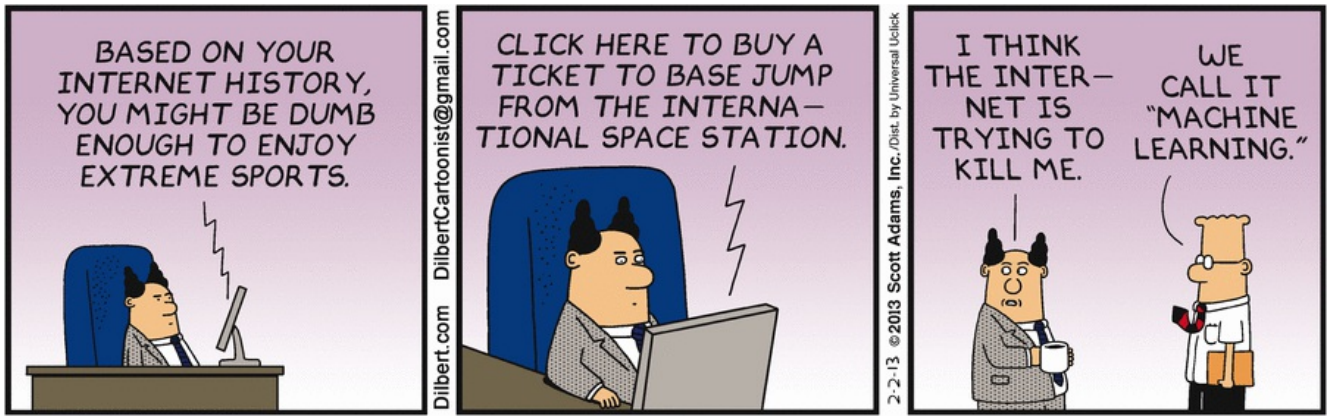
Лабораторная работа 2. Введение в машинное обучение.



Результат лабораторной работы – отчет. Мы предпочитаем принимать отчеты в формате ноутбуков Jupyter (ipynb-файл). Постарайтесь сделать ваш отчет интересным рассказом, последовательно отвечающим на вопросы из заданий. Помимо ответов на вопросы, в отчете так же должен быть код, однако чем меньше кода, тем лучше всем: нам – меньше проверять, вам — проще найти ошибку или дополнить эксперимент. При проверке оценивается четкость ответов на вопросы, аккуратность отчета и кода.

Оценивание и штрафы

- Каждая из задач имеет определенную «стоимость» (указана в скобках около задачи)
- Максимально допустимая оценка за работу — 15 баллов
- Сдавать задание после указанного срока сдачи нельзя
- «Похожие» решения считаются плагиатом и все задействованные студенты (в том числе те, у кого списали) не могут получить за него больше 0 баллов и понижают карму (подробнее о плагиате см. на странице курса)
- Если вы нашли решение какого-то из заданий в открытом источнике, необходимо прислать ссылку на этот источник (скорее всего вы будете не единственным, кто это нашел, поэтому чтобы исключить подозрение в плагиате, необходима ссылка на источник)
- Не оцениваются задания с удалёнными формулировкам
- Не оценивается лабораторная работа целиком, если она была выложена в открытый источник

Правила сдачи

Работу необходимо сдавать в систему Anytask (более подробную информацию можно найти на странице курса).

Метрика качества

Обучение и оценка качества модели производится на независимых множествах примеров. Как правило, имеющующиеся примеры разбивают на два подмножества: обучающее (train) и тестовое (test). Выбор пропорции разбиения — компромисс. Действительно, большой размер обучения ведет к более качественным алгоритмам, но бОльшему шуму при оценке модели на тесте. И наоборот, большой размер тестовой выборки ведет к менее шумной оценке качества, однако обученные модели получаются менее точными.

Многие модели классификации предсказывают оценку принадлежности положительному классу $\tilde{y}(x) \in R$ (например, вероятность принадлежности классу 1). После этого принимают решение о классе объекта путем сравнения оценки с некоторым порогом θ:

$$y(x) = \begin{cases} +1, & \text{если } \tilde{y}(x) \geq \theta \\ -1, & \text{если } \tilde{y}(x) < \theta \end{cases}$$

В этом случае можно рассматривать метрики, которые умеют работать с исходным ответом классификатора. В задании мы будем работать с метрикой AUC-ROC, которую в данном случае можно считать как долю неправильно упорядоченных пар объектов, отсортированных по возрастанию предсказанной оценки принадлежности классу 1 (более подробно можно узнать на следующих лекциях или, например, здесь). Детального понимания принципов работы метрики AUC-ROC для выполнения этой лабораторной не требуется.

