1_discretiztion

March 15, 2023

1 Discretization

The aim of the notebook is to evaluate the performance of CategoricalHMM on discretized data

[21]:
```
import numpy as np
from hmmlearn import hmm
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd
import urllib
import itertools
from scipy.stats import multivariate_normal
from source.model.discretized_HMM import DiscreteHMM, DISCRETIZATION_TECHNIQUES
```

[22]:
```
import ssm
from ssm.util import find_permutation
from ssm.plots import gradient_cmap, white_to_color_cmap

import matplotlib.pyplot as plt
%matplotlib inline

import seaborn as sns
sns.set_style("white")
# sns.set_context("talk")

# https://xkcd.com/color/rgb/

with urllib.request.urlopen('https://xkcd.com/color/rgb.txt') as f:
    colors = f.readlines()
color_names = [str(c)[2:].split('\\t')[0] for c in colors[1:]]

colors = sns.xkcd_palette(color_names)
cmap = gradient_cmap(colors)
```

[23]:
```
colors
```

[23]:
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```

[24]:
```
# https://hmmlearn.readthedocs.io/en/latest/tutorial.html

np.random.seed(42)

true_model3 = hmm.GaussianHMM(n_components=3, covariance_type="full")
true_model3.startprob_ = np.array([0.6, 0.3, 0.1])
true_model3.transmat_ = np.array([[0.7, 0.2, 0.1],
                                  [0.3, 0.5, 0.2],
                                  [0.3, 0.3, 0.4]])

true_model3.means_ = np.array([[0.0, 0.0], [3.0, -3.0], [4.0, 3.0]])
true_model3.covars_ = np.array([[[1, -.5], [-.5, 1.2]], [[.6, -.5], [-.5, 1.
 ↪2]], [[1.5, .5], [.5, 2.2]]]) * .8

true_model3.sample(10)
```

[24]:
```
(array([[ 0.9694375 , -0.83691634],
        [-0.72845739,  1.72027549],
        [ 0.13888981, -0.73856628],
        [-1.19070703, -0.62107079],
        [-1.39713416,  0.05274311],
        [-0.09710759, -1.41211893],
        [ 0.77049997, -0.29208482],
        [ 0.45061783, -0.42945405],
        [ 0.93529815, -0.11410115],
        [ 1.41712714,  0.27877223]]),
 array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0]))
```

[25]:
```
true_model2 = hmm.GaussianHMM(n_components=2, covariance_type="full")
true_model2.startprob_ = true_model3.startprob_[:2] / true_model3.startprob_[:
 ↪2].sum()
true_model2.transmat_ = true_model3.transmat_[:2, :2] / true_model3.transmat_[:
 ↪2, :2].sum(axis=1).reshape(-1, 1)

true_model2.means_ = true_model3.means_[:2]
true_model2.covars_ = true_model3.covars_[:2]

true_model2.sample(10)
```

[25]:
```
(array([[ 0.38101918, -0.47075945],
        [ 2.02364148, -2.5232011 ],
        [-1.36473817,  2.95830902],
        [-0.44026515,  0.72275594],
        [-0.11525016, -1.57529795],
        [ 0.89312562,  0.05620838],
        [ 0.88485255, -0.93366053],
        [ 3.63129627, -3.48988934],
        [ 0.05286998,  0.89759822],
        [ 0.43951158, -0.871224  ]]),
 array([0, 1, 0, 0, 0, 0, 0, 1, 0, 0]))
```

[26]:
```
norm1 = multivariate_normal(true_model3.means_[0], true_model3.covars_[0])
norm2 = multivariate_normal(true_model3.means_[1], true_model3.covars_[1])
norm3 = multivariate_normal(true_model3.means_[2], true_model3.covars_[2])
```

[27]:
```
sample_sizes = [50, 100, 1000, 10000]
nodes_numbers = [3, 5, 7, 10, 15, 20, 25, 30, 40, 50, 75, 100]
```

[28]:
```
def eval_model(n_components, number_of_nodes, discretizing, X, Z):
    if discretizing is None:
        myHMM = hmm.GaussianHMM(n_components, n_iter=150)
    else:
        myHMM = DiscreteHMM(discretizing, number_of_nodes, n_components,␣
 ↪n_iter=150)
    myHMM.fit(X)

    if discretizing is None:
        Z_hat = myHMM.predict(X)
        ll = myHMM.score(X)
    else:
        Xd = myHMM._discretize(X, False)
        Z_hat = myHMM.predict(Xd)
        ll = myHMM.score(Xd)

    if np.unique(Z_hat).shape[0] == n_components:
        Z_hat = find_permutation(Z, Z_hat)[Z_hat]
        acc = (Z_hat == Z).mean()
    else:
        print(f"Recognized {np.unique(Z_hat).shape[0]} instead of␣
 ↪{n_components} states!")
        acc = -1
    return myHMM, ll, acc


def provide_grid(X):
    x1, y1 = X.min(axis=0) * 1.1
```

```
    x2, y2 = X.max(axis=0) * 1.1

    XX, YY = np.meshgrid(np.linspace(x1, x2, 100), np.linspace(y1, y2, 100))
    data = np.column_stack((XX.ravel(), YY.ravel()))
    lls = np.concatenate([norm1.pdf(data).reshape(-1, 1), norm2.pdf(data).
 ↪reshape(-1, 1), norm3.pdf(data).reshape(-1, 1)], axis=1)
    return XX, YY, lls


def plot_true_HMM(X, Z, n_components, XX, YY, lls):
    plt.figure(figsize=(5, 5))
    for k in range(n_components):
        plt.plot(X[Z==k, 0], X[Z==k, 1], 'o', mfc=colors[k], mec='none', ms=4,␣
 ↪alpha=.5)
        plt.contour(XX, YY, np.exp(lls[:,k]).reshape(XX.shape),␣
 ↪cmap=white_to_color_cmap(colors[k]), levels=8)

    plt.plot(X[:,0], X[:,1], '-k', lw=1, alpha=.1)
    plt.xlabel("$x_1$")
    plt.ylabel("$x_2$")
    plt.title("Observation Distributions")
    plt.show()

    return XX, YY, lls

def compare_models(models, X, XX, YY, lls, target_ll):
    fig, axs = plt.subplots(len(nodes_numbers), len(DISCRETIZATION_TECHNIQUES),␣
 ↪sharex=True, sharey=True, figsize=(10, 10))
    summary = []
    for i, j in itertools.product(range(len(DISCRETIZATION_TECHNIQUES) + 1),␣
 ↪range(len(nodes_numbers))):
        discretizing, number_of_nodes = [*DISCRETIZATION_TECHNIQUES, None][i],␣
 ↪nodes_numbers[j]
        if number_of_nodes > sample_size:
            continue
        summary.append({
            'discretizing': discretizing, 'number_of_nodes': number_of_nodes,
            'accuracy': models[discretizing, number_of_nodes]['acc'],
            'log-likelihood': models[discretizing, number_of_nodes]['ll'],
            'likelihood-ratio': np.exp(models[discretizing,␣
 ↪number_of_nodes]['ll'] - target_ll)
        })

        if discretizing is not None:
            myHMM = models[discretizing, number_of_nodes]['model']
            Xd = myHMM._discretize(X, False)
```

```
            for k in range(2):
                axs[j, i].contour(XX, YY, np.exp(lls[:,k]).reshape(XX.shape),␣
↪cmap=white_to_color_cmap(colors[k]), levels=5, alpha=.4)
            for k in range(number_of_nodes):
                axs[j, i].plot(X[Xd[:, 0] == k, 0], X[Xd[:, 0] == k, 1], 'o',␣
↪mec='none', ms=2, alpha=.5, mfc=colors[k % len(colors)])
            for k in range(number_of_nodes):
                axs[j, i].plot(myHMM.nodes[0, k], myHMM.nodes[1, k], '*',␣
↪mec='none', ms=4, color='black', mfc=colors[k % len(colors)])

    for ax, col in zip(axs[0], DISCRETIZATION_TECHNIQUES):
        ax.set_title(col)

    for ax, row in zip(axs[:,0], nodes_numbers):
        ax.set_ylabel(row, rotation=90, size='large')

    fig.tight_layout()
    plt.show()
    summary = pd.DataFrame(summary).sort_values('number_of_nodes')
    display(summary)
    print(summary.to_latex())
    sns.lineplot(data=summary, x='number_of_nodes', y='accuracy',␣
↪hue='discretizing')
    plt.title("Accuracy")
    plt.show()
    sns.lineplot(data=summary, x='number_of_nodes', y='log-likelihood',␣
↪hue='discretizing')
    plt.title("Log-likelihood")
    plt.show()


def evaluation(sample_size, n_components):
    true_model = true_model2 if n_components == 2 else true_model3
    X, Z = true_model.sample(sample_size)
    ll_target = true_model.score(X)

    XX, YY, lls = provide_grid(X)
    models = dict()
    for discretizing, number_of_nodes in itertools.
↪product([*DISCRETIZATION_TECHNIQUES, None], nodes_numbers):
        if number_of_nodes > sample_size:
            continue
        myHMM, ll, acc = eval_model(n_components, number_of_nodes,␣
↪discretizing, X, Z)
        models[discretizing, number_of_nodes] = {'ll': ll, 'acc': acc, 'model':␣
↪myHMM}
```

```
    XX, YY, lls = provide_grid(X)
    plot_true_HMM(X, Z, n_components, XX, YY, lls)
    compare_models(models, X, XX, YY, lls, ll_target)
```

[29]:
```
for sample_size in sample_sizes:
    print(f"sample_size = {sample_size}")
    evaluation(sample_size, 2)
    evaluation(sample_size, 3)
```

```
Fitting a model with 51 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 61 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 81 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 101 free scalar parameters with only 50 data points will
result in a degenerate solution.

sample_size = 50

Fitting a model with 61 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 81 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 101 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 51 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 61 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 81 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 95 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 51 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 53 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 79 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 91 free scalar parameters with only 50 data points will
result in a degenerate solution.
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

```
Recognized 1 instead of 2 states!
Recognized 1 instead of 2 states!

/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
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/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

Observation Distributions
1
0
−1
−2
−3
−4
−5
x_2
−1
0
1
2
3
4
x_1

	discretizing	number_of_nodes	accuracy	log-likelihood	likelihood-ratio
0	random	3	0.96	-41.526897	3.176693e+40
30	uniform	3	0.52	-44.611755	1.452910e+39
20	latin_cube_q	3	0.90	-50.210981	5.376821e+36
40	None	3	0.98	-138.261531	3.094979e-02
10	latin_cube_u	3	0.94	-28.688368	1.195853e+46
21	latin_cube_q	5	0.54	-73.833036	2.962086e+26
41	None	5	0.98	-138.261526	3.094993e-02
11	latin_cube_u	5	0.56	-44.684450	1.351038e+39
1	random	5	0.70	-71.702807	2.493126e+27
31	uniform	5	-1.00	-50.397929	4.460002e+36
42	None	7	0.98	-138.261526	3.094993e-02
22	latin_cube_q	7	0.52	-76.683048	1.713377e+25

