MO431A - Trabalho 4

Renata Falguera Gonçalves - RA: 262889
Pedro Santos de Rezende Alves - RA:262886

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Neste trabalho, O objetivo foi de buscar os melhores hiperparametros de uma SVM para Regressão num banco de dados em particular. Há 3 hiperparâmetros que consideramos como os mais importantes: C, gamma, e epsilon.

Dentre os algoritimos de otimização propostos para este trabalho, temos:

- Random search;
- Grid search;
- Bayesian optimization;
- PSO;
- Simulated aneeling;
- CMA-ES.

Para a utilziação de cada um dos algoritimos acima fizemos o uso da bibliotecas: sklearn.svm, hyperopt, pyswarm and optuna.

Vamos fazer a busca no seguinte range:

- **C** entre 2^{-5} e 2^{15} (uniforme nos expoentes);
- **gamma** entre 2^{-15} e 2^{3} (uniforme nos expoentes);
- **episilon** entre 0.05 e 1.0 (uniforme neste intervalo).

Para o desenvolvimento utilizamos dois conjuntos de dados destintos a fim de realizarmos uma validação correta dos dados. O conjunto de dados foi dividido em conjunto de treino representado pelos dados $Xtreino5.npy$ e $ytreino5.npy$ e devem ser utilzados ddurante a faze de treinamento e busca dos hiperparâmetros. O segundo conjunto de dados é definido como conjunto de testes, onde uma validação em um conjunto distinto ao de treino é realizada a fim de verificarmos o queão acertivo o treinamento foi na seleção dos hiperparâmetros. O conjunto de testes é dado por $Xteste5.npy$ e $yteste5.npy$.

Todos os arquivos foram disponibilzados na página do trabalho *https://www.ic.unicamp.br/ wainer/cursos/1s2020/431/ex4.html*.

1 Importação das Bibliotecas

Como primeiro passo, importamos as bibliotecas necessárias para a implementação desse trabalho:

[1]:
```
import numpy as np
from sklearn.svm import SVR
from sklearn.model_selection import RandomizedSearchCV, GridSearchCV
from sklearn import metrics
import pyspark
from hyperopt import fmin, tpe, hp, SparkTrials, STATUS_OK, Trials
from sklearn.model_selection import cross_val_score

from pyswarm import pso
import optuna
from scipy.stats import loguniform
import random
```

2 Leitura e Exibição dos arquivos

Após importamos as bibliotecas necessárias, realizamos a leitura dos arquivos *.npy* disponibilizados para uso neste trabalho. Para isso fizemos uso da função *load*() da biblioteca numpy. Armazenamos cada um dos arquivos de treino e de teste em variáveis locais.

[2]:
```
x_treino = np.load('data/Xtreino5.npy')
x_teste = np.load('data/Xteste5.npy')
y_treino = np.load('data/ytreino5.npy')
y_teste = np.load('data/yteste5.npy')
```

3 Medida de erro

Para cada um dos algoritimos de otimização, o valor utilizado para a avaliação do conjunto de hiperparâmetros será o Erro Absoluto Médio (MAE), que será medido através da diferença de resposta para o problema de regressão SVM executando com os hiperparâmetros selecionados durante a otimização, o que gerará uma predição dos dados de teste, e os valores groudtruth fornecidos pelo conjunto yteste.

4 Algoritmos de Otimização

4.1 Randomized Search

O primeiro algoritimo de otimização proposto foi o Randomized Search. Para a sua implementação utilizamos a biblioteca sklearn.model_selection, trabalhando com a função RandomizedSearchCV ().

Primeiramente geramos o espaço de hiperparâmetro proposto para a busca. Vale ressaltar que para os parâmetros ***C*** e ***gamma*** a busca é linear/uniforme no expoente do parametro.

[3]:
```
n_combinations = 125

# Hyperparameters Search Space
```

```
C_range = np.random.uniform(-5, 15, n_combinations).astype(float)
C_range = 2**C_range

gamma_range = np.random.uniform(-15, 3, n_combinations).astype(float)
gamma_range = 2**gamma_range

epsilon_range = np.random.uniform(0.05, 1.0, n_combinations).astype(float)


hyperparameters = {'gamma': list(gamma_range),
                   'C': list(C_range),
                 'epsilon': list(epsilon_range)}
```

Após definido o espaço de hiperparâmtro, realizamos o treinamento do SVM usando as amostras de treino, obtendo como resultado os melhores valores para cada um dos hiperparâmtros C, gamma e epsilon:

[4]:
```
# Run randomized search
randomCV = RandomizedSearchCV(SVR(kernel='rbf'),␣
 ↪param_distributions=hyperparameters, n_iter=20)
randomCV.fit(x_treino, y_treino)

# Identify optimal hyperparameter values
best_gamma  = randomCV.best_params_['gamma']
best_C      = randomCV.best_params_['C']
best_epsilon= randomCV.best_params_['epsilon']

print("The best performing C value is: {:5.2f}".format(best_C))
print("The best performing gamma value is: {:5.5f}".format(best_gamma))
print("The best performing epsilon value is: {:5.2f}".format(best_epsilon))
```

```
The best performing C value is: 188.52
The best performing gamma value is: 0.00009
The best performing epsilon value is:  0.45
```

Como resultado, obtivemos 188.52 para o hiperparêmetro C, 0.00009 para o gamma e 0.45 para o epsilon. Como próximo passo, realizamos a validação destes parâmetros aplicando o teste no SVM usando os valores de hiperparâmetros encontrados e calculando o Erro Médio Absoluto (MAE) para o conjunto de teste:

[5]:
```
# Validation

svr  = SVR(kernel='rbf', gamma=best_gamma, epsilon=best_epsilon, C=best_C)
svr.fit(x_treino, y_treino)

pred = svr.predict(x_teste)
```

```
# print(regression.score(x_teste, y_teste))
print("MAE: ", metrics.mean_absolute_error(y_true=y_teste, y_pred=pred))
```

```
MAE:  3.5487968270739882
```

Como resultado, obtivemos um Erro Absloluto Médio de aproximadamente **3.549** para o algoritimo Randomized Search.

4.2 Grid Search

O próximo algoritimo de otimização proposto foi o Grid Search. ara a sua implementação utilizamos a biblioteca sklearn.model_selection, trabalhando com a função GridSearchCV(). Seguindo a especificação de uma busca em uma grid de 5x5x5, o espaço de hiperparâmetros foi gerando para a busca:

[6]:
```
# Hyperparameters Search Space
n_combinations = 5

# Taken 5 samples randomly
grid_c = random.sample(list(C_range), k=n_combinations)
grid_gamma = random.sample(list(gamma_range), k=n_combinations)
grid_episolon = random.sample(list(epsilon_range), k=n_combinations)

hyperparameters_grid = {'gamma': list(grid_gamma),
                        'C': list(grid_c),
                        'epsilon': list(grid_episolon)}
```

Após definido o espaço de hiperparâmtro, realizamos o treinamento do SVM usando as amostras de treino, obtendo como resultado os melhores valores para cada um dos hiperparâmtros C, gamma e epsilon:

[7]:
```
# Run Grid Search
grid_sr = GridSearchCV(SVR(kernel='rbf'), param_grid=hyperparameters_grid, cv =␣
 ↪5)
grid_sr.fit(x_treino, y_treino)

# Identify optimal hyperparameter values
best_gamma  = grid_sr.best_params_['gamma']
best_C      = grid_sr.best_params_['C']
best_epsilon= grid_sr.best_params_['epsilon']

print("The best performing gamma value is: {:5.5f}".format(best_gamma))
print("The best performing C value is: {:5.2f}".format(best_C))
print("The best performing epsilon value is: {:5.2f}".format(best_epsilon))
```

```
The best performing gamma value is: 0.00058
The best performing C value is: 49.70
The best performing epsilon value is:  0.77
```

Como resultado, obtivemos 49,70 para o hiperparêmetro C, 0.00058 para o gamma e 0.77 para o epsilon. Como próximo passo, realizamos o teste no SVM usando os valores de hiperparâmetros encontrado, e calculamos o Erro Médio Absoluto (MAE) para o conjunto de teste:

[8]:
```
# Validation

svr  = SVR(kernel='rbf', gamma=best_gamma, epsilon=best_epsilon, C=best_C)
svr.fit(x_treino, y_treino)

pred = svr.predict(x_teste)

# print(regression.score(x_teste, y_teste))
print("MAE: ", metrics.mean_absolute_error(y_true=y_teste, y_pred=pred))
```

```
MAE:  3.6237947770473338
```

Como resultado, obtivemos um Erro Absloluto Médio de aproximandamente **3.624** para o algoritimo Grid Search.

4.3 Otimização Bayesiana

Outro algoritimo proposto foi a otimização bayesiana. Para a sua implementação utilziamos a biblioteca hyperopt, que dispnibiliza o regressor (TPE) para modelar a distribuição de probabilidades que é muito mais rápido que a implementação padrão utilizando "processos gaussianos".

Esta implementação foi feita em 6 passos:

- Definição da função de mínimo;
- Definição do espaço de pesquisa sobre os hiperparâmteros;
- Seleção do algoritimo de busca;
- Execução do algoritimo de ajuste com hyperopt fmin().
- Treino e Teste do SVM.