Подбор гиперпараметров модели

В задачах машинного обучения следует различать параметры модели и гиперпараметры (структурные параметры). Обычно параметры модели настраиваются в ходе обучения (например, веса в линейной модели или структура решающего дерева), в то время как гиперпараметры задаются заранее (например, значение силы регуляризации в линейной модели или максимальная глубина решающего дерева). Каждая модель, как правило, имеет множество гиперпараметров и нет универсальных наборов гиперпараметров, оптимально работающих во всех задачах, поэтому для каждой задачи нужно подбирать свой набор.

Для оптимизации гиперпараметров модели часто используют *перебор по сетке (grid search)*: для каждого гиперпараметра выбирается несколько значений, далее перебираются все комбинации значений и выбирается комбинация, на которой модель показывает лучшее качество (с точки зрения оптимизируемой метрики). Однако, в этом случае нужно грамотно оценивать построенную модель, а именно делать разбиение на обучающую и тестовую выборку. Есть несколько схем, как это можно реализовать:

- Разбить имеющуюся выборку на обучающую и тестовую. В этом случае сравнение большого числа моделей при переборе гиперпараметров приводит к ситуации, когда лучшая на тестовой подвыборке модель не сохраняет свои качества на новых данных. Можно сказать, что происходит *переобучение* на тестовую выборку.
- Для устранения описанной выше проблемы, можно разбить данные на 3 непересекающихся подвыборки: обучение, валидация и тест. Валидационную подвыборку используют для сравнения моделей, а тестовую — для окончательной оценки качества и сравнения семейств моделей с подобранными гиперпараметрами.
- Другой способ сравнения моделей — кросс-валидация . Существуют различные схемы кросс-валидации:
  - Leave-One-Out
  - K-Fold
  - Многократное случайное разбиение выборки

Кросс-валидация вычислительно затратна, особенно если вы делаете перебор по сетке с очень большим числом комбинации. С учетом конечности времени на выполнение задания, возникает ряд компромиссов:

- сетку гиперпараметров можно делать более разреженной, перебирая меньше значений каждого гиперпараметра; однако, не стоит забывать, что в таком случае можно пропустить хорошую комбинацию гиперпараметров;
- кросс-валидацию можно делать с меньшим числом разбиений или фолдов, но в таком случае оценка качества становится более шумной и увеличивается риск выбрать неоптимальный набор гиперпараметров из-за случайности разбиения;
- гиперпараметры можно оптимизировать последовательно (жадно) — один за другим, а не перебирать все комбинации; такая стратегия не всегда приводит к оптимальному набору;
- перебирать не все комбинации гиперпараметров, а небольшое число случайно выбранных.

Задание

В этой лабораторной работе мы научимся обучать модели машинного обучения, корректно ставить эксперименты, подбирать гиперпараметры, сравнивать и смешивать модели. Вам предлагается решить задачу бинарной классификации, а именно построить алгоритм, определяющий превысит ли средний заработок человека порог $50k.

Более подробно про признаки можно почитать здесь. Целевой признак записан в переменной *>50K,<=50K*.

Загрузите набор данных *data.adult.csv*. Чтобы лучше понимать, с чем вы работаете/корректно ли вы загрузили данные можно вывести несколько первых строк на экран.

In [2]:

```
import pandas as pd
import numpy as np
from sklearn.metrics import roc_auc_score

data = pd.read_csv("data.adult.csv")
data.head()
```

Out[2]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	>50K, <=50K
0	34	Local-gov	284843	HS-grad	9	Never-married	Farming-fishing	Not-in-family	Black	Male	594	0	60	<=50K
1	40	Private	190290	Some-college	10	Divorced	Sales	Not-in-family	White	Male	0	0	40	<=50K
2	36	Local-gov	177858	Bachelors	13	Married-civ-	Prof-specialty	Own-child	White	Male	0	0	40	<=50K

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week	>50K, <=50K
3	22	Private	184756	Some college	10	Never-married	Sales	Own-child	White	Female	0	0	30	<=50K
4	47	Private	149700	Bachelors	13	Married-civ-spouse	Tech-support	Husband	White	Male	15024	0	40	>50K

Иногда в данных встречаются пропуски. Способ обозначения пропусков либо прописывается в описании к данным, либо на месте пропуска после чтения данных оказывается значение NaN. Более подробно о работе с пропусками в Pandas можно прочитать например здесь.

В данном датасете пропущенные значения обозначены как "?".