2	random	7	0.90	-71.578960	2.821825e+27
12	latin_cube_u	7	0.70	-78.816360	2.029398e+24
32	uniform	7	0.50	-64.024572	5.387154e+30
23	latin_cube_q	10	0.50	-85.395144	2.819926e+21
43	None	10	0.98	-138.261526	3.094994e-02
3	random	10	0.60	-96.926505	2.768416e+16
33	uniform	10	-1.00	-78.206321	3.735113e+24
13	latin_cube_u	10	0.80	-79.481328	1.043699e+24
44	None	15	0.98	-138.261527	3.094991e-02
34	uniform	15	0.94	-90.549430	1.628395e+19
24	latin_cube_q	15	0.96	-98.956653	3.635375e+15
4	random	15	0.54	-116.798388	6.486077e+07
14	latin_cube_u	15	0.56	-92.070992	3.555935e+18
5	random	20	0.54	-123.986170	4.901940e+04
25	latin_cube_q	20	0.56	-117.361457	3.693552e+07
35	uniform	20	0.94	-79.433561	1.094764e+24
45	None	20	0.98	-138.261527	3.094992e-02
15	latin_cube_u	20	0.90	-109.893584	6.466967e+10
36	uniform	25	0.62	-86.062338	1.447034e+21
16	latin_cube_u	25	0.82	-113.828089	1.264639e+09
46	None	25	0.98	-138.261526	3.094994e-02
26	latin_cube_q	25	0.92	-120.840128	1.139401e+06
6	random	25	0.80	-139.131405	1.296810e-02
17	latin_cube_u	30	0.56	-131.931937	1.736062e+01
27	latin_cube_q	30	0.54	-125.032959	1.720891e+04
47	None	30	0.98	-138.261526	3.094993e-02
37	uniform	30	0.64	-108.874296	1.792138e+11
7	random	30	0.70	-162.218601	1.219648e-12
18	latin_cube_u	40	0.66	-131.364801	3.061042e+01
38	uniform	40	0.50	-122.817038	1.578031e+05
28	latin_cube_q	40	0.54	-127.526491	1.421759e+03
48	None	40	0.98	-138.261528	3.094987e-02
8	random	40	0.50	-152.626025	1.787462e-08
39	uniform	50	0.54	-121.422615	6.363647e+05
19	latin_cube_u	50	0.54	-147.890627	2.036078e-06
9	random	50	0.52	-176.238097	9.945911e-19
29	latin_cube_q	50	0.54	-132.665569	8.335908e+00
49	None	50	0.98	-138.261527	3.094990e-02

```
/tmp/ipykernel_7714/2508230348.py:83: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(summary.to_latex())
```

```
\begin{tabular}{llrrrr}
\toprule
{} &  discretizing &  number\_of\_nodes &  accuracy &  log-likelihood &
```

```
likelihood-ratio \\
\midrule
0  &        random &                 3 &      0.96 &      -41.526897 &
3.176693e+40 \\
30 &       uniform &                 3 &      0.52 &      -44.611755 &
1.452910e+39 \\
20 &  latin\_cube\_q &                 3 &      0.90 &      -50.210981 &
5.376821e+36 \\
40 &          None &                 3 &      0.98 &     -138.261531 &
3.094979e-02 \\
10 &  latin\_cube\_u &                 3 &      0.94 &      -28.688368 &
1.195853e+46 \\
21 &  latin\_cube\_q &                 5 &      0.54 &      -73.833036 &
2.962086e+26 \\
41 &          None &                 5 &      0.98 &     -138.261526 &
3.094993e-02 \\
11 &  latin\_cube\_u &                 5 &      0.56 &      -44.684450 &
1.351038e+39 \\
1  &        random &                 5 &      0.70 &      -71.702807 &
2.493126e+27 \\
31 &       uniform &                 5 &     -1.00 &      -50.397929 &
4.460002e+36 \\
42 &          None &                 7 &      0.98 &     -138.261526 &
3.094993e-02 \\
22 &  latin\_cube\_q &                 7 &      0.52 &      -76.683048 &
1.713377e+25 \\
2  &        random &                 7 &      0.90 &      -71.578960 &
2.821825e+27 \\
12 &  latin\_cube\_u &                 7 &      0.70 &      -78.816360 &
2.029398e+24 \\
32 &       uniform &                 7 &      0.50 &      -64.024572 &
5.387154e+30 \\
23 &  latin\_cube\_q &                10 &      0.50 &      -85.395144 &
2.819926e+21 \\
43 &          None &                10 &      0.98 &     -138.261526 &
3.094994e-02 \\
3  &        random &                10 &      0.60 &      -96.926505 &
2.768416e+16 \\
33 &       uniform &                10 &     -1.00 &      -78.206321 &
3.735113e+24 \\
13 &  latin\_cube\_u &                10 &      0.80 &      -79.481328 &
1.043699e+24 \\
44 &          None &                15 &      0.98 &     -138.261527 &
3.094991e-02 \\
34 &       uniform &                15 &      0.94 &      -90.549430 &
1.628395e+19 \\
24 &  latin\_cube\_q &                15 &      0.96 &      -98.956653 &
3.635375e+15 \\
```

```
4  &        random &                15 &      0.54 &     -116.798388 &
6.486077e+07 \\
14 &  latin\_cube\_u &                15 &      0.56 &      -92.070992 &
3.555935e+18 \\
5  &        random &                20 &      0.54 &     -123.986170 &
4.901940e+04 \\
25 &  latin\_cube\_q &                20 &      0.56 &     -117.361457 &
3.693552e+07 \\
35 &       uniform &                20 &      0.94 &      -79.433561 &
1.094764e+24 \\
45 &          None &                20 &      0.98 &     -138.261527 &
3.094992e-02 \\
15 &  latin\_cube\_u &                20 &      0.90 &     -109.893584 &
6.466967e+10 \\
36 &       uniform &                25 &      0.62 &      -86.062338 &
1.447034e+21 \\
16 &  latin\_cube\_u &                25 &      0.82 &     -113.828089 &
1.264639e+09 \\
46 &          None &                25 &      0.98 &     -138.261526 &
3.094994e-02 \\
26 &  latin\_cube\_q &                25 &      0.92 &     -120.840128 &
1.139401e+06 \\
6  &        random &                25 &      0.80 &     -139.131405 &
1.296810e-02 \\
17 &  latin\_cube\_u &                30 &      0.56 &     -131.931937 &
1.736062e+01 \\
27 &  latin\_cube\_q &                30 &      0.54 &     -125.032959 &
1.720891e+04 \\
47 &          None &                30 &      0.98 &     -138.261526 &
3.094993e-02 \\
37 &       uniform &                30 &      0.64 &     -108.874296 &
1.792138e+11 \\
7  &        random &                30 &      0.70 &     -162.218601 &
1.219648e-12 \\
18 &  latin\_cube\_u &                40 &      0.66 &     -131.364801 &
3.061042e+01 \\
38 &       uniform &                40 &      0.50 &     -122.817038 &
1.578031e+05 \\
28 &  latin\_cube\_q &                40 &      0.54 &     -127.526491 &
1.421759e+03 \\
48 &          None &                40 &      0.98 &     -138.261528 &
3.094987e-02 \\
8  &        random &                40 &      0.50 &     -152.626025 &
1.787462e-08 \\
39 &       uniform &                50 &      0.54 &     -121.422615 &
6.363647e+05 \\
19 &  latin\_cube\_u &                50 &      0.54 &     -147.890627 &
2.036078e-06 \\
```

```
9  &        random &                50 &      0.52 &     -176.238097 &
9.945911e-19 \\
29 &  latin\_cube\_q &                50 &      0.54 &     -132.665569 &
8.335908e+00 \\
49 &          None &                50 &      0.98 &     -138.261527 &
3.094990e-02 \\
\bottomrule
\end{tabular}
```

```
Fitting a model with 65 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 80 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 95 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 125 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 155 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 65 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 80 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 92 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 125 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 149 free scalar parameters with only 50 data points will
result in a degenerate solution.
```

```
Fitting a model with 65 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 80 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 95 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 125 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 152 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 65 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 80 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 92 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 125 free scalar parameters with only 50 data points will
result in a degenerate solution.
Fitting a model with 152 free scalar parameters with only 50 data points will
result in a degenerate solution.
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

```
Recognized 1 instead of 3 states!
```

```
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
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  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
```

```
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
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  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
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  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

Observation Distributions
4
2
0
−2
−4
x_2
−2
−1
0
1
2
3
4
5
x_1

	discretizing	number_of_nodes	accuracy	log-likelihood	likelihood-ratio
0	random	3	0.18	-44.295856	2.764414e+53
30	uniform	3	-1.00	-49.882841	1.035633e+51
20	latin_cube_q	3	0.20	-31.399525	1.102576e+59
40	None	3	0.98	-168.307037	3.839118e-01
10	latin_cube_u	3	0.30	-36.336895	7.909260e+56
21	latin_cube_q	5	0.28	-69.922069	2.052485e+42
41	None	5	0.84	-171.925763	1.029529e-02
11	latin_cube_u	5	0.22	-63.518985	1.239093e+45
1	random	5	0.64	-66.724567	5.022703e+43
31	uniform	5	0.70	-53.809675	2.040816e+49
42	None	7	0.98	-168.307436	3.837587e-01
22	latin_cube_q	7	0.16	-71.707733	3.441725e+41

