random.seed(0)
# load data
data = sio.loadmat('tennis_data.mat')
# Array containing the names of each player
W = data['W']
# loop over array to format more nicely
for i, player in enumerate(W):
    W[i] = player[0]
# Array of size num_games x 2. The first entry in each row is the winner of␣
 ↪game i, the second is the loser
G = data['G'] - 1
# Number of players
M = W.shape[0]
# Number of Games
N = G.shape[0]
```

1 Gibbs sampling (This may take a minute)

[200]:
```
# number of iterations
num_iters = 1_100
# perform gibbs sampling, skill samples is an num_players x num_samples array
skill_samples = gibbs_sample(G, M, num_iters)#, random_nums)
```

```
100%|                                                |
1100/1100 [00:15<00:00, 70.49it/s]
```

[23]:
```
skill_samples[:2,:5]
```

[23]:
```
array([[ 0.74497722,  0.86013712,  0.87339386,  1.14594926,  1.43669619],
       [ 0.08228189,  0.09047983, -0.09037934, -0.31796221,  0.27614328]])
```

[181]:
```
# Code for plotting the autocorrelation function for player p
threshold = 0.02
iats = np.zeros(M)
```

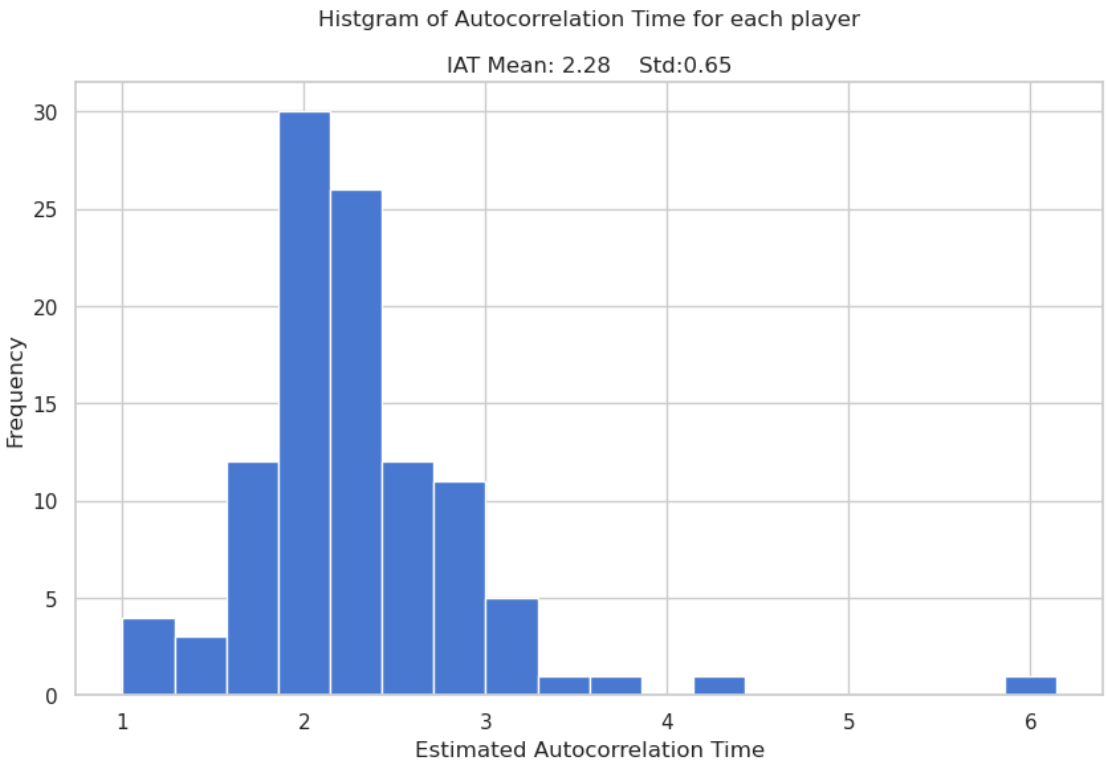
```
for p in range(M):
    autocor = np.zeros(20)
    for i in range(20):
        autocor[i]=pandas.Series.autocorr(pandas.Series(skill_samples[p,:
 ↪]),lag=i)

    effective_lags = np.where(autocor[1:] < threshold)[0][0]  # First lag where␣
 ↪ACF < threshold
    iat = 1 + 2 * np.sum(autocor[1: effective_lags])
    iats[p] = iat
    #plt.plot(autocor)
    #plt.grid()
    #plt.title(f"ACF for {W[p][0]}   IAT=")
    #plt.show()
    print(f"Integrated Auto-correlation Time: {iat}")
```

```
Integrated Auto-correlation Time: 2.7386211990591662
Integrated Auto-correlation Time: 2.3098082050118314
Integrated Auto-correlation Time: 2.587593653476782
Integrated Auto-correlation Time: 1.712218708365642
Integrated Auto-correlation Time: 4.182621928635882
Integrated Auto-correlation Time: 2.8242667465687186
Integrated Auto-correlation Time: 3.2022321785740804
Integrated Auto-correlation Time: 2.826479302181099
Integrated Auto-correlation Time: 2.099066733545937
Integrated Auto-correlation Time: 2.5211822969945805
Integrated Auto-correlation Time: 3.7611006154041133
Integrated Auto-correlation Time: 2.4865761258528254
Integrated Auto-correlation Time: 2.0113403007692217
Integrated Auto-correlation Time: 2.174280451513435
Integrated Auto-correlation Time: 2.1183017704647957
Integrated Auto-correlation Time: 6.143431449067261
Integrated Auto-correlation Time: 1.7514706693082804
Integrated Auto-correlation Time: 2.2546117045808165
Integrated Auto-correlation Time: 1.9459051653061148
Integrated Auto-correlation Time: 2.147552836543392
Integrated Auto-correlation Time: 1.9761320271482505
Integrated Auto-correlation Time: 2.411224464565814
Integrated Auto-correlation Time: 2.013584348105113
Integrated Auto-correlation Time: 2.8222901331149
Integrated Auto-correlation Time: 2.4197724679845187
Integrated Auto-correlation Time: 3.4569863467739066
Integrated Auto-correlation Time: 2.3552120338453943
Integrated Auto-correlation Time: 2.12493559925518
Integrated Auto-correlation Time: 2.043600129640633
Integrated Auto-correlation Time: 3.058355646063801
Integrated Auto-correlation Time: 2.222606505492819
```

```
Integrated Auto-correlation Time: 2.4473719969065586
Integrated Auto-correlation Time: 1.9896844822528554
Integrated Auto-correlation Time: 2.385067862895564
Integrated Auto-correlation Time: 1.7524220881270718
Integrated Auto-correlation Time: 1.9989586821876537
Integrated Auto-correlation Time: 2.1468323408656618
Integrated Auto-correlation Time: 2.64452545998331
Integrated Auto-correlation Time: 2.078669041912413
Integrated Auto-correlation Time: 1.7250464285344034
Integrated Auto-correlation Time: 2.0089688479371786
Integrated Auto-correlation Time: 2.3366541088586055
Integrated Auto-correlation Time: 2.4244566611124467
Integrated Auto-correlation Time: 1.989686669524317
Integrated Auto-correlation Time: 2.817997195954212
Integrated Auto-correlation Time: 2.9520112180918785
Integrated Auto-correlation Time: 2.8230769971303804
Integrated Auto-correlation Time: 2.5151125538583963
Integrated Auto-correlation Time: 1.6800678163799023
Integrated Auto-correlation Time: 1.7442444460903679
Integrated Auto-correlation Time: 2.6465155394176385
Integrated Auto-correlation Time: 2.642186870924612
Integrated Auto-correlation Time: 2.0446553026374774
Integrated Auto-correlation Time: 2.9204447705202337
Integrated Auto-correlation Time: 2.122142357795559
Integrated Auto-correlation Time: 2.363482306752073
Integrated Auto-correlation Time: 2.1799047385476116
Integrated Auto-correlation Time: 2.4168847938400604
Integrated Auto-correlation Time: 2.4373493791004877
Integrated Auto-correlation Time: 2.286286381281042
Integrated Auto-correlation Time: 2.299481116585911
Integrated Auto-correlation Time: 1.905861151280118
Integrated Auto-correlation Time: 1.9971765002756348
Integrated Auto-correlation Time: 1.908856544201394
Integrated Auto-correlation Time: 1.652451626034784
Integrated Auto-correlation Time: 2.2151240725794374
Integrated Auto-correlation Time: 2.587542559587485
Integrated Auto-correlation Time: 2.789607849421565
Integrated Auto-correlation Time: 2.0446130570116514
Integrated Auto-correlation Time: 2.025436401361464
Integrated Auto-correlation Time: 2.5071735217471245
Integrated Auto-correlation Time: 1.8754468990625102
Integrated Auto-correlation Time: 2.366080227960119
Integrated Auto-correlation Time: 2.2538298042417857
Integrated Auto-correlation Time: 3.1086255594214363
Integrated Auto-correlation Time: 3.149315587040732
Integrated Auto-correlation Time: 1.6621563760160756
Integrated Auto-correlation Time: 1.9698669922331826
Integrated Auto-correlation Time: 2.0636066217616014
```

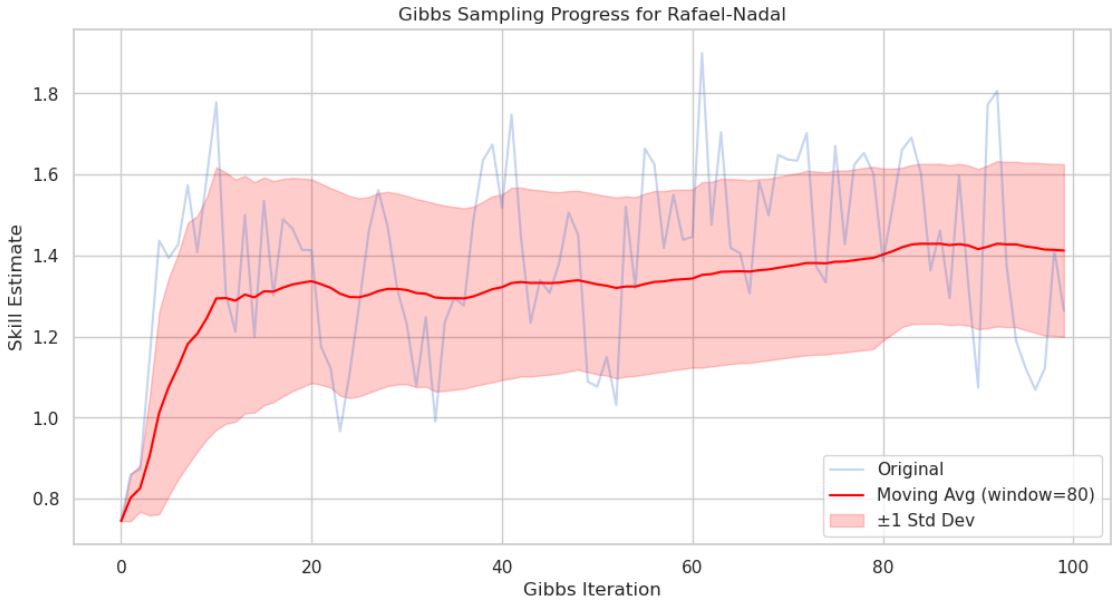
```
Integrated Auto-correlation Time: 2.75007826878252
Integrated Auto-correlation Time: 2.1448343691130196
Integrated Auto-correlation Time: 2.159470322175853
Integrated Auto-correlation Time: 2.749532812231335
Integrated Auto-correlation Time: 2.4069836617141354
Integrated Auto-correlation Time: 3.2377711736906702
Integrated Auto-correlation Time: 2.065981034618625
Integrated Auto-correlation Time: 2.099137669644132
Integrated Auto-correlation Time: 2.190269024562277
Integrated Auto-correlation Time: 1.8846670432790387
Integrated Auto-correlation Time: 1.744830865955448
Integrated Auto-correlation Time: 1.8631281908183526
Integrated Auto-correlation Time: 1.6754680731521039
Integrated Auto-correlation Time: 1.9181644246998126
Integrated Auto-correlation Time: 1.6899727243775344
Integrated Auto-correlation Time: 2.100799289129351
Integrated Auto-correlation Time: 2.231483462494693
Integrated Auto-correlation Time: 1.5875834818605705
Integrated Auto-correlation Time: 1.908212287640458
Integrated Auto-correlation Time: 1.4964015117575993
Integrated Auto-correlation Time: 1.5499690976461007
Integrated Auto-correlation Time: 1.0
Integrated Auto-correlation Time: 2.4210428123428596
Integrated Auto-correlation Time: 1.0
Integrated Auto-correlation Time: 1.0
Integrated Auto-correlation Time: 2.684327328202632
Integrated Auto-correlation Time: 1.5610210849906656
Integrated Auto-correlation Time: 1.0437171192484958
```

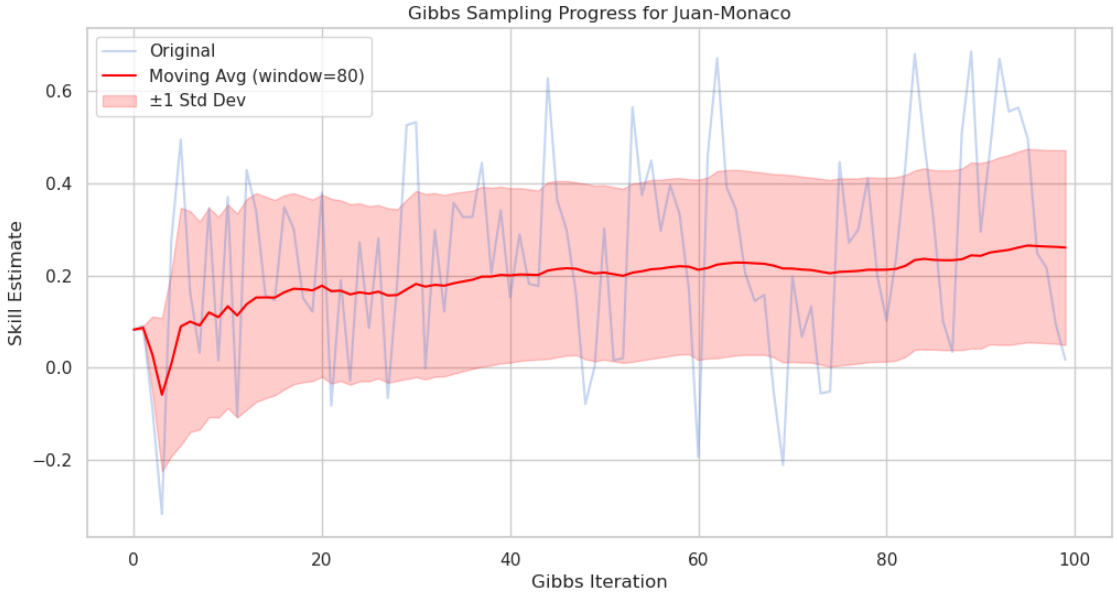
[187]:
```
plt.figure(figsize=(10,6))
plt.hist(iats, bins=18)
mn = round(iats.mean(),2)
std = round(iats.std(), 2)
plt.title(f"Histgram of Autocorrelation Time for each player\n\n"+f"IAT Mean:␣
 ↪{mn}    Std:{std}")
plt.xlabel("Estimated Autocorrelation Time")
plt.ylabel("Frequency")
plt.savefig("hist_autocorr_time.png")
```

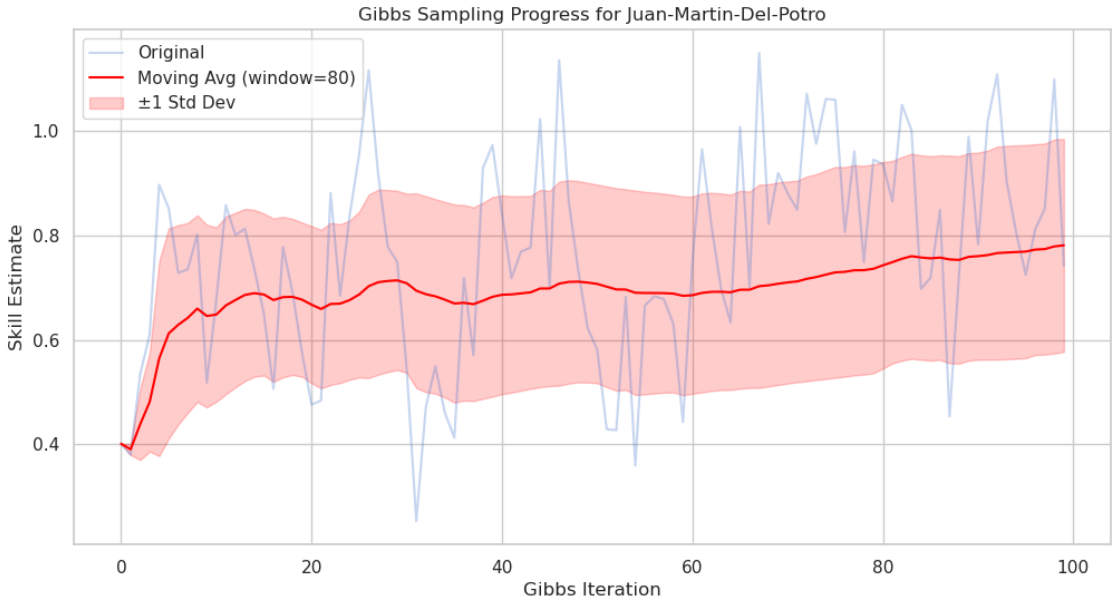


[202]:
```
import pandas as pd
import numpy as np

# Define the moving average function with error handling for n < 200
def dynamic_moving_average(data, window_size):
    means = []
    stds = []
    for i in range(len(data)):
        n = min(i + 1, window_size)  # Use up to the window size or available␣
 ↪samples
        mean = np.mean(data[max(0, i - n + 1):i + 1])
        std = np.std(data[max(0, i - n + 1):i + 1])
        means.append(mean)
        stds.append(std)
    return np.array(means), np.array(stds)

# Set moving average window size
window_size = 80

# Plot the Gibbs sampling progress with moving average and error bars
for player_id in range(3):  # First three players
    plt.figure(figsize=(12, 6))
```

```
    # Compute moving average and standard deviation
    ma_skill_samples, ma_std = dynamic_moving_average(skill_samples[player_id, :
↪], window_size)

    # Plot original skill samples
    sns.lineplot(
        x=iterations[:100],
        y=skill_samples[player_id, :100],
        label="Original",
        alpha=0.3,  # Make the original plot more transparent
    )

    # Plot moving average
    sns.lineplot(
        x=iterations[:100],
        y=ma_skill_samples[:100],
        label=f"Moving Avg (window={window_size})",
        color="red"
    )

    # Add error bars
    plt.fill_between(
        iterations[:100],
        (ma_skill_samples - ma_std)[:100],
        (ma_skill_samples + ma_std)[:100],
        color="red",
        alpha=0.2,
        label="±1 Std Dev"
    )