(1 балл) Задание 1. Обычно после загрузки датасета всегда необходима его некоторая предобработка. В данном случае она будет заключаться в следующем:

- Найдите все признаки, имеющие пропущенные значения. Удалите из выборки все объекты с пропусками.
- Сохраните целевую переменную (ту, которую мы хотим предсказывать) в отдельную переменную, удалите ее из датасета и преобразуйте к бинарному формату.
- Обратите внимание, что не все признаки являются вещественными (числовыми). В начале мы будем работать только с вещественными признаками. Сохраните их отдельно.

In [3]:

```
for name in list(data.columns.values):
    data[name].replace('?', np.nan, inplace=True)
    data.dropna(subset=[name], inplace=True)
y = np.array(data['>50K,<=50K'])
data = data.drop(columns=['>50K,<=50K'])
y[y == '>50K'] = 1
y[y == '<=50K'] = 0
```

При отображении "data.adult.csv" видим, что числовыми являются столбцы 'age', 'fnlwgt', 'education-num', 'capital-gain', 'capital-loss', 'hours-per-week'. Их и сохраняем в отдельные переменные.

In [4]:

```
age = np.array(data['age'])
fnlwgt = np.array(data['fnlwgt'])
education_num = np.array(data['education-num'])
capital_gain = np.array(data['capital-gain'])
capital_loss = np.array(data['capital-loss'])
hours_per_week = np.array(data['hours-per-week'])
```

(7 баллов) Обучение классификаторов на вещественных признаках

В данном разделе будет необходимо работать только с вещественными признаками и целевой переменной.

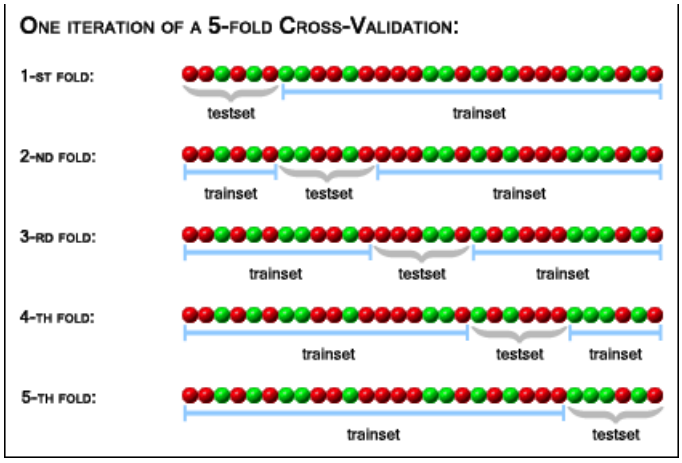
В начале посмотрим как работает подбор гиперпараметров по сетке и как влияет на качество разбиение выборки. Сейчас и далее будем рассматривать 4 алгоритма:

- kNN
- DecisonTree
- SGD Linear Classifier
- RandomForest

Для начала у первых трёх алгоритмов выберем один гиперпараметр, который будем оптимизировать:

- kNN — число соседей (*n_neighbors*)
- DecisonTree — глубина дерева (*max_depth*)
- SGD Linear Classifier — оптимизируемая функция (*loss*)

Значения остальных гиперпараметров оставляйте по умолчанию. Для подбора гиперпараметров воспользуйтесь перебором по сетке, который реализован в классе GridSearchCV. В качестве схемы кросс-валидации используйте 5-Fold CV, которую можно задать с помощью класса KFoldCV.



(1.5 балла) Задание 2. Для каждого алгоритма подберите оптимальные значения указанных гиперпараметров. Постройте график среднего значения качества по кросс-валидации алгоритма при заданном значении гиперпараметра, на котором также отобразите доверительный интервал.

Для получения значения качества на каждом фолде, среднего значение качества и другой полезной информации можно воспользоваться полем *cv results_*

У какого алгоритма наибольшее среднее значение качества? Наибольший доверительный интервал?

In [5]:

```
from sklearn.neighbors import KNeighborsClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.linear_model import SGDClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import GridSearchCV, KFold

#print(np.shape(X), np.shape(Y))

#for train_index, test_index in kf.split(X):
#    X_train, X_test = X[train_index], X[test_index]
#    Y_train, Y_test = Y[train_index], Y[test_index]
```

```
/anaconda3/lib/python3.6/site-packages/sklearn/ensemble/weight_boosting.py:29: DeprecationWarning:
numpy.core.umath_tests is an internal NumPy module and should not be imported. It will be removed
in a future NumPy release.
  from numpy.core.umath_tests import inner1d
```