4.3.1 Definição da Função de mínimo

Como estamos fazendo a busca para um SVM, definimos um parâmetro params ['type'] como o nome do modelo, e uma função para executar o treinamento e retornar a precisão da validação cruzada. Como estamos tentando maximizar a precisão da validação cruzada, devemos negar esse valor para o hyperopt, pois o hyperopt sabe apenas como minimizar uma função.

[9]:
```
def get_acc_status(clf,X_,y):
    acc = cross_val_score(clf, X_, y, cv=5).mean()
    return {'loss': -acc, 'status': STATUS_OK}
```

[10]:
```
def objective(params):
    classifier_type = params['type']
    del params['type']
    if classifier_type == 'svm':
```

```
        clf = SVR(**params)
    else:
        return 0
    accuracy = cross_val_score(clf, x_treino, y_treino).mean()

    return {'loss': -accuracy, 'status': STATUS_OK}
```

4.3.2 Definição do espaço de pesquisa sobre os hiperparâmetros

Definimos o espaço de pesquisa dos hiperparâmetros C, gamma, e episolon de acordo com o range proposto para este trabalho:

[11]:
```
search_space = hp.choice('classifier_type', [
    {
        'type': 'svm',
        'C': hp.uniform('C', (2**-5), (2**15)),
        'gamma': hp.uniform('gamma', (2**-15), (2**3)),
        'epsilon': hp.uniform('epsilon', 0.05, 1.0),
        'kernel': hp.choice('kernel', ['rbf'])
    },
])
```

4.3.3 Seleção um algoritimo de busca

As duas opções principais de algoritmos de busca são:

- hyperopt.tpe.suggest: Estimadores da Árvore de Parzen, uma abordagem bayesiana que seleciona iterativa e adaptativamente novas configurações de hiperparâmetro para explorar com base em resultados anteriores;
- hyperopt.rand.suggest: Pesquisa aleatória, uma abordagem não adaptativa que mostra o espaço de pesquisa.

Conforme pedido, utilizamos o algoritimo o TPE.

4.3.4 Execução do algoritmo de ajuste com hyperopt fmin()

Após a definição da função mínimo, realizamos o treinamento do SVM usando as amostrasde treino, obtendo como resultado os melhores valores para cada um dos hiperparâmtros C,gamma e epsilon

[12]:
```
hypopt_trials = Trials()

best_params = fmin(objective, search_space, algo=tpe.suggest,
max_evals=125, trials= hypopt_trials)

best_gamma  = best_params['gamma']
best_C      = best_params['C']
best_epsilon= best_params['epsilon']
```

```
print("The best performing gamma value is: {:5.5f}".format(best_gamma))
print("The best performing C value is: {:5.2f}".format(best_C))
print("The best performing epsilon value is: {:5.2f}".format(best_epsilon))
```

```
100%|| 125/125 [00:20<00:00,  5.98trial/s, best loss:
-0.512377857326078]
The best performing gamma value is: 0.00383
The best performing C value is: 23889.46
The best performing epsilon value is:  0.35
```

Como resultado, obtivemos 23889.46 para o hiperparêmetro C, 0.00383 para o gamma e 0.35 para o epsilon. Como próximo passo, realizamos o teste no SVM usando os valores de hiperparâmetros encontrado, e calculamos o Erro Médio Absoluto (MAE) para o conjunto de teste:

[13]:
```
# Validation

svr  = SVR(kernel='rbf', gamma=best_gamma, epsilon=best_epsilon, C=best_C)
svr.fit(x_treino, y_treino)

pred = svr.predict(x_teste)

# print(regression.score(x_teste, y_teste))
print("MAE: ", metrics.mean_absolute_error(y_true=y_teste, y_pred=pred))
```

```
MAE:  4.424817673220065
```

Como resultado, obtivemos um Erro Absloluto Médio de aproximadamente **4.425** para o algoritimo de Otimização Bayesiana.

4.4 PSO

Outro algoritimo de otimização proposto foi o PSO. Para a sua implementação utilizamos a biblioteca pswarm.

Geramos o espaço de hiperparâmetro proposto para a busca, realizamos o treinamento do SVM e seu teste, obtendo como resultado os melhores valores para cada um dos hiperparâmtros e o Erro Médio Absoluto (MAE) para o conjunto de teste. Vale ressaltar quepara os parâmetros C e gammaa busca é linear/uniforme no expoente do parâmetro:

[14]:
```
# PARAMETERS
C_MIN = 2**(-5)
C_MAX = 2**15

GAMMA_MIN = 2**(-15)
GAMMA_MAX = 2**3

EPSILON_MIN = 0.05
EPSILON_MAX = 1.0
```

```
lb = np.array([C_MIN, GAMMA_MIN, EPSILON_MIN])
ub = np.array([C_MAX, GAMMA_MAX, EPSILON_MAX])

# FUNCTION
def svr_fun(X):
    c = X[0]
    g = X[1]
    eps = X[2]

    svr  = SVR(kernel='rbf', C=c, gamma=g, epsilon=eps)
    svr.fit(x_treino, y_treino)

    pred = svr.predict(x_teste)
    mae = metrics.mean_absolute_error(y_true=y_teste, y_pred=pred)

    return mae

print("PSO...")
x_opt, y_opt = pso(svr_fun, lb, ub, swarmsize=11, maxiter=11)

print(" C optimal: "+ str(x_opt[0])+
     "\n Gamma Optimal: "+ str(x_opt[1])+
     "\n Epsilon Optimal: "+ str(x_opt[2]))
print("MAE: ", str(y_opt))
```

```
PSO...
Stopping search: maximum iterations reached --> 11
 C optimal: 14140.294288841924
 Gamma Optimal: 3.0517578125e-05
 Epsilon Optimal: 0.5295739641377515
MAE:  2.358170016556401
```

Como resultado dos hiperparâmetros, obtivemos 14140.294 para o hiperparêmetro C, 3.052para o gamma e 0.53 parao epsilon. Já como resultado do Erro Médio Absoluto (MAE) obtivemos o valore de **2.358** para o algoritimo de otimização PSO.

4.5 Simulated Annealing

Para a implementação dos Métodos de Simmulate Annealing e CMA-ES foi utilizado a biblioteca optuna.

Para o método de Simulated Annealing a biblioteca fornece uma implementação via classe através dos chamados "samplers" para determinar os valores dos parâmetros a serem avaliados durante o teste. Para o Simmulated Annealing o sampler é implementado via classe explicitamente (vale ressaltar que estamos utilizando a implementação proposta pela própria documentação).

[15]:
```
class SimulatedAnnealingSampler(optuna.samplers.BaseSampler):
    def __init__(self, temperature=100):
        self._rng = np.random.RandomState()
        self._temperature = temperature  # Current temperature.
        self._current_trial = None  # Current state.

    def sample_relative(self, study, trial, search_space):
        if search_space == {}:
            return {}

        #
        # An implementation of SA algorithm.
        #

        # Calculate transition probability.
        prev_trial = study.trials[-2]
        if self._current_trial is None or prev_trial.value <= self.
↪_current_trial.value:
            probability = 1.0
        else:
            probability = np.exp((self._current_trial.value - prev_trial.value) /
↪ self._temperature)
        self._temperature *= 0.9  # Decrease temperature.

        # Transit the current state if the previous result is accepted.
        if self._rng.uniform(0, 1) < probability:
            self._current_trial = prev_trial

        # Sample parameters from the neighborhood of the current point.
        #
        # The sampled parameters will be used during the next execution of
        # the objective function passed to the study.
        params = {}
        for param_name, param_distribution in search_space.items():
            if not isinstance(param_distribution, optuna.distributions.
↪UniformDistribution):
                raise NotImplementedError('Only suggest_uniform() is supported')

            current_value = self._current_trial.params[param_name]
            width = (param_distribution.high - param_distribution.low) * 0.1
            neighbor_low = max(current_value - width, param_distribution.low)
            neighbor_high = min(current_value + width, param_distribution.high)
            params[param_name] = self._rng.uniform(neighbor_low, neighbor_high)

        return params

    #
```

```
    # The rest is boilerplate code and unrelated to SA algorithm.
    #
    def infer_relative_search_space(self, study, trial):
        return optuna.samplers.intersection_search_space(study)

    def sample_independent(self, study, trial, param_name, param_distribution):
        independent_sampler = optuna.samplers.RandomSampler()
        return independent_sampler.sample_independent(study, trial, param_name,␣
↪param_distribution)
```

Por fim o é necessário criar uma função objetivo a qual deseja-se otimizar, em nosso caso procuramos minimizar o Erro Médio Absoluto (MAE) com uma validação no conjunto de testes da aplicação dos hyperparâmetros encontrados para o problema do SVM Regressor.