    # Add labels and title
    plt.xlabel("Gibbs Iteration")
    plt.ylabel("Skill Estimate")
    plt.title(f"Gibbs Sampling Progress for {W[player_id][0]}")
    plt.legend()
    plt.savefig(f"task_a_gibbs_{W[player_id][0]}")
```


Gibbs Sampling Progress for Rafael-Nadal
Skill Estimate
Gibbs Iteration
Original
Moving Avg (window=80)
±1 Std Dev
1.8
1.6
1.4
1.2
1.0
0.8
0
20
40
60
80
100

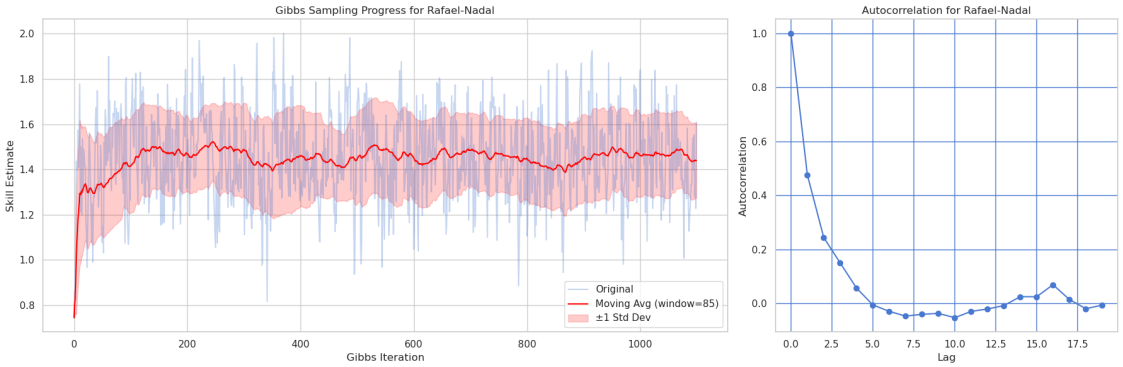

Gibbs Sampling Progress for Juan-Monaco
Skill Estimate
Gibbs Iteration
Original
Moving Avg (window=80)
±1 Std Dev
0.6
0.4
0.2
0.0
−0.2
0
20
40
60
80
100

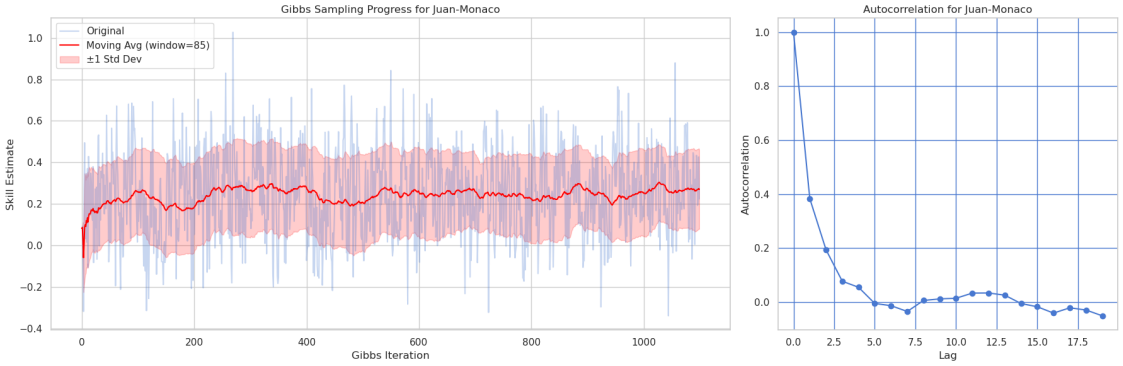


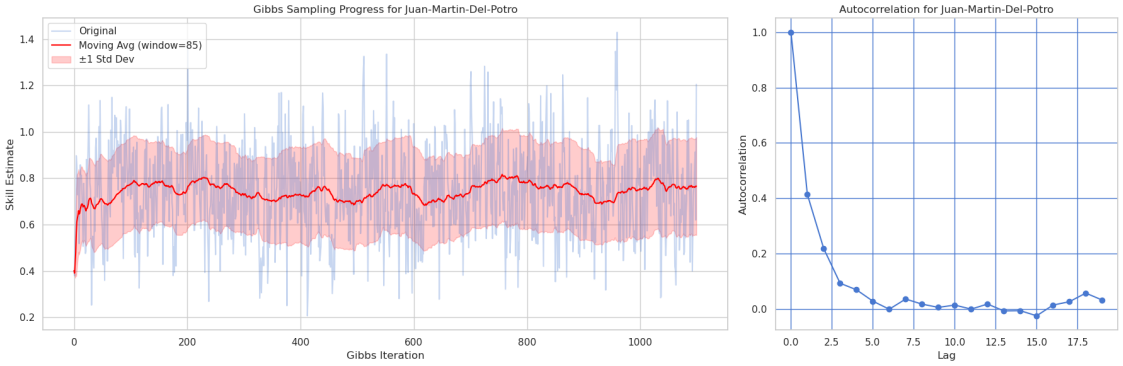
[201]:
```
import matplotlib.gridspec as gridspec

# Define the moving average function with dynamic computation for n < 200
def dynamic_moving_average(data, window_size):
    means = []
    stds = []
    for i in range(len(data)):
        n = min(i + 1, window_size)  # Use up to the window size or available␣
 ↪samples
        mean = np.mean(data[max(0, i - n + 1):i + 1])
        std = np.std(data[max(0, i - n + 1):i + 1])
        means.append(mean)
        stds.append(std)
    return np.array(means), np.array(stds)

# Set moving average window size
window_size = 85

# Plot the Gibbs sampling progress and autocorrelation for the first 3 players
for player_id in range(3):  # First three players
    fig = plt.figure(figsize=(18, 6))
    spec = gridspec.GridSpec(1, 2, width_ratios=[2, 1])  # Two subplots, 2:1␣
 ↪width ratio

    # Trajectory Plot
    ax0 = fig.add_subplot(spec[0])
    iterations = np.arange(skill_samples.shape[1])
```

```
    # Compute moving average and standard deviation
    ma_skill_samples, ma_std = dynamic_moving_average(skill_samples[player_id, :
↪], window_size)

    # Original skill samples
    sns.lineplot(
        ax=ax0,
        x=iterations,
        y=skill_samples[player_id, :],
        label="Original",
        alpha=0.3
    )

    # Moving average
    sns.lineplot(
        ax=ax0,
        x=iterations,
        y=ma_skill_samples,
        label=f"Moving Avg (window={window_size})",
        color="red"
    )

    # Error bars
    ax0.fill_between(
        iterations,
        ma_skill_samples - ma_std,
        ma_skill_samples + ma_std,
        color="red",
        alpha=0.2,
        label="±1 Std Dev"
    )
    ax0.set_xlabel("Gibbs Iteration")
    ax0.set_ylabel("Skill Estimate")
    ax0.set_title(f"Gibbs Sampling Progress for {W[player_id][0]}")
    ax0.legend()

    # Autocorrelation Plot
    ax1 = fig.add_subplot(spec[1])
    autocor = np.zeros(20)
    for lag in range(20):
        autocor[lag] = pd.Series(skill_samples[player_id, :]).autocorr(lag=lag)

    ax1.plot(range(20), autocor, marker="o")
    ax1.set_xlabel("Lag")
    ax1.set_ylabel("Autocorrelation")
    ax1.set_title(f"Autocorrelation for {W[player_id][0]}")
```

```
    ax1.grid( which='major', color='b')
    # Adjust layout and show the plot
    plt.tight_layout()
    plt.savefig(f"sample_ranking_id{player_id}.png")
    plt.show()
```

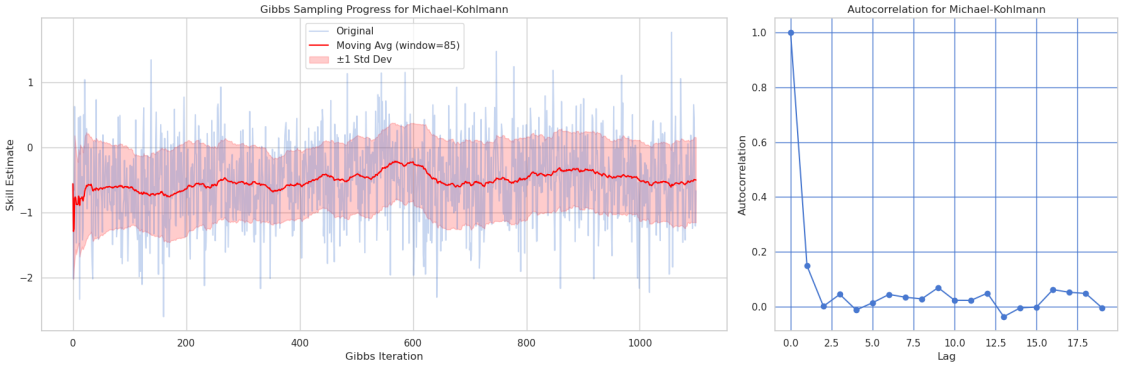


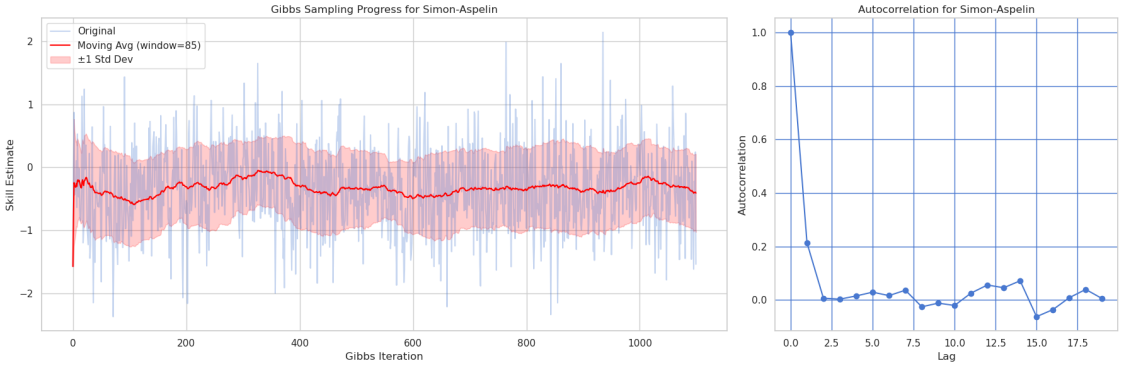


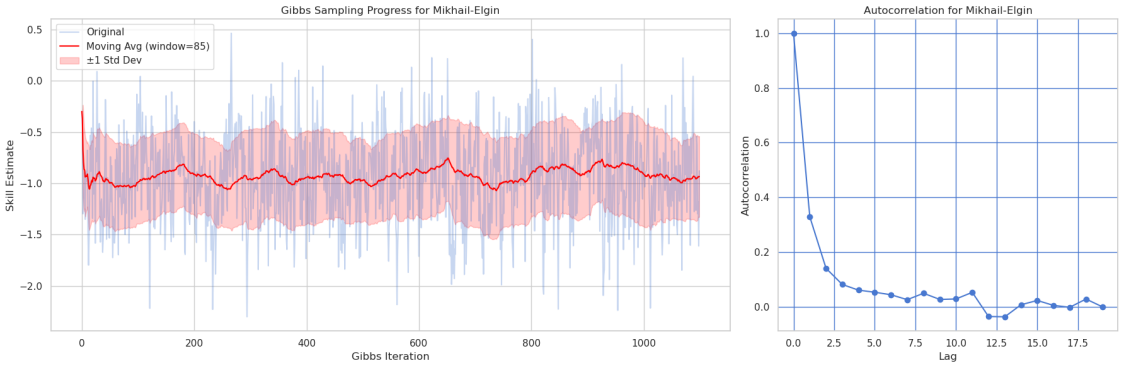


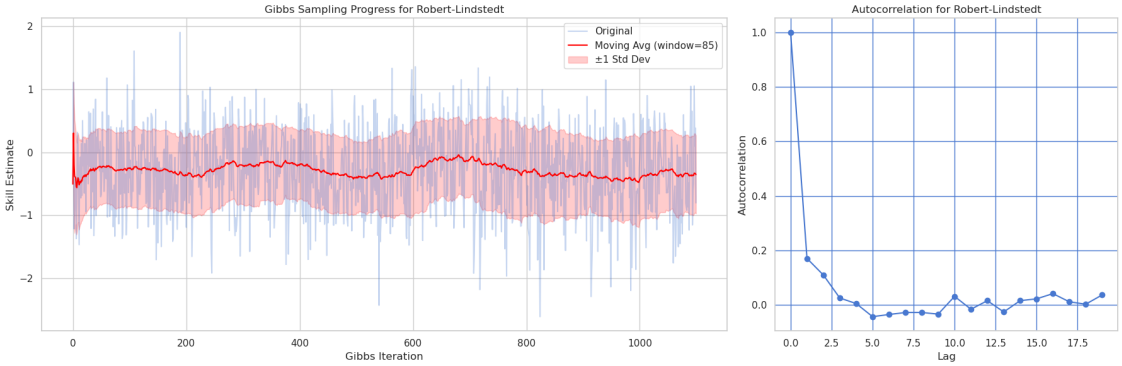
[167]:
```
for player_id in range(M-5, M):
    fig = plt.figure(figsize=(18, 6))
    spec = gridspec.GridSpec(1, 2, width_ratios=[2, 1])  # Two subplots, 2:1␣
 ↪width ratio

    # Trajectory Plot
    ax0 = fig.add_subplot(spec[0])
    iterations = np.arange(skill_samples.shape[1])

    # Compute moving average and standard deviation
    ma_skill_samples, ma_std = dynamic_moving_average(skill_samples[player_id, :
 ↪], window_size)

    # Original skill samples
    sns.lineplot(
        ax=ax0,
        x=iterations,
        y=skill_samples[player_id, :],
        label="Original",
        alpha=0.3
    )

    # Moving average
    sns.lineplot(
        ax=ax0,
        x=iterations,
        y=ma_skill_samples,
        label=f"Moving Avg (window={window_size})",
        color="red"
    )

    # Error bars
    ax0.fill_between(
        iterations,
        ma_skill_samples - ma_std,
        ma_skill_samples + ma_std,
        color="red",
        alpha=0.2,
        label="±1 Std Dev"
    )
    ax0.set_xlabel("Gibbs Iteration")
    ax0.set_ylabel("Skill Estimate")
    ax0.set_title(f"Gibbs Sampling Progress for {W[player_id][0]}")
    ax0.legend()

    # Autocorrelation Plot
    ax1 = fig.add_subplot(spec[1])
```

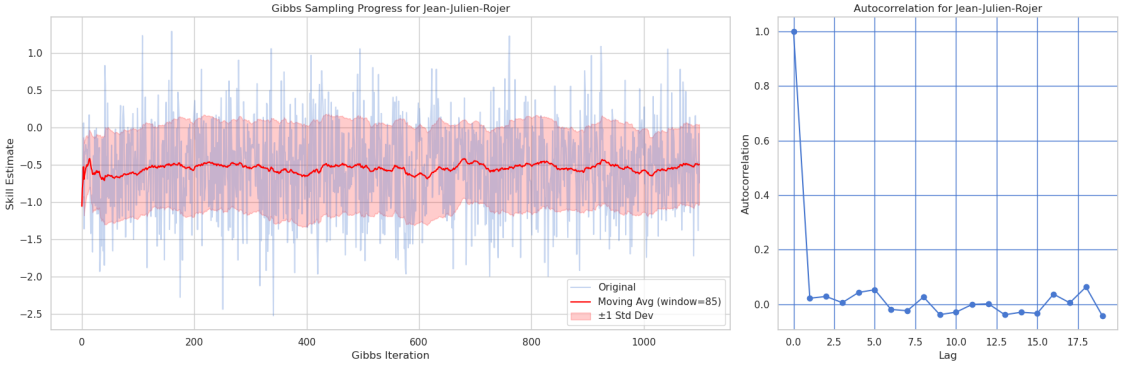
```
    autocor = np.zeros(20)
    for lag in range(20):
        autocor[lag] = pd.Series(skill_samples[player_id, :]).autocorr(lag=lag)

    ax1.plot(range(20), autocor, marker="o")
    ax1.set_xlabel("Lag")
    ax1.set_ylabel("Autocorrelation")
    ax1.set_title(f"Autocorrelation for {W[player_id][0]}")
    ax1.grid(which='major', color='b')
    # Adjust layout and show the plot
    plt.tight_layout()
    plt.savefig(f"sample_ranking_id{player_id}.png")
    plt.show()
```











2 MCMC Burn-in

2.1 Gelman-Rubin Statistic for MCMC Termination

To terminate a MCMC sampler, we need to set the threshold for the burn-in phase. One way to do this is to use the Gelman-Rubin statistic. The Gelman-Rubin statistic compares the variance between chains to the variance within chains. If the chains have converged, the variance between

chains should be similar to the variance within chains. The Gelman-Rubin statistic is defined as: R = sqrt(V / W), where V is the variance between chains and W is the variance within chains.

[ ]:

[58]:
```
def sample_seeds(num_experiments:int):
    np.random.seed(0)
    return np.random.randint(0, 2**32 - 1, size=num_experiments)

def gelman_rubin(x, return_var=False):
    """ Returns estimate of R for a set of traces.

    The Gelman-Rubin diagnostic tests for lack of convergence by comparing
    the variance between multiple chains to the variance within each chain.
    If convergence has been achieved, the between-chain and within-chain
    variances should be identical. To be most effective in detecting evidence
    for nonconvergence, each chain should have been initialized to starting
    values that are dispersed relative to the target distribution.

    Parameters
    ----------
    x : array-like
      An array containing the 2 or more traces of a stochastic parameter. That␣
 ↪is, an array of dimension m x n x k, where m is the number of traces, n the␣
 ↪number of samples, and k the dimension of the stochastic.

    return_var : bool
      Flag for returning the marginal posterior variance instead of R-hat␣
 ↪(defaults of False).

    Returns
    -------
    Rhat : float
      Return the potential scale reduction factor, :math:`\hat{R}`
    -----

    The diagnostic is computed by:

      .. math:: \hat{R} = \sqrt{\frac{\hat{V}}{W}}

    where :math:`W` is the within-chain variance and :math:`\hat{V}` is
    the posterior variance estimate for the pooled traces. This is the
    potential scale reduction factor, which converges to unity when each
    of the traces is a sample from the target posterior. Values greater
    than one indicate that one or more chains have not yet converged.
    References
    ----------
```

```
    Brooks and Gelman (1998)
    Gelman and Rubin (1992)"""

    if np.shape(x) < (2,):
        raise ValueError(
            'Gelman-Rubin diagnostic requires multiple chains of the same␣
↪length.')

    try:
        m, n = np.shape(x)
    except ValueError:
        return [gelman_rubin(np.transpose(y)) for y in np.transpose(x)]

    # Calculate between-chain variance
    B_over_n = np.sum((np.mean(x, 1) - np.mean(x)) ** 2) / (m - 1)

    # Calculate within-chain variances
    W = np.sum(
        [(x[i] - xbar) ** 2 for i,
         xbar in enumerate(np.mean(x,
                                   1))]) / (m * (n - 1))