In [6]:

```
kf = KFold(n_splits=5)
X = np.concatenate([[age], [fnlwgt], [education_num], [capital_gain], [capital_loss], [hours_per_we
ek]], axis=0).T
Y = np.array(y, dtype='bool')
```

In [7]:

```
kNN = KNeighborsClassifier()
tree = DecisionTreeClassifier()
SGD = SGDClassifier()

kNN_params = {'n_neighbors' : list(range(1, 150, 2))}
tree_params = {'max_depth' : list(range(1, 51))}
SGD_params = {'loss' : ["hinge", "log", "modified_huber", "squared_hinge",
                        "perceptron", "squared_loss", "huber", "epsilon_insensitive",
                        "squared_epsilon_insensitive"]}
```

In [8]:

```
kNN_clf = GridSearchCV(kNN, kNN_params, cv=kf, verbose=2, n_jobs=4, scoring='roc_auc')
tree_clf = GridSearchCV(tree, tree_params, cv=kf, verbose=2, n_jobs=4, scoring='roc_auc')
SGD_clf = GridSearchCV(SGD, SGD_params, cv=kf, verbose=2, n_jobs=4, scoring='roc_auc')
```

In [9]:

```
kNN_clf.fit(X, Y)

knn_param = kNN_clf.best_params_['n_neighbors']
```

```
Fitting 5 folds for each of 75 candidates, totalling 375 fits
[CV] n_neighbors=1 ...................................................
[CV] n_neighbors=1 ...................................................
[CV] n_neighbors=1 ...................................................
[CV] n_neighbors=1 ...................................................
[CV] ..................................... n_neighbors=1, total=   0.2s
[CV] ..................................... n_neighbors=1, total=   0.2s
[CV] ..................................... n_neighbors=1, total=   0.2s
[CV] n_neighbors=1 ...................................................
[CV] n_neighbors=3 ...................................................
[CV] ..................................... n_neighbors=1, total=   0.2s
[CV] n_neighbors=3 ...................................................
[CV] n_neighbors=3 ...................................................
[CV] ..................................... n_neighbors=1, total=   0.2s
[CV] n_neighbors=3 ...................................................
[CV] ..................................... n_neighbors=3, total=   0.2s
[CV] n_neighbors=3 ...................................................
[CV] ..................................... n_neighbors=3, total=   0.1s
[CV] ..................................... n_neighbors=3, total=   0.2s
[CV] n_neighbors=5 ...................................................
[CV] n_neighbors=5 ...................................................
[CV] ..................................... n_neighbors=3, total=   0.2s
[CV] ..................................... n_neighbors=3, total=   0.2s
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[CV] ..................................... n_neighbors=5, total=   0.2s
[CV] ..................................... n_neighbors=5, total=   0.2s
[CV] n_neighbors=5 ...................................................
[CV] n_neighbors=7 ...................................................
[CV] ..................................... n_neighbors=5, total=   0.3s
[CV] n_neighbors=7 ...................................................
[CV] ..................................... n_neighbors=5, total=   0.3s
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[CV] ..................................... n_neighbors=5, total=   0.2s
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[CV] ..................................... n_neighbors=7, total=   0.2s
[CV] n_neighbors=7 ...................................................
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[CV] ..................................... n_neighbors=7, total=   0.2s
[CV] n_neighbors=9 ...................................................
[CV] n_neighbors=9 ...................................................
[CV] ..................................... n_neighbors=7, total=   0.1s
[CV] ..................................... n_neighbors=7, total=   0.2s
[CV] n_neighbors=9 ...................................................
[CV] n_neighbors=9 ...................................................
[CV] ..................................... n_neighbors=9, total=   0.2s
[CV] n_neighbors=9 ...................................................
[CV] ..................................... n_neighbors=9, total=   0.2s
[CV] n_neighbors=11 ..................................................
[CV] ..................................... n_neighbors=9, total=   0.1s
[CV] n_neighbors=11 ..................................................
[CV] ..................................... n_neighbors=9, total=   0.1s
[CV] n_neighbors=11 ..................................................
[CV] ..................................... n_neighbors=9, total=   0.2s
[CV] n_neighbors=11 ..................................................
[CV] .................................... n_neighbors=11, total=   0.2s
[CV] .................................... n_neighbors=11, total=   0.1s
[CV] n_neighbors=11 ..................................................
[CV] n_neighbors=13 ..................................................
[CV] .................................... n_neighbors=11, total=   0.1s
[CV] n_neighbors=13 ..................................................
[CV] .................................... n_neighbors=11, total=   0.2s
[CV] n_neighbors=13 ..................................................
[CV] .................................... n_neighbors=11, total=   0.1s
[CV] n_neighbors=13 ..................................................
[CV] .................................... n_neighbors=13, total=   0.2s
[CV] n_neighbors=13 ..................................................