[16]:
```
def objective(trial):
    c = trial.suggest_uniform('c', 2**(-5),  2**15)
    gamma = trial.suggest_uniform('gamma', 2**(-15),  2**3)
    epsilon = trial.suggest_uniform('epsilon', 0.05,  1.0)

    svr  = SVR(kernel='rbf', C=c, gamma=gamma, epsilon=epsilon)
    svr.fit(x_treino, y_treino)

    pred = svr.predict(x_teste)
    mae = metrics.mean_absolute_error(y_true=y_teste, y_pred=pred)

    return mae


sampler = SimulatedAnnealingSampler()
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=125)
```

```
[I 2020-05-06 08:50:42,475] Finished trial#0 with value:
5.753026268898263 with parameters: {'gamma': 1.2777035066242113, 'epsilon':
0.21554336378436367, 'c': 29826.680409225304}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:42,545] Finished trial#1 with value:
5.755605547348953 with parameters: {'gamma': 1.7797694187200348, 'epsilon':
0.2741210530764465, 'c': 31722.02629226882}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:42,619] Finished trial#2 with value:
5.755892891579987 with parameters: {'gamma': 1.6306628833299577, 'epsilon':
0.2883215834183387, 'c': 31751.35771399103}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:42,692] Finished trial#3 with value:
5.755568128428115 with parameters: {'gamma': 1.4683103067632908, 'epsilon':
0.2848167743723801, 'c': 32024.02962290317}. Best is trial#0 with value:
5.753026268898263.
```

```
[I 2020-05-06 08:50:42,766] Finished trial#4 with value:
5.755242160321546 with parameters: {'gamma': 2.07678095991698, 'epsilon':
0.25385487597853257, 'c': 30786.866256283145}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:42,838] Finished trial#5 with value:
5.758144771738561 with parameters: {'gamma': 2.2998118049811365, 'epsilon':
0.3385769930757133, 'c': 32054.928836132793}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:42,911] Finished trial#6 with value:
5.758040423504684 with parameters: {'gamma': 2.6248200059721913, 'epsilon':
0.3290481408760891, 'c': 30254.28745476136}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:42,985] Finished trial#7 with value:
5.755491094946731 with parameters: {'gamma': 2.390689012552282, 'epsilon':
0.253964958545829, 'c': 27216.110082467338}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:43,058] Finished trial#8 with value:
5.7583513191427915 with parameters: {'gamma': 2.4828158909602607, 'epsilon':
0.3411176170843043, 'c': 25565.404354543884}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:43,133] Finished trial#9 with value:
5.75648464059955 with parameters: {'gamma': 1.741502379277364, 'epsilon':
0.3026459956730544, 'c': 27381.332304274314}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:43,207] Finished trial#10 with value:
5.75376147514665 with parameters: {'gamma': 2.0081940062773733, 'epsilon':
0.20891089350261974, 'c': 27215.122689534706}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:43,283] Finished trial#11 with value:
5.754075792172724 with parameters: {'gamma': 1.521460500975535, 'epsilon':
0.23618110971704398, 'c': 26453.073378171917}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:43,359] Finished trial#12 with value:
5.755953955245427 with parameters: {'gamma': 1.826571918422743, 'epsilon':
0.2833765909396938, 'c': 29542.877309521733}. Best is trial#0 with value:
5.753026268898263.
[I 2020-05-06 08:50:43,438] Finished trial#13 with value:
5.752935042749474 with parameters: {'gamma': 1.7129992315841327, 'epsilon':
0.19260478136507833, 'c': 32559.055455544767}. Best is trial#13 with value:
5.752935042749474.
[I 2020-05-06 08:50:43,514] Finished trial#14 with value:
5.752850940700861 with parameters: {'gamma': 1.8992917121790192, 'epsilon':
0.18341527828850304, 'c': 29367.419232590688}. Best is trial#14 with value:
5.752850940700861.
[I 2020-05-06 08:50:43,592] Finished trial#15 with value:
5.750187424724563 with parameters: {'gamma': 2.0608247550479586, 'epsilon':
0.09256567638947756, 'c': 27907.42653797897}. Best is trial#15 with value:
5.750187424724563.
```

```
[I 2020-05-06 08:50:43,667] Finished trial#16 with value:
5.751935292113626 with parameters: {'gamma': 2.062646083566795, 'epsilon':
0.14892145914725663, 'c': 25059.08394236084}. Best is trial#15 with value:
5.750187424724563.
[I 2020-05-06 08:50:43,743] Finished trial#17 with value:
5.749866969835715 with parameters: {'gamma': 2.8603122185012024, 'epsilon':
0.062322455030104855, 'c': 22226.74603889884}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:43,820] Finished trial#18 with value:
5.751222940443675 with parameters: {'gamma': 2.975022733687518, 'epsilon':
0.10536932253205208, 'c': 21832.351977286988}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:43,897] Finished trial#19 with value:
5.750359603507409 with parameters: {'gamma': 2.8599751819625645, 'epsilon':
0.0794025450277012, 'c': 24381.56640373512}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:43,974] Finished trial#20 with value:
5.750200676818766 with parameters: {'gamma': 2.4489840405997403, 'epsilon':
0.08259690707407857, 'c': 23104.539976509735}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,054] Finished trial#21 with value:
5.7523944056789595 with parameters: {'gamma': 2.0831193321162087, 'epsilon':
0.16327161156851894, 'c': 19965.389861433545}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,133] Finished trial#22 with value:
5.752496872602009 with parameters: {'gamma': 2.7957039179787033, 'epsilon':
0.15003612280539003, 'c': 19065.813135789176}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,213] Finished trial#23 with value:
5.754724137003283 with parameters: {'gamma': 2.000158221072782, 'epsilon':
0.23970919259580845, 'c': 16958.10670867192}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,290] Finished trial#24 with value:
5.757784633515346 with parameters: {'gamma': 2.223676901015721, 'epsilon':
0.32934696012670106, 'c': 16920.82212465028}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,369] Finished trial#25 with value:
5.76027369568139 with parameters: {'gamma': 2.1398697626804717, 'epsilon':
0.4073546910189424, 'c': 18360.895717096664}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,450] Finished trial#26 with value:
5.759472306709581 with parameters: {'gamma': 2.638676334017955, 'epsilon':
0.372362198745042, 'c': 16119.009542511692}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,530] Finished trial#27 with value:
5.759685014009064 with parameters: {'gamma': 3.1548333325781399, 'epsilon':
0.370978480758698, 'c': 14557.327674823944}. Best is trial#17 with value:
5.749866969835715.
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[I 2020-05-06 08:50:44,607] Finished trial#28 with value:
5.758398716484393 with parameters: {'gamma': 3.3075313302986786, 'epsilon':
0.32971916408026264, 'c': 15176.691476299227}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,684] Finished trial#29 with value:
5.761115163956885 with parameters: {'gamma': 4.011210749989826, 'epsilon':
0.4050562615183133, 'c': 18187.131318133906}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,760] Finished trial#30 with value:
5.763673419167543 with parameters: {'gamma': 4.735830612361402, 'epsilon':
0.47690425109911194, 'c': 20173.612529212325}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,836] Finished trial#31 with value:
5.7608242133772825 with parameters: {'gamma': 4.040458246992169, 'epsilon':
0.39557553444046234, 'c': 19172.18473387048}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,918] Finished trial#32 with value:
5.761777182597349 with parameters: {'gamma': 3.6541274062809426, 'epsilon':
0.4290668158885744, 'c': 16557.717332901942}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:44,997] Finished trial#33 with value:
5.7642012697481935 with parameters: {'gamma': 3.171997155700177, 'epsilon':
0.5064911448510258, 'c': 15030.02029466065}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,076] Finished trial#34 with value:
5.762366971313073 with parameters: {'gamma': 2.8479422142104873, 'epsilon':
0.4571624689406673, 'c': 14748.672900798769}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,156] Finished trial#35 with value:
5.759963415039053 with parameters: {'gamma': 2.6571291858118866, 'epsilon':
0.3870800123727839, 'c': 12453.929814056226}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,234] Finished trial#36 with value:
5.763026009114833 with parameters: {'gamma': 2.667449862225153, 'epsilon':
0.47971281602422383, 'c': 14327.837811762398}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,313] Finished trial#37 with value:
5.7605519193347385 with parameters: {'gamma': 2.6931985912112624, 'epsilon':
0.4049115769602307, 'c': 16920.717353230364}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,392] Finished trial#38 with value:
5.757620677292336 with parameters: {'gamma': 2.7512613823305374, 'epsilon':
0.3136869004195555, 'c': 17598.864048391883}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,471] Finished trial#39 with value:
5.7547278060226335 with parameters: {'gamma': 2.664611337440977, 'epsilon':
0.22419989888995537, 'c': 20043.1424205602}. Best is trial#17 with value:
5.749866969835715.
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[I 2020-05-06 08:50:45,550] Finished trial#40 with value:
5.754381446998018 with parameters: {'gamma': 2.260827384261927, 'epsilon':
0.22181820404644578, 'c': 16861.207697657857}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,628] Finished trial#41 with value:
5.753097216914115 with parameters: {'gamma': 2.166673741272016, 'epsilon':
0.18332497282937632, 'c': 18384.6364542864}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,707] Finished trial#42 with value:
5.752880447829835 with parameters: {'gamma': 2.3378533785318543, 'epsilon':
0.17208151428761476, 'c': 15421.44228671145}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,786] Finished trial#43 with value:
5.754969255753048 with parameters: {'gamma': 1.7211864548653, 'epsilon':
0.256295893153923, 'c': 18576.547933838458}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,866] Finished trial#44 with value:
5.752085560511974 with parameters: {'gamma': 1.5497665266800653, 'epsilon':
0.17248180837986668, 'c': 16201.620499987352}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:45,947] Finished trial#45 with value:
5.750733721804509 with parameters: {'gamma': 2.2663825002519884, 'epsilon':
0.10427894944528, 'c': 16281.984509677928}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:46,027] Finished trial#46 with value:
5.749922725278455 with parameters: {'gamma': 1.9635725108993347, 'epsilon':
0.08719924386894974, 'c': 14372.60323882235}. Best is trial#17 with value:
5.749866969835715.
[I 2020-05-06 08:50:46,107] Finished trial#47 with value:
5.74876400778166 with parameters: {'gamma': 1.4073573466017422, 'epsilon':
0.07429484776254813, 'c': 15534.780156077532}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,189] Finished trial#48 with value:
5.749972178005766 with parameters: {'gamma': 1.4272875874154805, 'epsilon':
0.11132124825652114, 'c': 16443.624405855277}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,271] Finished trial#49 with value:
5.749274363916554 with parameters: {'gamma': 1.8434059222811694, 'epsilon':
0.0702193725145559, 'c': 17225.892989185304}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,353] Finished trial#50 with value:
5.750050561789997 with parameters: {'gamma': 2.5848777367687825, 'epsilon':
0.07452116938473205, 'c': 19069.974592472892}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,436] Finished trial#51 with value:
5.749680042159358 with parameters: {'gamma': 2.990296394524973, 'epsilon':
0.05335396394537105, 'c': 20273.89486466213}. Best is trial#47 with value:
5.74876400778166.
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[I 2020-05-06 08:50:46,518] Finished trial#52 with value:
5.7522423256789 with parameters: {'gamma': 2.511846087241636, 'epsilon':
0.1473608816506991, 'c': 20071.399093447362}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,601] Finished trial#53 with value:
5.750212884178049 with parameters: {'gamma': 1.8417391651397708, 'epsilon':
0.10073701914002259, 'c': 22660.43416377205}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,683] Finished trial#54 with value:
5.751414729035164 with parameters: {'gamma': 2.299928125014598, 'epsilon':
0.12534888724331872, 'c': 21147.152944231162}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,765] Finished trial#55 with value:
5.749083545670945 with parameters: {'gamma': 2.0319477193655873, 'epsilon':
0.05651597373939906, 'c': 19283.52381589052}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,848] Finished trial#56 with value:
5.749571311135517 with parameters: {'gamma': 2.467418835807809, 'epsilon':
0.0605964693393103, 'c': 20581.67737428537}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:46,943] Finished trial#57 with value:
5.750957360645912 with parameters: {'gamma': 2.3662660321332307, 'epsilon':
0.10895766293941936, 'c': 21127.3666027417}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,027] Finished trial#58 with value:
5.748939501865445 with parameters: {'gamma': 1.9120512654931248, 'epsilon':
0.055930204332360664, 'c': 22813.413793201253}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,109] Finished trial#59 with value:
5.749605820409482 with parameters: {'gamma': 2.572110240329599, 'epsilon':
0.05927768499810643, 'c': 24047.898763430923}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,193] Finished trial#60 with value:
5.7494645899405 with parameters: {'gamma': 1.97632450131953, 'epsilon':
0.07170788592611896, 'c': 25451.832982907246}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,276] Finished trial#61 with value:
5.7508123995549925 with parameters: {'gamma': 2.1224966850628455, 'epsilon':
0.11078953028606421, 'c': 26763.376849847547}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,362] Finished trial#62 with value:
5.750293221479779 with parameters: {'gamma': 2.1192184273401, 'epsilon':
0.09420287246682861, 'c': 24074.127392538518}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,448] Finished trial#63 with value:
5.750557545450795 with parameters: {'gamma': 2.1188382963514956, 'epsilon':
0.10270530070966077, 'c': 21274.198755581405}. Best is trial#47 with value:
5.74876400778166.
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[I 2020-05-06 08:50:47,534] Finished trial#64 with value:
5.749825262846574 with parameters: {'gamma': 2.1215822735842202, 'epsilon':
0.07909946914738994, 'c': 19303.852591095896}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,621] Finished trial#65 with value:
5.750636135617252 with parameters: {'gamma': 2.624112558130448, 'epsilon':
0.09284415293789902, 'c': 21002.916852703012}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,708] Finished trial#66 with value:
5.75120585451198 with parameters: {'gamma': 2.732379646433157, 'epsilon':
0.10912345031510207, 'c': 23725.251182392494}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,794] Finished trial#67 with value:
5.752791620058939 with parameters: {'gamma': 2.4483448012682056, 'epsilon':
0.16671187050013747, 'c': 20959.621182584626}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,878] Finished trial#68 with value:
5.753989394759091 with parameters: {'gamma': 1.834837736945479, 'epsilon':
0.22159338356193287, 'c': 21425.086137113925}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:47,965] Finished trial#69 with value:
5.7517833853012466 with parameters: {'gamma': 2.493982092246412, 'epsilon':
0.13265076847717042, 'c': 23402.421603560608}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,049] Finished trial#70 with value:
5.752135894810202 with parameters: {'gamma': 3.2606403666773236, 'epsilon':
0.13054901598215163, 'c': 24258.84830017671}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,133] Finished trial#71 with value:
5.753627539513848 with parameters: {'gamma': 3.62804796009636, 'epsilon':
0.17438400174016977, 'c': 22850.284755726272}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,219] Finished trial#72 with value:
5.756024007980531 with parameters: {'gamma': 3.888912423483351, 'epsilon':
0.24809217824229426, 'c': 22206.919374399145}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,303] Finished trial#73 with value:
5.754801723643467 with parameters: {'gamma': 4.503342485680559, 'epsilon':
0.20225649080055969, 'c': 20057.783967932002}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,391] Finished trial#74 with value:
5.7516163778201905 with parameters: {'gamma': 3.71241225251057, 'epsilon':
0.10771193316921411, 'c': 19838.188503079764}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,476] Finished trial#75 with value:
5.7532307572301296 with parameters: {'gamma': 2.9200425647447266, 'epsilon':
0.1717428740746989, 'c': 16966.535882243257}. Best is trial#47 with value:
5.74876400778166.
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[I 2020-05-06 08:50:48,561] Finished trial#76 with value:
5.753678998712005 with parameters: {'gamma': 2.1647211554459957, 'epsilon':
0.20189866949403695, 'c': 19751.936409611004}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,647] Finished trial#77 with value:
5.753085314558185 with parameters: {'gamma': 2.4271600775295106, 'epsilon':
0.17656138872163718, 'c': 22026.402329024786}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,733] Finished trial#78 with value:
5.752856727595084 with parameters: {'gamma': 1.789439943831732, 'epsilon':
0.18734132929056702, 'c': 23648.077884325718}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,820] Finished trial#79 with value:
5.753748640216123 with parameters: {'gamma': 2.4898225926310404, 'epsilon':
0.19639137902091475, 'c': 22970.987831428327}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,907] Finished trial#80 with value:
5.755056326689753 with parameters: {'gamma': 2.914464298017858, 'epsilon':
0.23033222916308593, 'c': 26233.007439613048}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:48,995] Finished trial#81 with value:
5.753121875842386 with parameters: {'gamma': 2.7885484516450383, 'epsilon':
0.17051683362738795, 'c': 26941.39022935803}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,082] Finished trial#82 with value:
5.755096574381745 with parameters: {'gamma': 2.4212099226370127, 'epsilon':
0.24091702034167167, 'c': 27962.20788553022}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,170] Finished trial#83 with value:
5.752591932098558 with parameters: {'gamma': 1.681287234775687, 'epsilon':
0.18298723949180612, 'c': 26582.29207883055}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,258] Finished trial#84 with value:
5.7527566452085654 with parameters: {'gamma': 1.5166234122057332, 'epsilon':
0.195008755661291, 'c': 29686.865604271865}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,347] Finished trial#85 with value:
5.75176167517248 with parameters: {'gamma': 2.1490399983663195, 'epsilon':
0.14067664835914592, 'c': 32683.70278501384}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,436] Finished trial#86 with value:
5.749921287006399 with parameters: {'gamma': 1.9578008951694392, 'epsilon':
0.08734505681463096, 'c': 32105.230737453952}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,525] Finished trial#87 with value:
5.750369422246908 with parameters: {'gamma': 1.6479288926415179, 'epsilon':
0.1134114447902531, 'c': 31275.056726506566}. Best is trial#47 with value:
5.74876400778166.
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[I 2020-05-06 08:50:49,615] Finished trial#88 with value:
5.752291151627873 with parameters: {'gamma': 1.6345286507720358, 'epsilon':
0.17537530698568105, 'c': 31115.682771647647}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,704] Finished trial#89 with value:
5.752337671800994 with parameters: {'gamma': 1.7743141536137383, 'epsilon':
0.17148358713527925, 'c': 28477.683633234996}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,795] Finished trial#90 with value:
5.74922570672994 with parameters: {'gamma': 1.1420999962436076, 'epsilon':
0.09748900689260503, 'c': 30957.25628490265}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,887] Finished trial#91 with value:
5.750588238778255 with parameters: {'gamma': 0.9197772871617539, 'epsilon':
0.09171465356104525, 'c': 29779.673434124263}. Best is trial#47 with value:
5.74876400778166.
[I 2020-05-06 08:50:49,979] Finished trial#92 with value:
5.653269849621623 with parameters: {'gamma': 0.23658372521395488, 'epsilon':
0.1796782596511433, 'c': 26887.184637403225}. Best is trial#92 with value:
5.653269849621623.
[I 2020-05-06 08:50:50,071] Finished trial#93 with value:
5.742456653208486 with parameters: {'gamma': 0.4369624620979731, 'epsilon':
0.22009778413604852, 'c': 24841.037303190547}. Best is trial#92 with value:
5.653269849621623.
[I 2020-05-06 08:50:50,163] Finished trial#94 with value:
5.740417225931475 with parameters: {'gamma': 0.4463744830033918, 'epsilon':
0.09365434863639673, 'c': 29167.958362423247}. Best is trial#92 with value:
5.653269849621623.
[I 2020-05-06 08:50:50,255] Finished trial#95 with value:
5.720057398576405 with parameters: {'gamma': 0.34727144962593454, 'epsilon':
0.10917416032077057, 'c': 25752.27899312643}. Best is trial#92 with value:
5.653269849621623.
[I 2020-05-06 08:50:50,350] Finished trial#96 with value:
5.7550811940762605 with parameters: {'gamma': 0.8423284385499025, 'epsilon':
0.25556545561342925, 'c': 25765.840224355194}. Best is trial#92 with value:
5.653269849621623.
[I 2020-05-06 08:50:50,442] Finished trial#97 with value:
5.751594395073394 with parameters: {'gamma': 0.5927469147211605, 'epsilon':
0.16742529716832838, 'c': 26842.021718775417}. Best is trial#92 with value:
5.653269849621623.
[I 2020-05-06 08:50:50,532] Finished trial#98 with value:
5.751891076280987 with parameters: {'gamma': 0.8489967507423429, 'epsilon':
0.12807901141524886, 'c': 28371.566962525394}. Best is trial#92 with value:
5.653269849621623.
[I 2020-05-06 08:50:50,623] Finished trial#99 with value:
5.750177190370425 with parameters: {'gamma': 0.9677550293763812, 'epsilon':
0.08804319104974485, 'c': 24892.203664722034}. Best is trial#92 with value:
5.653269849621623.
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[I 2020-05-06 08:50:50,714] Finished trial#100 with value:
5.7535540383708765 with parameters: {'gamma': 0.6252585537231459, 'epsilon':
0.21918501434966306, 'c': 26738.61295020016}. Best is trial#92 with value:
5.653269849621623.
[I 2020-05-06 08:50:50,809] Finished trial#101 with value:
4.914415581730898 with parameters: {'gamma': 0.05646102006512832, 'epsilon':
0.14319787931678946, 'c': 26025.458578405214}. Best is trial#101 with value:
4.914415581730898.
[I 2020-05-06 08:50:50,901] Finished trial#102 with value:
5.667123778504726 with parameters: {'gamma': 0.2492168712831818, 'epsilon':
0.21287376151761145, 'c': 26419.97994693843}. Best is trial#101 with value:
4.914415581730898.
[I 2020-05-06 08:50:50,995] Finished trial#103 with value:
5.744805785922472 with parameters: {'gamma': 0.4660705485146748, 'epsilon':
0.17987193641173488, 'c': 23543.499019095263}. Best is trial#101 with value:
4.914415581730898.
[I 2020-05-06 08:50:51,088] Finished trial#104 with value:
5.719273976655145 with parameters: {'gamma': 0.33840126709754387, 'epsilon':
0.1885955556695973, 'c': 25813.441131789397}. Best is trial#101 with value:
4.914415581730898.
[I 2020-05-06 08:50:51,214] Finished trial#105 with value:
3.9512357645739202 with parameters: {'gamma': 0.009248559171403896, 'epsilon':
0.15248316050999622, 'c': 24553.048016203276}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:51,307] Finished trial#106 with value:
5.706035216914074 with parameters: {'gamma': 0.31100295367408176, 'epsilon':
0.1260177045210718, 'c': 27254.935443836326}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:51,400] Finished trial#107 with value:
5.753597175660965 with parameters: {'gamma': 0.7180281020753472, 'epsilon':
0.18695607547002935, 'c': 25860.18049010385}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:51,495] Finished trial#108 with value:
5.614748870047244 with parameters: {'gamma': 0.20980057794804913, 'epsilon':
0.06502314523891844, 'c': 26328.251264855186}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:51,588] Finished trial#109 with value:
5.747670203097624 with parameters: {'gamma': 0.4939126066962896, 'epsilon':
0.19723361661322633, 'c': 27030.970400136477}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:51,681] Finished trial#110 with value:
5.7524233678447 with parameters: {'gamma': 0.7567328978093638, 'epsilon':
0.1377936272610092, 'c': 25267.566368386648}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:51,775] Finished trial#111 with value:
5.751091791021267 with parameters: {'gamma': 0.574144930837575, 'epsilon':
0.16901129797463496, 'c': 27629.460755512453}. Best is trial#105 with value:
3.9512357645739202.
```

```
[I 2020-05-06 08:50:51,869] Finished trial#112 with value:
5.751453492838074 with parameters: {'gamma': 0.7591823629225204, 'epsilon':
0.09780872174095455, 'c': 22099.227199456815}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:51,965] Finished trial#113 with value:
5.753184625067194 with parameters: {'gamma': 0.60940163247569, 'epsilon':
0.2164933204870637, 'c': 24683.515600374292}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,060] Finished trial#114 with value:
5.751225681380369 with parameters: {'gamma': 0.5514577918468562, 'epsilon':
0.20847827318041076, 'c': 24704.303967336462}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,154] Finished trial#115 with value:
5.754781039033066 with parameters: {'gamma': 0.7478877371899536, 'epsilon':
0.23368855165868085, 'c': 24718.21951437136}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,252] Finished trial#116 with value:
5.035878836335825 with parameters: {'gamma': 0.065746016098409, 'epsilon':
0.15560421317771142, 'c': 25022.813242180702}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,348] Finished trial#117 with value:
5.661598141629126 with parameters: {'gamma': 0.248171924662401, 'epsilon':
0.08570380241714383, 'c': 23556.513790207096}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,446] Finished trial#118 with value:
5.74371824155255 with parameters: {'gamma': 0.4636713119791396, 'epsilon':
0.14724681958157318, 'c': 23514.573114017516}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,542] Finished trial#119 with value:
5.51199000650995 with parameters: {'gamma': 0.15430867130217263, 'epsilon':
0.24571608731375313, 'c': 22336.30593747008}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,639] Finished trial#120 with value:
5.752788230394961 with parameters: {'gamma': 0.735979776666509, 'epsilon':
0.15261964186787252, 'c': 26724.09373208331}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,737] Finished trial#121 with value:
5.696135652256032 with parameters: {'gamma': 0.2934971797693578, 'epsilon':
0.10400847383573797, 'c': 25432.089665531334}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,839] Finished trial#122 with value:
5.688370353555387 with parameters: {'gamma': 0.2799563251222198, 'epsilon':
0.12441630525467777, 'c': 24286.61151257248}. Best is trial#105 with value:
3.9512357645739202.
[I 2020-05-06 08:50:52,936] Finished trial#123 with value:
5.73619495956455 with parameters: {'gamma': 0.39753526815181567, 'epsilon':
0.22577590347879745, 'c': 24117.725871403643}. Best is trial#105 with value:
3.9512357645739202.
```

```
[I 2020-05-06 08:50:53,038] Finished trial#124 with value:
5.554124258039338 with parameters: {'gamma': 0.17448235689892813, 'epsilon':
0.12388142876068961, 'c': 23854.007322043508}. Best is trial#105 with value:
3.9512357645739202.
```