    # (over) estimate of variance
    s2 = W * (n - 1) / n + B_over_n

    if return_var:
        return s2

    # Pooled posterior variance estimate
    V = s2 + B_over_n / m

    # Calculate PSRF
    R = V / W

    return np.sqrt(R)
```

[52]:
```
#number of seeds
nseeds = 10
seeds = sample_seeds(nseeds)
# number of iterations
num_iters = 1_100
# perform gibbs sampling, skill samples is an num_players x num_samples array
ensemble = np.zeros((nseeds, M, num_iters))
print(out.shape)
from tqdm import tqdm
for i in tqdm(range(nseeds)):
    ensemble[i,:,:] = gibbs_sample(G, M, num_iters)
```

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482/1100 [00:06<00:08, 70.27it/s]
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490/1100 [00:07<00:08, 70.79it/s]
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514/1100 [00:07<00:08, 71.36it/s]
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522/1100 [00:07<00:08, 70.20it/s]
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530/1100 [00:07<00:08, 70.82it/s]
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554/1100 [00:07<00:07, 71.21it/s]
 51%|                                                            |
562/1100 [00:08<00:07, 69.85it/s]
 52%|                                                            |
569/1100 [00:08<00:07, 68.23it/s]
 52%|                                                            |
577/1100 [00:08<00:07, 69.08it/s]
 53%|                                                           |
584/1100 [00:08<00:07, 69.03it/s]
 54%|                                                           |
591/1100 [00:08<00:07, 69.08it/s]
 54%|                                                          |
599/1100 [00:08<00:07, 68.94it/s]
 55%|                                                          |
606/1100 [00:08<00:07, 68.25it/s]
 56%|                                                          |
614/1100 [00:08<00:07, 69.28it/s]
 57%|                                                          |
622/1100 [00:08<00:06, 69.86it/s]
 57%|                                                         |
630/1100 [00:09<00:06, 70.16it/s]
 58%|                                                         |
638/1100 [00:09<00:06, 70.29it/s]
 59%|                                                         |
646/1100 [00:09<00:06, 70.01it/s]
 59%|                                                         |
654/1100 [00:09<00:06, 70.37it/s]
 60%|                                                        |
662/1100 [00:09<00:06, 70.28it/s]
 61%|                                                        |
670/1100 [00:09<00:06, 70.90it/s]
 62%|                                                        |
678/1100 [00:09<00:06, 69.91it/s]
```

```
 62%|                                                    |
685/1100 [00:09<00:05, 69.84it/s]
 63%|                                                    |
693/1100 [00:09<00:05, 70.21it/s]
 64%|                                                    |
701/1100 [00:10<00:05, 70.37it/s]
 64%|                                                    |
709/1100 [00:10<00:05, 70.71it/s]
 65%|                                                   |
717/1100 [00:10<00:05, 71.42it/s]
 66%|                                                   |
725/1100 [00:10<00:05, 70.94it/s]
 67%|                                                   |
733/1100 [00:10<00:05, 71.10it/s]
 67%|                                                   |
741/1100 [00:10<00:05, 68.89it/s]
 68%|                                                   |
749/1100 [00:10<00:05, 69.65it/s]
 69%|                                                   |
756/1100 [00:10<00:04, 69.52it/s]
 69%|                                                  |
763/1100 [00:10<00:04, 69.53it/s]
 70%|                                                  |
770/1100 [00:11<00:04, 66.50it/s]
 71%|                                                  |
778/1100 [00:11<00:04, 68.03it/s]
 71%|                                                  |
786/1100 [00:11<00:04, 69.14it/s]
 72%|                                                 |
793/1100 [00:11<00:04, 68.59it/s]
 73%|                                                 |
801/1100 [00:11<00:04, 69.19it/s]
 74%|                                                 |
809/1100 [00:11<00:04, 69.74it/s]
 74%|                                                 |
817/1100 [00:11<00:04, 70.36it/s]
 75%|                                                |
825/1100 [00:11<00:03, 70.19it/s]
 76%|                                                |
833/1100 [00:11<00:03, 70.60it/s]
 76%|                                               |
841/1100 [00:12<00:03, 70.84it/s]
 77%|                                               |
849/1100 [00:12<00:03, 71.23it/s]
 78%|                                              |
857/1100 [00:12<00:03, 71.24it/s]
 79%|                                              |
865/1100 [00:12<00:03, 71.54it/s]
```

```
 79%|                                                  |
873/1100 [00:12<00:03, 71.30it/s]
 80%|                                                  |
881/1100 [00:12<00:03, 70.30it/s]
 81%|                                                  |
889/1100 [00:12<00:03, 70.30it/s]
 82%|                                                 |
897/1100 [00:12<00:02, 69.68it/s]
 82%|                                                 |
904/1100 [00:12<00:02, 69.65it/s]
 83%|                                                 |
912/1100 [00:13<00:02, 70.25it/s]
 84%|                                                 |
920/1100 [00:13<00:02, 70.70it/s]
 84%|                                                |
928/1100 [00:13<00:02, 69.80it/s]
 85%|                                                 |
936/1100 [00:13<00:02, 70.24it/s]
 86%|                                                |
944/1100 [00:13<00:02, 70.75it/s]
 87%|                                                 |
952/1100 [00:13<00:02, 70.36it/s]
 87%|                                                |
960/1100 [00:13<00:01, 70.55it/s]
 88%|                                                 |
968/1100 [00:13<00:01, 70.28it/s]
 89%|                                                |
976/1100 [00:13<00:01, 69.80it/s]
 89%|                                                |
983/1100 [00:14<00:01, 68.91it/s]
 90%|                                                |
991/1100 [00:14<00:01, 69.81it/s]
 91%|                                               |
999/1100 [00:14<00:01, 70.62it/s]
 92%|                                               |
1007/1100 [00:14<00:01, 70.84it/s]
 92%|                                              |
1015/1100 [00:14<00:01, 70.10it/s]
 93%|                                              |
1023/1100 [00:14<00:01, 69.10it/s]
 94%|                                             |
1031/1100 [00:14<00:00, 69.66it/s]
 94%|                                             |
1039/1100 [00:14<00:00, 70.04it/s]
 95%|                                            |
1047/1100 [00:14<00:00, 69.98it/s]
 96%|                                            |
1055/1100 [00:15<00:00, 69.09it/s]
```

```
 97%|                                                |
1062/1100 [00:15<00:00, 66.69it/s]
 97%|                                                |
1070/1100 [00:15<00:00, 67.95it/s]
 98%|                                               |
1078/1100 [00:15<00:00, 69.05it/s]
 99%|                                               |
1086/1100 [00:15<00:00, 69.45it/s]
 99%|                                              |
1093/1100 [00:15<00:00, 69.51it/s]
100%|                                              |
1100/1100 [00:15<00:00, 69.80it/s]
 20%|
| 2/10 [00:31<02:06, 15.84s/it]
  0%|
| 0/1100 [00:00<?, ?it/s]
  1%|
| 8/1100 [00:00<00:14, 72.83it/s]
  1%|
| 16/1100 [00:00<00:15, 70.80it/s]
  2%|
| 24/1100 [00:00<00:15, 69.42it/s]
  3%|
| 32/1100 [00:00<00:15, 69.84it/s]
  4%|
| 39/1100 [00:00<00:15, 69.44it/s]
  4%|
| 47/1100 [00:00<00:15, 68.83it/s]
  5%|
| 55/1100 [00:00<00:15, 69.54it/s]
  6%|
| 62/1100 [00:00<00:15, 69.02it/s]
  6%|
| 69/1100 [00:00<00:14, 69.21it/s]
  7%|
| 77/1100 [00:01<00:14, 69.38it/s]
  8%|
| 84/1100 [00:01<00:15, 67.63it/s]
  8%|
| 92/1100 [00:01<00:14, 68.67it/s]
  9%|
| 99/1100 [00:01<00:14, 68.87it/s]
 10%|                                                                              |
106/1100 [00:01<00:14, 68.89it/s]
 10%|                                                                              |
113/1100 [00:01<00:14, 68.68it/s]
 11%|                                                                              |
120/1100 [00:01<00:14, 68.91it/s]
```

```
 12%|                                                  |
127/1100 [00:01<00:14, 67.75it/s]
 12%|                                                  |
134/1100 [00:01<00:14, 68.09it/s]
 13%|                                                 |
141/1100 [00:02<00:14, 68.46it/s]
 14%|                                                 |
149/1100 [00:02<00:13, 69.03it/s]
 14%|                                                 |
157/1100 [00:02<00:13, 69.93it/s]
 15%|                                                 |
164/1100 [00:02<00:13, 69.64it/s]
 16%|                                                |
171/1100 [00:02<00:13, 69.57it/s]
 16%|                                                |
179/1100 [00:02<00:13, 69.90it/s]
 17%|                                                |
186/1100 [00:02<00:13, 69.76it/s]
 18%|                                                |
193/1100 [00:02<00:13, 69.69it/s]
 18%|                                                |
201/1100 [00:02<00:12, 70.08it/s]
 19%|                                                |
209/1100 [00:03<00:13, 68.52it/s]
 20%|                                               |
217/1100 [00:03<00:12, 69.22it/s]
 20%|                                               |
224/1100 [00:03<00:12, 68.37it/s]
 21%|                                               |
232/1100 [00:03<00:12, 69.21it/s]
 22%|                                               |
239/1100 [00:03<00:12, 68.94it/s]
 22%|                                               |
247/1100 [00:03<00:12, 69.58it/s]
 23%|                                              |
255/1100 [00:03<00:12, 69.96it/s]
 24%|                                              |
263/1100 [00:03<00:11, 70.12it/s]
 25%|                                              |
271/1100 [00:03<00:11, 70.46it/s]
 25%|                                              |
279/1100 [00:04<00:11, 70.60it/s]
 26%|                                              |
287/1100 [00:04<00:11, 69.08it/s]
 27%|                                              |
294/1100 [00:04<00:11, 69.06it/s]
 27%|                                             |
301/1100 [00:04<00:11, 68.74it/s]
```

```
 28%|                                                  |
309/1100 [00:04<00:11, 69.25it/s]
 29%|                                                  |
317/1100 [00:04<00:11, 70.04it/s]
 30%|                                                  |
325/1100 [00:04<00:11, 70.18it/s]
 30%|                                                  |
333/1100 [00:04<00:11, 68.41it/s]
 31%|                                                  |
341/1100 [00:04<00:10, 69.20it/s]
 32%|                                                  |
348/1100 [00:05<00:10, 69.39it/s]
 32%|                                                  |
356/1100 [00:05<00:10, 69.86it/s]
 33%|                                                  |
363/1100 [00:05<00:10, 69.81it/s]
 34%|                                                  |
370/1100 [00:05<00:10, 67.00it/s]
 34%|                                                  |
377/1100 [00:05<00:10, 67.53it/s]
 35%|                                                  |
385/1100 [00:05<00:10, 68.45it/s]
 36%|                                                  |
392/1100 [00:05<00:10, 68.18it/s]
 36%|                                                  |
399/1100 [00:05<00:10, 67.75it/s]
 37%|                                                  |
406/1100 [00:05<00:10, 68.16it/s]
 38%|                                                  |
414/1100 [00:05<00:09, 68.96it/s]
 38%|                                                  |
422/1100 [00:06<00:09, 69.44it/s]
 39%|                                                  |
429/1100 [00:06<00:09, 69.29it/s]
 40%|                                                  |
437/1100 [00:06<00:09, 68.89it/s]
 40%|                                                  |
444/1100 [00:06<00:09, 68.21it/s]
 41%|                                                  |
451/1100 [00:06<00:09, 68.64it/s]
 42%|                                                  |
459/1100 [00:06<00:09, 68.92it/s]
 42%|                                                  |
466/1100 [00:06<00:09, 68.98it/s]
 43%|                                                  |
473/1100 [00:06<00:09, 68.81it/s]
 44%|                                                  |
481/1100 [00:06<00:08, 69.57it/s]
```

```
 44%|                                                           |
489/1100 [00:07<00:08, 69.85it/s]
 45%|                                                           |
496/1100 [00:07<00:08, 69.72it/s]
 46%|                                                           |
504/1100 [00:07<00:08, 70.14it/s]
 47%|                                                          |
512/1100 [00:07<00:08, 69.45it/s]
 47%|                                                          |
520/1100 [00:07<00:08, 70.10it/s]
 48%|                                                          |
528/1100 [00:07<00:08, 70.09it/s]
 49%|                                                          |
536/1100 [00:07<00:08, 70.47it/s]
 49%|                                                         |
544/1100 [00:07<00:07, 70.72it/s]
 50%|                                                         |
552/1100 [00:07<00:07, 71.12it/s]
 51%|                                                         |
560/1100 [00:08<00:08, 67.20it/s]
 52%|                                                        |
567/1100 [00:08<00:07, 67.56it/s]
 52%|                                                        |
575/1100 [00:08<00:07, 68.46it/s]
 53%|                                                        |
582/1100 [00:08<00:07, 68.67it/s]
 54%|                                                        |
590/1100 [00:08<00:07, 69.32it/s]
 54%|                                                       |
597/1100 [00:08<00:07, 69.43it/s]
 55%|                                                       |
605/1100 [00:08<00:07, 70.31it/s]
 56%|                                                       |
613/1100 [00:08<00:06, 70.72it/s]
 56%|                                                       |
621/1100 [00:08<00:06, 70.36it/s]
 57%|                                                      |
629/1100 [00:09<00:06, 70.72it/s]
 58%|                                                      |
637/1100 [00:09<00:06, 71.34it/s]
 59%|                                                      |
645/1100 [00:09<00:06, 71.10it/s]
 59%|                                                      |
653/1100 [00:09<00:06, 71.61it/s]
 60%|                                                     |
661/1100 [00:09<00:06, 71.62it/s]
 61%|                                                     |
669/1100 [00:09<00:06, 70.50it/s]
```

```
 62%|                                                    |
677/1100 [00:09<00:05, 70.55it/s]
 62%|                                                    |
685/1100 [00:09<00:05, 70.53it/s]
 63%|                                                    |
693/1100 [00:09<00:05, 69.44it/s]
 64%|                                                    |
701/1100 [00:10<00:05, 70.23it/s]
 64%|                                                    |
709/1100 [00:10<00:05, 70.10it/s]
 65%|                                                    |
717/1100 [00:10<00:05, 70.08it/s]
 66%|                                                    |
725/1100 [00:10<00:05, 69.84it/s]
 67%|                                                    |
732/1100 [00:10<00:05, 69.88it/s]
 67%|                                                    |
739/1100 [00:10<00:05, 69.49it/s]
 68%|                                                    |
747/1100 [00:10<00:05, 69.78it/s]
 69%|                                                    |
755/1100 [00:10<00:04, 69.97it/s]
 69%|                                                    |
762/1100 [00:10<00:04, 69.36it/s]
 70%|                                                    |
769/1100 [00:11<00:04, 69.05it/s]
 71%|                                                    |
777/1100 [00:11<00:04, 69.25it/s]
 71%|                                                    |
784/1100 [00:11<00:04, 68.59it/s]
 72%|                                                    |
791/1100 [00:11<00:04, 68.86it/s]
 73%|                                                    |
799/1100 [00:11<00:04, 69.24it/s]
 73%|                                                    |
806/1100 [00:11<00:04, 69.18it/s]
 74%|                                                    |
814/1100 [00:11<00:04, 69.50it/s]
 75%|                                                    |
822/1100 [00:11<00:03, 69.93it/s]
 75%|                                                    |
830/1100 [00:11<00:03, 70.15it/s]
 76%|                                                    |
838/1100 [00:12<00:03, 69.57it/s]
 77%|                                                    |
846/1100 [00:12<00:03, 70.06it/s]
 78%|                                                    |
854/1100 [00:12<00:03, 69.57it/s]
```

```
 78%|                                                  |
861/1100 [00:12<00:03, 69.42it/s]
 79%|                                                  |
868/1100 [00:12<00:03, 68.68it/s]
 80%|                                                  |
875/1100 [00:12<00:03, 68.90it/s]
 80%|                                                 |
882/1100 [00:12<00:03, 69.15it/s]
 81%|                                                 |
890/1100 [00:12<00:03, 69.67it/s]
 82%|                                                 |
897/1100 [00:12<00:02, 69.67it/s]
 82%|                                                 |
905/1100 [00:13<00:02, 69.67it/s]
 83%|                                                |
912/1100 [00:13<00:02, 67.80it/s]
 84%|                                                |
919/1100 [00:13<00:02, 67.74it/s]
 84%|                                                |
927/1100 [00:13<00:02, 68.71it/s]
 85%|                                                |
935/1100 [00:13<00:02, 69.23it/s]
 86%|                                               |
943/1100 [00:13<00:02, 69.69it/s]
 86%|                                               |
950/1100 [00:13<00:02, 69.03it/s]
 87%|                                              |
958/1100 [00:13<00:02, 69.64it/s]
 88%|                                              |
965/1100 [00:13<00:01, 68.55it/s]
 88%|                                              |
973/1100 [00:14<00:01, 69.43it/s]
 89%|                                              |
981/1100 [00:14<00:01, 69.90it/s]
 90%|                                             |
989/1100 [00:14<00:01, 70.48it/s]
 91%|                                             |
997/1100 [00:14<00:01, 66.52it/s]
 91%|                                            |
1004/1100 [00:14<00:01, 67.14it/s]
 92%|                                           |
1012/1100 [00:14<00:01, 68.29it/s]
 93%|                                           |
1019/1100 [00:14<00:01, 68.00it/s]
 93%|                                          |
1027/1100 [00:14<00:01, 69.25it/s]
 94%|                                          |
1035/1100 [00:14<00:00, 70.26it/s]
```

```
 95%|                                                  |
1043/1100 [00:15<00:00, 70.41it/s]
 96%|                                                  |
1051/1100 [00:15<00:00, 69.31it/s]
 96%|                                                 |
1058/1100 [00:15<00:00, 69.03it/s]
 97%|                                                 |
1065/1100 [00:15<00:00, 67.13it/s]
 98%|                                                |
1073/1100 [00:15<00:00, 68.39it/s]
 98%|                                                |
1081/1100 [00:15<00:00, 69.06it/s]
 99%|                                               |
1088/1100 [00:15<00:00, 69.08it/s]
100%|                                               |
1100/1100 [00:15<00:00, 69.34it/s]
 30%|
| 3/10 [00:47<01:50, 15.85s/it]
  0%|
| 0/1100 [00:00<?, ?it/s]
  1%|
| 8/1100 [00:00<00:14, 74.54it/s]
  1%|
| 16/1100 [00:00<00:15, 71.13it/s]
  2%|
| 24/1100 [00:00<00:15, 70.04it/s]
  3%|
| 32/1100 [00:00<00:15, 70.14it/s]
  4%|
| 40/1100 [00:00<00:14, 70.71it/s]
  4%|
| 48/1100 [00:00<00:14, 71.02it/s]
  5%|
| 56/1100 [00:00<00:15, 67.76it/s]
  6%|
| 63/1100 [00:00<00:15, 68.30it/s]
  6%|
| 71/1100 [00:01<00:15, 68.45it/s]
  7%|
| 78/1100 [00:01<00:15, 68.10it/s]
  8%|
| 86/1100 [00:01<00:14, 69.03it/s]
  8%|
| 93/1100 [00:01<00:14, 69.20it/s]
  9%|                                                                                |
101/1100 [00:01<00:14, 69.49it/s]
 10%|                                                                               |
108/1100 [00:01<00:14, 69.58it/s]
```

```
 10%|                                                                    |
115/1100 [00:01<00:14, 69.21it/s]
 11%|                                                                    |
122/1100 [00:01<00:14, 69.44it/s]
 12%|                                                                    |
130/1100 [00:01<00:13, 69.88it/s]
 12%|                                                                    |
137/1100 [00:01<00:13, 69.52it/s]
 13%|                                                                    |
144/1100 [00:02<00:14, 66.84it/s]
 14%|                                                                    |
152/1100 [00:02<00:13, 68.26it/s]
 14%|                                                                    |
159/1100 [00:02<00:13, 68.36it/s]
 15%|                                                                    |
167/1100 [00:02<00:13, 69.00it/s]
 16%|                                                                    |
174/1100 [00:02<00:13, 68.61it/s]
 16%|                                                                    |
181/1100 [00:02<00:13, 68.99it/s]
 17%|                                                                    |
188/1100 [00:02<00:13, 68.78it/s]
 18%|                                                                    |
195/1100 [00:02<00:13, 68.87it/s]
 18%|                                                                    |
203/1100 [00:02<00:12, 69.59it/s]
 19%|                                                                    |
211/1100 [00:03<00:12, 69.91it/s]
 20%|                                                                    |
219/1100 [00:03<00:12, 70.19it/s]
 21%|                                                                    |
227/1100 [00:03<00:12, 68.10it/s]
 21%|                                                                    |
234/1100 [00:03<00:13, 63.09it/s]
 22%|                                                                    |
242/1100 [00:03<00:13, 65.39it/s]
 23%|                                                                    |
250/1100 [00:03<00:12, 67.10it/s]
 23%|                                                                    |
258/1100 [00:03<00:12, 68.04it/s]
 24%|                                                                    |
265/1100 [00:03<00:12, 68.29it/s]
 25%|                                                                    |
273/1100 [00:03<00:11, 69.25it/s]
 26%|                                                                    |
281/1100 [00:04<00:11, 69.79it/s]
 26%|                                                                    |
288/1100 [00:04<00:11, 69.68it/s]
```

```
 27%|                                                              |
296/1100 [00:04<00:11, 69.00it/s]
 28%|                                                              |
303/1100 [00:04<00:11, 67.63it/s]
 28%|                                                              |
310/1100 [00:04<00:11, 67.41it/s]
 29%|                                                              |
318/1100 [00:04<00:11, 68.81it/s]
 30%|                                                              |
325/1100 [00:04<00:12, 64.22it/s]
 30%|                                                              |
332/1100 [00:04<00:11, 65.39it/s]
 31%|                                                              |
339/1100 [00:04<00:11, 66.62it/s]
 32%|                                                              |
347/1100 [00:05<00:11, 67.49it/s]
 32%|                                                              |
354/1100 [00:05<00:10, 68.02it/s]
 33%|                                                              |
362/1100 [00:05<00:10, 68.77it/s]
 34%|                                                              |
370/1100 [00:05<00:10, 69.53it/s]
 34%|                                                              |
377/1100 [00:05<00:10, 69.50it/s]
 35%|                                                              |
385/1100 [00:05<00:10, 69.94it/s]
 36%|                                                              |
392/1100 [00:05<00:10, 69.86it/s]
 36%|                                                              |
399/1100 [00:05<00:10, 69.88it/s]
 37%|                                                              |
406/1100 [00:05<00:10, 66.52it/s]
 38%|                                                              |
414/1100 [00:06<00:10, 67.96it/s]
 38%|                                                              |
421/1100 [00:06<00:09, 68.48it/s]
 39%|                                                              |
429/1100 [00:06<00:09, 69.29it/s]
 40%|                                                              |
437/1100 [00:06<00:09, 69.95it/s]
 40%|                                                              |
445/1100 [00:06<00:09, 70.08it/s]
 41%|                                                              |
453/1100 [00:06<00:09, 69.53it/s]
 42%|                                                              |
460/1100 [00:06<00:09, 68.94it/s]
 42%|                                                              |
467/1100 [00:06<00:09, 69.05it/s]
```

```
 43%|                                                              |
474/1100 [00:06<00:09, 68.93it/s]
 44%|                                                             |
481/1100 [00:07<00:09, 68.77it/s]
 44%|                                                             |
488/1100 [00:07<00:08, 68.55it/s]
 45%|                                                             |
496/1100 [00:07<00:08, 69.13it/s]
 46%|                                                             |
504/1100 [00:07<00:08, 69.59it/s]
 46%|                                                            |
511/1100 [00:07<00:08, 69.55it/s]
 47%|                                                            |
518/1100 [00:07<00:08, 69.09it/s]
 48%|                                                            |
526/1100 [00:07<00:08, 69.66it/s]
 49%|                                                            |
534/1100 [00:07<00:08, 69.95it/s]
 49%|                                                           |
541/1100 [00:07<00:08, 69.35it/s]
 50%|                                                           |
549/1100 [00:07<00:07, 70.12it/s]
 51%|                                                           |
557/1100 [00:08<00:07, 70.57it/s]
 51%|                                                           |
565/1100 [00:08<00:07, 70.78it/s]
 52%|                                                          |
573/1100 [00:08<00:07, 66.91it/s]
 53%|                                                          |
580/1100 [00:08<00:07, 67.57it/s]
 53%|                                                          |