[CV] .................................... n_neighbors=13, total=   0.2s
[CV] n_neighbors=15 ..................................................
[CV] .................................... n_neighbors=13, total=   0.2s
[CV] n_neighbors=15 ..................................................
[CV] .................................... n_neighbors=13, total=   0.2s
```

```
[CV] ..... n_neighbors=15, total=   0.2s
[CV] n_neighbors=15 ..................................................
[CV] ..... n_neighbors=15, total=   0.2s
[CV] n_neighbors=15 ..................................................
[CV] ..... n_neighbors=13, total=   0.2s
[CV] n_neighbors=15 ..................................................

[Parallel(n_jobs=4)]: Done  33 tasks      | elapsed:    3.7s

[CV] ..... n_neighbors=15, total=   0.2s
[CV] n_neighbors=17 ..................................................
[CV] ..... n_neighbors=15, total=   0.2s
[CV] n_neighbors=17 ..................................................
[CV] ..... n_neighbors=15, total=   0.1s
[CV] n_neighbors=17 ..................................................
[CV] ..... n_neighbors=15, total=   0.1s
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[CV] ..... n_neighbors=17, total=   0.2s
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[CV] ..... n_neighbors=17, total=   0.1s
[CV] n_neighbors=19 ..................................................
[CV] ..... n_neighbors=17, total=   0.2s
[CV] n_neighbors=19 ..................................................
[CV] ..... n_neighbors=17, total=   0.1s
[CV] n_neighbors=19 ..................................................
[CV] ..... n_neighbors=17, total=   0.2s
[CV] n_neighbors=19 ..................................................
[CV] ..... n_neighbors=19, total=   0.2s
[CV] n_neighbors=19 ..................................................
[CV] ..... n_neighbors=19, total=   0.2s
[CV] n_neighbors=21 ..................................................
[CV] ..... n_neighbors=19, total=   0.2s
[CV] n_neighbors=21 ..................................................
[CV] ..... n_neighbors=19, total=   0.2s
[CV] n_neighbors=21 ..................................................
[CV] ..... n_neighbors=19, total=   0.3s
[CV] n_neighbors=21 ..................................................
[CV] ..... n_neighbors=21, total=   0.3s
[CV] n_neighbors=21 ..................................................
[CV] ..... n_neighbors=21, total=   0.2s
[CV] n_neighbors=23 ..................................................
[CV] ..... n_neighbors=21, total=   0.1s
[CV] n_neighbors=23 ..................................................
[CV] ..... n_neighbors=21, total=   0.2s
[CV] n_neighbors=23 ..................................................
[CV] ..... n_neighbors=21, total=   0.2s
[CV] n_neighbors=23 ..................................................
[CV] ..... n_neighbors=23, total=   0.2s
[CV] n_neighbors=23 ..................................................
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```

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[CV] ................................ n_neighbors=119, total=   0.3s
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[CV] n_neighbors=145 ..................................................

[Parallel(n_jobs=4)]: Done 357 tasks      | elapsed:  1.5min

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[CV] ..................................... n_neighbors=145, total=   0.4s
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[CV] ..................................... n_neighbors=149, total=   0.3s
[CV] ..................................... n_neighbors=149, total=   0.4s
[CV] ..................................... n_neighbors=149, total=   0.3s
[CV] ..................................... n_neighbors=149, total=   0.3s
```

```
[Parallel(n_jobs=4)]: Done 375 out of 375 | elapsed:  1.6min finished
```

In [10]:

```
print("Best kNN parameter:", knn_param)
```

```
Best kNN parameter: 5
```

In [11]:

```
tree_clf.fit(X, Y)
tree_param = tree_clf.best_params_['max_depth']
```

```
Fitting 5 folds for each of 50 candidates, totalling 250 fits
[CV] max_depth=1 .....................................................
[CV] max_depth=1 .....................................................
[CV] max_depth=1 .....................................................
[CV] ..................................... max_depth=1, total=   0.0s
[CV] max_depth=1 .....................................................
[CV] ..................................... max_depth=1, total=   0.0s
[CV] max_depth=1 .....................................................
[CV] ..................................... max_depth=1, total=   0.0s
[CV] ..................................... max_depth=1, total=   0.0s
[CV] max_depth=2 .....................................................
[CV] ..................................... max_depth=1, total=   0.0s
[CV] max_depth=2 .....................................................
[CV] max_depth=2 .....................................................
[CV] max_depth=2 .....................................................
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[CV] ..................................... max_depth=2, total=   0.0s
[CV] max_depth=3 .....................................................
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[CV] ..................................... max_depth=2, total=   0.0s
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[CV] max_depth=6 .....................................................
[CV] ..................................... max_depth=7, total=   0.1s
```