Logo, como resultado os melhores parâmetros encontrados durante a busca são mostrados:

[17]:
```
study.best_params
```

[17]:
```
{'c': 24553.048016203276,
 'epsilon': 0.15248316050999622,
 'gamma': 0.009248559171403896}
```

Obtivemos 24553.05 para o hiperparêmetro C, 0.0092 para o gamma e 0.1525 para o epsilon.Bem como o resultado para o erro absoluto médio (MAE) no conjunto de teste com esses parâmetros:

[18]:
```
study.best_value
```

[18]:
```
3.9512357645739202
```

Como resultado, obtivemos um Erro Absloluto Médio de **3.951** para o algoritimo de Simulated Annealing.

4.6 CMA-ES

Semelhantemente ao algoritmo de Simullate Annealing, a implementação do algoritmo de otimização CMA-ES também foi feita via biblioteca optunza. A implementação porém é encapsulada em um sampler default fornecido pela própria biblioteca, assim não sendo necessário a implementação de uma classe sampler específica, somente a função objetivo.

[19]:
```
def objective(trial):
    c = trial.suggest_uniform('c', 2**(-5),  2**15)
    gamma = trial.suggest_uniform('gamma', 2**(-15),  2**3)
    epsilon = trial.suggest_uniform('epsilon', 0.05,  1.0)

    svr  = SVR(kernel='rbf', C=c, gamma=gamma, epsilon=epsilon)
    svr.fit(x_treino, y_treino)

    pred = svr.predict(x_teste)
    mae = metrics.mean_absolute_error(y_true=y_teste, y_pred=pred)

    return mae


sampler = optuna.samplers.CmaEsSampler()
study = optuna.create_study(sampler=sampler)
study.optimize(objective, n_trials=125)
```

```
[I 2020-05-06 08:50:53,177] Finished trial#0 with value:
5.773771560110476 with parameters: {'gamma': 4.2989136542038455, 'epsilon':
0.7572201522434417, 'c': 6048.840633131541}. Best is trial#0 with value:
5.773771560110476.
[I 2020-05-06 08:50:53,252] Finished trial#1 with value:
5.762963306102457 with parameters: {'gamma': 4.266163346771949, 'epsilon':
0.4581913875147416, 'c': 16383.869710978033}. Best is trial#1 with value:
5.762963306102457.
[I 2020-05-06 08:50:53,326] Finished trial#2 with value:
5.757551045919005 with parameters: {'gamma': 3.8082608575686168, 'epsilon':
0.29696435013509526, 'c': 16384.080196256407}. Best is trial#2 with value:
5.757551045919005.
[I 2020-05-06 08:50:53,400] Finished trial#3 with value:
5.762054999979861 with parameters: {'gamma': 3.7277367531197747, 'epsilon':
0.43658862228063444, 'c': 16384.0094607236}. Best is trial#2 with value:
5.757551045919005.
[I 2020-05-06 08:50:53,469] Finished trial#4 with value:
5.766810941996621 with parameters: {'gamma': 4.012035610386193, 'epsilon':
0.5699652802157129, 'c': 16383.954914482481}. Best is trial#2 with value:
5.757551045919005.
[I 2020-05-06 08:50:53,541] Finished trial#5 with value:
5.766601264652528 with parameters: {'gamma': 3.963693182621948, 'epsilon':
0.5646093697098041, 'c': 16384.071123302583}. Best is trial#2 with value:
5.757551045919005.
[I 2020-05-06 08:50:53,611] Finished trial#6 with value:
5.7653045931340365 with parameters: {'gamma': 3.9568659224999703, 'epsilon':
0.5286137365392999, 'c': 16384.140720960404}. Best is trial#2 with value:
5.757551045919005.
[I 2020-05-06 08:50:53,688] Finished trial#7 with value:
5.76101262910525 with parameters: {'gamma': 3.629132329296557, 'epsilon':
0.4062070101799285, 'c': 16384.212665175866}. Best is trial#2 with value:
5.757551045919005.
[I 2020-05-06 08:50:53,760] Finished trial#8 with value:
5.765624012045299 with parameters: {'gamma': 3.963588191706637, 'epsilon':
0.5374313344020732, 'c': 16383.932763161629}. Best is trial#2 with value:
5.757551045919005.
[I 2020-05-06 08:50:53,835] Finished trial#9 with value:
5.7549855309593445 with parameters: {'gamma': 3.793696003170971, 'epsilon':
0.21599565785650715, 'c': 16384.124370206693}. Best is trial#9 with value:
5.7549855309593445.
[I 2020-05-06 08:50:53,911] Finished trial#10 with value:
5.753850057491131 with parameters: {'gamma': 3.8784494282884596, 'epsilon':
0.17852166932894167, 'c': 16384.131150472684}. Best is trial#10 with value:
5.753850057491131.
[I 2020-05-06 08:50:53,983] Finished trial#11 with value:
5.771298862733338 with parameters: {'gamma': 3.82060863332218, 'epsilon':
0.6941058416017636, 'c': 16383.994026386248}. Best is trial#10 with value:
5.753850057491131.
```

```
[I 2020-05-06 08:50:54,060] Finished trial#12 with value:
5.75395786776588 with parameters: {'gamma': 3.4561477489532693, 'epsilon':
0.1871918994354483, 'c': 16383.875446273016}. Best is trial#10 with value:
5.753850057491131.
[I 2020-05-06 08:50:54,135] Finished trial#13 with value:
5.7542137682395476 with parameters: {'gamma': 3.5460111087536696, 'epsilon':
0.19424463624895377, 'c': 16383.956233148212}. Best is trial#10 with value:
5.753850057491131.
[I 2020-05-06 08:50:54,209] Finished trial#14 with value:
5.764496203494265 with parameters: {'gamma': 3.871417837050226, 'epsilon':
0.5070416723819455, 'c': 16383.871935527377}. Best is trial#10 with value:
5.753850057491131.
[I 2020-05-06 08:50:54,285] Finished trial#15 with value:
5.750997589018267 with parameters: {'gamma': 3.7654978262202974, 'epsilon':
0.08698478983732576, 'c': 16384.04955355946}. Best is trial#15 with value:
5.750997589018267.
[I 2020-05-06 08:50:54,362] Finished trial#16 with value:
5.755333072456681 with parameters: {'gamma': 3.556871846430916, 'epsilon':
0.23004805186847563, 'c': 16384.122117221843}. Best is trial#15 with value:
5.750997589018267.
[I 2020-05-06 08:50:54,438] Finished trial#17 with value:
5.7554252860665835 with parameters: {'gamma': 3.6245948371312022, 'epsilon':
0.2321607071077732, 'c': 16384.081136271594}. Best is trial#15 with value:
5.750997589018267.
[I 2020-05-06 08:50:54,514] Finished trial#18 with value:
5.750444440962776 with parameters: {'gamma': 3.5223110610132813, 'epsilon':
0.07173427491801455, 'c': 16384.00342303718}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:54,590] Finished trial#19 with value:
5.756559226775022 with parameters: {'gamma': 3.831664394885874, 'epsilon':
0.26547904792804183, 'c': 16384.01946390406}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:54,668] Finished trial#20 with value:
5.764418578732007 with parameters: {'gamma': 4.186884056296162, 'epsilon':
0.5018355276605955, 'c': 16384.028502097735}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:54,744] Finished trial#21 with value:
5.7586554101410705 with parameters: {'gamma': 3.6238495408957845, 'epsilon':
0.33367998994312087, 'c': 16384.03047085501}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:54,822] Finished trial#22 with value:
5.752327979152903 with parameters: {'gamma': 3.7556735658679106, 'epsilon':
0.1302692790083247, 'c': 16383.994136795902}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:54,901] Finished trial#23 with value:
5.758622011995341 with parameters: {'gamma': 3.7277011980400374, 'epsilon':
0.3314622837747237, 'c': 16384.194807148135}. Best is trial#18 with value:
5.750444440962776.
```

```
[I 2020-05-06 08:50:54,979] Finished trial#24 with value:
5.758295352781205 with parameters: {'gamma': 3.2306889702432757, 'epsilon':
0.3275696554844899, 'c': 16384.364426454365}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,058] Finished trial#25 with value:
5.754272593746502 with parameters: {'gamma': 3.2925043469752473, 'epsilon':
0.19950045369173108, 'c': 16384.255561113532}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,136] Finished trial#26 with value:
5.756870020801537 with parameters: {'gamma': 3.6947983943577083, 'epsilon':
0.2768575480582992, 'c': 16384.01627341902}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,218] Finished trial#27 with value:
5.754638014205643 with parameters: {'gamma': 3.7614529503573593, 'epsilon':
0.2052115932570157, 'c': 16384.22731987178}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,295] Finished trial#28 with value:
5.762852759688209 with parameters: {'gamma': 3.8181262297364085, 'epsilon':
0.45957533083585567, 'c': 16384.144916662866}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,371] Finished trial#29 with value:
5.76530594512652 with parameters: {'gamma': 3.9556276967837296, 'epsilon':
0.5286659163331932, 'c': 16384.081886584223}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,450] Finished trial#30 with value:
5.750460813834351 with parameters: {'gamma': 3.2924680749068775, 'epsilon':
0.07570023889317531, 'c': 16384.046092791676}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,529] Finished trial#31 with value:
5.753095547934192 with parameters: {'gamma': 3.686518203293624, 'epsilon':
0.15646469306299537, 'c': 16384.336973173373}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,609] Finished trial#32 with value:
5.75123728288507 with parameters: {'gamma': 3.7971857420510307, 'epsilon':
0.09438066554766741, 'c': 16384.05229448573}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,689] Finished trial#33 with value:
5.753490096586525 with parameters: {'gamma': 3.6103672779369527, 'epsilon':
0.17019404380045702, 'c': 16384.10266491615}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,767] Finished trial#34 with value:
5.761821279341518 with parameters: {'gamma': 3.603951461072477, 'epsilon':
0.43096337295831166, 'c': 16384.252510882456}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:55,850] Finished trial#35 with value:
5.763243682487366 with parameters: {'gamma': 3.8988691810040734, 'epsilon':
0.47045816740665214, 'c': 16383.88357459448}. Best is trial#18 with value:
5.750444440962776.
```

```
[I 2020-05-06 08:50:55,930] Finished trial#36 with value:
5.75576786701317 with parameters: {'gamma': 3.6262522499243532, 'epsilon':
0.24314339878596636, 'c': 16383.951588855507}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,009] Finished trial#37 with value:
5.751485037558685 with parameters: {'gamma': 3.451378471052369, 'epsilon':
0.10680086980537931, 'c': 16384.162529916783}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,089] Finished trial#38 with value:
5.752141007552208 with parameters: {'gamma': 3.8307075589845954, 'epsilon':
0.1232996528147261, 'c': 16384.042229057155}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,168] Finished trial#39 with value:
5.756016217630617 with parameters: {'gamma': 3.6127877640839907, 'epsilon':
0.2510636327193108, 'c': 16383.984565236673}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,249] Finished trial#40 with value:
5.757820087035603 with parameters: {'gamma': 3.665935277353267, 'epsilon':
0.30709598999697846, 'c': 16384.000222543025}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,330] Finished trial#41 with value:
5.751422986475521 with parameters: {'gamma': 3.1601196065331942, 'epsilon':
0.10892369778547623, 'c': 16384.135709522423}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,411] Finished trial#42 with value:
5.750987680337595 with parameters: {'gamma': 3.0189797725058014, 'epsilon':
0.0970361852546237, 'c': 16384.15260237308}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,492] Finished trial#43 with value:
5.751888403483097 with parameters: {'gamma': 3.1324443751797113, 'epsilon':
0.12442559268422651, 'c': 16384.338875939473}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,573] Finished trial#44 with value:
5.751041282096323 with parameters: {'gamma': 3.1515671120980286, 'epsilon':
0.09668888641003752, 'c': 16383.772241148148}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,654] Finished trial#45 with value:
5.752426824967838 with parameters: {'gamma': 3.5897570462738324, 'epsilon':
0.1355554283953749, 'c': 16384.287060436356}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,736] Finished trial#46 with value:
5.751444190855891 with parameters: {'gamma': 3.242790568669008, 'epsilon':
0.10838613014382477, 'c': 16384.041961187297}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,817] Finished trial#47 with value:
5.754831646305065 with parameters: {'gamma': 2.8245651605742386, 'epsilon':
0.22463638145741682, 'c': 16384.05816401963}. Best is trial#18 with value:
5.750444440962776.
```

```
[I 2020-05-06 08:50:56,899] Finished trial#48 with value:
5.753360061426541 with parameters: {'gamma': 3.4533409686917214, 'epsilon':
0.16803370432349135, 'c': 16384.27115584044}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:56,981] Finished trial#49 with value:
5.7570047898916386 with parameters: {'gamma': 2.5519060806084592, 'epsilon':
0.29799784433535254, 'c': 16384.348262010717}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,065] Finished trial#50 with value:
5.758384843421655 with parameters: {'gamma': 3.8130393674299534, 'epsilon':
0.32315326940964073, 'c': 16383.789071311601}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,147] Finished trial#51 with value:
5.766867802357711 with parameters: {'gamma': 3.8108284427088313, 'epsilon':
0.5735409934254344, 'c': 16384.38628761014}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,233] Finished trial#52 with value:
5.752053580348768 with parameters: {'gamma': 3.465267755970692, 'epsilon':
0.12505209399555348, 'c': 16383.859301870722}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,314] Finished trial#53 with value:
5.762099173438629 with parameters: {'gamma': 3.0266364958455267, 'epsilon':
0.4465578421484633, 'c': 16384.04274774957}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,398] Finished trial#54 with value:
5.751559084824647 with parameters: {'gamma': 3.240048689751821, 'epsilon':
0.11214982041234808, 'c': 16384.204921991073}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,481] Finished trial#55 with value:
5.753063131456136 with parameters: {'gamma': 3.314454654302279, 'epsilon':
0.16038669599742664, 'c': 16384.030922539878}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,565] Finished trial#56 with value:
5.751789092148325 with parameters: {'gamma': 2.8179375348871547, 'epsilon':
0.12640635414723272, 'c': 16383.996716148335}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,649] Finished trial#57 with value:
5.7548779101192435 with parameters: {'gamma': 3.303753995437713, 'epsilon':
0.21877088105631545, 'c': 16384.31956963774}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,732] Finished trial#58 with value:
5.754112472714326 with parameters: {'gamma': 4.009295980102918, 'epsilon':
0.1854501333530037, 'c': 16384.227858528444}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,818] Finished trial#59 with value:
5.757039213321717 with parameters: {'gamma': 3.41781891824377, 'epsilon':
0.28560022753581904, 'c': 16384.174303903284}. Best is trial#18 with value:
5.750444440962776.
```