2	random	7	0.72	-78.177140	5.335168e+38
12	latin_cube_u	7	0.54	-73.264580	7.255143e+40
32	uniform	7	0.44	-60.478602	2.591348e+46
23	latin_cube_q	10	0.44	-92.579028	2.968163e+32
43	None	10	0.98	-168.306926	3.839542e-01
3	random	10	0.18	-91.115926	1.282050e+33
33	uniform	10	0.74	-62.158054	4.832245e+45
13	latin_cube_u	10	0.74	-68.739376	6.697567e+42
44	None	15	0.98	-168.306892	3.839673e-01
34	uniform	15	0.58	-91.515935	8.593758e+32
24	latin_cube_q	15	0.16	-101.509282	3.927603e+28
4	random	15	0.14	-106.165227	3.733160e+26
14	latin_cube_u	15	0.72	-85.205236	4.730258e+35
5	random	20	0.38	-121.860084	5.700158e+19
25	latin_cube_q	20	0.46	-98.703017	6.499395e+29
35	uniform	20	0.54	-96.403697	6.478210e+30
45	None	20	0.72	-183.793304	7.221557e-08
15	latin_cube_u	20	0.46	-103.925584	3.505428e+27
36	uniform	25	0.64	-110.793394	3.648287e+24
16	latin_cube_u	25	0.50	-95.827427	1.152726e+31
46	None	25	0.98	-168.306921	3.839561e-01
26	latin_cube_q	25	0.50	-115.433242	3.523943e+22
6	random	25	0.32	-138.289013	4.177280e+12
17	latin_cube_u	30	0.54	-106.906700	1.778521e+26
27	latin_cube_q	30	0.42	-115.905164	2.198242e+22
47	None	30	0.66	-200.125041	5.832404e-15
37	uniform	30	0.56	-113.740010	1.915976e+23
7	random	30	0.42	-136.976589	1.551930e+13
18	latin_cube_u	40	0.40	-112.490227	6.685964e+23
38	uniform	40	0.30	-113.682999	2.028382e+23
28	latin_cube_q	40	0.44	-129.158851	3.855429e+16
48	None	40	0.70	-183.305699	1.175967e-07
8	random	40	0.44	-145.597171	2.798985e+09
39	uniform	50	0.50	-125.433763	1.599033e+18
19	latin_cube_u	50	0.58	-114.407842	9.825489e+22
9	random	50	0.40	-157.084871	2.870490e+04
29	latin_cube_q	50	0.34	-123.810834	8.103766e+18
49	None	50	0.00	-169.433114	1.245037e-01

```
/tmp/ipykernel_7714/2508230348.py:83: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(summary.to_latex())
```

```
\begin{tabular}{llrrrr}
\toprule
{} &  discretizing &  number\_of\_nodes &  accuracy &  log-likelihood &
```

```
likelihood-ratio \\
\midrule
0  &        random &                 3 &      0.18 &      -44.295856 &
2.764414e+53 \\
30 &       uniform &                 3 &     -1.00 &      -49.882841 &
1.035633e+51 \\
20 &  latin\_cube\_q &                 3 &      0.20 &      -31.399525 &
1.102576e+59 \\
40 &          None &                 3 &      0.98 &     -168.307037 &
3.839118e-01 \\
10 &  latin\_cube\_u &                 3 &      0.30 &      -36.336895 &
7.909260e+56 \\
21 &  latin\_cube\_q &                 5 &      0.28 &      -69.922069 &
2.052485e+42 \\
41 &          None &                 5 &      0.84 &     -171.925763 &
1.029529e-02 \\
11 &  latin\_cube\_u &                 5 &      0.22 &      -63.518985 &
1.239093e+45 \\
1  &        random &                 5 &      0.64 &      -66.724567 &
5.022703e+43 \\
31 &       uniform &                 5 &      0.70 &      -53.809675 &
2.040816e+49 \\
42 &          None &                 7 &      0.98 &     -168.307436 &
3.837587e-01 \\
22 &  latin\_cube\_q &                 7 &      0.16 &      -71.707733 &
3.441725e+41 \\
2  &        random &                 7 &      0.72 &      -78.177140 &
5.335168e+38 \\
12 &  latin\_cube\_u &                 7 &      0.54 &      -73.264580 &
7.255143e+40 \\
32 &       uniform &                 7 &      0.44 &      -60.478602 &
2.591348e+46 \\
23 &  latin\_cube\_q &                10 &      0.44 &      -92.579028 &
2.968163e+32 \\
43 &          None &                10 &      0.98 &     -168.306926 &
3.839542e-01 \\
3  &        random &                10 &      0.18 &      -91.115926 &
1.282050e+33 \\
33 &       uniform &                10 &      0.74 &      -62.158054 &
4.832245e+45 \\
13 &  latin\_cube\_u &                10 &      0.74 &      -68.739376 &
6.697567e+42 \\
44 &          None &                15 &      0.98 &     -168.306892 &
3.839673e-01 \\
34 &       uniform &                15 &      0.58 &      -91.515935 &
8.593758e+32 \\
24 &  latin\_cube\_q &                15 &      0.16 &     -101.509282 &
3.927603e+28 \\
```

```
4  &        random &                15 &      0.14 &     -106.165227 &
3.733160e+26 \\
14 &  latin\_cube\_u &                15 &      0.72 &      -85.205236 &
4.730258e+35 \\
5  &        random &                20 &      0.38 &     -121.860084 &
5.700158e+19 \\
25 &  latin\_cube\_q &                20 &      0.46 &      -98.703017 &
6.499395e+29 \\
35 &       uniform &                20 &      0.54 &      -96.403697 &
6.478210e+30 \\
45 &          None &                20 &      0.72 &     -183.793304 &
7.221557e-08 \\
15 &  latin\_cube\_u &                20 &      0.46 &     -103.925584 &
3.505428e+27 \\
36 &       uniform &                25 &      0.64 &     -110.793394 &
3.648287e+24 \\
16 &  latin\_cube\_u &                25 &      0.50 &      -95.827427 &
1.152726e+31 \\
46 &          None &                25 &      0.98 &     -168.306921 &
3.839561e-01 \\
26 &  latin\_cube\_q &                25 &      0.50 &     -115.433242 &
3.523943e+22 \\
6  &        random &                25 &      0.32 &     -138.289013 &
4.177280e+12 \\
17 &  latin\_cube\_u &                30 &      0.54 &     -106.906700 &
1.778521e+26 \\
27 &  latin\_cube\_q &                30 &      0.42 &     -115.905164 &
2.198242e+22 \\
47 &          None &                30 &      0.66 &     -200.125041 &
5.832404e-15 \\
37 &       uniform &                30 &      0.56 &     -113.740010 &
1.915976e+23 \\
7  &        random &                30 &      0.42 &     -136.976589 &
1.551930e+13 \\
18 &  latin\_cube\_u &                40 &      0.40 &     -112.490227 &
6.685964e+23 \\
38 &       uniform &                40 &      0.30 &     -113.682999 &
2.028382e+23 \\
28 &  latin\_cube\_q &                40 &      0.44 &     -129.158851 &
3.855429e+16 \\
48 &          None &                40 &      0.70 &     -183.305699 &
1.175967e-07 \\
8  &        random &                40 &      0.44 &     -145.597171 &
2.798985e+09 \\
39 &       uniform &                50 &      0.50 &     -125.433763 &
1.599033e+18 \\
19 &  latin\_cube\_u &                50 &      0.58 &     -114.407842 &
9.825489e+22 \\
```

```
9  &        random &                50 &      0.40 &     -157.084871 &
2.870490e+04 \\
29 &  latin\_cube\_q &                50 &      0.34 &     -123.810834 &
8.103766e+18 \\
49 &          None &                50 &      0.00 &     -169.433114 &
1.245037e-01 \\
\bottomrule
\end{tabular}
```

```
sample_size = 100

Fitting a model with 101 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 151 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 201 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 101 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 149 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 197 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 101 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 151 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 201 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 149 free scalar parameters with only 100 data points will
```

```
result in a degenerate solution.
Fitting a model with 177 free scalar parameters with only 100 data points will
result in a degenerate solution.
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

```
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

	discretizing	number_of_nodes	accuracy	log-likelihood	likelihood-ratio
0	random	3	0.87	-60.496297	7.892350e+103
24	latin_cube_q	3	0.87	-74.206770	8.766447e+97
36	uniform	3	0.65	-101.388530	1.373837e+86
12	latin_cube_u	3	0.65	-97.493734	6.751862e+87
48	None	3	0.96	-315.200622	1.907759e-07
37	uniform	5	0.81	-109.701244	3.371082e+82
25	latin_cube_q	5	0.65	-137.688549	2.360680e+70
49	None	5	0.96	-315.200512	1.907969e-07
13	latin_cube_u	5	0.64	-129.776327	6.445727e+73
1	random	5	0.82	-132.361675	4.858132e+72
26	latin_cube_q	7	0.56	-165.690712	1.628743e+58
2	random	7	0.62	-165.080730	2.997534e+58

14	latin_cube_u	7	0.51	-145.360717	1.099151e+67
38	uniform	7	0.52	-138.782476	7.905890e+69
50	None	7	0.96	-315.200640	1.907725e-07
27	latin_cube_q	10	0.88	-191.039525	1.595890e+47
3	random	10	0.81	-198.670123	7.745979e+43
39	uniform	10	0.86	-151.563756	2.223882e+64
51	None	10	0.96	-315.200562	1.907874e-07
15	latin_cube_u	10	0.54	-198.882867	6.261563e+43
4	random	15	0.59	-249.479002	6.653661e+21
28	latin_cube_q	15	0.55	-244.037386	1.535764e+24
52	None	15	0.96	-315.200532	1.907931e-07
16	latin_cube_u	15	0.65	-218.671886	1.593753e+35
40	uniform	15	0.81	-188.584183	1.859279e+48
53	None	20	0.96	-315.200658	1.907691e-07
41	uniform	20	0.62	-193.104970	2.022979e+46
29	latin_cube_q	20	0.78	-250.129521	3.471710e+21
5	random	20	0.50	-275.669477	2.809840e+10
17	latin_cube_u	20	0.72	-230.285191	1.441540e+30
30	latin_cube_q	25	0.56	-267.717388	7.984173e+13
6	random	25	0.57	-286.003704	9.132376e+05
42	uniform	25	0.59	-214.978508	6.403756e+36
54	None	25	0.96	-315.200513	1.907968e-07
18	latin_cube_u	25	0.54	-252.578597	2.998634e+20
43	uniform	30	0.60	-239.963833	9.024970e+25
7	random	30	0.50	-306.602888	1.033884e-03
19	latin_cube_u	30	0.55	-266.944303	1.729723e+14
55	None	30	0.96	-315.200536	1.907923e-07
31	latin_cube_q	30	0.85	-269.504805	1.336487e+13
8	random	40	0.55	-325.298382	7.854564e-12
56	None	40	0.96	-315.200585	1.907831e-07
32	latin_cube_q	40	0.79	-300.660064	3.939199e-01
44	uniform	40	0.73	-247.194412	6.534997e+22
20	latin_cube_u	40	0.67	-277.322075	5.382294e+09
21	latin_cube_u	50	0.56	-321.241891	4.537679e-10
33	latin_cube_q	50	0.54	-328.361262	3.672233e-13
45	uniform	50	0.53	-290.003698	1.672664e+04
57	None	50	0.96	-315.200523	1.907949e-07
9	random	50	0.55	-346.841205	3.460931e-21
22	latin_cube_u	75	0.50	-318.727118	5.610297e-09
46	uniform	75	0.52	-292.294326	1.692784e+03
34	latin_cube_q	75	0.53	-340.454544	2.055344e-18
58	None	75	0.96	-315.200642	1.907721e-07
10	random	75	0.51	-380.391448	9.300529e-36
47	uniform	100	0.75	-323.455034	4.962242e-11
23	latin_cube_u	100	0.52	-336.317894	1.286498e-16
11	random	100	0.52	-421.407532	1.430371e-53
35	latin_cube_q	100	0.62	-349.006390	3.970681e-22
59	None	100	0.96	-315.200516	1.907961e-07

```
/tmp/ipykernel_7714/2508230348.py:83: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(summary.to_latex())
```

```
\begin{tabular}{llrrrr}
\toprule
{} &  discretizing &  number\_of\_nodes &  accuracy &  log-likelihood &
likelihood-ratio \\
\midrule
0  &        random &                3 &      0.87 &      -60.496297 &
7.892350e+103 \\
24 &  latin\_cube\_q &                3 &      0.87 &      -74.206770 &
8.766447e+97 \\
36 &       uniform &                3 &      0.65 &     -101.388530 &
1.373837e+86 \\
12 &  latin\_cube\_u &                3 &      0.65 &      -97.493734 &
6.751862e+87 \\
48 &          None &                3 &      0.96 &     -315.200622 &
1.907759e-07 \\
37 &       uniform &                5 &      0.81 &     -109.701244 &
3.371082e+82 \\
25 &  latin\_cube\_q &                5 &      0.65 &     -137.688549 &
2.360680e+70 \\
49 &          None &                5 &      0.96 &     -315.200512 &
1.907969e-07 \\
13 &  latin\_cube\_u &                5 &      0.64 &     -129.776327 &
6.445727e+73 \\
1  &        random &                5 &      0.82 &     -132.361675 &
4.858132e+72 \\
26 &  latin\_cube\_q &                7 &      0.56 &     -165.690712 &
1.628743e+58 \\
2  &        random &                7 &      0.62 &     -165.080730 &
2.997534e+58 \\
14 &  latin\_cube\_u &                7 &      0.51 &     -145.360717 &
1.099151e+67 \\
38 &       uniform &                7 &      0.52 &     -138.782476 &
7.905890e+69 \\
50 &          None &                7 &      0.96 &     -315.200640 &
1.907725e-07 \\
27 &  latin\_cube\_q &               10 &      0.88 &     -191.039525 &
1.595890e+47 \\
3  &        random &               10 &      0.81 &     -198.670123 &
7.745979e+43 \\
39 &       uniform &               10 &      0.86 &     -151.563756 &
2.223882e+64 \\
```

```
51 &          None &                10 &      0.96 &     -315.200562 &
1.907874e-07 \\
15 &  latin\_cube\_u &               10 &      0.54 &     -198.882867 &
6.261563e+43 \\
4  &        random &                15 &      0.59 &     -249.479002 &
6.653661e+21 \\
28 &  latin\_cube\_q &               15 &      0.55 &     -244.037386 &
1.535764e+24 \\
52 &          None &                15 &      0.96 &     -315.200532 &
1.907931e-07 \\
16 &  latin\_cube\_u &               15 &      0.65 &     -218.671886 &
1.593753e+35 \\
40 &       uniform &                15 &      0.81 &     -188.584183 &
1.859279e+48 \\
53 &          None &                20 &      0.96 &     -315.200658 &
1.907691e-07 \\
41 &       uniform &                20 &      0.62 &     -193.104970 &
2.022979e+46 \\
29 &  latin\_cube\_q &               20 &      0.78 &     -250.129521 &
3.471710e+21 \\
5  &        random &                20 &      0.50 &     -275.669477 &
2.809840e+10 \\
17 &  latin\_cube\_u &               20 &      0.72 &     -230.285191 &
1.441540e+30 \\
30 &  latin\_cube\_q &               25 &      0.56 &     -267.717388 &
7.984173e+13 \\
6  &        random &                25 &      0.57 &     -286.003704 &
9.132376e+05 \\
42 &       uniform &                25 &      0.59 &     -214.978508 &
6.403756e+36 \\
54 &          None &                25 &      0.96 &     -315.200513 &
1.907968e-07 \\
18 &  latin\_cube\_u &               25 &      0.54 &     -252.578597 &
2.998634e+20 \\
43 &       uniform &                30 &      0.60 &     -239.963833 &
9.024970e+25 \\
7  &        random &                30 &      0.50 &     -306.602888 &
1.033884e-03 \\
19 &  latin\_cube\_u &               30 &      0.55 &     -266.944303 &
1.729723e+14 \\
55 &          None &                30 &      0.96 &     -315.200536 &
1.907923e-07 \\
31 &  latin\_cube\_q &               30 &      0.85 &     -269.504805 &
1.336487e+13 \\
8  &        random &                40 &      0.55 &     -325.298382 &
7.854564e-12 \\
56 &          None &                40 &      0.96 &     -315.200585 &
1.907831e-07 \\
```

```
32 &  latin\_cube\_q &                40 &      0.79 &     -300.660064 &
3.939199e-01 \\
44 &       uniform &               40 &      0.73 &     -247.194412 &
6.534997e+22 \\
20 &  latin\_cube\_u &                40 &      0.67 &     -277.322075 &
5.382294e+09 \\
21 &  latin\_cube\_u &                50 &      0.56 &     -321.241891 &
4.537679e-10 \\
33 &  latin\_cube\_q &                50 &      0.54 &     -328.361262 &
3.672233e-13 \\
45 &       uniform &               50 &      0.53 &     -290.003698 &
1.672664e+04 \\
57 &          None &               50 &      0.96 &     -315.200523 &
1.907949e-07 \\
9  &        random &               50 &      0.55 &     -346.841205 &
3.460931e-21 \\
22 &  latin\_cube\_u &                75 &      0.50 &     -318.727118 &
5.610297e-09 \\
46 &       uniform &               75 &      0.52 &     -292.294326 &
1.692784e+03 \\
34 &  latin\_cube\_q &                75 &      0.53 &     -340.454544 &
2.055344e-18 \\
58 &          None &               75 &      0.96 &     -315.200642 &
1.907721e-07 \\
10 &        random &               75 &      0.51 &     -380.391448 &
9.300529e-36 \\
47 &       uniform &              100 &      0.75 &     -323.455034 &
4.962242e-11 \\
23 &  latin\_cube\_u &               100 &      0.52 &     -336.317894 &
1.286498e-16 \\
11 &        random &              100 &      0.52 &     -421.407532 &
1.430371e-53 \\
35 &  latin\_cube\_q &               100 &      0.62 &     -349.006390 &
3.970681e-22 \\
59 &          None &              100 &      0.96 &     -315.200516 &
1.907961e-07 \\
\bottomrule
\end{tabular}
```