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```

```
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[CV] max_depth=19 .....................................................
[CV] ..................................... max_depth=21, total=   0.1s
[CV] max_depth=21 .....................................................
[CV] ..................................... max_depth=20, total=   0.1s
[CV] max_depth=20 .....................................................
[CV] ..................................... max_depth=19, total=   0.1s
[CV] ..................................... max_depth=19, total=   0.1s
[CV] max_depth=20 .....................................................
[CV] max_depth=21 .....................................................
[CV] ..................................... max_depth=21, total=   0.1s
[CV] max_depth=21 .....................................................
[CV] ..................................... max_depth=20, total=   0.1s
[CV] max_depth=20 .....................................................
[CV] ..................................... max_depth=20, total=   0.1s
[CV] max_depth=22 .....................................................
[CV] ..................................... max_depth=21, total=   0.1s
[CV] max_depth=22 .....................................................
[CV] ..................................... max_depth=21, total=   0.1s
[CV] max_depth=21 .....................................................
[CV] ..................................... max_depth=20, total=   0.1s
[CV] ..................................... max_depth=22, total=   0.1s
[CV] max_depth=23 .....................................................
```

```
[CV] ..................................... max_depth=22, total=   0.1s
[CV] max_depth=22 .....................................................
[CV] max_depth=22 .....................................................
[CV] ..................................... max_depth=21, total=   0.1s
[CV] max_depth=24 .....................................................
[CV] ..................................... max_depth=22, total=   0.1s
[CV] ..................................... max_depth=23, total=   0.1s
[CV] max_depth=23 .....................................................
[CV] max_depth=23 .....................................................
[CV] ..................................... max_depth=22, total=   0.1s
[CV] max_depth=22 .....................................................
[CV] ..................................... max_depth=24, total=   0.1s
[CV] max_depth=24 .....................................................
[CV] ..................................... max_depth=23, total=   0.1s
[CV] max_depth=23 .....................................................
[CV] ..................................... max_depth=23, total=   0.1s
[CV] max_depth=23 .....................................................
[CV] ..................................... max_depth=22, total=   0.1s
[CV] max_depth=25 .....................................................
[CV] ..................................... max_depth=24, total=   0.1s
[CV] max_depth=24 .....................................................
[CV] ..................................... max_depth=23, total=   0.1s
[CV] max_depth=24 .....................................................
[CV] ..................................... max_depth=23, total=   0.1s
[CV] max_depth=25 .....................................................
[CV] ..................................... max_depth=25, total=   0.1s
[CV] max_depth=25 .....................................................

[Parallel(n_jobs=4)]: Done 108 tasks      | elapsed:    3.1s

[CV] ..................................... max_depth=24, total=   0.2s
[CV] max_depth=24 .....................................................
[CV] ..................................... max_depth=24, total=   0.2s
[CV] max_depth=26 .....................................................
[CV] ..................................... max_depth=25, total=   0.1s
[CV] max_depth=25 .....................................................
[CV] ..................................... max_depth=25, total=   0.2s
[CV] max_depth=26 .....................................................
[CV] ..................................... max_depth=24, total=   0.1s
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=26, total=   0.1s
[CV] max_depth=26 .....................................................
[CV] ..................................... max_depth=25, total=   0.1s
[CV] max_depth=25 .....................................................
[CV] ..................................... max_depth=26, total=   0.1s
[CV] max_depth=26 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=26, total=   0.1s
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=25, total=   0.1s
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=26, total=   0.1s
[CV] max_depth=26 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=26, total=   0.1s
[CV] ..................................... max_depth=28, total=   0.1s
[CV] max_depth=29 .....................................................
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=29 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=29, total=   0.2s
[CV] max_depth=29 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=29, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
[CV] max_depth=28
```

```
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=29, total=   0.1s
[CV] max_depth=29 .....................................................
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=29, total=   0.1s
[CV] max_depth=29 .....................................................
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=29, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=31 .....................................................
[CV] max_depth=33 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] max_depth=33 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] ..................................... max_depth=33, total=   0.1s
[CV] max_depth=33 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] ..................................... max_depth=33, total=   0.1s
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=33, total=   0.1s
[CV] max_depth=33 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] ..................................... max_depth=34, total=   0.1s
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=34, total=   0.1s
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=33, total=   0.1s
[CV] max_depth=33 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=35 .....................................................
[CV] ..................................... max_depth=34, total=   0.1s
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=34, total=   0.1s
[CV] max_depth=35 .....................................................
[CV] ..................................... max_depth=33, total=   0.1s
[CV] max_depth=36 .....................................................
[CV] ..................................... max_depth=35, total=   0.1s
[CV] max_depth=35 .....................................................
[CV] ..................................... max_depth=34, total=   0.1s
[CV] ..................................... max_depth=35, total=   0.1s
[CV] max_depth=35 .....................................................
[CV] ..................................... max_depth=36, total=   0.1s
[CV] max_depth=36 .....................................................
[CV] ..................................... max_depth=35, total=   0.1s
[CV] max_depth=35 .....................................................
[CV] max_depth=37 .....................................................
[CV] ..................................... max_depth=35, total=   0.1s
[CV] max_depth=37 .....................................................
[CV] ..................................... max_depth=35, total=   0.1s
[CV] ..................................... max_depth=36, total=   0.1s
[CV] max_depth=36 .....................................................
[CV] max_depth=36 .....................................................
[CV] ..................................... max_depth=37, total=   0.1s
[CV] max_depth=37 .....................................................
[CV] ..................................... max_depth=37, total=   0.1s