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[I 2020-05-06 08:50:57,904] Finished trial#60 with value:
5.753097893040806 with parameters: {'gamma': 3.3898750931077717, 'epsilon':
0.16046899357167543, 'c': 16384.03514693787}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:57,988] Finished trial#61 with value:
5.751174674310262 with parameters: {'gamma': 3.355434683316822, 'epsilon':
0.09804730081383202, 'c': 16384.10970426544}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:58,072] Finished trial#62 with value:
5.758554701687759 with parameters: {'gamma': 3.040877563365143, 'epsilon':
0.33809657870693255, 'c': 16384.41709456131}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:58,156] Finished trial#63 with value:
5.756712657284251 with parameters: {'gamma': 3.4182631660483342, 'epsilon':
0.27532221230144205, 'c': 16384.369535915917}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:58,239] Finished trial#64 with value:
5.754515711127314 with parameters: {'gamma': 3.513152504044049, 'epsilon':
0.20435982924648194, 'c': 16383.955574846683}. Best is trial#18 with value:
5.750444440962776.
[I 2020-05-06 08:50:58,325] Finished trial#65 with value:
5.750370626494153 with parameters: {'gamma': 3.8185197489250107, 'epsilon':
0.06515411077189903, 'c': 16384.454635300284}. Best is trial#65 with value:
5.750370626494153.
[I 2020-05-06 08:50:58,408] Finished trial#66 with value:
5.75629928086482 with parameters: {'gamma': 3.739607399933259, 'epsilon':
0.2583815186807771, 'c': 16384.082174051775}. Best is trial#65 with value:
5.750370626494153.
[I 2020-05-06 08:50:58,494] Finished trial#67 with value:
5.753009374656854 with parameters: {'gamma': 2.9376319940425613, 'epsilon':
0.16435642966134922, 'c': 16384.02509196776}. Best is trial#65 with value:
5.750370626494153.
[I 2020-05-06 08:50:58,578] Finished trial#68 with value:
5.750269428546219 with parameters: {'gamma': 3.4824675674274146, 'epsilon':
0.06616369126197993, 'c': 16384.1791860742}. Best is trial#68 with value:
5.750269428546219.
[I 2020-05-06 08:50:58,663] Finished trial#69 with value:
5.753469660279561 with parameters: {'gamma': 3.4964338683413194, 'epsilon':
0.1709922595934187, 'c': 16384.082002130763}. Best is trial#68 with value:
5.750269428546219.
[I 2020-05-06 08:50:58,747] Finished trial#70 with value:
5.755885728153833 with parameters: {'gamma': 4.115632095649502, 'epsilon':
0.24124085828723935, 'c': 16383.822167549466}. Best is trial#68 with value:
5.750269428546219.
[I 2020-05-06 08:50:58,832] Finished trial#71 with value:
5.75101686606926 with parameters: {'gamma': 3.7410091693459266, 'epsilon':
0.08790797700937551, 'c': 16384.246084427497}. Best is trial#68 with value:
5.750269428546219.
```

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[I 2020-05-06 08:50:58,916] Finished trial#72 with value:
5.753900192050059 with parameters: {'gamma': 3.5046916390756375, 'epsilon':
0.18470633648653584, 'c': 16383.874236517388}. Best is trial#68 with value:
5.750269428546219.
[I 2020-05-06 08:50:59,003] Finished trial#73 with value:
5.7552586414674565 with parameters: {'gamma': 3.3797594823852295, 'epsilon':
0.22995917165267904, 'c': 16384.301101828503}. Best is trial#68 with value:
5.750269428546219.
[I 2020-05-06 08:50:59,088] Finished trial#74 with value:
5.750238958388299 with parameters: {'gamma': 3.5574787650810293, 'epsilon':
0.0640292621673333, 'c': 16384.654554153756}. Best is trial#74 with value:
5.750238958388299.
[I 2020-05-06 08:50:59,174] Finished trial#75 with value:
5.754392229769289 with parameters: {'gamma': 4.009560275352786, 'epsilon':
0.19443536585428545, 'c': 16384.043782136738}. Best is trial#74 with value:
5.750238958388299.
[I 2020-05-06 08:50:59,261] Finished trial#76 with value:
5.754955332745986 with parameters: {'gamma': 3.4868095001251795, 'epsilon':
0.21881616578022875, 'c': 16384.23884234777}. Best is trial#74 with value:
5.750238958388299.
[I 2020-05-06 08:50:59,349] Finished trial#77 with value:
5.752067949085318 with parameters: {'gamma': 3.8409835278495508, 'epsilon':
0.12080844430352991, 'c': 16384.27629857473}. Best is trial#74 with value:
5.750238958388299.
[I 2020-05-06 08:50:59,437] Finished trial#78 with value:
5.750143455634304 with parameters: {'gamma': 3.569688225075333, 'epsilon':
0.06051067468364264, 'c': 16384.53808330987}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:50:59,523] Finished trial#79 with value:
5.7506602611095 with parameters: {'gamma': 3.8297716812687206, 'epsilon':
0.07517754436015102, 'c': 16384.571732093373}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:50:59,611] Finished trial#80 with value:
5.751700412333346 with parameters: {'gamma': 3.6815338297970324, 'epsilon':
0.11081792733284004, 'c': 16384.463829671007}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:50:59,697] Finished trial#81 with value:
5.7528518160405495 with parameters: {'gamma': 3.861392181586274, 'epsilon':
0.14623087945118352, 'c': 16384.96751572945}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:50:59,784] Finished trial#82 with value:
5.7556148141536685 with parameters: {'gamma': 3.4024075817298187, 'epsilon':
0.2410910194530499, 'c': 16384.445385894767}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:50:59,871] Finished trial#83 with value:
5.752663110597812 with parameters: {'gamma': 3.785661510065662, 'epsilon':
0.14090563027393602, 'c': 16384.603348905115}. Best is trial#78 with value:
5.750143455634304.
```