587/1100 [00:08<00:07, 65.34it/s]
 54%|                                                          |
594/1100 [00:08<00:07, 66.60it/s]
 55%|                                                         |
602/1100 [00:08<00:07, 66.95it/s]
 55%|                                                         |
609/1100 [00:08<00:07, 67.72it/s]
 56%|                                                         |
617/1100 [00:08<00:07, 67.71it/s]
 57%|                                                         |
625/1100 [00:09<00:06, 69.05it/s]
 58%|                                                        |
633/1100 [00:09<00:06, 69.65it/s]
 58%|                                                        |
640/1100 [00:09<00:06, 69.74it/s]
 59%|                                                        |
648/1100 [00:09<00:06, 69.55it/s]
```

```
 60%|                                                  |
655/1100 [00:09<00:06, 68.01it/s]
 60%|                                                  |
663/1100 [00:09<00:06, 69.08it/s]
 61%|                                                 |
671/1100 [00:09<00:06, 69.62it/s]
 62%|                                                 |
679/1100 [00:09<00:05, 70.31it/s]
 62%|                                                 |
687/1100 [00:09<00:05, 69.80it/s]
 63%|                                                 |
694/1100 [00:10<00:05, 69.42it/s]
 64%|                                                |
702/1100 [00:10<00:05, 69.69it/s]
 64%|                                                |
709/1100 [00:10<00:05, 69.72it/s]
 65%|                                                |
717/1100 [00:10<00:05, 70.28it/s]
 66%|                                                |
725/1100 [00:10<00:05, 70.42it/s]
 67%|                                               |
733/1100 [00:10<00:05, 70.62it/s]
 67%|                                               |
741/1100 [00:10<00:05, 68.72it/s]
 68%|                                               |
749/1100 [00:10<00:05, 69.51it/s]
 69%|                                               |
756/1100 [00:10<00:04, 69.54it/s]
 69%|                                              |
764/1100 [00:11<00:04, 69.48it/s]
 70%|                                              |
772/1100 [00:11<00:04, 70.33it/s]
 71%|                                              |
780/1100 [00:11<00:04, 70.43it/s]
 72%|                                              |
788/1100 [00:11<00:04, 70.03it/s]
 72%|                                             |
796/1100 [00:11<00:04, 70.41it/s]
 73%|                                             |
804/1100 [00:11<00:04, 70.57it/s]
 74%|                                             |
812/1100 [00:11<00:04, 71.02it/s]
 75%|                                            |
820/1100 [00:11<00:04, 69.81it/s]
 75%|                                            |
828/1100 [00:12<00:03, 70.08it/s]
 76%|                                            |
836/1100 [00:12<00:03, 70.24it/s]
```

```
 77%|                                                  |
844/1100 [00:12<00:03, 69.95it/s]
 77%|                                                  |
851/1100 [00:12<00:03, 69.39it/s]
 78%|                                                  |
859/1100 [00:12<00:03, 69.74it/s]
 79%|                                                 |
866/1100 [00:12<00:03, 69.70it/s]
 79%|                                                 |
873/1100 [00:12<00:03, 69.38it/s]
 80%|                                                 |
881/1100 [00:12<00:03, 70.07it/s]
 81%|                                                 |
889/1100 [00:12<00:03, 69.66it/s]
 81%|                                                |
896/1100 [00:12<00:03, 67.89it/s]
 82%|                                                 |
904/1100 [00:13<00:02, 68.61it/s]
 83%|                                                |
911/1100 [00:13<00:02, 68.86it/s]
 84%|                                                |
919/1100 [00:13<00:02, 69.61it/s]
 84%|                                               |
927/1100 [00:13<00:02, 70.11it/s]
 85%|                                               |
935/1100 [00:13<00:02, 70.45it/s]
 86%|                                              |
943/1100 [00:13<00:02, 70.73it/s]
 86%|                                              |
951/1100 [00:13<00:02, 70.91it/s]
 87%|                                             |
959/1100 [00:13<00:01, 71.09it/s]
 88%|                                             |
967/1100 [00:13<00:01, 70.77it/s]
 89%|                                            |
975/1100 [00:14<00:01, 67.82it/s]
 89%|                                            |
983/1100 [00:14<00:01, 69.00it/s]
 90%|                                            |
991/1100 [00:14<00:01, 69.55it/s]
 91%|                                           |
998/1100 [00:14<00:01, 68.79it/s]
 91%|                                           |
1006/1100 [00:14<00:01, 69.57it/s]
 92%|                                          |
1013/1100 [00:14<00:01, 68.51it/s]
 93%|                                          |
1021/1100 [00:14<00:01, 69.21it/s]
```

```
 93%|                                                |
1028/1100 [00:14<00:01, 67.51it/s]
 94%|                                                |
1036/1100 [00:15<00:00, 68.87it/s]
 95%|                                               |
1043/1100 [00:15<00:00, 66.05it/s]
 95%|                                               |
1050/1100 [00:15<00:00, 65.99it/s]
 96%|                                              |
1057/1100 [00:15<00:00, 66.58it/s]
 97%|                                               |
1065/1100 [00:15<00:00, 68.04it/s]
 97%|                                              |
1072/1100 [00:15<00:00, 68.57it/s]
 98%|                                              |
1080/1100 [00:15<00:00, 69.26it/s]
 99%|                                             |
1087/1100 [00:15<00:00, 69.11it/s]
100%|                                             |
1100/1100 [00:15<00:00, 69.00it/s]
 40%|
| 4/10 [01:03<01:35, 15.89s/it]
  0%|
| 0/1100 [00:00<?, ?it/s]
  1%|
| 8/1100 [00:00<00:16, 67.53it/s]
  1%|
| 15/1100 [00:00<00:16, 67.57it/s]
  2%|
| 23/1100 [00:00<00:15, 69.02it/s]
  3%|
| 31/1100 [00:00<00:15, 70.52it/s]
  4%|
| 39/1100 [00:00<00:14, 71.15it/s]
  4%|
| 47/1100 [00:00<00:14, 70.99it/s]
  5%|
| 55/1100 [00:00<00:14, 71.03it/s]
  6%|
| 63/1100 [00:00<00:14, 70.22it/s]
  6%|
| 71/1100 [00:01<00:14, 69.63it/s]
  7%|
| 78/1100 [00:01<00:14, 69.51it/s]
  8%|
| 86/1100 [00:01<00:14, 69.30it/s]
  9%|
| 94/1100 [00:01<00:14, 69.89it/s]
```

```
  9%|                                                          |
102/1100 [00:01<00:14, 70.46it/s]
 10%|                                                         |
110/1100 [00:01<00:14, 70.35it/s]
 11%|                                                         |
118/1100 [00:01<00:13, 70.49it/s]
 11%|                                                         |
126/1100 [00:01<00:14, 69.13it/s]
 12%|                                                         |
133/1100 [00:01<00:13, 69.17it/s]
 13%|                                                        |
141/1100 [00:02<00:13, 69.64it/s]
 13%|                                                        |
148/1100 [00:02<00:14, 66.75it/s]
 14%|                                                        |
155/1100 [00:02<00:14, 67.36it/s]
 15%|                                                        |
162/1100 [00:02<00:14, 66.51it/s]
 15%|                                                       |
169/1100 [00:02<00:13, 67.47it/s]
 16%|                                                       |
177/1100 [00:02<00:13, 68.56it/s]
 17%|                                                       |
185/1100 [00:02<00:13, 69.31it/s]
 18%|                                                       |
193/1100 [00:02<00:12, 69.90it/s]
 18%|                                                      |
200/1100 [00:02<00:12, 69.32it/s]
 19%|                                                      |
208/1100 [00:02<00:12, 69.84it/s]
 20%|                                                      |
215/1100 [00:03<00:13, 67.97it/s]
 20%|                                                      |
222/1100 [00:03<00:13, 67.17it/s]
 21%|                                                     |
229/1100 [00:03<00:13, 66.93it/s]
 21%|                                                     |
236/1100 [00:03<00:12, 67.67it/s]
 22%|                                                     |
244/1100 [00:03<00:12, 68.67it/s]
 23%|                                                     |
252/1100 [00:03<00:12, 69.29it/s]
 24%|                                                    |
259/1100 [00:03<00:12, 69.45it/s]
 24%|                                                    |
267/1100 [00:03<00:11, 69.72it/s]
 25%|                                                    |
275/1100 [00:03<00:11, 70.17it/s]
```

```
 26%|                                                            |
283/1100 [00:04<00:12, 68.03it/s]
 26%|                                                            |
291/1100 [00:04<00:11, 68.69it/s]
 27%|                                                            |
298/1100 [00:04<00:11, 67.70it/s]
 28%|                                                            |
306/1100 [00:04<00:11, 68.55it/s]
 29%|                                                            |
314/1100 [00:04<00:11, 69.35it/s]
 29%|                                                            |
321/1100 [00:04<00:11, 69.51it/s]
 30%|                                                            |
329/1100 [00:04<00:11, 69.84it/s]
 31%|                                                            |
336/1100 [00:04<00:10, 69.78it/s]
 31%|                                                            |
343/1100 [00:04<00:11, 67.85it/s]
 32%|                                                            |
350/1100 [00:05<00:11, 66.24it/s]
 32%|                                                            |
357/1100 [00:05<00:11, 66.89it/s]
 33%|                                                            |
364/1100 [00:05<00:10, 67.65it/s]
 34%|                                                            |
371/1100 [00:05<00:10, 67.87it/s]
 34%|                                                            |
378/1100 [00:05<00:10, 68.41it/s]
 35%|                                                            |
386/1100 [00:05<00:10, 68.92it/s]
 36%|                                                            |
393/1100 [00:05<00:10, 68.79it/s]
 36%|                                                            |
401/1100 [00:05<00:10, 69.56it/s]
 37%|                                                            |
408/1100 [00:05<00:10, 68.83it/s]
 38%|                                                            |
415/1100 [00:06<00:10, 64.37it/s]
 38%|                                                            |
423/1100 [00:06<00:10, 66.39it/s]
 39%|                                                            |
431/1100 [00:06<00:09, 67.66it/s]
 40%|                                                            |
438/1100 [00:06<00:09, 67.39it/s]
 40%|                                                            |
445/1100 [00:06<00:09, 67.64it/s]
 41%|                                                            |
452/1100 [00:06<00:09, 67.94it/s]
```

```
 42%|                                                          |
459/1100 [00:06<00:09, 68.29it/s]
 42%|                                                          |
466/1100 [00:06<00:09, 68.30it/s]
 43%|                                                          |
474/1100 [00:06<00:09, 68.94it/s]
 44%|                                                          |
481/1100 [00:07<00:09, 62.76it/s]
 44%|                                                          |
488/1100 [00:07<00:09, 64.28it/s]
 45%|                                                         |
496/1100 [00:07<00:09, 65.37it/s]
 46%|                                                         |
504/1100 [00:07<00:08, 67.24it/s]
 46%|                                                         |
511/1100 [00:07<00:08, 67.09it/s]
 47%|                                                         |
519/1100 [00:07<00:08, 68.12it/s]
 48%|                                                        |
527/1100 [00:07<00:08, 68.90it/s]
 49%|                                                        |
535/1100 [00:07<00:08, 69.54it/s]
 49%|                                                        |
542/1100 [00:07<00:08, 69.14it/s]
 50%|                                                        |
549/1100 [00:08<00:07, 69.33it/s]
 51%|                                                       |
557/1100 [00:08<00:07, 70.06it/s]
 51%|                                                       |
565/1100 [00:08<00:07, 70.20it/s]
 52%|                                                       |
573/1100 [00:08<00:07, 69.83it/s]
 53%|                                                       |
580/1100 [00:08<00:07, 69.84it/s]
 53%|                                                      |
587/1100 [00:08<00:07, 69.73it/s]
 54%|                                                      |
595/1100 [00:08<00:07, 70.03it/s]
 55%|                                                      |
603/1100 [00:08<00:07, 69.22it/s]
 56%|                                                      |
611/1100 [00:08<00:07, 69.77it/s]
 56%|                                                     |
618/1100 [00:09<00:06, 69.56it/s]
 57%|                                                     |
626/1100 [00:09<00:06, 69.59it/s]
 58%|                                                     |
634/1100 [00:09<00:06, 69.84it/s]
```

```
 58%|                                                    |
641/1100 [00:09<00:06, 69.45it/s]
 59%|                                                    |
648/1100 [00:09<00:06, 68.03it/s]
 60%|                                                    |
655/1100 [00:09<00:06, 68.41it/s]
 60%|                                                    |
662/1100 [00:09<00:06, 66.26it/s]
 61%|                                                    |
669/1100 [00:09<00:06, 67.08it/s]
 61%|                                                    |
676/1100 [00:09<00:06, 67.36it/s]
 62%|                                                    |
683/1100 [00:09<00:06, 67.76it/s]
 63%|                                                    |
690/1100 [00:10<00:05, 68.34it/s]
 63%|                                                    |
698/1100 [00:10<00:05, 69.04it/s]
 64%|                                                    |
705/1100 [00:10<00:05, 69.15it/s]
 65%|                                                    |
712/1100 [00:10<00:05, 69.21it/s]
 65%|                                                    |
719/1100 [00:10<00:05, 66.08it/s]
 66%|                                                    |
726/1100 [00:10<00:05, 66.61it/s]
 67%|                                                    |
734/1100 [00:10<00:05, 67.73it/s]
 67%|                                                    |
741/1100 [00:10<00:05, 68.28it/s]
 68%|                                                    |
749/1100 [00:10<00:05, 68.78it/s]
 69%|                                                    |
756/1100 [00:11<00:05, 67.72it/s]
 69%|                                                    |
764/1100 [00:11<00:04, 68.63it/s]
 70%|                                                    |
771/1100 [00:11<00:04, 68.57it/s]
 71%|                                                    |
778/1100 [00:11<00:04, 66.59it/s]
 71%|                                                    |
785/1100 [00:11<00:04, 66.68it/s]
 72%|                                                    |
792/1100 [00:11<00:04, 65.59it/s]
 73%|                                                    |
799/1100 [00:11<00:04, 66.04it/s]
 73%|                                                    |
807/1100 [00:11<00:04, 67.69it/s]
```

```
 74%|                                                  |
815/1100 [00:11<00:04, 68.96it/s]
 75%|                                                  |
823/1100 [00:12<00:03, 70.01it/s]
 75%|                                                  |
830/1100 [00:12<00:03, 69.70it/s]
 76%|                                                  |
837/1100 [00:12<00:03, 67.71it/s]
 77%|                                                  |
844/1100 [00:12<00:03, 67.18it/s]
 77%|                                                  |
852/1100 [00:12<00:03, 68.51it/s]
 78%|                                                  |
859/1100 [00:12<00:03, 68.93it/s]
 79%|                                                  |
866/1100 [00:12<00:03, 69.23it/s]
 79%|                                                  |
874/1100 [00:12<00:03, 69.47it/s]
 80%|                                                  |
882/1100 [00:12<00:03, 69.84it/s]
 81%|                                                  |
889/1100 [00:12<00:03, 69.26it/s]
 81%|                                                  |
896/1100 [00:13<00:02, 69.37it/s]
 82%|                                                  |
903/1100 [00:13<00:02, 68.74it/s]
 83%|                                                  |
910/1100 [00:13<00:02, 68.89it/s]
 83%|                                                  |
918/1100 [00:13<00:02, 69.02it/s]
 84%|                                                  |
925/1100 [00:13<00:02, 68.93it/s]
 85%|                                                  |
933/1100 [00:13<00:02, 69.56it/s]
 85%|                                                  |
940/1100 [00:13<00:02, 69.43it/s]
 86%|                                                  |
948/1100 [00:13<00:02, 69.79it/s]
 87%|                                                 |
956/1100 [00:13<00:02, 70.24it/s]
 88%|                                                 |
964/1100 [00:14<00:02, 67.61it/s]
 88%|                                                 |
971/1100 [00:14<00:01, 68.21it/s]
 89%|                                                 |
978/1100 [00:14<00:01, 68.33it/s]
 90%|                                                 |
985/1100 [00:14<00:01, 68.78it/s]
```

```
 90%|                                                  |
992/1100 [00:14<00:01, 68.68it/s]
 91%|                                                  |
1000/1100 [00:14<00:01, 69.26it/s]
 92%|                                                  |
1007/1100 [00:14<00:01, 69.26it/s]
 92%|                                                  |
1015/1100 [00:14<00:01, 70.08it/s]
 93%|                                                  |
1023/1100 [00:14<00:01, 66.83it/s]
 94%|                                                 |
1031/1100 [00:15<00:01, 67.93it/s]
 94%|                                                 |
1039/1100 [00:15<00:00, 68.74it/s]
 95%|                                                 |
1047/1100 [00:15<00:00, 69.26it/s]
 96%|                                                 |
1054/1100 [00:15<00:00, 69.44it/s]
 97%|                                                |
1062/1100 [00:15<00:00, 69.37it/s]
 97%|                                                |
1070/1100 [00:15<00:00, 70.03it/s]
 98%|                                               |
1078/1100 [00:15<00:00, 69.88it/s]
 99%|                                               |
1085/1100 [00:15<00:00, 68.85it/s]
 99%|                                              |
1093/1100 [00:15<00:00, 69.79it/s]
100%|                                              |
1100/1100 [00:16<00:00, 68.60it/s]
 50%|
| 5/10 [01:19<01:19, 15.94s/it]
  0%|
| 0/1100 [00:00<?, ?it/s]
  1%|
| 8/1100 [00:00<00:14, 73.30it/s]
  1%|
| 16/1100 [00:00<00:15, 72.22it/s]
  2%|
| 24/1100 [00:00<00:15, 71.29it/s]
  3%|
| 32/1100 [00:00<00:15, 66.90it/s]
  4%|
| 40/1100 [00:00<00:15, 68.10it/s]
  4%|
| 48/1100 [00:00<00:15, 68.71it/s]
  5%|
| 55/1100 [00:00<00:15, 66.43it/s]
```

```
  6%|
| 62/1100 [00:00<00:15, 66.86it/s]
  6%|
| 70/1100 [00:01<00:15, 68.10it/s]
  7%|
| 78/1100 [00:01<00:14, 69.40it/s]
  8%|
| 85/1100 [00:01<00:14, 69.48it/s]
  8%|
| 92/1100 [00:01<00:15, 66.87it/s]
  9%|
| 99/1100 [00:01<00:14, 67.27it/s]
 10%|                                                                    |
107/1100 [00:01<00:14, 68.40it/s]
 10%|                                                                    |
114/1100 [00:01<00:14, 68.37it/s]
 11%|                                                                   |
121/1100 [00:01<00:14, 68.73it/s]
 12%|                                                                   |
129/1100 [00:01<00:14, 69.31it/s]
 12%|                                                                  |
136/1100 [00:01<00:13, 69.29it/s]
 13%|                                                                   |
144/1100 [00:02<00:13, 70.02it/s]
 14%|                                                                  |
151/1100 [00:02<00:14, 67.65it/s]
 14%|                                                                   |
158/1100 [00:02<00:14, 66.63it/s]
 15%|                                                                   |
165/1100 [00:02<00:14, 65.79it/s]
 16%|                                                                  |
172/1100 [00:02<00:13, 66.75it/s]
 16%|                                                                  |
180/1100 [00:02<00:13, 67.95it/s]
 17%|                                                                 |
187/1100 [00:02<00:13, 68.24it/s]
 18%|                                                                  |
194/1100 [00:02<00:13, 68.19it/s]
 18%|                                                                 |
202/1100 [00:02<00:12, 69.19it/s]
 19%|                                                                 |
209/1100 [00:03<00:13, 68.32it/s]
 20%|                                                                |
216/1100 [00:03<00:12, 68.38it/s]
 20%|                                                                |
224/1100 [00:03<00:12, 69.51it/s]
 21%|                                                               |
231/1100 [00:03<00:12, 68.59it/s]
```

```
 22%|                                                                    |
239/1100 [00:03<00:12, 69.35it/s]
 22%|                                                                   |
246/1100 [00:03<00:12, 68.84it/s]
 23%|                                                                   |
254/1100 [00:03<00:12, 69.44it/s]
 24%|                                                                   |
261/1100 [00:03<00:12, 69.16it/s]
 24%|                                                                   |
268/1100 [00:03<00:12, 64.38it/s]
 25%|                                                                  |
275/1100 [00:04<00:12, 65.58it/s]
 26%|                                                                  |
282/1100 [00:04<00:12, 66.81it/s]
 26%|                                                                  |
290/1100 [00:04<00:11, 68.08it/s]
 27%|                                                                  |
297/1100 [00:04<00:11, 68.14it/s]
 28%|                                                                 |
304/1100 [00:04<00:11, 67.32it/s]
 28%|                                                                 |
312/1100 [00:04<00:11, 68.68it/s]
 29%|                                                                 |
320/1100 [00:04<00:11, 69.36it/s]
 30%|                                                                 |
327/1100 [00:04<00:11, 66.44it/s]
 30%|                                                                |
335/1100 [00:04<00:11, 67.75it/s]
 31%|                                                                |
343/1100 [00:05<00:10, 68.86it/s]
 32%|                                                                |
351/1100 [00:05<00:10, 69.69it/s]
 33%|                                                                |
358/1100 [00:05<00:10, 69.06it/s]
 33%|                                                               |
365/1100 [00:05<00:10, 69.21it/s]
 34%|                                                               |
373/1100 [00:05<00:10, 68.19it/s]
 35%|                                                               |
380/1100 [00:05<00:10, 66.28it/s]
 35%|                                                               |
387/1100 [00:05<00:10, 65.50it/s]
 36%|                                                              |
394/1100 [00:05<00:10, 66.67it/s]
 36%|                                                              |
401/1100 [00:05<00:10, 66.89it/s]
 37%|                                                              |
409/1100 [00:06<00:10, 68.40it/s]
```

```
 38%|                                                            |
417/1100 [00:06<00:09, 69.04it/s]
 39%|                                                            |
424/1100 [00:06<00:09, 69.19it/s]
 39%|                                                            |
431/1100 [00:06<00:10, 66.64it/s]
 40%|                                                            |
439/1100 [00:06<00:09, 67.98it/s]
 41%|                                                            |
446/1100 [00:06<00:09, 68.35it/s]
 41%|                                                            |
454/1100 [00:06<00:09, 69.23it/s]
 42%|                                                            |
462/1100 [00:06<00:09, 69.62it/s]
 43%|                                                            |
470/1100 [00:06<00:08, 70.44it/s]
 43%|                                                            |
478/1100 [00:06<00:08, 70.11it/s]
 44%|                                                            |
486/1100 [00:07<00:08, 69.23it/s]
 45%|                                                            |
494/1100 [00:07<00:08, 70.15it/s]
 46%|                                                            |
502/1100 [00:07<00:08, 70.12it/s]
 46%|                                                            |
510/1100 [00:07<00:08, 69.91it/s]
 47%|                                                            |
517/1100 [00:07<00:08, 68.10it/s]
 48%|                                                            |
524/1100 [00:07<00:08, 68.38it/s]
 48%|                                                            |
532/1100 [00:07<00:08, 69.07it/s]
 49%|                                                            |
539/1100 [00:07<00:08, 66.52it/s]
 50%|                                                            |
546/1100 [00:08<00:08, 66.55it/s]
 50%|                                                            |
553/1100 [00:08<00:08, 67.11it/s]
 51%|                                                            |
560/1100 [00:08<00:07, 67.63it/s]
 52%|                                                            |
567/1100 [00:08<00:07, 68.06it/s]
 52%|                                                            |
574/1100 [00:08<00:07, 67.82it/s]
 53%|                                                            |
581/1100 [00:08<00:07, 68.24it/s]
 53%|                                                            |
588/1100 [00:08<00:07, 65.55it/s]
```

```
 54%|                                                            |
596/1100 [00:08<00:07, 66.70it/s]
 55%|                                                            |
604/1100 [00:08<00:07, 68.14it/s]
 56%|                                                            |
611/1100 [00:08<00:07, 68.37it/s]
 56%|                                                           |
618/1100 [00:09<00:07, 67.76it/s]
 57%|                                                           |
625/1100 [00:09<00:06, 68.32it/s]
 57%|                                                          |
632/1100 [00:09<00:06, 68.70it/s]
 58%|                                                          |
639/1100 [00:09<00:06, 66.65it/s]
 59%|                                                          |
646/1100 [00:09<00:06, 67.59it/s]
 59%|                                                          |
654/1100 [00:09<00:06, 68.50it/s]