[CV] max_depth=38 .....................................................
[CV]                                       max_depth=37, total=   0.1s
```

```
[CV] ..... max_depth=37, total=   0.1s
[CV] ..... max_depth=36, total=   0.1s
[CV] max_depth=37 .....................................................
[CV] ..... max_depth=36, total=   0.1s
[CV] max_depth=38 .....................................................
[CV] max_depth=36 .....................................................
[CV] ..... max_depth=38, total=   0.1s
[CV] max_depth=38 .....................................................
[CV] ..... max_depth=38, total=   0.1s
[CV] max_depth=38 .....................................................
[CV] ..... max_depth=37, total=   0.1s
[CV] max_depth=37 .....................................................
[CV] ..... max_depth=36, total=   0.1s
[CV] max_depth=39 .....................................................
[CV] ..... max_depth=38, total=   0.1s
[CV] ..... max_depth=37, total=   0.1s
[CV] max_depth=38 .....................................................
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[CV] ..... max_depth=38, total=   0.1s
[CV] max_depth=39 .....................................................
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=39 .....................................................
[CV] ..... max_depth=38, total=   0.1s
[CV] max_depth=41 .....................................................
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[CV] max_depth=40 .....................................................
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=39 .....................................................
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=39 .....................................................
[CV] ..... max_depth=40, total=   0.1s
[CV] ..... max_depth=41, total=   0.1s
[CV] max_depth=41 .....................................................
[CV] max_depth=40 .....................................................
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=41 .....................................................
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=40 .....................................................
[CV] ..... max_depth=40, total=   0.1s
[CV] ..... max_depth=41, total=   0.1s
[CV] max_depth=40 .....................................................
[CV] max_depth=41 .....................................................
[CV] ..... max_depth=41, total=   0.1s
[CV] ..... max_depth=40, total=   0.1s
[CV] max_depth=42 .....................................................
[CV] max_depth=42 .....................................................
[CV] ..... max_depth=41, total=   0.1s
[CV] ..... max_depth=40, total=   0.1s
[CV] max_depth=43 .....................................................
[CV] max_depth=41 .....................................................
[CV] ..... max_depth=42, total=   0.1s
[CV] max_depth=42 .....................................................
[CV] ..... max_depth=42, total=   0.1s
[CV] max_depth=42 .....................................................
[CV] ..... max_depth=41, total=   0.1s
[CV] max_depth=44 .....................................................
[CV] ..... max_depth=43, total=   0.1s
[CV] max_depth=43 .....................................................
[CV] ..... max_depth=42, total=   0.1s
[CV] max_depth=42 .....................................................
[CV] ..... max_depth=42, total=   0.1s
[CV] max_depth=43 .....................................................
[CV] ..... max_depth=43, total=   0.1s
[CV] ..... max_depth=44, total=   0.1s
[CV] max_depth=44 .....................................................
[CV] max_depth=43 .....................................................
[CV] ..... max_depth=42, total=   0.1s
[CV] max_depth=45 .....................................................
[CV] ..... max_depth=43, total=   0.1s
[CV] max_depth=43 .....................................................
[CV] ..... max_depth=43, total=   0.1s
[CV] max_depth=44 .....................................................
[CV] ..... max_depth=44, total=   0.1s
[CV] max_depth=44 .....................................................
[CV] ..... max_depth=45, total=   0.1s
[CV] max_depth=45 .....................................................
[CV] ..... max_depth=43, total=   0.1s
[CV] max_depth=45
```

```
[CV] max_depth=45 .....................................................
[CV] ..................................... max_depth=44, total=   0.1s
[CV] ..................................... max_depth=44, total=   0.2s
[CV] max_depth=44 .....................................................
[CV] max_depth=46 .....................................................
[CV] ..................................... max_depth=45, total=   0.1s
[CV] max_depth=45 .....................................................
[CV] ..................................... max_depth=45, total=   0.1s
[CV] max_depth=46 .....................................................
[CV] ..................................... max_depth=44, total=   0.1s
[CV] max_depth=47 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=46 .....................................................
[CV] ..................................... max_depth=45, total=   0.1s
[CV] max_depth=45 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=46 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=47 .....................................................
[CV] ..................................... max_depth=47, total=   0.1s
[CV] max_depth=47 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] ..................................... max_depth=45, total=   0.1s
[CV] max_depth=46 .....................................................
[CV] max_depth=48 .....................................................
[CV] ..................................... max_depth=47, total=   0.1s
[CV] ..................................... max_depth=47, total=   0.1s
[CV] max_depth=47 .....................................................
[CV] max_depth=47 .....................................................
[CV] ..................................... max_depth=48, total=   0.1s
[CV] max_depth=48 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=49 .....................................................
[CV] ..................................... max_depth=47, total=   0.1s
[CV] max_depth=48 .....................................................
[CV] ..................................... max_depth=47, total=   0.1s
[CV] ..................................... max_depth=48, total=   0.1s
[CV] max_depth=49 .....................................................
[CV] ..................................... max_depth=49, total=   0.1s
[CV] max_depth=49 .....................................................
[CV] max_depth=48 .....................................................
[CV] ..................................... max_depth=48, total=   0.1s
[CV] ..................................... max_depth=49, total=   0.1s
[CV] max_depth=50 .....................................................
[CV] max_depth=50 .....................................................
[CV] ..................................... max_depth=49, total=   0.1s
[CV] max_depth=49 .....................................................
[CV] ..................................... max_depth=48, total=   0.1s
[CV] max_depth=48 .....................................................
[CV] ..................................... max_depth=50, total=   0.1s
[CV] ..................................... max_depth=50, total=   0.1s
[CV] max_depth=50 .....................................................
[CV] max_depth=50 .....................................................
[CV] ..................................... max_depth=48, total=   0.1s
[CV] ..................................... max_depth=49, total=   0.1s
[CV] max_depth=49 .....................................................
[CV] ..................................... max_depth=50, total=   0.1s
[CV] ..................................... max_depth=50, total=   0.1s
[CV] max_depth=50 .....................................................
[CV] ..................................... max_depth=49, total=   0.1s
[CV] ..................................... max_depth=50, total=   0.1s

[Parallel(n_jobs=4)]: Done 250 out of 250 | elapsed:    8.0s finished
```