Accuracy
discretizing
random
latin_cube_q
uniform
latin_cube_u
accuracy
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0
20
40
60
80
100
number_of_nodes

```
Fitting a model with 125 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 155 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 230 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 305 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 122 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 155 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 227 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 302 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 119 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 152 free scalar parameters with only 100 data points will
result in a degenerate solution.
```

```
Fitting a model with 218 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 305 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 122 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 152 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 230 free scalar parameters with only 100 data points will
result in a degenerate solution.
Fitting a model with 302 free scalar parameters with only 100 data points will
result in a degenerate solution.
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
```

```
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
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explicitly to suppress the warning
  warnings.warn(
```

Observation Distributions
6
4
2
0
−2
−4
x_2
−2
0
2
4
6
x_1

	discretizing	number_of_nodes	accuracy	log-likelihood	likelihood-ratio
0	random	3	0.64	-70.494707	1.167039e+128
24	latin_cube_q	3	0.21	-91.622727	7.785791e+118
36	uniform	3	0.22	-74.733851	1.682862e+126
12	latin_cube_u	3	0.41	-82.766463	5.464235e+122
48	None	3	0.97	-364.265495	3.048268e+00
37	uniform	5	0.28	-107.834977	7.086178e+111
25	latin_cube_q	5	0.48	-140.314409	5.556150e+97
49	None	5	0.97	-364.265505	3.048238e+00
13	latin_cube_u	5	0.55	-100.115102	1.596287e+115
1	random	5	0.47	-117.953667	2.857070e+107
26	latin_cube_q	7	0.65	-130.604796	9.153880e+101
2	random	7	0.46	-143.829740	1.652285e+96

14	latin_cube_u	7	0.50	-124.826272	2.959284e+104
38	uniform	7	0.60	-134.521572	1.822096e+100
50	None	7	0.03	-364.265418	3.048503e+00
27	latin_cube_q	10	0.34	-168.234781	4.160166e+85
3	random	10	0.27	-188.102817	9.784355e+76
39	uniform	10	0.42	-172.227223	7.677415e+83
51	None	10	0.97	-364.265341	3.048737e+00
15	latin_cube_u	10	0.54	-171.012395	2.587071e+84
4	random	15	0.41	-224.657767	1.302924e+61
28	latin_cube_q	15	0.31	-187.853120	1.255956e+77
52	None	15	0.03	-364.265427	3.048474e+00
16	latin_cube_u	15	0.63	-189.166839	3.376239e+76
40	uniform	15	0.42	-202.616185	4.869189e+70
53	None	20	0.03	-364.265428	3.048472e+00
41	uniform	20	0.13	-206.239570	1.299691e+69
29	latin_cube_q	20	0.52	-192.546840	1.149522e+75
5	random	20	0.26	-256.751808	1.501946e+47
17	latin_cube_u	20	0.38	-196.290505	2.720597e+73
30	latin_cube_q	25	0.49	-241.301178	7.705087e+53
6	random	25	0.51	-288.668679	2.066965e+33
42	uniform	25	0.42	-227.178000	1.048084e+60
54	None	25	0.03	-364.265632	3.047851e+00
18	latin_cube_u	25	0.55	-216.457447	4.745399e+64
43	uniform	30	0.39	-240.961933	1.081708e+54
7	random	30	0.27	-275.588771	9.905237e+38
19	latin_cube_u	30	0.35	-223.601243	3.747673e+61
55	None	30	0.97	-364.265609	3.047920e+00
31	latin_cube_q	30	0.36	-226.960333	1.302949e+60
8	random	40	0.40	-319.534911	8.133898e+19
56	None	40	0.97	-364.265494	3.048270e+00
32	latin_cube_q	40	0.46	-258.962235	1.646941e+46
44	uniform	40	0.45	-239.051648	7.306950e+54
20	latin_cube_u	40	0.51	-262.441023	5.079948e+44
21	latin_cube_u	50	0.40	-254.140246	2.045695e+48
33	latin_cube_q	50	0.38	-289.756958	6.961451e+32
45	uniform	50	0.57	-271.386844	6.618182e+40
57	None	50	0.97	-364.265489	3.048287e+00
9	random	50	0.36	-350.842761	2.058127e+06
22	latin_cube_u	75	0.27	-266.986202	5.394031e+42
46	uniform	75	0.29	-300.473092	1.544335e+28
34	latin_cube_q	75	0.33	-304.218055	3.650270e+26
58	None	75	0.97	-364.265488	3.048290e+00
10	random	75	0.41	-354.481296	5.410992e+04
47	uniform	100	0.43	-305.848718	7.147220e+25
23	latin_cube_u	100	0.37	-281.738865	2.113067e+36
11	random	100	0.29	-386.396216	7.461106e-10
35	latin_cube_q	100	0.49	-309.203317	2.496049e+24
59	None	100	0.03	-364.265404	3.048546e+00

```
/tmp/ipykernel_7714/2508230348.py:83: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(summary.to_latex())
```

```
\begin{tabular}{llrrrr}
\toprule
{} &  discretizing &  number\_of\_nodes &  accuracy &  log-likelihood &
likelihood-ratio \\
\midrule
0  &        random &                3 &      0.64 &      -70.494707 &
1.167039e+128 \\
24 &  latin\_cube\_q &                3 &      0.21 &      -91.622727 &
7.785791e+118 \\
36 &       uniform &                3 &      0.22 &      -74.733851 &
1.682862e+126 \\
12 &  latin\_cube\_u &                3 &      0.41 &      -82.766463 &
5.464235e+122 \\
48 &          None &                3 &      0.97 &     -364.265495 &
3.048268e+00 \\
37 &       uniform &                5 &      0.28 &     -107.834977 &
7.086178e+111 \\
25 &  latin\_cube\_q &                5 &      0.48 &     -140.314409 &
5.556150e+97 \\
49 &          None &                5 &      0.97 &     -364.265505 &
3.048238e+00 \\
13 &  latin\_cube\_u &                5 &      0.55 &     -100.115102 &
1.596287e+115 \\
1  &        random &                5 &      0.47 &     -117.953667 &
2.857070e+107 \\
26 &  latin\_cube\_q &                7 &      0.65 &     -130.604796 &
9.153880e+101 \\
2  &        random &                7 &      0.46 &     -143.829740 &
1.652285e+96 \\
14 &  latin\_cube\_u &                7 &      0.50 &     -124.826272 &
2.959284e+104 \\
38 &       uniform &                7 &      0.60 &     -134.521572 &
1.822096e+100 \\
50 &          None &                7 &      0.03 &     -364.265418 &
3.048503e+00 \\
27 &  latin\_cube\_q &               10 &      0.34 &     -168.234781 &
4.160166e+85 \\
3  &        random &               10 &      0.27 &     -188.102817 &
9.784355e+76 \\
39 &       uniform &               10 &      0.42 &     -172.227223 &
7.677415e+83 \\
```

```
51 &          None &                10 &      0.97 &     -364.265341 &
3.048737e+00 \\
15 &  latin\_cube\_u &               10 &      0.54 &     -171.012395 &
2.587071e+84 \\
4  &        random &                15 &      0.41 &     -224.657767 &
1.302924e+61 \\
28 &  latin\_cube\_q &               15 &      0.31 &     -187.853120 &
1.255956e+77 \\
52 &          None &                15 &      0.03 &     -364.265427 &
3.048474e+00 \\
16 &  latin\_cube\_u &               15 &      0.63 &     -189.166839 &
3.376239e+76 \\
40 &       uniform &                15 &      0.42 &     -202.616185 &
4.869189e+70 \\
53 &          None &                20 &      0.03 &     -364.265428 &
3.048472e+00 \\
41 &       uniform &                20 &      0.13 &     -206.239570 &
1.299691e+69 \\
29 &  latin\_cube\_q &               20 &      0.52 &     -192.546840 &
1.149522e+75 \\
5  &        random &                20 &      0.26 &     -256.751808 &
1.501946e+47 \\
17 &  latin\_cube\_u &               20 &      0.38 &     -196.290505 &
2.720597e+73 \\
30 &  latin\_cube\_q &               25 &      0.49 &     -241.301178 &
7.705087e+53 \\
6  &        random &                25 &      0.51 &     -288.668679 &
2.066965e+33 \\
42 &       uniform &                25 &      0.42 &     -227.178000 &
1.048084e+60 \\
54 &          None &                25 &      0.03 &     -364.265632 &
3.047851e+00 \\
18 &  latin\_cube\_u &               25 &      0.55 &     -216.457447 &
4.745399e+64 \\
43 &       uniform &                30 &      0.39 &     -240.961933 &
1.081708e+54 \\
7  &        random &                30 &      0.27 &     -275.588771 &
9.905237e+38 \\
19 &  latin\_cube\_u &               30 &      0.35 &     -223.601243 &
3.747673e+61 \\
55 &          None &                30 &      0.97 &     -364.265609 &
3.047920e+00 \\
31 &  latin\_cube\_q &               30 &      0.36 &     -226.960333 &
1.302949e+60 \\
8  &        random &                40 &      0.40 &     -319.534911 &
8.133898e+19 \\
56 &          None &                40 &      0.97 &     -364.265494 &
3.048270e+00 \\
```

```
32 &  latin\_cube\_q &                40 &      0.46 &     -258.962235 &
1.646941e+46 \\
44 &       uniform &               40 &      0.45 &     -239.051648 &
7.306950e+54 \\
20 &  latin\_cube\_u &                40 &      0.51 &     -262.441023 &
5.079948e+44 \\
21 &  latin\_cube\_u &                50 &      0.40 &     -254.140246 &
2.045695e+48 \\
33 &  latin\_cube\_q &                50 &      0.38 &     -289.756958 &
6.961451e+32 \\
45 &       uniform &               50 &      0.57 &     -271.386844 &
6.618182e+40 \\
57 &          None &               50 &      0.97 &     -364.265489 &
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9  &        random &               50 &      0.36 &     -350.842761 &
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5.394031e+42 \\
46 &       uniform &               75 &      0.29 &     -300.473092 &
1.544335e+28 \\
34 &  latin\_cube\_q &                75 &      0.33 &     -304.218055 &
3.650270e+26 \\
58 &          None &               75 &      0.97 &     -364.265488 &
3.048290e+00 \\
10 &        random &               75 &      0.41 &     -354.481296 &
5.410992e+04 \\
47 &       uniform &              100 &      0.43 &     -305.848718 &
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23 &  latin\_cube\_u &               100 &      0.37 &     -281.738865 &
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11 &        random &              100 &      0.29 &     -386.396216 &
7.461106e-10 \\
35 &  latin\_cube\_q &               100 &      0.49 &     -309.203317 &
2.496049e+24 \\
59 &          None &              100 &      0.03 &     -364.265404 &
3.048546e+00 \\
\bottomrule
\end{tabular}
```