 60%|                                                         |
662/1100 [00:09<00:06, 69.15it/s]
 61%|                                                         |
669/1100 [00:09<00:06, 67.63it/s]
 62%|                                                         |
677/1100 [00:09<00:06, 68.75it/s]
 62%|                                                         |
685/1100 [00:10<00:06, 69.11it/s]
 63%|                                                        |
692/1100 [00:10<00:06, 66.05it/s]
 64%|                                                        |
700/1100 [00:10<00:05, 67.61it/s]
 64%|                                                        |
708/1100 [00:10<00:05, 68.71it/s]
 65%|                                                        |
715/1100 [00:10<00:05, 68.98it/s]
 66%|                                                       |
723/1100 [00:10<00:05, 70.00it/s]
 66%|                                                       |
731/1100 [00:10<00:05, 69.95it/s]
 67%|                                                       |
738/1100 [00:10<00:05, 69.55it/s]
 68%|                                                       |
745/1100 [00:10<00:05, 66.18it/s]
 68%|                                                      |
752/1100 [00:11<00:05, 67.10it/s]
 69%|                                                      |
760/1100 [00:11<00:05, 67.21it/s]
 70%|                                                      |
768/1100 [00:11<00:04, 68.64it/s]
```

```
 71%|                                                    |
776/1100 [00:11<00:04, 69.39it/s]
 71%|                                                    |
784/1100 [00:11<00:04, 70.13it/s]
 72%|                                                    |
792/1100 [00:11<00:04, 70.36it/s]
 73%|                                                    |
800/1100 [00:11<00:04, 69.59it/s]
 73%|                                                   |
808/1100 [00:11<00:04, 70.21it/s]
 74%|                                                    |
816/1100 [00:11<00:04, 70.84it/s]
 75%|                                                   |
824/1100 [00:12<00:03, 70.44it/s]
 76%|                                                    |
832/1100 [00:12<00:03, 70.39it/s]
 76%|                                                   |
840/1100 [00:12<00:03, 69.71it/s]
 77%|                                                   |
848/1100 [00:12<00:03, 70.29it/s]
 78%|                                                  |
856/1100 [00:12<00:03, 69.42it/s]
 79%|                                                   |
864/1100 [00:12<00:03, 69.93it/s]
 79%|                                                  |
871/1100 [00:12<00:03, 69.87it/s]
 80%|                                                  |
879/1100 [00:12<00:03, 70.32it/s]
 81%|                                                  |
887/1100 [00:12<00:03, 70.33it/s]
 81%|                                                 |
895/1100 [00:13<00:02, 69.60it/s]
 82%|                                                  |
902/1100 [00:13<00:02, 69.67it/s]
 83%|                                                 |
909/1100 [00:13<00:02, 65.62it/s]
 83%|                                                  |
917/1100 [00:13<00:02, 67.19it/s]
 84%|                                                 |
925/1100 [00:13<00:02, 68.62it/s]
 85%|                                                  |
932/1100 [00:13<00:02, 68.34it/s]
 85%|                                                 |
940/1100 [00:13<00:02, 69.70it/s]
 86%|                                                 |
947/1100 [00:13<00:02, 69.74it/s]
 87%|                                                |
954/1100 [00:13<00:02, 69.58it/s]
```

```
 87%|                                                  |
961/1100 [00:14<00:02, 68.61it/s]
 88%|                                                  |
969/1100 [00:14<00:01, 69.62it/s]
 89%|                                                  |
976/1100 [00:14<00:01, 69.46it/s]
 89%|                                                  |
984/1100 [00:14<00:01, 69.45it/s]
 90%|                                                  |
991/1100 [00:14<00:01, 69.50it/s]
 91%|                                                  |
999/1100 [00:14<00:01, 69.96it/s]
 91%|                                                 |
1006/1100 [00:14<00:01, 69.34it/s]
 92%|                                                 |
1013/1100 [00:14<00:01, 67.41it/s]
 93%|                                                 |
1020/1100 [00:14<00:01, 68.09it/s]
 93%|                                                 |
1027/1100 [00:14<00:01, 68.40it/s]
 94%|                                                 |
1035/1100 [00:15<00:00, 68.86it/s]
 95%|                                                |
1042/1100 [00:15<00:00, 68.47it/s]
 95%|                                                |
1049/1100 [00:15<00:00, 68.41it/s]
 96%|                                                |
1056/1100 [00:15<00:00, 68.74it/s]
 97%|                                                |
1063/1100 [00:15<00:00, 68.53it/s]
 97%|                                                |
1070/1100 [00:15<00:00, 67.75it/s]
 98%|                                               |
1077/1100 [00:15<00:00, 67.65it/s]
 99%|                                               |
1085/1100 [00:15<00:00, 68.55it/s]
100%|                                              |
1100/1100 [00:16<00:00, 68.53it/s]
 60%|
| 6/10 [01:35<01:03, 15.98s/it]
  0%|
| 0/1100 [00:00<?, ?it/s]
  1%|
| 8/1100 [00:00<00:15, 71.92it/s]
  1%|
| 16/1100 [00:00<00:16, 64.89it/s]
  2%|
| 24/1100 [00:00<00:15, 67.49it/s]
```

```
  3%|
| 31/1100 [00:00<00:15, 67.90it/s]
  4%|
| 39/1100 [00:00<00:15, 68.69it/s]
  4%|
| 46/1100 [00:00<00:15, 68.64it/s]
  5%|
| 54/1100 [00:00<00:15, 69.57it/s]
  6%|
| 62/1100 [00:00<00:15, 69.00it/s]
  6%|
| 69/1100 [00:01<00:15, 67.57it/s]
  7%|
| 76/1100 [00:01<00:15, 67.35it/s]
  8%|
| 84/1100 [00:01<00:14, 68.64it/s]
  8%|
| 91/1100 [00:01<00:14, 68.67it/s]
  9%|
| 99/1100 [00:01<00:14, 68.62it/s]
 10%|                                                                    |
106/1100 [00:01<00:14, 68.94it/s]
 10%|                                                                    |
113/1100 [00:01<00:14, 68.82it/s]
 11%|                                                                    |
120/1100 [00:01<00:14, 67.97it/s]
 12%|                                                                   |
128/1100 [00:01<00:14, 68.98it/s]
 12%|                                                                   |
135/1100 [00:01<00:14, 68.87it/s]
 13%|                                                                  |
143/1100 [00:02<00:13, 69.27it/s]
 14%|                                                                  |
151/1100 [00:02<00:13, 69.86it/s]
 14%|                                                                  |
159/1100 [00:02<00:13, 70.14it/s]
 15%|                                                                 |
167/1100 [00:02<00:13, 70.15it/s]
 16%|                                                                 |
175/1100 [00:02<00:13, 69.12it/s]
 17%|                                                                |
183/1100 [00:02<00:13, 69.88it/s]
 17%|                                                                |
191/1100 [00:02<00:12, 70.16it/s]
 18%|                                                               |
199/1100 [00:02<00:12, 69.82it/s]
 19%|                                                               |
207/1100 [00:02<00:12, 70.43it/s]
```

```
 20%|                                                            |
215/1100 [00:03<00:12, 69.42it/s]
 20%|                                                            |
222/1100 [00:03<00:13, 66.59it/s]
 21%|                                                           |
229/1100 [00:03<00:13, 66.04it/s]
 22%|                                                           |
237/1100 [00:03<00:12, 67.94it/s]
 22%|                                                           |
244/1100 [00:03<00:12, 68.06it/s]
 23%|                                                           |
252/1100 [00:03<00:12, 68.95it/s]
 24%|                                                          |
260/1100 [00:03<00:12, 68.48it/s]
 24%|                                                          |
267/1100 [00:03<00:12, 67.43it/s]
 25%|                                                          |
274/1100 [00:03<00:12, 67.21it/s]
 26%|                                                          |
281/1100 [00:04<00:12, 67.90it/s]
 26%|                                                         |
289/1100 [00:04<00:11, 67.81it/s]
 27%|                                                         |
296/1100 [00:04<00:11, 67.74it/s]
 28%|                                                         |
304/1100 [00:04<00:11, 68.38it/s]
 28%|                                                         |
311/1100 [00:04<00:11, 67.96it/s]
 29%|                                                        |
318/1100 [00:04<00:11, 67.59it/s]
 30%|                                                        |
325/1100 [00:04<00:11, 67.37it/s]
 30%|                                                        |
332/1100 [00:04<00:11, 67.76it/s]
 31%|                                                        |
340/1100 [00:04<00:11, 68.73it/s]
 32%|                                                       |
347/1100 [00:05<00:10, 68.55it/s]
 32%|                                                       |
354/1100 [00:05<00:10, 68.67it/s]
 33%|                                                       |
362/1100 [00:05<00:10, 68.45it/s]
 34%|                                                       |
369/1100 [00:05<00:10, 67.07it/s]
 34%|                                                      |
376/1100 [00:05<00:10, 66.55it/s]
 35%|                                                      |
384/1100 [00:05<00:10, 68.03it/s]
```

```
 36%|                                                          |
392/1100 [00:05<00:10, 69.02it/s]
 36%|                                                          |
399/1100 [00:05<00:10, 68.11it/s]
 37%|                                                         |
406/1100 [00:05<00:10, 68.05it/s]
 38%|                                                         |
414/1100 [00:06<00:09, 69.01it/s]
 38%|                                                         |
421/1100 [00:06<00:09, 69.12it/s]
 39%|                                                         |
428/1100 [00:06<00:09, 67.48it/s]
 40%|                                                        |
436/1100 [00:06<00:09, 68.80it/s]
 40%|                                                        |
444/1100 [00:06<00:09, 70.22it/s]
 41%|                                                        |
453/1100 [00:06<00:08, 74.93it/s]
 42%|                                                        |
462/1100 [00:06<00:08, 77.21it/s]
 43%|                                                       |
471/1100 [00:06<00:07, 79.84it/s]
 44%|                                                       |
480/1100 [00:06<00:07, 81.28it/s]
 44%|                                                       |
489/1100 [00:07<00:07, 82.41it/s]
 45%|                                                      |
498/1100 [00:07<00:07, 83.35it/s]
 46%|                                                      |
507/1100 [00:07<00:07, 83.75it/s]
 47%|                                                      |
516/1100 [00:07<00:06, 84.75it/s]
 48%|                                                     |
525/1100 [00:07<00:06, 86.00it/s]
 49%|                                                     |
534/1100 [00:07<00:06, 81.61it/s]
 49%|                                                     |
543/1100 [00:07<00:07, 77.30it/s]
 50%|                                                     |
551/1100 [00:07<00:07, 75.52it/s]
 51%|                                                    |
559/1100 [00:07<00:07, 73.82it/s]
 52%|                                                    |
567/1100 [00:08<00:07, 72.51it/s]
 52%|                                                    |
575/1100 [00:08<00:07, 72.09it/s]
 53%|                                                   |
583/1100 [00:08<00:07, 67.90it/s]
```

```
 54%|                                                   |
590/1100 [00:08<00:07, 68.20it/s]
 54%|                                                   |
598/1100 [00:08<00:07, 66.66it/s]
 55%|                                                   |
606/1100 [00:08<00:07, 67.72it/s]
 56%|                                                  |
613/1100 [00:08<00:07, 68.17it/s]
 56%|                                                  |
620/1100 [00:08<00:07, 68.12it/s]
 57%|                                                  |
627/1100 [00:08<00:06, 67.82it/s]
 58%|                                                  |
634/1100 [00:09<00:06, 68.34it/s]
 58%|                                                  |
641/1100 [00:09<00:06, 68.38it/s]
 59%|                                                 |
649/1100 [00:09<00:06, 69.13it/s]
 60%|                                                 |
657/1100 [00:09<00:06, 69.65it/s]
 60%|                                                 |
665/1100 [00:09<00:06, 69.95it/s]
 61%|                                                |
672/1100 [00:09<00:06, 65.56it/s]
 62%|                                                |
679/1100 [00:09<00:06, 66.69it/s]
 62%|                                                |
687/1100 [00:09<00:06, 67.78it/s]
 63%|                                                |
695/1100 [00:09<00:05, 68.77it/s]
 64%|                                               |
703/1100 [00:10<00:05, 69.53it/s]
 65%|                                               |
711/1100 [00:10<00:05, 69.97it/s]
 65%|                                               |
719/1100 [00:10<00:05, 68.19it/s]
 66%|                                               |
726/1100 [00:10<00:05, 68.22it/s]
 67%|                                              |
734/1100 [00:10<00:05, 69.01it/s]
 67%|                                              |
741/1100 [00:10<00:05, 68.98it/s]
 68%|                                              |
749/1100 [00:10<00:05, 69.45it/s]
 69%|                                              |
757/1100 [00:10<00:04, 70.01it/s]
 70%|                                             |
765/1100 [00:10<00:04, 67.95it/s]
```

```
 70%|                                                    |
773/1100 [00:11<00:04, 69.06it/s]
 71%|                                                    |
780/1100 [00:11<00:04, 68.62it/s]
 72%|                                                    |
787/1100 [00:11<00:04, 68.59it/s]
 72%|                                                   |
794/1100 [00:11<00:04, 68.64it/s]
 73%|                                                   |
801/1100 [00:11<00:04, 68.04it/s]
 73%|                                                  |
808/1100 [00:11<00:04, 66.36it/s]
 74%|                                                  |
815/1100 [00:11<00:04, 66.66it/s]
 75%|                                                  |
822/1100 [00:11<00:04, 64.58it/s]
 75%|                                                  |
829/1100 [00:11<00:04, 65.68it/s]
 76%|                                                 |
836/1100 [00:11<00:03, 66.44it/s]
 77%|                                                 |
844/1100 [00:12<00:03, 67.78it/s]
 77%|                                                 |
852/1100 [00:12<00:03, 68.65it/s]
 78%|                                                 |
859/1100 [00:12<00:03, 68.51it/s]
 79%|                                                |
867/1100 [00:12<00:03, 69.54it/s]
 80%|                                                |
875/1100 [00:12<00:03, 70.06it/s]
 80%|                                                |
883/1100 [00:12<00:03, 69.14it/s]
 81%|                                                |
890/1100 [00:12<00:03, 69.20it/s]
 82%|                                               |
898/1100 [00:12<00:02, 69.16it/s]
 82%|                                               |
905/1100 [00:12<00:02, 67.33it/s]
 83%|                                              |
912/1100 [00:13<00:02, 67.95it/s]
 84%|                                              |
920/1100 [00:13<00:02, 68.67it/s]
 84%|                                              |
928/1100 [00:13<00:02, 69.75it/s]
 85%|                                              |
935/1100 [00:13<00:02, 69.23it/s]
 86%|                                             |
942/1100 [00:13<00:02, 69.29it/s]
```

```
 86%|                                                  |
949/1100 [00:13<00:02, 68.21it/s]
 87%|                                                  |
956/1100 [00:13<00:02, 65.44it/s]
 88%|                                                  |
963/1100 [00:13<00:02, 65.09it/s]
 88%|                                                  |
970/1100 [00:13<00:01, 66.37it/s]
 89%|                                                  |
978/1100 [00:14<00:01, 67.73it/s]
 90%|                                                 |
985/1100 [00:14<00:01, 67.95it/s]
 90%|                                                 |
993/1100 [00:14<00:01, 68.67it/s]
 91%|                                                |
1000/1100 [00:14<00:01, 65.96it/s]
 92%|                                                 |
1008/1100 [00:14<00:01, 67.49it/s]
 92%|                                                |
1015/1100 [00:14<00:01, 67.99it/s]
 93%|                                                |
1023/1100 [00:14<00:01, 68.55it/s]
 94%|                                               |
1031/1100 [00:14<00:00, 69.04it/s]
 94%|                                               |
1038/1100 [00:14<00:00, 68.81it/s]
 95%|                                              |
1045/1100 [00:15<00:00, 68.94it/s]
 96%|                                              |
1053/1100 [00:15<00:00, 69.39it/s]
 96%|                                             |
1061/1100 [00:15<00:00, 69.74it/s]
 97%|                                             |
1068/1100 [00:15<00:00, 69.67it/s]
 98%|                                            |
1075/1100 [00:15<00:00, 69.62it/s]
 98%|                                            |
1083/1100 [00:15<00:00, 70.18it/s]
 99%|                                           |
1091/1100 [00:15<00:00, 69.40it/s]
100%|                                           |
1100/1100 [00:15<00:00, 69.44it/s]
 70%|
| 7/10 [01:51<00:47, 15.94s/it]
  0%|
| 0/1100 [00:00<?, ?it/s]
  1%|
| 8/1100 [00:00<00:15, 71.50it/s]
```

```
  1%|
| 16/1100 [00:00<00:15, 70.57it/s]
  2%|
| 24/1100 [00:00<00:15, 70.27it/s]
  3%|
| 32/1100 [00:00<00:15, 70.61it/s]
  4%|
| 40/1100 [00:00<00:15, 68.46it/s]
  4%|
| 47/1100 [00:00<00:15, 66.35it/s]
  5%|
| 54/1100 [00:00<00:15, 66.60it/s]
  6%|
| 62/1100 [00:00<00:15, 68.29it/s]
  6%|
| 69/1100 [00:01<00:15, 68.07it/s]
  7%|
| 76/1100 [00:01<00:15, 67.25it/s]
  8%|
| 83/1100 [00:01<00:14, 67.90it/s]
  8%|
| 91/1100 [00:01<00:14, 68.91it/s]
  9%|
| 98/1100 [00:01<00:14, 68.83it/s]
 10%|                                                                    |
106/1100 [00:01<00:14, 68.08it/s]
 10%|                                                                    |
113/1100 [00:01<00:14, 68.00it/s]
 11%|                                                                   |
121/1100 [00:01<00:14, 68.73it/s]
 12%|                                                                    |
128/1100 [00:01<00:14, 69.06it/s]
 12%|                                                                    |
135/1100 [00:01<00:13, 69.05it/s]
 13%|                                                                   |
142/1100 [00:02<00:13, 69.21it/s]
 14%|                                                                    |
150/1100 [00:02<00:13, 70.03it/s]
 14%|                                                                   |
158/1100 [00:02<00:13, 67.43it/s]
 15%|                                                                    |
165/1100 [00:02<00:13, 67.34it/s]
 16%|                                                                   |
172/1100 [00:02<00:13, 67.88it/s]
 16%|                                                                   |
180/1100 [00:02<00:13, 68.80it/s]
 17%|                                                                  |
187/1100 [00:02<00:13, 68.87it/s]
```

```
 18%|                                                                        |
194/1100 [00:02<00:13, 66.09it/s]
 18%|                                                                        |
201/1100 [00:02<00:15, 59.28it/s]
 19%|                                                                        |
208/1100 [00:03<00:14, 60.15it/s]
 20%|                                                                       |
215/1100 [00:03<00:14, 62.59it/s]
 20%|                                                                       |
222/1100 [00:03<00:13, 63.83it/s]
 21%|                                                                      |
229/1100 [00:03<00:13, 65.38it/s]
 21%|                                                                      |
236/1100 [00:03<00:13, 64.50it/s]
 22%|                                                                      |
243/1100 [00:03<00:13, 65.33it/s]
 23%|                                                                      |
250/1100 [00:03<00:12, 66.49it/s]
 23%|                                                                     |
258/1100 [00:03<00:12, 68.10it/s]
 24%|                                                                     |
266/1100 [00:03<00:12, 68.86it/s]
 25%|                                                                     |
273/1100 [00:04<00:12, 68.49it/s]
 25%|                                                                     |
280/1100 [00:04<00:12, 66.13it/s]
 26%|                                                                    |
287/1100 [00:04<00:12, 67.19it/s]
 27%|                                                                    |
295/1100 [00:04<00:11, 68.43it/s]
 28%|                                                                    |
303/1100 [00:04<00:11, 69.50it/s]
 28%|                                                                    |
310/1100 [00:04<00:11, 69.21it/s]
 29%|                                                                   |
317/1100 [00:04<00:11, 69.00it/s]
 30%|                                                                   |
325/1100 [00:04<00:11, 69.93it/s]
 30%|                                                                   |
332/1100 [00:04<00:11, 69.10it/s]
 31%|                                                                   |
340/1100 [00:05<00:10, 69.54it/s]
 32%|                                                                  |
347/1100 [00:05<00:10, 69.38it/s]
 32%|                                                                  |
355/1100 [00:05<00:10, 69.57it/s]
 33%|                                                                  |
362/1100 [00:05<00:10, 69.03it/s]
```

```
 34%|                                                              |
370/1100 [00:05<00:10, 69.96it/s]
 34%|                                                              |
378/1100 [00:05<00:10, 70.36it/s]
 35%|                                                              |
386/1100 [00:05<00:10, 70.38it/s]
 36%|                                                              |
394/1100 [00:05<00:10, 69.91it/s]
 37%|                                                              |
402/1100 [00:05<00:09, 70.27it/s]
 37%|                                                              |
410/1100 [00:06<00:09, 70.11it/s]
 38%|                                                              |
418/1100 [00:06<00:09, 69.48it/s]
 39%|                                                              |
426/1100 [00:06<00:09, 70.32it/s]
 39%|                                                              |
434/1100 [00:06<00:09, 70.69it/s]
 40%|                                                              |
442/1100 [00:06<00:09, 70.25it/s]
 41%|                                                              |
450/1100 [00:06<00:09, 70.43it/s]
 42%|                                                              |
458/1100 [00:06<00:09, 69.94it/s]
 42%|                                                              |
465/1100 [00:06<00:09, 68.24it/s]
 43%|                                                              |
473/1100 [00:06<00:09, 68.92it/s]
 44%|                                                              |
480/1100 [00:07<00:09, 68.75it/s]
 44%|                                                              |
487/1100 [00:07<00:08, 68.61it/s]
 45%|                                                              |
494/1100 [00:07<00:08, 68.38it/s]
 46%|                                                              |
501/1100 [00:07<00:08, 68.83it/s]
 46%|                                                              |
508/1100 [00:07<00:08, 69.16it/s]
 47%|                                                              |
516/1100 [00:07<00:08, 69.57it/s]
 48%|                                                              |
524/1100 [00:07<00:08, 69.79it/s]
 48%|                                                              |
531/1100 [00:07<00:08, 69.41it/s]
 49%|                                                              |
538/1100 [00:07<00:08, 69.50it/s]
 50%|                                                              |
545/1100 [00:07<00:08, 69.37it/s]
```

```
 50%|                                                        |
553/1100 [00:08<00:07, 69.86it/s]
 51%|                                                        |
561/1100 [00:08<00:07, 70.17it/s]
 52%|                                                       |
569/1100 [00:08<00:07, 70.33it/s]
 52%|                                                       |
577/1100 [00:08<00:07, 69.12it/s]
 53%|                                                      |
584/1100 [00:08<00:07, 66.58it/s]
 54%|                                                      |
592/1100 [00:08<00:07, 67.71it/s]
 55%|                                                     |
600/1100 [00:08<00:07, 68.63it/s]
 55%|                                                     |
607/1100 [00:08<00:07, 68.99it/s]
 56%|                                                    |
614/1100 [00:08<00:07, 69.06it/s]
 57%|                                                    |
622/1100 [00:09<00:06, 69.32it/s]
 57%|                                                   |
630/1100 [00:09<00:06, 69.68it/s]
 58%|                                                   |
637/1100 [00:09<00:06, 69.46it/s]
 59%|                                                  |
645/1100 [00:09<00:06, 70.09it/s]
 59%|                                                  |
653/1100 [00:09<00:06, 70.86it/s]
 60%|                                                 |
661/1100 [00:09<00:06, 70.82it/s]
 61%|                                                 |
669/1100 [00:09<00:06, 70.73it/s]
 62%|                                                |
677/1100 [00:09<00:06, 69.26it/s]
 62%|                                                |
684/1100 [00:09<00:06, 67.79it/s]
 63%|                                               |
691/1100 [00:10<00:06, 67.89it/s]
 63%|                                               |
698/1100 [00:10<00:06, 66.92it/s]
 64%|                                              |
706/1100 [00:10<00:05, 69.29it/s]
 65%|                                              |
715/1100 [00:10<00:05, 74.01it/s]
 66%|                                             |
724/1100 [00:10<00:04, 77.53it/s]
 67%|                                            |
733/1100 [00:10<00:04, 78.91it/s]
```

```
 67%|                                                    |
742/1100 [00:10<00:04, 81.06it/s]
 68%|                                                    |
751/1100 [00:10<00:04, 82.66it/s]
 69%|                                                    |