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[I 2020-05-06 08:50:59,960] Finished trial#84 with value:
5.752528723022606 with parameters: {'gamma': 3.966501384211048, 'epsilon':
0.13429577929728553, 'c': 16384.39082364931}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:51:00,049] Finished trial#85 with value:
5.7524388944883595 with parameters: {'gamma': 3.6055480385919534, 'epsilon':
0.13574890204799492, 'c': 16384.26472007641}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:51:00,138] Finished trial#86 with value:
5.751051508441491 with parameters: {'gamma': 3.8529696046389517, 'epsilon':
0.08768138057332993, 'c': 16384.48903107124}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:51:00,226] Finished trial#87 with value:
5.750772738804607 with parameters: {'gamma': 3.491982952459417, 'epsilon':
0.0831612197098057, 'c': 16384.368194149083}. Best is trial#78 with value:
5.750143455634304.
[I 2020-05-06 08:51:00,314] Finished trial#88 with value:
5.750059230211943 with parameters: {'gamma': 3.7063953091481436, 'epsilon':
0.05569224902072307, 'c': 16384.902851775034}. Best is trial#88 with value:
5.750059230211943.
[I 2020-05-06 08:51:00,403] Finished trial#89 with value:
5.75188036856518 with parameters: {'gamma': 3.828592207831123, 'epsilon':
0.11486883988098376, 'c': 16384.612065578887}. Best is trial#88 with value:
5.750059230211943.
[I 2020-05-06 08:51:00,494] Finished trial#90 with value:
5.752687314826667 with parameters: {'gamma': 3.964677095001273, 'epsilon':
0.13954731996273956, 'c': 16384.35553860443}. Best is trial#88 with value:
5.750059230211943.
[I 2020-05-06 08:51:00,584] Finished trial#91 with value:
5.750542835821231 with parameters: {'gamma': 3.5199551822198516, 'epsilon':
0.07522030024941706, 'c': 16384.635103567827}. Best is trial#88 with value:
5.750059230211943.
[I 2020-05-06 08:51:00,686] Finished trial#92 with value:
5.7511984132296154 with parameters: {'gamma': 3.6669288655984267, 'epsilon':
0.09471747264823079, 'c': 16385.10198891371}. Best is trial#88 with value:
5.750059230211943.
[I 2020-05-06 08:51:00,776] Finished trial#93 with value:
5.750800942655458 with parameters: {'gamma': 3.7721704768224424, 'epsilon':
0.08052507253856339, 'c': 16384.82193059312}. Best is trial#88 with value:
5.750059230211943.
[I 2020-05-06 08:51:00,866] Finished trial#94 with value:
5.751902644628178 with parameters: {'gamma': 4.057578450616661, 'epsilon':
0.11293825695333468, 'c': 16385.145054274548}. Best is trial#88 with value:
5.750059230211943.
[I 2020-05-06 08:51:00,956] Finished trial#95 with value:
5.753941793165269 with parameters: {'gamma': 3.7771116201700634, 'epsilon':
0.18266364707688515, 'c': 16384.606262927326}. Best is trial#88 with value:
5.750059230211943.
```

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[I 2020-05-06 08:51:01,046] Finished trial#96 with value:
5.74961570676165 with parameters: {'gamma': 3.0522055878323093, 'epsilon':
0.05001045583639091, 'c': 16384.279869473503}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,138] Finished trial#97 with value:
5.7508739739669865 with parameters: {'gamma': 3.369066007948811, 'epsilon':
0.08810896838515846, 'c': 16384.795167472334}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,227] Finished trial#98 with value:
5.750572146945546 with parameters: {'gamma': 3.578236361299704, 'epsilon':
0.07543663169625232, 'c': 16384.157174511685}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,319] Finished trial#99 with value:
5.750076575405939 with parameters: {'gamma': 3.451859957059642, 'epsilon':
0.059839575516718604, 'c': 16385.134265970373}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,412] Finished trial#100 with value:
5.7547890000812645 with parameters: {'gamma': 2.7167900269213505, 'epsilon':
0.22518197218624555, 'c': 16383.70890442905}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,505] Finished trial#101 with value:
5.753942704923384 with parameters: {'gamma': 2.8579977590954533, 'epsilon':
0.1955942843735915, 'c': 16384.066839544103}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,598] Finished trial#102 with value:
5.7557570759997 with parameters: {'gamma': 3.4217395096114136, 'epsilon':
0.24535950754336266, 'c': 16384.09286820593}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,691] Finished trial#103 with value:
5.752386151916453 with parameters: {'gamma': 4.046177711815869, 'epsilon':
0.12875734612315476, 'c': 16384.835946945797}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,783] Finished trial#104 with value:
5.750464455490373 with parameters: {'gamma': 3.016116119901812, 'epsilon':
0.08013683549794899, 'c': 16384.224783935628}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,874] Finished trial#105 with value:
5.750463948905145 with parameters: {'gamma': 2.7945766973006707, 'epsilon':
0.08395837274909462, 'c': 16384.027824502395}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:01,966] Finished trial#106 with value:
5.753289202277974 with parameters: {'gamma': 2.556958408317694, 'epsilon':
0.18030403699859943, 'c': 16384.268914684886}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,057] Finished trial#107 with value:
5.752899797426057 with parameters: {'gamma': 3.4902183430025673, 'epsilon':
0.15253810354292202, 'c': 16384.800330357913}. Best is trial#96 with value:
5.74961570676165.
```

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[I 2020-05-06 08:51:02,150] Finished trial#108 with value:
5.750930625476087 with parameters: {'gamma': 3.9270420497752503, 'epsilon':
0.08288872403949041, 'c': 16385.60512517013}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,244] Finished trial#109 with value:
5.751687537435643 with parameters: {'gamma': 2.826423355508601, 'epsilon':
0.1229682271296565, 'c': 16384.626501608123}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,337] Finished trial#110 with value:
5.752523433317532 with parameters: {'gamma': 3.5358498134444885, 'epsilon':
0.13946516231871198, 'c': 16385.912045628036}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,429] Finished trial#111 with value:
5.752704479355443 with parameters: {'gamma': 3.133956086321023, 'epsilon':
0.15119513373317198, 'c': 16384.28063181041}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,523] Finished trial#112 with value:
5.750722273892497 with parameters: {'gamma': 3.4452728173510483, 'epsilon':
0.08214755215211665, 'c': 16384.90584813268}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,616] Finished trial#113 with value:
5.754349109956618 with parameters: {'gamma': 3.3747611694201383, 'epsilon':
0.20082633508097741, 'c': 16383.581612947197}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,710] Finished trial#114 with value:
5.757436504276194 with parameters: {'gamma': 3.5415574861239607, 'epsilon':
0.2965394275618866, 'c': 16385.84099721429}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,802] Finished trial#115 with value:
5.75548976661902 with parameters: {'gamma': 4.557327143913586, 'epsilon':
0.2238121183108856, 'c': 16385.542479219035}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,894] Finished trial#116 with value:
5.75102313821628 with parameters: {'gamma': 1.9475791172407446, 'epsilon':
0.12299184869024116, 'c': 16383.3393317448}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:02,987] Finished trial#117 with value:
5.757372834547976 with parameters: {'gamma': 5.12464880440256, 'epsilon':
0.2812227195395915, 'c': 16386.455634189035}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:03,080] Finished trial#118 with value:
5.757217928477643 with parameters: {'gamma': 3.9853075844764794, 'epsilon':
0.2844758102541063, 'c': 16384.778310586895}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:03,171] Finished trial#119 with value:
5.7541178976792935 with parameters: {'gamma': 2.4801808372640957, 'epsilon':
0.2083884013549554, 'c': 16384.3968520471}. Best is trial#96 with value:
5.74961570676165.
```

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[I 2020-05-06 08:51:03,260] Finished trial#120 with value:
5.775265894131883 with parameters: {'gamma': 1.680925851428745, 'epsilon':
0.8294109284094751, 'c': 16381.465442249082}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:03,354] Finished trial#121 with value:
5.759523147706428 with parameters: {'gamma': 4.3052923909152945, 'epsilon':
0.35279944846771305, 'c': 16386.342734148435}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:03,447] Finished trial#122 with value:
5.7599072161123885 with parameters: {'gamma': 2.695075330410789, 'epsilon':
0.3846600059516876, 'c': 16383.126521715774}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:03,540] Finished trial#123 with value:
5.752362237554631 with parameters: {'gamma': 2.6686124795072965, 'epsilon':
0.14803355049378975, 'c': 16385.260045626997}. Best is trial#96 with value:
5.74961570676165.
[I 2020-05-06 08:51:03,634] Finished trial#124 with value:
5.752634825337857 with parameters: {'gamma': 0.6547958150805557, 'epsilon':
0.16432560058644777, 'c': 16381.332857126408}. Best is trial#96 with value:
5.74961570676165.
```

Logo, como resultado os melhores parâmetros encontrados durante a busca são mostrados:

[20]:
```
study.best_params
```

[20]:
```
{'c': 16384.279869473503,
 'epsilon': 0.05001045583639091,
 'gamma': 3.0522055878323093}
```

Obtivemos 16384.28 para o hiperparêmetro C, 3.0522 para o gamma e 0.05 para o epsilon. Bem como o resultado para o erro absoluto médio (MAE) no conjunto de teste com esses parâmetros:

[21]:
```
study.best_value
```

[21]:
```
5.74961570676165
```

Como resultado, obtivemos um Erro Absloluto Médio de **5.75** para o algoritimo de CMA-ES.