Accuracy
discretizing
random
latin_cube_q
uniform
latin_cube_u
accuracy
0.6
0.5
0.4
0.3
0.2
0
20
40
60
80
100
number_of_nodes

```
sample_size = 1000
Recognized 1 instead of 2 states!

/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
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/home/kabalce/.local/lib/python3.10/site-
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/home/kabalce/.local/lib/python3.10/site-
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/home/kabalce/.local/lib/python3.10/site-
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`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
```

```
explicitly to suppress the warning
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/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
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/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
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/home/kabalce/.local/lib/python3.10/site-
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packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
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/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
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/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
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explicitly to suppress the warning
  warnings.warn(
```

```
/tmp/ipykernel_7714/2508230348.py:60: RuntimeWarning: overflow encountered in
exp
  'likelihood-ratio': np.exp(models[discretizing, number_of_nodes]['ll'] -
target_ll)
```

	discretizing	number_of_nodes	accuracy	log-likelihood	likelihood-ratio
0	random	3	0.608	-1028.755722	inf
24	latin_cube_q	3	0.959	-1008.794595	inf
36	uniform	3	0.777	-487.687638	inf
12	latin_cube_u	3	0.504	-982.190023	inf
48	None	3	0.978	-3175.506750	3.813524e-57
37	uniform	5	0.955	-1393.511561	inf
25	latin_cube_q	5	0.523	-1567.726783	inf
49	None	5	0.978	-3175.506412	3.814813e-57
13	latin_cube_u	5	0.521	-898.296609	inf
1	random	5	0.964	-1279.443044	inf
26	latin_cube_q	7	-1.000	-1240.776406	inf
2	random	7	0.956	-1641.210042	inf

14	latin_cube_u	7	0.584	-1448.159875	inf
38	uniform	7	0.915	-1011.860315	inf
50	None	7	0.978	-3175.506458	3.814637e-57
27	latin_cube_q	10	0.677	-1986.404314	inf
3	random	10	0.967	-2061.249105	inf
39	uniform	10	0.945	-1391.447586	inf
51	None	10	0.978	-3175.506773	3.813434e-57
15	latin_cube_u	10	0.516	-2095.276578	inf
4	random	15	0.969	-2409.611139	1.605328e+276
28	latin_cube_q	15	0.926	-2349.615482	1.825352e+302
52	None	15	0.978	-3175.506588	3.814142e-57
16	latin_cube_u	15	0.961	-2049.318150	inf
40	uniform	15	0.944	-1581.873003	inf
53	None	20	0.978	-3175.506277	3.815325e-57
41	uniform	20	0.512	-2098.134651	inf
29	latin_cube_q	20	0.502	-2723.689797	6.352371e+139
5	random	20	0.938	-2738.664302	1.993383e+133
17	latin_cube_u	20	0.636	-2542.037421	4.938105e+218
30	latin_cube_q	25	0.508	-2894.831577	2.999199e+65
6	random	25	0.948	-2973.687727	1.699082e+31
42	uniform	25	0.506	-2452.209332	5.074624e+257
54	None	25	0.978	-3175.506550	3.814285e-57
18	latin_cube_u	25	0.516	-2800.477936	2.846236e+106
43	uniform	30	0.512	-2361.536691	1.213477e+297
7	random	30	0.509	-3217.657781	1.885238e-75
19	latin_cube_u	30	0.511	-2793.104216	4.535622e+109
55	None	30	0.978	-3175.506358	3.815019e-57
31	latin_cube_q	30	0.538	-3147.983150	3.425104e-45
8	random	40	0.518	-3480.474148	1.366685e-189
56	None	40	0.978	-3175.506377	3.814945e-57
32	latin_cube_q	40	0.915	-3226.499022	2.726868e-79
44	uniform	40	0.926	-2501.003643	3.268164e+236
20	latin_cube_u	40	0.947	-3164.932406	1.491783e-52
21	latin_cube_u	50	0.513	-3173.763578	2.179598e-56
33	latin_cube_q	50	0.521	-3547.204808	1.428601e-218
45	uniform	50	0.515	-3003.670980	1.616788e+18
57	None	50	0.978	-3175.506749	3.813526e-57
9	random	50	0.903	-3649.252710	6.855990e-263
22	latin_cube_u	75	0.919	-3546.094886	4.334548e-218
46	uniform	75	0.946	-2567.663970	3.665150e+207
34	latin_cube_q	75	0.507	-3864.496910	0.000000e+00
58	None	75	0.978	-3175.506244	3.815453e-57
10	random	75	0.850	-4041.115354	0.000000e+00
47	uniform	100	0.567	-3559.226820	8.586522e-224
23	latin_cube_u	100	0.506	-3761.100312	1.825047e-311
11	random	100	0.835	-4296.388879	0.000000e+00
35	latin_cube_q	100	0.512	-4231.231227	0.000000e+00
59	None	100	0.978	-3175.506265	3.815373e-57

```
/tmp/ipykernel_7714/2508230348.py:83: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(summary.to_latex())
```

```
\begin{tabular}{llrrrr}
\toprule
{} &  discretizing &  number\_of\_nodes &  accuracy &  log-likelihood &
likelihood-ratio \\
\midrule
0  &        random &                3 &     0.608 &    -1028.755722 &
inf \\
24 &  latin\_cube\_q &                3 &     0.959 &    -1008.794595 &
inf \\
36 &       uniform &                3 &     0.777 &     -487.687638 &
inf \\
12 &  latin\_cube\_u &                3 &     0.504 &     -982.190023 &
inf \\
48 &          None &                3 &     0.978 &    -3175.506750 &
3.813524e-57 \\
37 &       uniform &                5 &     0.955 &    -1393.511561 &
inf \\
25 &  latin\_cube\_q &                5 &     0.523 &    -1567.726783 &
inf \\
49 &          None &                5 &     0.978 &    -3175.506412 &
3.814813e-57 \\
13 &  latin\_cube\_u &                5 &     0.521 &     -898.296609 &
inf \\
1  &        random &                5 &     0.964 &    -1279.443044 &
inf \\
26 &  latin\_cube\_q &                7 &    -1.000 &    -1240.776406 &
inf \\
2  &        random &                7 &     0.956 &    -1641.210042 &
inf \\
14 &  latin\_cube\_u &                7 &     0.584 &    -1448.159875 &
inf \\
38 &       uniform &                7 &     0.915 &    -1011.860315 &
inf \\
50 &          None &                7 &     0.978 &    -3175.506458 &
3.814637e-57 \\
27 &  latin\_cube\_q &               10 &     0.677 &    -1986.404314 &
inf \\
3  &        random &               10 &     0.967 &    -2061.249105 &
inf \\
39 &       uniform &               10 &     0.945 &    -1391.447586 &
inf \\
```

```
51 &          None &                10 &     0.978 &    -3175.506773 &
3.813434e-57 \\
15 &  latin\_cube\_u &               10 &     0.516 &    -2095.276578 &
inf \\
4  &        random &                15 &     0.969 &    -2409.611139 &
1.605328e+276 \\
28 &  latin\_cube\_q &               15 &     0.926 &    -2349.615482 &
1.825352e+302 \\
52 &          None &                15 &     0.978 &    -3175.506588 &
3.814142e-57 \\
16 &  latin\_cube\_u &               15 &     0.961 &    -2049.318150 &
inf \\
40 &       uniform &                15 &     0.944 &    -1581.873003 &
inf \\
53 &          None &                20 &     0.978 &    -3175.506277 &
3.815325e-57 \\
41 &       uniform &                20 &     0.512 &    -2098.134651 &
inf \\
29 &  latin\_cube\_q &               20 &     0.502 &    -2723.689797 &
6.352371e+139 \\
5  &        random &                20 &     0.938 &    -2738.664302 &
1.993383e+133 \\
17 &  latin\_cube\_u &               20 &     0.636 &    -2542.037421 &
4.938105e+218 \\
30 &  latin\_cube\_q &               25 &     0.508 &    -2894.831577 &
2.999199e+65 \\
6  &        random &                25 &     0.948 &    -2973.687727 &
1.699082e+31 \\
42 &       uniform &                25 &     0.506 &    -2452.209332 &
5.074624e+257 \\
54 &          None &                25 &     0.978 &    -3175.506550 &
3.814285e-57 \\
18 &  latin\_cube\_u &               25 &     0.516 &    -2800.477936 &
2.846236e+106 \\
43 &       uniform &                30 &     0.512 &    -2361.536691 &
1.213477e+297 \\
7  &        random &                30 &     0.509 &    -3217.657781 &
1.885238e-75 \\
19 &  latin\_cube\_u &               30 &     0.511 &    -2793.104216 &
4.535622e+109 \\
55 &          None &                30 &     0.978 &    -3175.506358 &
3.815019e-57 \\
31 &  latin\_cube\_q &               30 &     0.538 &    -3147.983150 &
3.425104e-45 \\
8  &        random &                40 &     0.518 &    -3480.474148 &
1.366685e-189 \\
56 &          None &                40 &     0.978 &    -3175.506377 &
3.814945e-57 \\
```

```
32 &  latin\_cube\_q &                40 &     0.915 &    -3226.499022 &
2.726868e-79 \\
44 &       uniform &               40 &     0.926 &    -2501.003643 &
3.268164e+236 \\
20 &  latin\_cube\_u &                40 &     0.947 &    -3164.932406 &
1.491783e-52 \\
21 &  latin\_cube\_u &                50 &     0.513 &    -3173.763578 &
2.179598e-56 \\
33 &  latin\_cube\_q &                50 &     0.521 &    -3547.204808 &
1.428601e-218 \\
45 &       uniform &               50 &     0.515 &    -3003.670980 &
1.616788e+18 \\
57 &          None &               50 &     0.978 &    -3175.506749 &
3.813526e-57 \\
9  &        random &               50 &     0.903 &    -3649.252710 &
6.855990e-263 \\
22 &  latin\_cube\_u &                75 &     0.919 &    -3546.094886 &
4.334548e-218 \\
46 &       uniform &               75 &     0.946 &    -2567.663970 &
3.665150e+207 \\
34 &  latin\_cube\_q &                75 &     0.507 &    -3864.496910 &
0.000000e+00 \\
58 &          None &               75 &     0.978 &    -3175.506244 &
3.815453e-57 \\
10 &        random &               75 &     0.850 &    -4041.115354 &
0.000000e+00 \\
47 &       uniform &              100 &     0.567 &    -3559.226820 &
8.586522e-224 \\
23 &  latin\_cube\_u &               100 &     0.506 &    -3761.100312 &
1.825047e-311 \\
11 &        random &              100 &     0.835 &    -4296.388879 &
0.000000e+00 \\
35 &  latin\_cube\_q &               100 &     0.512 &    -4231.231227 &
0.000000e+00 \\
59 &          None &              100 &     0.978 &    -3175.506265 &
3.815373e-57 \\
\bottomrule
\end{tabular}
```