760/1100 [00:10<00:04, 83.78it/s]
 70%|                                                    |
769/1100 [00:11<00:03, 84.41it/s]
 71%|                                                   |
778/1100 [00:11<00:03, 85.00it/s]
 72%|                                                    |
787/1100 [00:11<00:03, 85.25it/s]
 72%|                                                   |
796/1100 [00:11<00:03, 83.22it/s]
 73%|                                                   |
805/1100 [00:11<00:03, 79.34it/s]
 74%|                                                   |
813/1100 [00:11<00:03, 76.90it/s]
 75%|                                                  |
821/1100 [00:11<00:03, 75.46it/s]
 75%|                                                  |
829/1100 [00:11<00:03, 73.86it/s]
 76%|                                                  |
837/1100 [00:11<00:03, 73.10it/s]
 77%|                                                  |
845/1100 [00:12<00:03, 72.37it/s]
 78%|                                                 |
853/1100 [00:12<00:03, 71.98it/s]
 78%|                                                 |
861/1100 [00:12<00:03, 70.60it/s]
 79%|                                                 |
869/1100 [00:12<00:03, 69.58it/s]
 80%|                                                 |
877/1100 [00:12<00:03, 70.07it/s]
 80%|                                                |
885/1100 [00:12<00:03, 70.50it/s]
 81%|                                                |
893/1100 [00:12<00:02, 70.63it/s]
 82%|                                               |
901/1100 [00:12<00:02, 71.22it/s]
 83%|                                               |
909/1100 [00:12<00:02, 71.51it/s]
 83%|                                               |
917/1100 [00:13<00:02, 69.08it/s]
 84%|                                              |
925/1100 [00:13<00:02, 69.58it/s]
 85%|                                              |
933/1100 [00:13<00:02, 70.17it/s]
```

```
 86%|                                                  |
941/1100 [00:13<00:02, 70.06it/s]
 86%|                                                  |
949/1100 [00:13<00:02, 70.26it/s]
 87%|                                                  |
957/1100 [00:13<00:02, 70.77it/s]
 88%|                                                  |
965/1100 [00:13<00:01, 70.74it/s]
 88%|                                                 |
973/1100 [00:13<00:01, 70.63it/s]
 89%|                                                  |
981/1100 [00:13<00:01, 70.13it/s]
 90%|                                                 |
989/1100 [00:14<00:01, 70.45it/s]
 91%|                                                 |
997/1100 [00:14<00:01, 70.86it/s]
 91%|                                                |
1005/1100 [00:14<00:01, 71.16it/s]
 92%|                                                |
1013/1100 [00:14<00:01, 70.62it/s]
 93%|                                                |
1021/1100 [00:14<00:01, 68.11it/s]
 94%|                                               |
1029/1100 [00:14<00:01, 69.12it/s]
 94%|                                               |
1036/1100 [00:14<00:00, 69.24it/s]
 95%|                                               |
1043/1100 [00:14<00:00, 68.39it/s]
 96%|                                               |
1051/1100 [00:15<00:00, 69.29it/s]
 96%|                                              |
1059/1100 [00:15<00:00, 69.84it/s]
 97%|                                              |
1067/1100 [00:15<00:00, 70.06it/s]
 98%|                                             |
1075/1100 [00:15<00:00, 69.94it/s]
 98%|                                             |
1082/1100 [00:15<00:00, 69.49it/s]
 99%|                                            |
1089/1100 [00:15<00:00, 67.60it/s]
100%|                                            |
1100/1100 [00:15<00:00, 69.98it/s]
 80%|
| 8/10 [02:07<00:31, 15.87s/it]
  0%|
| 0/1100 [00:00<?, ?it/s]
  1%|
| 8/1100 [00:00<00:15, 71.55it/s]
```

```
  1%|
| 16/1100 [00:00<00:15, 69.33it/s]
  2%|
| 24/1100 [00:00<00:15, 70.63it/s]
  3%|
| 32/1100 [00:00<00:14, 71.28it/s]
  4%|
| 40/1100 [00:00<00:15, 70.28it/s]
  4%|
| 48/1100 [00:00<00:14, 70.37it/s]
  5%|
| 56/1100 [00:00<00:15, 68.97it/s]
  6%|
| 65/1100 [00:00<00:13, 74.25it/s]
  7%|
| 74/1100 [00:01<00:13, 77.68it/s]
  7%|
| 82/1100 [00:01<00:13, 75.73it/s]
  8%|
| 91/1100 [00:01<00:12, 78.55it/s]
  9%|                                                                    |
100/1100 [00:01<00:12, 80.96it/s]
 10%|                                                                    |
109/1100 [00:01<00:11, 83.05it/s]
 11%|                                                                    |
118/1100 [00:01<00:11, 83.40it/s]
 12%|                                                                   |
127/1100 [00:01<00:11, 84.17it/s]
 12%|                                                                   |
136/1100 [00:01<00:11, 82.77it/s]
 13%|                                                                   |
145/1100 [00:01<00:12, 79.50it/s]
 14%|                                                                  |
153/1100 [00:02<00:12, 75.36it/s]
 15%|                                                                  |
161/1100 [00:02<00:12, 73.06it/s]
 15%|                                                                 |
169/1100 [00:02<00:13, 71.04it/s]
 16%|                                                                  |
177/1100 [00:02<00:13, 70.57it/s]
 17%|                                                                 |
185/1100 [00:02<00:12, 70.87it/s]
 18%|                                                                 |
193/1100 [00:02<00:13, 69.75it/s]
 18%|                                                                |
200/1100 [00:02<00:13, 69.21it/s]
 19%|                                                                |
208/1100 [00:02<00:12, 69.18it/s]
```

```
 20%|                                                                   |
216/1100 [00:02<00:13, 67.16it/s]
 20%|                                                                   |
223/1100 [00:03<00:13, 66.93it/s]
 21%|                                                                  |
231/1100 [00:03<00:12, 68.53it/s]
 22%|                                                                  |
238/1100 [00:03<00:12, 68.80it/s]
 22%|                                                                 |
246/1100 [00:03<00:12, 69.51it/s]
 23%|                                                                 |
254/1100 [00:03<00:12, 70.29it/s]
 24%|                                                                |
262/1100 [00:03<00:11, 70.28it/s]
 25%|                                                                |
270/1100 [00:03<00:12, 67.14it/s]
 25%|                                                                |
278/1100 [00:03<00:12, 68.07it/s]
 26%|                                                               |
287/1100 [00:03<00:11, 72.51it/s]
 27%|                                                               |
296/1100 [00:04<00:10, 76.52it/s]
 28%|                                                              |
305/1100 [00:04<00:10, 79.01it/s]
 29%|                                                              |
314/1100 [00:04<00:09, 79.53it/s]
 29%|                                                             |
323/1100 [00:04<00:09, 81.19it/s]
 30%|                                                             |
332/1100 [00:04<00:09, 80.79it/s]
 31%|                                                             |
341/1100 [00:04<00:09, 82.52it/s]
 32%|                                                            |
350/1100 [00:04<00:09, 83.31it/s]
 33%|                                                            |
359/1100 [00:04<00:08, 83.81it/s]
 33%|                                                            |
368/1100 [00:04<00:08, 82.32it/s]
 34%|                                                           |
377/1100 [00:05<00:09, 77.93it/s]
 35%|                                                           |
385/1100 [00:05<00:09, 74.31it/s]
 36%|                                                          |
393/1100 [00:05<00:09, 72.89it/s]
 36%|                                                          |
401/1100 [00:05<00:09, 72.10it/s]
 37%|                                                          |
409/1100 [00:05<00:09, 71.67it/s]
```

```
 38%|                                                                 |
417/1100 [00:05<00:09, 71.65it/s]
 39%|                                                                |
425/1100 [00:05<00:09, 71.15it/s]
 39%|                                                                |
433/1100 [00:05<00:09, 71.14it/s]
 40%|                                                                |
441/1100 [00:05<00:09, 70.63it/s]
 41%|                                                               |
449/1100 [00:06<00:09, 70.36it/s]
 42%|                                                               |
457/1100 [00:06<00:09, 70.76it/s]
 42%|                                                              |
465/1100 [00:06<00:08, 71.22it/s]
 43%|                                                              |
473/1100 [00:06<00:08, 70.78it/s]
 44%|                                                             |
481/1100 [00:06<00:08, 70.88it/s]
 44%|                                                             |
489/1100 [00:06<00:08, 70.81it/s]
 45%|                                                            |
497/1100 [00:06<00:08, 71.18it/s]
 46%|                                                            |
505/1100 [00:06<00:08, 70.66it/s]
 47%|                                                           |
513/1100 [00:06<00:08, 70.22it/s]
 47%|                                                           |
521/1100 [00:07<00:08, 66.38it/s]
 48%|                                                          |
528/1100 [00:07<00:08, 66.42it/s]
 49%|                                                          |
536/1100 [00:07<00:08, 67.88it/s]
 49%|                                                          |
544/1100 [00:07<00:08, 69.00it/s]
 50%|                                                         |
552/1100 [00:07<00:07, 69.55it/s]
 51%|                                                         |
560/1100 [00:07<00:07, 70.00it/s]
 52%|                                                        |
568/1100 [00:07<00:07, 70.58it/s]
 52%|                                                        |
576/1100 [00:07<00:07, 70.78it/s]
 53%|                                                        |
584/1100 [00:08<00:07, 70.80it/s]
 54%|                                                        |
592/1100 [00:08<00:07, 71.10it/s]
 55%|                                                       |
600/1100 [00:08<00:07, 70.37it/s]
```

```
 55%|                                                       |
608/1100 [00:08<00:07, 69.92it/s]
 56%|                                                      |
615/1100 [00:08<00:06, 69.75it/s]
 57%|                                                      |
623/1100 [00:08<00:06, 69.89it/s]
 57%|                                                      |
630/1100 [00:08<00:06, 69.24it/s]
 58%|                                                      |
637/1100 [00:08<00:06, 68.89it/s]
 59%|                                                     |
645/1100 [00:08<00:06, 69.34it/s]
 59%|                                                     |
653/1100 [00:08<00:06, 69.77it/s]
 60%|                                                     |
660/1100 [00:09<00:06, 69.42it/s]
 61%|                                                     |
667/1100 [00:09<00:06, 66.88it/s]
 61%|                                                    |
675/1100 [00:09<00:06, 68.13it/s]
 62%|                                                    |
683/1100 [00:09<00:06, 69.02it/s]
 63%|                                                    |
691/1100 [00:09<00:05, 69.75it/s]
 64%|                                                    |
699/1100 [00:09<00:05, 70.19it/s]
 64%|                                                   |
707/1100 [00:09<00:05, 70.59it/s]
 65%|                                                   |
715/1100 [00:09<00:05, 70.57it/s]
 66%|                                                   |
723/1100 [00:09<00:05, 70.39it/s]
 66%|                                                  |
731/1100 [00:10<00:05, 70.40it/s]
 67%|                                                  |
739/1100 [00:10<00:05, 70.88it/s]
 68%|                                                  |
747/1100 [00:10<00:05, 70.37it/s]
 69%|                                                  |
755/1100 [00:10<00:04, 70.03it/s]
 69%|                                                 |
763/1100 [00:10<00:04, 70.04it/s]
 70%|                                                 |
771/1100 [00:10<00:04, 70.38it/s]
 71%|                                                 |
779/1100 [00:10<00:04, 70.81it/s]
 72%|                                                 |
787/1100 [00:10<00:04, 70.78it/s]
```

```
 72%|                                                    |
795/1100 [00:11<00:04, 70.21it/s]
 73%|                                                    |
803/1100 [00:11<00:04, 66.70it/s]
 74%|                                                   |
811/1100 [00:11<00:04, 67.84it/s]
 74%|                                                   |
819/1100 [00:11<00:04, 69.05it/s]
 75%|                                                  |
826/1100 [00:11<00:03, 68.95it/s]
 76%|                                                   |
834/1100 [00:11<00:03, 69.94it/s]
 77%|                                                  |
842/1100 [00:11<00:03, 70.19it/s]
 77%|                                                 |
850/1100 [00:11<00:03, 70.14it/s]
 78%|                                                  |
858/1100 [00:11<00:03, 69.66it/s]
 79%|                                                 |
865/1100 [00:12<00:03, 69.72it/s]
 79%|                                                 |
872/1100 [00:12<00:03, 69.23it/s]
 80%|                                                |
879/1100 [00:12<00:03, 68.71it/s]
 81%|                                                 |
887/1100 [00:12<00:03, 69.39it/s]
 81%|                                                |
895/1100 [00:12<00:02, 69.89it/s]
 82%|                                                 |
902/1100 [00:12<00:02, 69.43it/s]
 83%|                                                |
909/1100 [00:12<00:02, 69.12it/s]
 83%|                                                |
916/1100 [00:12<00:02, 69.35it/s]
 84%|                                               |
924/1100 [00:12<00:02, 69.87it/s]
 85%|                                               |
931/1100 [00:12<00:02, 69.51it/s]
 85%|                                               |
938/1100 [00:13<00:02, 69.39it/s]
 86%|                                              |
946/1100 [00:13<00:02, 69.49it/s]
 87%|                                              |
953/1100 [00:13<00:02, 67.44it/s]
 87%|                                             |
961/1100 [00:13<00:02, 68.65it/s]
 88%|                                             |
968/1100 [00:13<00:01, 68.96it/s]
```

```
 89%|                                                  |
976/1100 [00:13<00:01, 69.54it/s]
 89%|                                                  |
983/1100 [00:13<00:01, 69.59it/s]
 90%|                                                  |
991/1100 [00:13<00:01, 70.11it/s]
 91%|                                                 |
999/1100 [00:13<00:01, 70.09it/s]
 92%|                                                 |
1007/1100 [00:14<00:01, 70.06it/s]
 92%|                                                 |
1015/1100 [00:14<00:01, 68.41it/s]
 93%|                                                 |
1022/1100 [00:14<00:01, 68.76it/s]
 94%|                                                |
1029/1100 [00:14<00:01, 68.84it/s]
 94%|                                                |
1037/1100 [00:14<00:00, 69.32it/s]
 95%|                                                |
1044/1100 [00:14<00:00, 69.03it/s]
 96%|                                                |
1052/1100 [00:14<00:00, 69.90it/s]
 96%|                                               |
1060/1100 [00:14<00:00, 70.30it/s]
 97%|                                               |
1068/1100 [00:14<00:00, 70.25it/s]
 98%|                                              |
1076/1100 [00:15<00:00, 70.45it/s]
 99%|                                              |
1084/1100 [00:15<00:00, 70.03it/s]
 99%|                                             |
1092/1100 [00:15<00:00, 70.37it/s]
100%|                                             |
1100/1100 [00:15<00:00, 71.36it/s]
 90%|
| 9/10 [02:22<00:15, 15.73s/it]
  0%|
| 0/1100 [00:00<?, ?it/s]
  1%|
| 8/1100 [00:00<00:15, 72.17it/s]
  1%|
| 16/1100 [00:00<00:15, 70.97it/s]
  2%|
| 24/1100 [00:00<00:15, 68.11it/s]
  3%|
| 32/1100 [00:00<00:15, 69.08it/s]
  4%|
| 39/1100 [00:00<00:15, 68.61it/s]
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  4%|
| 47/1100 [00:00<00:15, 69.31it/s]
  5%|
| 55/1100 [00:00<00:14, 69.69it/s]
  6%|
| 63/1100 [00:00<00:14, 70.01it/s]
  6%|
| 71/1100 [00:01<00:14, 70.51it/s]
  7%|
| 79/1100 [00:01<00:14, 70.43it/s]
  8%|
| 87/1100 [00:01<00:14, 69.58it/s]
  9%|
| 94/1100 [00:01<00:14, 69.26it/s]
  9%|                                                                    |
101/1100 [00:01<00:14, 69.37it/s]
 10%|                                                                    |
109/1100 [00:01<00:14, 69.76it/s]
 11%|                                                                    |
117/1100 [00:01<00:13, 70.21it/s]
 11%|                                                                   |
125/1100 [00:01<00:13, 70.58it/s]
 12%|                                                                   |
133/1100 [00:01<00:13, 69.22it/s]
 13%|                                                                  |
141/1100 [00:02<00:13, 69.61it/s]
 14%|                                                                   |
149/1100 [00:02<00:13, 70.17it/s]
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157/1100 [00:02<00:13, 70.11it/s]
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165/1100 [00:02<00:13, 69.94it/s]
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173/1100 [00:02<00:13, 70.54it/s]
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181/1100 [00:02<00:13, 69.76it/s]
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189/1100 [00:02<00:12, 70.52it/s]
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197/1100 [00:02<00:12, 70.75it/s]
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205/1100 [00:02<00:12, 70.19it/s]
 19%|                                                              |
213/1100 [00:03<00:12, 70.03it/s]
 20%|                                                              |
221/1100 [00:03<00:12, 69.76it/s]
 21%|                                                             |
228/1100 [00:03<00:13, 66.80it/s]
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 21%|                                                            |
236/1100 [00:03<00:12, 67.96it/s]
 22%|                                                            |
244/1100 [00:03<00:12, 69.21it/s]
 23%|                                                            |
252/1100 [00:03<00:12, 70.06it/s]
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260/1100 [00:03<00:11, 70.35it/s]
 24%|                                                            |
268/1100 [00:03<00:11, 70.55it/s]
 25%|                                                            |
276/1100 [00:03<00:11, 69.76it/s]
 26%|                                                            |
283/1100 [00:04<00:11, 69.77it/s]
 26%|                                                            |
291/1100 [00:04<00:11, 69.70it/s]
 27%|                                                            |
299/1100 [00:04<00:11, 70.44it/s]
 28%|                                                            |
307/1100 [00:04<00:11, 70.84it/s]
 29%|                                                            |
315/1100 [00:04<00:11, 70.98it/s]
 29%|                                                            |
323/1100 [00:04<00:11, 70.25it/s]
 30%|                                                            |
331/1100 [00:04<00:10, 70.70it/s]
 31%|                                                            |
339/1100 [00:04<00:10, 70.58it/s]
 32%|                                                            |
347/1100 [00:04<00:10, 70.42it/s]
 32%|                                                            |
355/1100 [00:05<00:10, 70.69it/s]
 33%|                                                            |
363/1100 [00:05<00:10, 71.07it/s]
 34%|                                                            |
371/1100 [00:05<00:10, 71.32it/s]
 34%|                                                            |
379/1100 [00:05<00:10, 71.13it/s]
 35%|                                                            |
387/1100 [00:05<00:10, 70.95it/s]
 36%|                                                            |
395/1100 [00:05<00:09, 71.26it/s]
 37%|                                                            |
403/1100 [00:05<00:09, 71.31it/s]
 37%|                                                            |
411/1100 [00:05<00:09, 70.67it/s]
 38%|                                                            |
419/1100 [00:05<00:09, 70.56it/s]
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 39%|                                                    |
427/1100 [00:06<00:09, 70.06it/s]
 40%|                                                    |
435/1100 [00:06<00:09, 70.03it/s]
 40%|                                                    |
443/1100 [00:06<00:09, 70.37it/s]
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451/1100 [00:06<00:09, 70.62it/s]
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459/1100 [00:06<00:09, 69.66it/s]
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467/1100 [00:06<00:09, 69.84it/s]
 43%|                                                    |
474/1100 [00:06<00:08, 69.65it/s]
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481/1100 [00:06<00:08, 69.58it/s]
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489/1100 [00:06<00:08, 69.94it/s]
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496/1100 [00:07<00:08, 69.95it/s]
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520/1100 [00:07<00:08, 70.34it/s]
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528/1100 [00:07<00:08, 70.15it/s]
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536/1100 [00:07<00:08, 70.28it/s]
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544/1100 [00:07<00:07, 70.16it/s]
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552/1100 [00:07<00:07, 69.85it/s]
 51%|                                                    |
560/1100 [00:07<00:07, 70.30it/s]
 52%|                                                    |
568/1100 [00:08<00:07, 70.27it/s]
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576/1100 [00:08<00:07, 70.52it/s]
 53%|                                                    |
584/1100 [00:08<00:07, 70.59it/s]
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592/1100 [00:08<00:07, 70.85it/s]
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600/1100 [00:08<00:07, 70.71it/s]
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608/1100 [00:08<00:06, 70.60it/s]
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 56%|                                                    |
616/1100 [00:08<00:06, 70.81it/s]
 57%|                                                    |
624/1100 [00:08<00:06, 68.31it/s]
 57%|                                                   |
631/1100 [00:09<00:06, 68.72it/s]
 58%|                                                   |
639/1100 [00:09<00:06, 70.79it/s]
 59%|                                                  |
648/1100 [00:09<00:05, 75.65it/s]
 60%|                                                  |
657/1100 [00:09<00:05, 79.07it/s]
 61%|                                                  |
666/1100 [00:09<00:05, 81.73it/s]
 61%|                                                 |
675/1100 [00:09<00:05, 81.17it/s]
 62%|                                                 |
684/1100 [00:09<00:05, 80.87it/s]
 63%|                                                 |
693/1100 [00:09<00:04, 83.09it/s]
 64%|                                                |
702/1100 [00:09<00:04, 81.87it/s]
 65%|                                                |
711/1100 [00:09<00:04, 82.08it/s]
 65%|                                                |
720/1100 [00:10<00:04, 82.69it/s]
 66%|                                                |
729/1100 [00:10<00:04, 83.24it/s]
 67%|                                               |
738/1100 [00:10<00:04, 83.70it/s]
 68%|                                               |
747/1100 [00:10<00:04, 84.39it/s]
 69%|                                               |
756/1100 [00:10<00:04, 85.36it/s]
 70%|                                              |
765/1100 [00:10<00:03, 85.98it/s]
 70%|                                              |
774/1100 [00:10<00:03, 86.35it/s]
 71%|                                              |
783/1100 [00:10<00:03, 86.69it/s]
 72%|                                             |
792/1100 [00:10<00:03, 86.72it/s]
 73%|                                             |
801/1100 [00:11<00:03, 86.16it/s]
 74%|                                             |
810/1100 [00:11<00:03, 84.70it/s]
 74%|                                             |
819/1100 [00:11<00:03, 85.47it/s]
```

```
 75%|                                                    |
828/1100 [00:11<00:03, 85.99it/s]
 76%|                                                    |
837/1100 [00:11<00:03, 86.37it/s]
 77%|                                                    |
846/1100 [00:11<00:02, 86.09it/s]
 78%|                                                   |
855/1100 [00:11<00:02, 85.53it/s]
 79%|                                                   |
864/1100 [00:11<00:02, 86.19it/s]
 79%|                                                   |
873/1100 [00:11<00:02, 85.38it/s]
 80%|                                                  |
882/1100 [00:11<00:02, 86.27it/s]
 81%|                                                  |
891/1100 [00:12<00:02, 86.37it/s]
 82%|                                                  |
900/1100 [00:12<00:02, 85.44it/s]
 83%|                                                 |
909/1100 [00:12<00:02, 84.00it/s]
 83%|                                                 |
918/1100 [00:12<00:02, 84.95it/s]
 84%|                                                 |
927/1100 [00:12<00:02, 85.72it/s]
 85%|                                                 |
936/1100 [00:12<00:01, 84.22it/s]
 86%|                                                |
945/1100 [00:12<00:01, 85.17it/s]
 87%|                                                |
954/1100 [00:12<00:01, 84.94it/s]
 88%|                                                |
963/1100 [00:12<00:01, 85.04it/s]
 88%|                                               |
972/1100 [00:13<00:01, 85.85it/s]
 89%|                                               |
981/1100 [00:13<00:01, 85.95it/s]
 90%|                                              |
990/1100 [00:13<00:01, 85.85it/s]
 91%|                                             |
999/1100 [00:13<00:01, 85.73it/s]
 92%|                                            |
1008/1100 [00:13<00:01, 84.90it/s]
 92%|                                           |
1017/1100 [00:13<00:00, 84.84it/s]
 93%|                                           |
1026/1100 [00:13<00:00, 84.73it/s]
 94%|                                          |
1035/1100 [00:13<00:00, 84.56it/s]
```

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 95%|                                                  |
1044/1100 [00:13<00:00, 85.19it/s]
 96%|                                                  |
1053/1100 [00:13<00:00, 85.10it/s]
 97%|                                                 |
1062/1100 [00:14<00:00, 84.65it/s]
 97%|                                                 |
1071/1100 [00:14<00:00, 85.21it/s]
 98%|                                                |
1080/1100 [00:14<00:00, 85.07it/s]
 99%|                                               |
1089/1100 [00:14<00:00, 78.01it/s]
100%|                                               |
1100/1100 [00:14<00:00, 75.58it/s]
100%|
 | 10/10 [02:37<00:00, 15.72s/it]
```

Perform a mock experiment in R^ metric computation. This ensures we are ok with the time limits.

[55]:
```
metrics_gelman = {}
for player_id in range(ensemble.shape[1]):
    print(F"_____________{W[player_id][0]}")
    metrics_gelman[W[player_id][0]] = gelman_rubin(ensemble[:, player_id, :])
    print(metrics[W[player_id][0]])
```

```
_____________Rafael-Nadal
1.0015802164534
_____________Juan-Monaco
1.0008875082145676
_____________Juan-Martin-Del-Potro
1.00114840351743
_____________Mardy-Fish
1.001962900351572
_____________Roger-Federer
1.0016873625359375
_____________Jo-Wilfried-Tsonga
1.0002906117335626
_____________Guillermo-Garcia-Lopez
1.0014391570086003
_____________Florian-Mayer
1.0004277115447164
_____________Milos-Raonic
1.0004653207691507
_____________Santiago-Giraldo
1.0008648983689004
_____________Andy-Murray
1.0006790301905655
_____________Richard-Gasquet
```

1.0008647534572055
_____David-Nalbandian
1.0007316126219956
_____Gilles-Muller
1.000841062351787
_____Andy-Roddick
1.0023944670268294
_____Novak-Djokovic
1.0008986001837674
_____Fernando-Verdasco
1.0004513141376254
_____Ivan-Dodig
1.0008323268449022
_____Ryan-Sweeting
1.0001394179544627
_____Radek-Stepanek
0.9998246762906501
_____John-Isner
1.0014430266624208
_____Pablo-Andujar
1.0010428069162867
_____Ivan-Ljubicic
1.000100600021446
_____Robin-Soderling
1.0005034283277565
_____Feliciano-Lopez
1.0004218233349516
_____Marin-Cilic
1.0006822749076258
_____Marcos-Baghdatis
1.0010208560047822
_____Michael-Llodra
1.0011798869391213
_____Gael-Monfils
1.0012214170531364
_____David-Ferrer
1.0009233495360197
_____Jarkko-Nieminen
0.9999531716746349
_____Kei-Nishikori
1.0019754719758431
_____Alexandr-Dolgopolov
1.0004060264970795
_____Tomas-Berdych
1.000283563963421
_____Somdev-K-Devvarman
1.001064113300657
_____Ivo-Karlovic

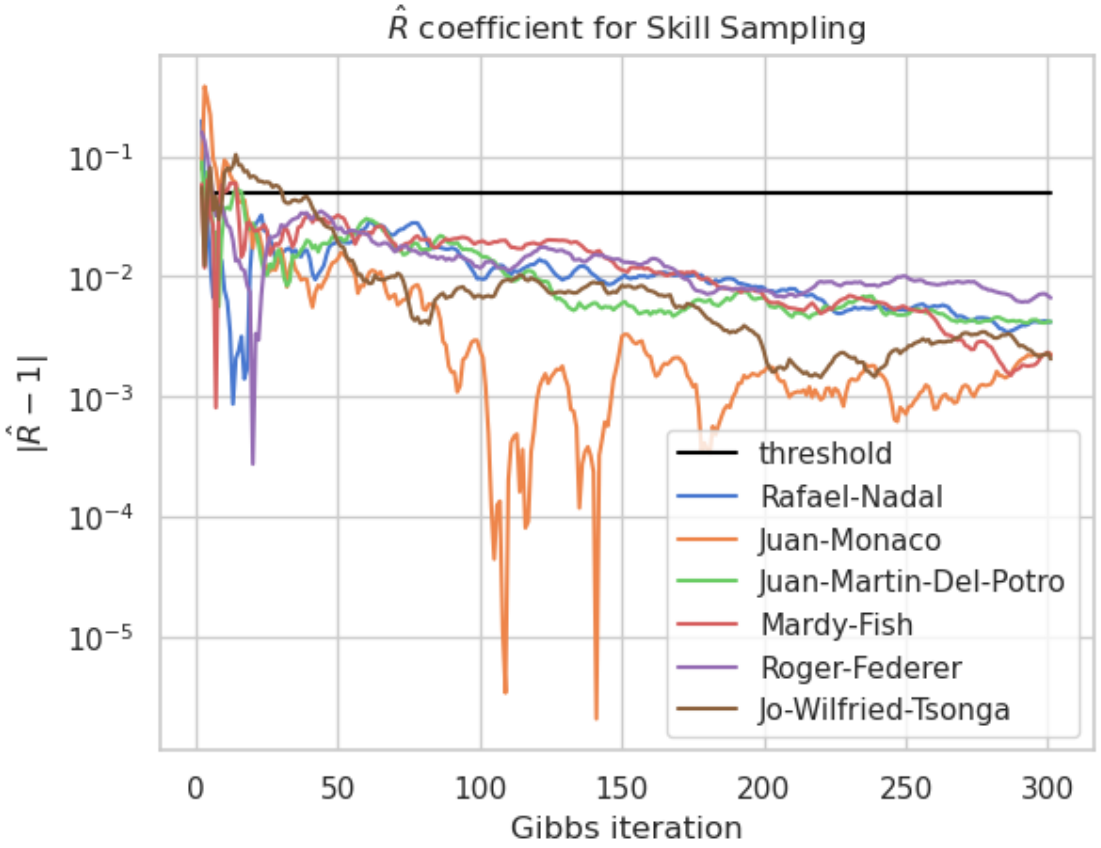
1.0023287099141642
_____Olivier-Rochus
1.0012593238051615
_____Bernard-Tomic
1.0003298559827611
_____Karol-Beck
0.9999855551985493
_____Ernests-Gulbis
0.9999701461372438
_____Nikolay-Davydenko
1.0001291018709395
_____Gilles-Simon
1.000366174544619
_____Nicolas-Almagro
1.0003525092115029
_____Fabio-Fognini
1.0009717311473298
_____Juan-Carlos-Ferrero
1.000397726062478
_____Marcel-Granollers
1.000934712744555
_____Stanislas-Wawrinka
1.0003888589765388
_____Janko-Tipsarevic
1.0001414218036957
_____Andreas-Seppi
1.0013483861894106
_____Simone-Bolelli
1.0009984215181913
_____Carlos-Berlocq
1.0010414087585968
_____Mikhail-Kukushkin
1.0006159716651386
_____Mikhail-Youzhny
1.000801202259435
_____Grigor-Dimitrov
1.0021643498948847
_____Sergiy-Stakhovsky
1.000263556062244
_____Victor-Hanescu
1.001063892254613
_____Horacio-Zeballos
1.0006978122145167
_____Pablo-Cuevas
1.0011375312990864
_____Eduardo-Schwank
1.0003464424552369
_____Robin-Haase

1.0007401387789403
_____Adrian-Mannarino
1.0003349865365103
_____Dmitry-Tursunov
1.0004834616297271
_____Kevin-Anderson
1.0005871470081966
_____Sam-Querrey
1.001308296297532
_____Philipp-Petzschner
1.0000262056712117
_____James-Blake
1.0007250010324584
_____Denis-Istomin
1.0005585780954527
_____Igor-Kunitsyn
1.0002947462637843
_____Philipp-Kohlschreiber
1.0001753160749
_____Tommy-Robredo
1.001647119102443
_____Lleyton-Hewitt
1.0011880439826577
_____Ryan-Harrison
1.001903053653184
_____Albert-Ramos
1.0001048039560032
_____Potito-Starace
1.0006249649133532
_____Rui-Machado
1.0006259849064736
_____Xavier-Malisse
1.0010458367031225
_____Jurgen-Melzer
0.9999608061696728
_____Igor-Andreev
1.0018661753488556
_____Juan-Ignacio-Chela
1.000724107974482
_____Viktor-Troicki
1.001010375675511
_____Yen-Hsun-Lu
0.9999031089501912
_____Alex-Bogomolov-Jr
1.0017070341941343
_____Fernando-Gonzalez
1.0010710567028198
_____Michael-Berrer

1.0004296590868464
_____Pere-Riba
1.0011444397758977
_____Ruben-Ramirez-Hidalgo
1.0005569867758586
_____Lukasz-Kubot
1.0006447175949371
_____Robert-Kendrick
0.9999916405603919
_____Dustin-Brown
1.000020032727234
_____Thomaz-Bellucci
1.0008340503601563
_____Albert-Montanes
1.0007927142335773
_____Andreas-Haider-Maurer
1.000557071301805
_____Jeremy-Chardy
1.0002790817570602
_____Arnaud-Clement
1.0014295424811193
_____Lukas-Rosol
1.0005953612132956
_____Rajeev-Ram
1.0002946275416136
_____Alexander-Peya
1.0007216824350518
_____Juan-Sebastian-Cabal
1.0002567771965347
_____Colin-Fleming
1.0002259072717306
_____Santiago-Gonzalez
0.9999676292595858
_____Marc-Lopez
0.999994086659364
_____Rohan-Bopanna
1.0002295332350097
_____Michael-Kohlmann
0.9997340703663712
_____Simon-Aspelin
0.9998643037585307
_____Mikhail-Elgin
1.0006213026172976
_____Robert-Lindstedt
1.000087338446047
_____Jean-Julien-Rojer
1.0001080114887198

[72]:
```
gelman_td = {}
for player_id in range(M):
    gelman_td[W[player_id][0]] = np.zeros((N-2))
    for t in range(2, N):
        gelman_td[W[player_id][0]][t-2] = gelman_rubin(ensemble[:, player_id, :
 ↪t])
```

[115]:
```
THRESHOLD =  5E-2
plt.figsize=(8, 6)
plt.plot(
    range(2, 300 + 2), THRESHOLD * np.ones_like(gelman_td[W[3][0]])[:300],
    c = "black",
    label="threshold"
)