Accuracy
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
accuracy
0
20
40
60
80
100
number_of_nodes
discretizing
random
latin_cube_q
uniform
latin_cube_u

```
Recognized 2 instead of 3 states!
```

```
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
```

```
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

```
/tmp/ipykernel_7714/2508230348.py:60: RuntimeWarning: overflow encountered in
exp
  'likelihood-ratio': np.exp(models[discretizing, number_of_nodes]['ll'] -
target_ll)
```

	discretizing	number_of_nodes	accuracy	log-likelihood	likelihood-ratio
0	random	3	0.619	-885.190873	inf
24	latin_cube_q	3	0.296	-898.597583	inf
36	uniform	3	0.733	-635.003981	inf
12	latin_cube_u	3	0.289	-832.234530	inf
48	None	3	0.982	-3533.806388	4.100229e-47
37	uniform	5	0.694	-1042.801643	inf
25	latin_cube_q	5	0.273	-1456.278884	inf
49	None	5	0.982	-3533.806282	4.100663e-47
13	latin_cube_u	5	0.571	-1023.111874	inf
1	random	5	-1.000	-1503.389707	inf
26	latin_cube_q	7	0.721	-1591.907424	inf
2	random	7	0.089	-1324.994324	inf

14	latin_cube_u	7	0.130	-1363.802036	inf
38	uniform	7	0.466	-1260.443814	inf
50	None	7	0.982	-3533.806133	4.101276e-47
27	latin_cube_q	10	0.305	-1906.001974	inf
3	random	10	0.781	-2080.448687	inf
39	uniform	10	0.340	-1426.027513	inf
51	None	10	0.008	-3533.806742	4.098778e-47
15	latin_cube_u	10	0.731	-1415.041002	inf
4	random	15	0.046	-2285.206151	inf
28	latin_cube_q	15	0.654	-2263.227077	inf
52	None	15	0.982	-3533.806335	4.100445e-47
16	latin_cube_u	15	0.533	-1542.979879	inf
40	uniform	15	0.367	-1962.649093	inf
53	None	20	0.982	-3533.806402	4.100171e-47
41	uniform	20	0.030	-1841.835780	inf
29	latin_cube_q	20	0.569	-2651.369536	inf
5	random	20	0.540	-2764.673275	4.396175e+287
17	latin_cube_u	20	0.191	-2067.349007	inf
30	latin_cube_q	25	0.373	-2740.253730	1.771530e+298
6	random	25	0.514	-2994.664394	5.743824e+187
42	uniform	25	0.682	-2215.133115	inf
54	None	25	0.982	-3533.806319	4.100513e-47
18	latin_cube_u	25	0.476	-1905.891115	inf
43	uniform	30	0.045	-2329.245308	inf
7	random	30	0.656	-3137.736854	4.203600e+125
19	latin_cube_u	30	0.529	-2132.613686	inf
55	None	30	0.008	-3533.806768	4.098673e-47
31	latin_cube_q	30	0.508	-2855.426502	1.696092e+248
8	random	40	0.202	-3479.580033	1.455509e-23
56	None	40	0.982	-3533.806372	4.100295e-47
32	latin_cube_q	40	0.074	-2999.664469	3.869869e+185
44	uniform	40	0.202	-2417.046968	inf
20	latin_cube_u	40	0.312	-2230.351391	inf
21	latin_cube_u	50	0.677	-2179.483572	inf
33	latin_cube_q	50	0.517	-3244.604363	1.627990e+79
45	uniform	50	0.445	-2517.126537	inf
57	None	50	0.982	-3533.806542	4.099600e-47
9	random	50	0.115	-3554.405140	4.643909e-56
22	latin_cube_u	75	0.475	-2674.872007	inf
46	uniform	75	0.094	-2872.672843	5.488560e+240
34	latin_cube_q	75	0.392	-3623.735605	3.606162e-86
58	None	75	0.982	-3533.806455	4.099956e-47
10	random	75	0.386	-4070.291043	4.173332e-280
47	uniform	100	0.532	-3075.752881	3.490749e+152
23	latin_cube_u	100	0.130	-2855.516518	1.550086e+248
11	random	100	0.234	-4322.194270	0.000000e+00
35	latin_cube_q	100	0.575	-3777.986060	3.689130e-153
59	None	100	0.982	-3533.806868	4.098261e-47

```
/tmp/ipykernel_7714/2508230348.py:83: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(summary.to_latex())
```

```
\begin{tabular}{llrrrr}
\toprule
{} &  discretizing &  number\_of\_nodes &  accuracy &  log-likelihood &
likelihood-ratio \\
\midrule
0  &        random &                3 &     0.619 &     -885.190873 &
inf \\
24 &  latin\_cube\_q &                3 &     0.296 &     -898.597583 &
inf \\
36 &       uniform &                3 &     0.733 &     -635.003981 &
inf \\
12 &  latin\_cube\_u &                3 &     0.289 &     -832.234530 &
inf \\
48 &          None &                3 &     0.982 &    -3533.806388 &
4.100229e-47 \\
37 &       uniform &                5 &     0.694 &    -1042.801643 &
inf \\
25 &  latin\_cube\_q &                5 &     0.273 &    -1456.278884 &
inf \\
49 &          None &                5 &     0.982 &    -3533.806282 &
4.100663e-47 \\
13 &  latin\_cube\_u &                5 &     0.571 &    -1023.111874 &
inf \\
1  &        random &                5 &    -1.000 &    -1503.389707 &
inf \\
26 &  latin\_cube\_q &                7 &     0.721 &    -1591.907424 &
inf \\
2  &        random &                7 &     0.089 &    -1324.994324 &
inf \\
14 &  latin\_cube\_u &                7 &     0.130 &    -1363.802036 &
inf \\
38 &       uniform &                7 &     0.466 &    -1260.443814 &
inf \\
50 &          None &                7 &     0.982 &    -3533.806133 &
4.101276e-47 \\
27 &  latin\_cube\_q &               10 &     0.305 &    -1906.001974 &
inf \\
3  &        random &               10 &     0.781 &    -2080.448687 &
inf \\
39 &       uniform &               10 &     0.340 &    -1426.027513 &
inf \\
```

```
51 &          None &                10 &     0.008 &    -3533.806742 &
4.098778e-47 \\
15 &  latin\_cube\_u &               10 &     0.731 &    -1415.041002 &
inf \\
4  &        random &                15 &     0.046 &    -2285.206151 &
inf \\
28 &  latin\_cube\_q &               15 &     0.654 &    -2263.227077 &
inf \\
52 &          None &                15 &     0.982 &    -3533.806335 &
4.100445e-47 \\
16 &  latin\_cube\_u &               15 &     0.533 &    -1542.979879 &
inf \\
40 &       uniform &                15 &     0.367 &    -1962.649093 &
inf \\
53 &          None &                20 &     0.982 &    -3533.806402 &
4.100171e-47 \\
41 &       uniform &                20 &     0.030 &    -1841.835780 &
inf \\
29 &  latin\_cube\_q &               20 &     0.569 &    -2651.369536 &
inf \\
5  &        random &                20 &     0.540 &    -2764.673275 &
4.396175e+287 \\
17 &  latin\_cube\_u &               20 &     0.191 &    -2067.349007 &
inf \\
30 &  latin\_cube\_q &               25 &     0.373 &    -2740.253730 &
1.771530e+298 \\
6  &        random &                25 &     0.514 &    -2994.664394 &
5.743824e+187 \\
42 &       uniform &                25 &     0.682 &    -2215.133115 &
inf \\
54 &          None &                25 &     0.982 &    -3533.806319 &
4.100513e-47 \\
18 &  latin\_cube\_u &               25 &     0.476 &    -1905.891115 &
inf \\
43 &       uniform &                30 &     0.045 &    -2329.245308 &
inf \\
7  &        random &                30 &     0.656 &    -3137.736854 &
4.203600e+125 \\
19 &  latin\_cube\_u &               30 &     0.529 &    -2132.613686 &
inf \\
55 &          None &                30 &     0.008 &    -3533.806768 &
4.098673e-47 \\
31 &  latin\_cube\_q &               30 &     0.508 &    -2855.426502 &
1.696092e+248 \\
8  &        random &                40 &     0.202 &    -3479.580033 &
1.455509e-23 \\
56 &          None &                40 &     0.982 &    -3533.806372 &
4.100295e-47 \\
```

```
32 &  latin\_cube\_q &                40 &     0.074 &    -2999.664469 &
3.869869e+185 \\
44 &       uniform &               40 &     0.202 &    -2417.046968 &
inf \\
20 &  latin\_cube\_u &                40 &     0.312 &    -2230.351391 &
inf \\
21 &  latin\_cube\_u &                50 &     0.677 &    -2179.483572 &
inf \\
33 &  latin\_cube\_q &                50 &     0.517 &    -3244.604363 &
1.627990e+79 \\
45 &       uniform &               50 &     0.445 &    -2517.126537 &
inf \\
57 &          None &               50 &     0.982 &    -3533.806542 &
4.099600e-47 \\
9  &        random &               50 &     0.115 &    -3554.405140 &
4.643909e-56 \\
22 &  latin\_cube\_u &                75 &     0.475 &    -2674.872007 &
inf \\
46 &       uniform &               75 &     0.094 &    -2872.672843 &
5.488560e+240 \\
34 &  latin\_cube\_q &                75 &     0.392 &    -3623.735605 &
3.606162e-86 \\
58 &          None &               75 &     0.982 &    -3533.806455 &
4.099956e-47 \\
10 &        random &               75 &     0.386 &    -4070.291043 &
4.173332e-280 \\
47 &       uniform &              100 &     0.532 &    -3075.752881 &
3.490749e+152 \\
23 &  latin\_cube\_u &               100 &     0.130 &    -2855.516518 &
1.550086e+248 \\
11 &        random &              100 &     0.234 &    -4322.194270 &
0.000000e+00 \\
35 &  latin\_cube\_q &               100 &     0.575 &    -3777.986060 &
3.689130e-153 \\
59 &          None &              100 &     0.982 &    -3533.806868 &
4.098261e-47 \\
\bottomrule
\end{tabular}
```

Accuracy
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
accuracy
0
20
40
60
80
100
number_of_nodes
discretizing
random
latin_cube_q
uniform
latin_cube_u

```
sample_size = 10000
```

```
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
```

```
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

```
/tmp/ipykernel_7714/2508230348.py:60: RuntimeWarning: overflow encountered in
exp
  'likelihood-ratio': np.exp(models[discretizing, number_of_nodes]['ll'] -
target_ll)
```

	discretizing	number_of_nodes	accuracy	log-likelihood	likelihood-ratio
0	random	3	0.9665	-9890.532018	inf
24	latin_cube_q	3	0.9734	-7676.743882	inf
36	uniform	3	0.9056	-5841.125844	inf
12	latin_cube_u	3	0.9722	-6495.966047	inf
48	None	3	0.9805	-31227.413174	0.000000e+00
37	uniform	5	0.9751	-10105.518134	inf
25	latin_cube_q	5	0.9318	-14464.866535	inf
49	None	5	0.9805	-31227.413172	0.000000e+00
13	latin_cube_u	5	0.6194	-7249.899815	inf
1	random	5	0.6189	-14136.809658	inf
26	latin_cube_q	7	0.5111	-16758.750848	inf
2	random	7	0.9672	-16375.082851	inf