for player_id in range(6):
    plt.plot(
        range(2, 300 + 2),
        np.abs(gelman_td[W[player_id][0]] - 1.0)[:300] ,
        label=f"{W[player_id][0]}"
    )
plt.yscale('log')
plt.xlabel("Gibbs iteration")
plt.ylabel("$|\hat{R} - 1|$")
plt.legend()
plt.title("$\hat{R}$ coefficient for Skill Sampling")
plt.show()
```

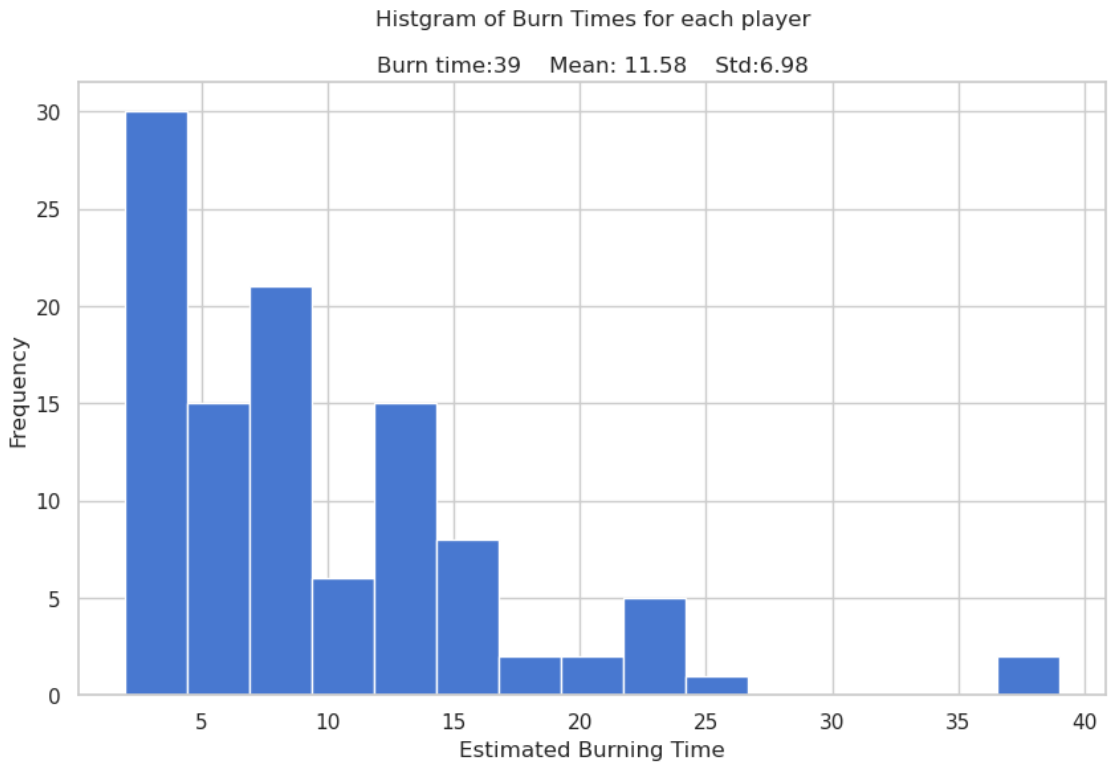


[129]:
```
THRESHOLD = 1E-1
burn_time = 0
burn_times={}
for player, trace in gelman_td.items():
    res = np.abs(np.abs(trace - 1.0) - THRESHOLD)
    curr = 2 + np.argmin(res)
    burn_times[player] = curr
    burn_time = max(burn_time, curr)
print(f"BURN TIME: {burn_time}")
```

```
BURN TIME: 39
```

[137]:
```
from scipy.stats import mode
plt.figure(figsize=(10,6))
plt.hist(burn_times.values(), bins=15)
mn = 2 + round(burn_np.mean(),2)
md = 2 + round(mode(burn_np,axis=None, keepdims=False).mode,2)
std = round(burn_np.std(), 2)
plt.title(f"Histgram of Burn Times for each player\n\n"+f"Burn time:{burn_time}␣
 ↪   Mean: {mn}    Std:{std}")
```

```
burn_np = np.array(list(burn_times.values()))
plt.xlabel("Estimated Burning Time")
plt.ylabel("Frequency")
plt.savefig("hist_burn_time.png")
```



2.2 Burn and Thin

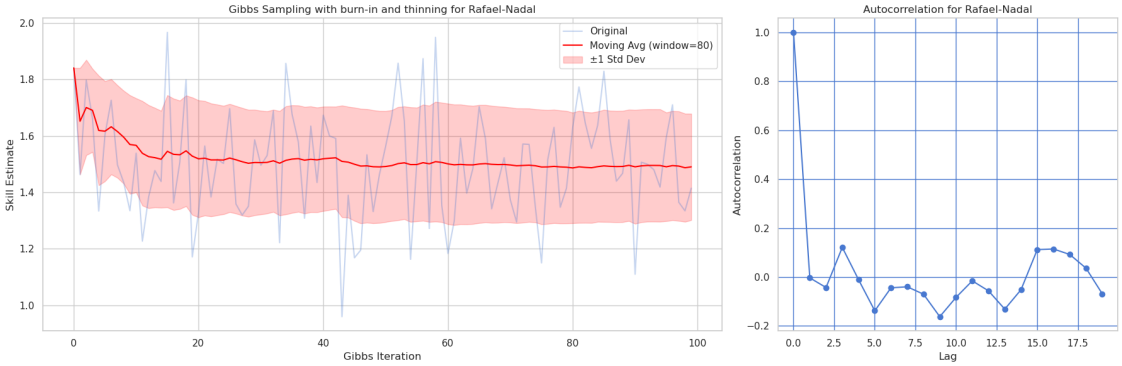
[204]:
```
thin_factor = 10
burn_factor = 1000
# number of iterations
num_samples_to_generate = 100
num_iters = burn_factor + num_samples_to_generate * thin_factor
# perform gibbs sampling, skill samples is an num_players x num_samples array
np.random.seed(0)
iid_samples = gibbs_sample(G, M, num_iters)[:,burn_factor::thin_factor]
```

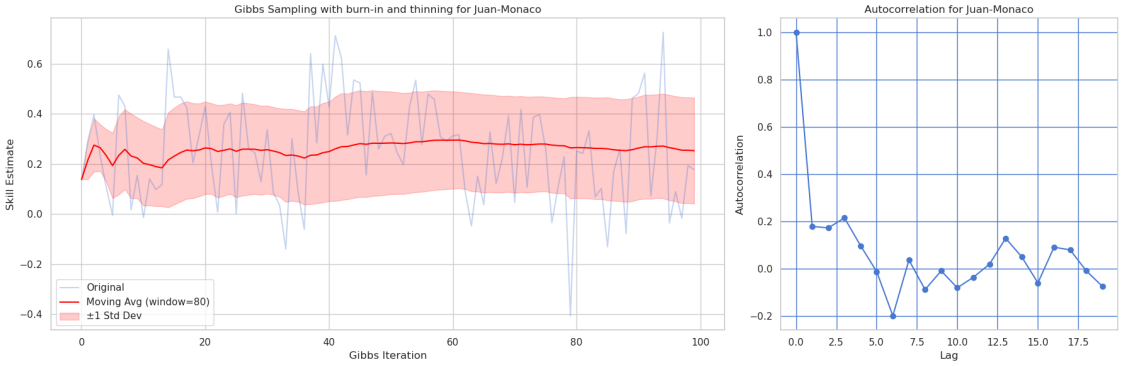
```
100%|                                                  |
2000/2000 [00:29<00:00, 68.47it/s]
```

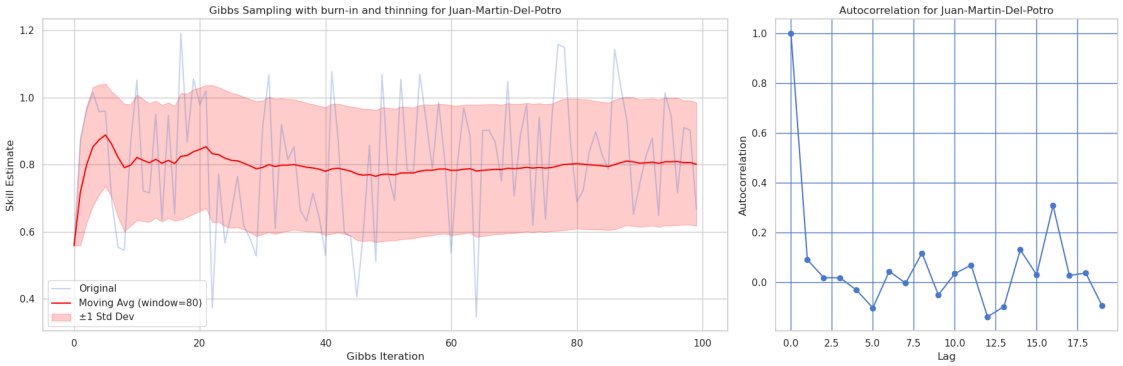
[205]:
```
# Plot the Gibbs sampling progress and autocorrelation for the first 3 players
for player_id in range(3):  # First three players
    fig = plt.figure(figsize=(18, 6))
```

```
    spec = gridspec.GridSpec(1, 2, width_ratios=[2, 1])  # Two subplots, 2:1␣
↪width ratio

    # Trajectory Plot
    ax0 = fig.add_subplot(spec[0])
    iterations = np.arange(iid_samples.shape[1])

    # Compute moving average and standard deviation
    ma_skill_samples, ma_std = dynamic_moving_average(iid_samples[player_id, :
↪], window_size)

    # Original skill samples
    sns.lineplot(
        ax=ax0,
        x=iterations,
        y=iid_samples[player_id, :],
        label="Original",
        alpha=0.3
    )

    # Moving average
    sns.lineplot(
        ax=ax0,
        x=iterations,
        y=ma_skill_samples,
        label=f"Moving Avg (window={window_size})",
        color="red"
    )

    # Error bars
    ax0.fill_between(
        iterations,
        ma_skill_samples - ma_std,
        ma_skill_samples + ma_std,
        color="red",
        alpha=0.2,
        label="±1 Std Dev"
    )
    ax0.set_xlabel("Gibbs Iteration")
    ax0.set_ylabel("Skill Estimate")
    ax0.set_title(f"Gibbs Sampling with burn-in and thinning for␣
↪{W[player_id][0]}")
    ax0.legend()

    # Autocorrelation Plot
    ax1 = fig.add_subplot(spec[1])
    autocor = np.zeros(20)
```

```
    for lag in range(20):
        autocor[lag] = pd.Series(iid_samples[player_id, :]).autocorr(lag=lag)

    ax1.plot(range(20), autocor, marker="o")
    ax1.set_xlabel("Lag")
    ax1.set_ylabel("Autocorrelation")
    ax1.set_title(f"Autocorrelation for {W[player_id][0]}")
    ax1.grid( which='major', color='b')
    # Adjust layout and show the plot
    plt.tight_layout()
    plt.savefig(f"iid_sample_ranking_id{player_id}.png")
    plt.show()
```

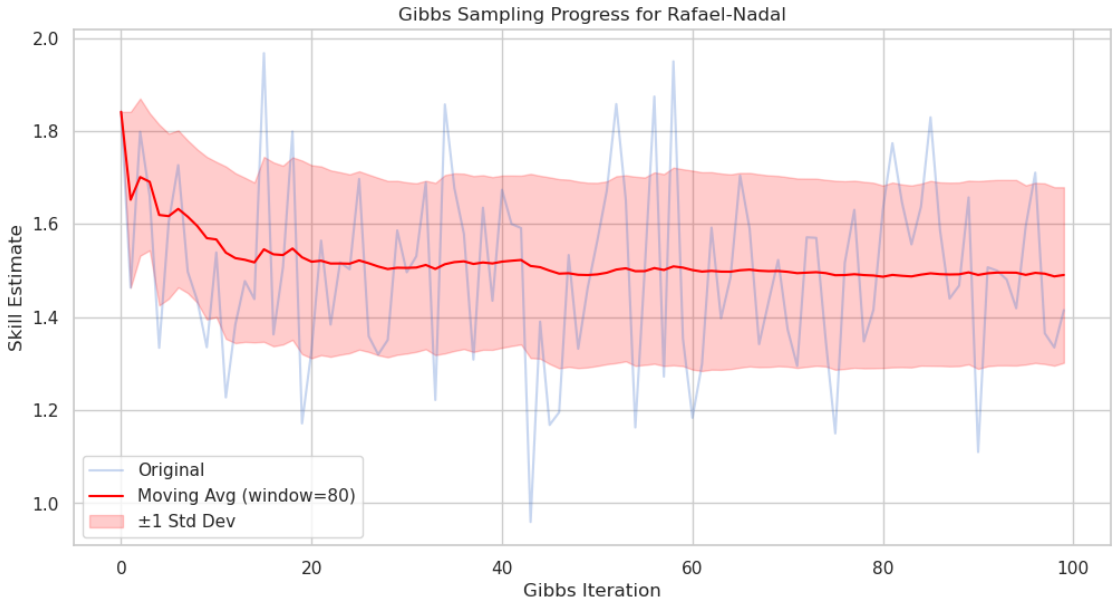


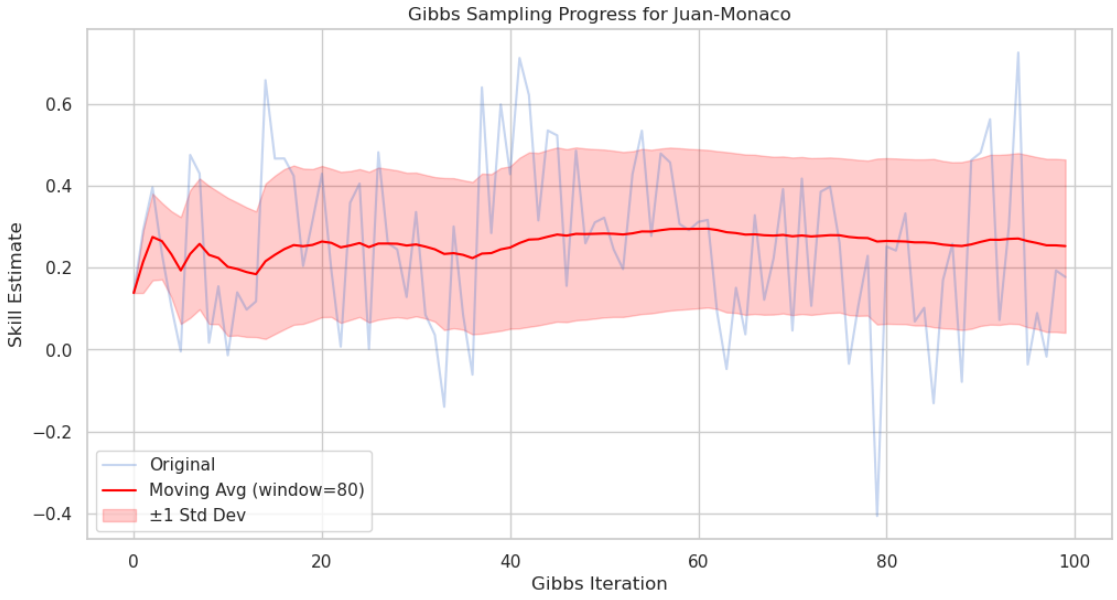


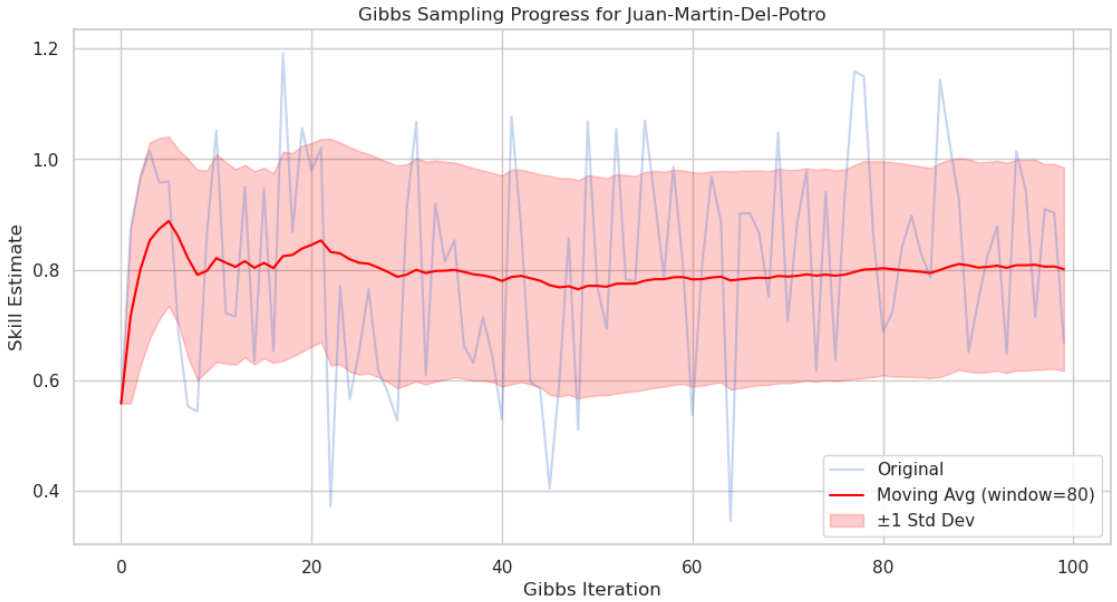


[206]:
```python
# Plot the Gibbs sampling progress with moving average and error bars
for player_id in range(3):  # First three players
    plt.figure(figsize=(12, 6))

    # Compute moving average and standard deviation
    ma_skill_samples, ma_std = dynamic_moving_average(iid_samples[player_id, :
 ↪], window_size)

    # Plot original skill samples
    sns.lineplot(
        x=iterations[:100],
        y=iid_samples[player_id, :100],
        label="Original",
        alpha=0.3,  # Make the original plot more transparent
    )

    # Plot moving average
    sns.lineplot(
        x=iterations[:100],
        y=ma_skill_samples[:100],
        label=f"Moving Avg (window={window_size})",
        color="red"
    )

    # Add error bars
    plt.fill_between(
        iterations[:100],
        (ma_skill_samples - ma_std)[:100],
        (ma_skill_samples + ma_std)[:100],
        color="red",
        alpha=0.2,
        label="±1 Std Dev"
    )
```

```
    # Add labels and title
    plt.xlabel("Gibbs Iteration")
    plt.ylabel("Skill Estimate")
    plt.title(f"Gibbs Sampling Progress for {W[player_id][0]}")
    plt.legend()
    plt.savefig(f"task_a_iid_gibbs_{W[player_id][0]}")
```







3 EP ranking

[207]:
```
num_iters = 3
# run message passing algorithm, returns mean and precision for each player
mean_player_skills, precision_player_skills = eprank(G, M, num_iters)
```