14	latin_cube_u	7	0.9751	-14017.914807	inf
38	uniform	7	0.9683	-11896.207136	inf
50	None	7	0.9805	-31227.413355	0.000000e+00
27	latin_cube_q	10	0.9719	-20123.272323	inf
3	random	10	0.9744	-19911.489835	inf
39	uniform	10	0.5001	-15474.627950	inf
51	None	10	0.9805	-31227.413199	0.000000e+00
15	latin_cube_u	10	0.9560	-13028.736922	inf
4	random	15	0.6135	-25837.292209	inf
28	latin_cube_q	15	0.5683	-25822.929679	inf
52	None	15	0.9805	-31227.413252	0.000000e+00
16	latin_cube_u	15	0.5135	-17684.930033	inf
40	uniform	15	0.9768	-17063.258458	inf
53	None	20	0.9805	-31227.413257	0.000000e+00
41	uniform	20	0.9302	-16861.138131	inf
29	latin_cube_q	20	0.9702	-25285.173897	inf
5	random	20	0.9766	-28210.538746	inf
17	latin_cube_u	20	0.5054	-22162.322673	inf
30	latin_cube_q	25	0.5114	-29744.288399	1.976246e+85
6	random	25	0.9637	-30161.014554	2.060495e-96
42	uniform	25	0.9787	-22864.939889	inf
54	None	25	0.9805	-31227.413231	0.000000e+00
18	latin_cube_u	25	0.5000	-22757.219904	inf
43	uniform	30	0.5912	-20026.016106	inf
7	random	30	0.9689	-31645.891299	0.000000e+00
19	latin_cube_u	30	0.5026	-26199.702970	inf
55	None	30	0.9805	-31227.413458	0.000000e+00
31	latin_cube_q	30	0.9577	-29883.723551	5.494447e+24
8	random	40	0.5059	-35261.150311	0.000000e+00
56	None	40	0.9805	-31227.413373	0.000000e+00
32	latin_cube_q	40	0.5446	-33226.068578	0.000000e+00
44	uniform	40	0.9717	-24430.748643	inf
20	latin_cube_u	40	0.5152	-26776.499897	inf
21	latin_cube_u	50	0.5441	-27156.564181	inf
33	latin_cube_q	50	0.5063	-35924.562300	0.000000e+00
45	uniform	50	0.9686	-25710.664490	inf
57	None	50	0.9805	-31227.413265	0.000000e+00
9	random	50	0.5063	-37436.367097	0.000000e+00
22	latin_cube_u	75	0.9648	-32935.024398	0.000000e+00
46	uniform	75	0.9736	-29336.904564	1.661088e+262
34	latin_cube_q	75	0.5682	-40336.511780	0.000000e+00
58	None	75	0.9805	-31227.413217	0.000000e+00
10	random	75	0.5196	-41656.055807	0.000000e+00
47	uniform	100	0.5409	-31451.458850	0.000000e+00
23	latin_cube_u	100	0.9707	-37224.281566	0.000000e+00
11	random	100	0.5048	-44301.237384	0.000000e+00
35	latin_cube_q	100	0.9557	-42127.471548	0.000000e+00
59	None	100	0.9805	-31227.413296	0.000000e+00

```
/tmp/ipykernel_7714/2508230348.py:83: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(summary.to_latex())
```

```
\begin{tabular}{llrrrr}
\toprule
{} &  discretizing &  number\_of\_nodes &  accuracy &  log-likelihood &
likelihood-ratio \\
\midrule
0  &        random &                3 &    0.9665 &    -9890.532018 &
inf \\
24 &  latin\_cube\_q &                3 &    0.9734 &    -7676.743882 &
inf \\
36 &       uniform &                3 &    0.9056 &    -5841.125844 &
inf \\
12 &  latin\_cube\_u &                3 &    0.9722 &    -6495.966047 &
inf \\
48 &          None &                3 &    0.9805 &   -31227.413174 &
0.000000e+00 \\
37 &       uniform &                5 &    0.9751 &   -10105.518134 &
inf \\
25 &  latin\_cube\_q &                5 &    0.9318 &   -14464.866535 &
inf \\
49 &          None &                5 &    0.9805 &   -31227.413172 &
0.000000e+00 \\
13 &  latin\_cube\_u &                5 &    0.6194 &    -7249.899815 &
inf \\
1  &        random &                5 &    0.6189 &   -14136.809658 &
inf \\
26 &  latin\_cube\_q &                7 &    0.5111 &   -16758.750848 &
inf \\
2  &        random &                7 &    0.9672 &   -16375.082851 &
inf \\
14 &  latin\_cube\_u &                7 &    0.9751 &   -14017.914807 &
inf \\
38 &       uniform &                7 &    0.9683 &   -11896.207136 &
inf \\
50 &          None &                7 &    0.9805 &   -31227.413355 &
0.000000e+00 \\
27 &  latin\_cube\_q &               10 &    0.9719 &   -20123.272323 &
inf \\
3  &        random &               10 &    0.9744 &   -19911.489835 &
inf \\
39 &       uniform &               10 &    0.5001 &   -15474.627950 &
inf \\
```

```
51 &          None &                10 &    0.9805 &   -31227.413199 &
0.000000e+00 \\
15 &  latin\_cube\_u &               10 &    0.9560 &   -13028.736922 &
inf \\
4  &        random &                15 &    0.6135 &   -25837.292209 &
inf \\
28 &  latin\_cube\_q &               15 &    0.5683 &   -25822.929679 &
inf \\
52 &          None &                15 &    0.9805 &   -31227.413252 &
0.000000e+00 \\
16 &  latin\_cube\_u &               15 &    0.5135 &   -17684.930033 &
inf \\
40 &       uniform &                15 &    0.9768 &   -17063.258458 &
inf \\
53 &          None &                20 &    0.9805 &   -31227.413257 &
0.000000e+00 \\
41 &       uniform &                20 &    0.9302 &   -16861.138131 &
inf \\
29 &  latin\_cube\_q &               20 &    0.9702 &   -25285.173897 &
inf \\
5  &        random &                20 &    0.9766 &   -28210.538746 &
inf \\
17 &  latin\_cube\_u &               20 &    0.5054 &   -22162.322673 &
inf \\
30 &  latin\_cube\_q &               25 &    0.5114 &   -29744.288399 &
1.976246e+85 \\
6  &        random &                25 &    0.9637 &   -30161.014554 &
2.060495e-96 \\
42 &       uniform &                25 &    0.9787 &   -22864.939889 &
inf \\
54 &          None &                25 &    0.9805 &   -31227.413231 &
0.000000e+00 \\
18 &  latin\_cube\_u &               25 &    0.5000 &   -22757.219904 &
inf \\
43 &       uniform &                30 &    0.5912 &   -20026.016106 &
inf \\
7  &        random &                30 &    0.9689 &   -31645.891299 &
0.000000e+00 \\
19 &  latin\_cube\_u &               30 &    0.5026 &   -26199.702970 &
inf \\
55 &          None &                30 &    0.9805 &   -31227.413458 &
0.000000e+00 \\
31 &  latin\_cube\_q &               30 &    0.9577 &   -29883.723551 &
5.494447e+24 \\
8  &        random &                40 &    0.5059 &   -35261.150311 &
0.000000e+00 \\
56 &          None &                40 &    0.9805 &   -31227.413373 &
0.000000e+00 \\
```

```
32 &  latin\_cube\_q &                40 &    0.5446 &   -33226.068578 &
0.000000e+00 \\
44 &       uniform &               40 &    0.9717 &   -24430.748643 &
inf \\
20 &  latin\_cube\_u &                40 &    0.5152 &   -26776.499897 &
inf \\
21 &  latin\_cube\_u &                50 &    0.5441 &   -27156.564181 &
inf \\
33 &  latin\_cube\_q &                50 &    0.5063 &   -35924.562300 &
0.000000e+00 \\
45 &       uniform &               50 &    0.9686 &   -25710.664490 &
inf \\
57 &          None &               50 &    0.9805 &   -31227.413265 &
0.000000e+00 \\
9  &        random &               50 &    0.5063 &   -37436.367097 &
0.000000e+00 \\
22 &  latin\_cube\_u &                75 &    0.9648 &   -32935.024398 &
0.000000e+00 \\
46 &       uniform &               75 &    0.9736 &   -29336.904564 &
1.661088e+262 \\
34 &  latin\_cube\_q &                75 &    0.5682 &   -40336.511780 &
0.000000e+00 \\
58 &          None &               75 &    0.9805 &   -31227.413217 &
0.000000e+00 \\
10 &        random &               75 &    0.5196 &   -41656.055807 &
0.000000e+00 \\
47 &       uniform &              100 &    0.5409 &   -31451.458850 &
0.000000e+00 \\
23 &  latin\_cube\_u &               100 &    0.9707 &   -37224.281566 &
0.000000e+00 \\
11 &        random &              100 &    0.5048 &   -44301.237384 &
0.000000e+00 \\
35 &  latin\_cube\_q &               100 &    0.9557 &   -42127.471548 &
0.000000e+00 \\
59 &          None &              100 &    0.9805 &   -31227.413296 &
0.000000e+00 \\
\bottomrule
\end{tabular}
```

Accuracy
1.0
0.9
0.8
0.7
0.6
0.5
accuracy
0
20
40
60
80
100
number_of_nodes
discretizing
random
latin_cube_q
uniform
latin_cube_u

```
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
```

```
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
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  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
/home/kabalce/.local/lib/python3.10/site-
packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
`n_init` will change from 10 to 'auto' in 1.4. Set the value of `n_init`
explicitly to suppress the warning
  warnings.warn(
```

```
/tmp/ipykernel_7714/2508230348.py:60: RuntimeWarning: overflow encountered in
exp
  'likelihood-ratio': np.exp(models[discretizing, number_of_nodes]['ll'] -
target_ll)
```

	discretizing	number_of_nodes	accuracy	log-likelihood	likelihood-ratio
0	random	3	0.6277	-9699.365007	inf
24	latin_cube_q	3	0.6254	-8304.206328	inf
36	uniform	3	0.6963	-8228.834102	inf
12	latin_cube_u	3	0.7489	-6266.741442	inf
48	None	3	0.9757	-35890.531169	0.000000e+00
37	uniform	5	0.5874	-7354.379353	inf
25	latin_cube_q	5	0.1773	-13879.188725	inf
49	None	5	0.0157	-38498.557971	0.000000e+00
13	latin_cube_u	5	0.0749	-10653.198231	inf
1	random	5	0.2663	-13288.183087	inf
26	latin_cube_q	7	0.0741	-14903.259406	inf
2	random	7	0.6196	-16595.958112	inf

14	latin_cube_u	7	0.1528	-10787.367516	inf
38	uniform	7	0.1316	-15112.226741	inf
50	None	7	0.0134	-35890.530729	0.000000e+00
27	latin_cube_q	10	0.9228	-18785.730095	inf
3	random	10	0.6721	-20532.879576	inf
39	uniform	10	0.7196	-16077.742406	inf
51	None	10	0.9757	-35890.531589	0.000000e+00
15	latin_cube_u	10	0.4435	-13369.148736	inf
4	random	15	0.7523	-25316.200720	inf
28	latin_cube_q	15	0.5501	-21315.052504	inf
52	None	15	0.9757	-35890.531192	0.000000e+00
16	latin_cube_u	15	0.7086	-15827.345471	inf
40	uniform	15	0.0351	-17081.538984	inf
53	None	20	0.9757	-35890.531242	0.000000e+00
41	uniform	20	0.3224	-15612.230751	inf
29	latin_cube_q	20	0.6456	-23674.243901	inf
5	random	20	0.7430	-27610.727985	inf
17	latin_cube_u	20	0.7097	-18944.943204	inf
30	latin_cube_q	25	0.7141	-27705.810591	inf
6	random	25	0.7228	-29476.784403	inf
42	uniform	25	0.7078	-19994.552346	inf
54	None	25	0.0134	-35890.531389	0.000000e+00
18	latin_cube_u	25	0.9395	-19348.795237	inf
43	uniform	30	0.7374	-23790.422698	inf
7	random	30	0.9324	-31433.860863	inf
19	latin_cube_u	30	0.0356	-18727.818083	inf
55	None	30	0.9757	-35890.531136	0.000000e+00
31	latin_cube_q	30	0.3638	-30815.358537	inf
8	random	40	0.0617	-34443.787800	4.496149e+125
56	None	40	0.0134	-35890.530944	0.000000e+00
32	latin_cube_q	40	0.3705	-32478.402869	inf
44	uniform	40	0.4382	-24892.335702	inf
20	latin_cube_u	40	0.3541	-22516.670768	inf
21	latin_cube_u	50	0.9257	-23684.437971	inf
33	latin_cube_q	50	0.9562	-33249.552347	inf
45	uniform	50	0.1921	-24246.409582	inf
57	None	50	0.9757	-35890.531652	0.000000e+00
9	random	50	0.6674	-36372.938211	0.000000e+00
22	latin_cube_u	75	0.2401	-26649.982399	inf
46	uniform	75	0.4358	-30512.273212	inf
34	latin_cube_q	75	0.1641	-36280.359900	0.000000e+00
58	None	75	0.9757	-35890.531229	0.000000e+00
10	random	75	0.6922	-41191.507616	0.000000e+00
47	uniform	100	0.0738	-30166.228754	inf
23	latin_cube_u	100	0.3462	-28743.032942	inf
11	random	100	0.6404	-43594.017479	0.000000e+00
35	latin_cube_q	100	0.3629	-39549.291696	0.000000e+00
59	None	100	0.9757	-35890.531033	0.000000e+00

```
/tmp/ipykernel_7714/2508230348.py:83: FutureWarning: In future versions
`DataFrame.to_latex` is expected to utilise the base implementation of
`Styler.to_latex` for formatting and rendering. The arguments signature may
therefore change. It is recommended instead to use `DataFrame.style.to_latex`
which also contains additional functionality.
  print(summary.to_latex())
```

```
\begin{tabular}{llrrrr}
\toprule
{} &  discretizing &  number\_of\_nodes &  accuracy &  log-likelihood &
likelihood-ratio \\
\midrule
0  &        random &                3 &    0.6277 &    -9699.365007 &
inf \\
24 &  latin\_cube\_q &                3 &    0.6254 &    -8304.206328 &
inf \\
36 &       uniform &                3 &    0.6963 &    -8228.834102 &
inf \\
12 &  latin\_cube\_u &                3 &    0.7489 &    -6266.741442 &
inf \\
48 &          None &                3 &    0.9757 &   -35890.531169 &
0.000000e+00 \\
37 &       uniform &                5 &    0.5874 &    -7354.379353 &
inf \\
25 &  latin\_cube\_q &                5 &    0.1773 &   -13879.188725 &
inf \\
49 &          None &                5 &    0.0157 &   -38498.557971 &
0.000000e+00 \\
13 &  latin\_cube\_u &                5 &    0.0749 &   -10653.198231 &
inf \\
1  &        random &                5 &    0.2663 &   -13288.183087 &
inf \\
26 &  latin\_cube\_q &                7 &    0.0741 &   -14903.259406 &
inf \\
2  &        random &                7 &    0.6196 &   -16595.958112 &
inf \\
14 &  latin\_cube\_u &                7 &    0.1528 &   -10787.367516 &
inf \\
38 &       uniform &                7 &    0.1316 &   -15112.226741 &
inf \\
50 &          None &                7 &    0.0134 &   -35890.530729 &
0.000000e+00 \\
27 &  latin\_cube\_q &               10 &    0.9228 &   -18785.730095 &
inf \\
3  &        random &               10 &    0.6721 &   -20532.879576 &
inf \\
39 &       uniform &               10 &    0.7196 &   -16077.742406 &
inf \\
```

```
51 &          None &                10 &    0.9757 &   -35890.531589 &
0.000000e+00 \\
15 &  latin\_cube\_u &               10 &    0.4435 &   -13369.148736 &
inf \\
4  &        random &                15 &    0.7523 &   -25316.200720 &
inf \\
28 &  latin\_cube\_q &               15 &    0.5501 &   -21315.052504 &
inf \\
52 &          None &                15 &    0.9757 &   -35890.531192 &
0.000000e+00 \\
16 &  latin\_cube\_u &               15 &    0.7086 &   -15827.345471 &
inf \\
40 &       uniform &                15 &    0.0351 &   -17081.538984 &
inf \\
53 &          None &                20 &    0.9757 &   -35890.531242 &
0.000000e+00 \\
41 &       uniform &                20 &    0.3224 &   -15612.230751 &
inf \\
29 &  latin\_cube\_q &               20 &    0.6456 &   -23674.243901 &
inf \\
5  &        random &                20 &    0.7430 &   -27610.727985 &
inf \\
17 &  latin\_cube\_u &               20 &    0.7097 &   -18944.943204 &
inf \\
30 &  latin\_cube\_q &               25 &    0.7141 &   -27705.810591 &
inf \\
6  &        random &                25 &    0.7228 &   -29476.784403 &
inf \\
42 &       uniform &                25 &    0.7078 &   -19994.552346 &
inf \\
54 &          None &                25 &    0.0134 &   -35890.531389 &
0.000000e+00 \\
18 &  latin\_cube\_u &               25 &    0.9395 &   -19348.795237 &
inf \\
43 &       uniform &                30 &    0.7374 &   -23790.422698 &
inf \\
7  &        random &                30 &    0.9324 &   -31433.860863 &
inf \\
19 &  latin\_cube\_u &               30 &    0.0356 &   -18727.818083 &
inf \\
55 &          None &                30 &    0.9757 &   -35890.531136 &
0.000000e+00 \\
31 &  latin\_cube\_q &               30 &    0.3638 &   -30815.358537 &
inf \\
8  &        random &                40 &    0.0617 &   -34443.787800 &
4.496149e+125 \\
56 &          None &                40 &    0.0134 &   -35890.530944 &
0.000000e+00 \\
```

```
32 &  latin\_cube\_q &               40 &    0.3705 &   -32478.402869 &
inf \\
44 &       uniform &               40 &    0.4382 &   -24892.335702 &
inf \\
20 &  latin\_cube\_u &               40 &    0.3541 &   -22516.670768 &
inf \\
21 &  latin\_cube\_u &               50 &    0.9257 &   -23684.437971 &
inf \\
33 &  latin\_cube\_q &               50 &    0.9562 &   -33249.552347 &
inf \\
45 &       uniform &               50 &    0.1921 &   -24246.409582 &
inf \\
57 &          None &               50 &    0.9757 &   -35890.531652 &
0.000000e+00 \\
9  &        random &               50 &    0.6674 &   -36372.938211 &
0.000000e+00 \\
22 &  latin\_cube\_u &               75 &    0.2401 &   -26649.982399 &
inf \\
46 &       uniform &               75 &    0.4358 &   -30512.273212 &
inf \\
34 &  latin\_cube\_q &               75 &    0.1641 &   -36280.359900 &
0.000000e+00 \\
58 &          None &               75 &    0.9757 &   -35890.531229 &
0.000000e+00 \\
10 &        random &               75 &    0.6922 &   -41191.507616 &
0.000000e+00 \\
47 &       uniform &              100 &    0.0738 &   -30166.228754 &
inf \\
23 &  latin\_cube\_u &              100 &    0.3462 &   -28743.032942 &
inf \\
11 &        random &              100 &    0.6404 &   -43594.017479 &
0.000000e+00 \\
35 &  latin\_cube\_q &              100 &    0.3629 &   -39549.291696 &
0.000000e+00 \\
59 &          None &              100 &    0.9757 &   -35890.531033 &
0.000000e+00 \\
\bottomrule
\end{tabular}
```

Accuracy
1.0
0.8
0.6
0.4
0.2
0.0
accuracy
0
20
40
60
80
100
number_of_nodes
discretizing
random
latin_cube_q
uniform
latin_cube_u

[30]:
```
nodes_numbers = [5, 10, 50]
sample_sizes = [200, 5000]

def evaluation_numeric(sample_size, n_components, results):
    true_model = true_model2 if n_components == 2 else true_model3
    X, Z = true_model.sample(sample_size)

    for discretizing, number_of_nodes in itertools.
 ↪product([*DISCRETIZATION_TECHNIQUES, None], nodes_numbers):
        if number_of_nodes > sample_size:
            continue
        myHMM, ll, acc = eval_model(n_components, number_of_nodes,␣
 ↪discretizing, X, Z)
        results.append({'ll': ll, 'acc': acc, 'number_of_nodes':␣
 ↪number_of_nodes,  'discretizing': discretizing, 'sample_size': sample_size,␣
 ↪'used_disc': myHMM.n_features})

    print("iter done")

results = []
```

[31]:
```
%%time
[evaluation_numeric(sample_size, n_components, results) for sample_size,␣
↪n_components in itertools.product([10000], [2]) for _ in range(50)]
```

```
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packages/sklearn/cluster/_kmeans.py:870: FutureWarning: The default value of
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Recognized 1 instead of 2 states!

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iter done
CPU times: user 31min 29s, sys: 6min 3s, total: 37min 32s
Wall time: 1h 27min 39s
```

[31]:
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[32]:
```
res = pd.DataFrame(results)
res.to_csv('results2.csv')

def plot_res(x):
    sns.lineplot(data=x, x='number_of_nodes', y='acc', hue='discretizing')
    plt.title("Accuracy")
    plt.show()
    sns.lineplot(data=res, x='number_of_nodes', y='ll', hue='discretizing')
    plt.title("Log-likelihood")
    plt.show()

res.groupby(['sample_size']).apply(plot_res)
```

Accuracy
acc
0.8
0.7
0.6
0.5
0.4
10
20
30
40
50
number_of_nodes
discretizing
random
latin_cube_u
latin_cube_q
uniform

[32]:
```
Empty DataFrame
Columns: []
Index: []
```

[33]:
```
results = []
[evaluation_numeric(sample_size, n_components, results) for sample_size,␣
↪n_components in itertools.product([10000], [3]) for _ in range(50)]
```

```
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Recognized 2 instead of 3 states!

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iter done
Recognized 2 instead of 3 states!

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[34]:
```
res = pd.DataFrame(results)
res.to_csv('results3.csv')
```

```python
def plot_res(x):
    sns.lineplot(data=x, x='number_of_nodes', y='acc', hue='discretizing')
    plt.title("Accuracy")
    plt.show()
    sns.lineplot(data=res, x='number_of_nodes', y='ll', hue='discretizing')
    plt.title("Log-likelihood")
    plt.show()

res.groupby(['sample_size']).apply(plot_res)
```

[34]:
```
Empty DataFrame
Columns: []
Index: []
```

[35]:
```
import pandas as pd

res3 = pd.read_csv('results3.csv')
```

[36]:
```
res3
```

[36]:
```
     Unnamed: 0            ll     acc  number_of_nodes  discretizing  \
0             0 -12391.577358  0.7238                5        random
1             1 -20431.949157  0.6788               10        random
2             2 -36478.786269  0.3763               50        random
3             3 -12091.040736  0.7314                5  latin_cube_u
4             4 -16716.393299  0.3448               10  latin_cube_u
..          …            …     …               …            …
745         745 -15355.999240  0.6198               10       uniform
746         746 -27341.373341  0.9350               50       uniform
747         747 -35842.486993  0.9765                5           NaN
```

```
748         748 -35842.486760  0.9765                10            NaN
749         749 -35842.487083  0.9765                50            NaN

     sample_size  used_disc
0          10000          5
1          10000         10
2          10000         50
3          10000          5
4          10000         10
..           …        …
745        10000         10
746        10000         50
747        10000          2
748        10000          2
749        10000          2

[750 rows x 7 columns]
```