In [12]:

```
print("Best DecisionTree parameter:", tree_param)
```

```
Best DecisionTree parameter: 7
```

In [13]:

```
import warnings
warnings.filterwarnings('ignore')
```

```
SGD_clf.fit(X, Y)

SGD_param = SGD_clf.best_params_['loss']
```

```
Fitting 5 folds for each of 9 candidates, totalling 45 fits
[CV] loss=hinge .....................................................
[CV] loss=hinge .....................................................
[CV] loss=hinge .....................................................
[CV] loss=hinge .....................................................
[CV] ..................................... loss=hinge, total=   0.0s
[CV] loss=hinge .....................................................
[CV] ..................................... loss=hinge, total=   0.0s
[CV] loss=log .......................................................
[CV] ..................................... loss=hinge, total=   0.0s
[CV] loss=log .......................................................
[CV] ..................................... loss=hinge, total=   0.0s
[CV] loss=log .......................................................
[CV] ..................................... loss=hinge, total=   0.1s
[CV] loss=log .......................................................
[CV] ....................................... loss=log, total=   0.0s
[CV] loss=modified_huber ............................................
[CV] ....................................... loss=log, total=   0.0s
[CV] loss=squared_hinge .............................................
[CV] ....................................... loss=log, total=   0.0s
[CV] loss=log .......................................................
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] loss=squared_hinge .............................................
[CV] ....................................... loss=log, total=   0.1s
[CV] loss=perceptron ................................................
[CV] ............................... loss=modified_huber, total=   0.1s
[CV] loss=modified_huber ............................................
[CV] ................................... loss=perceptron, total=   0.1s
[CV] ....................................... loss=log, total=   0.1s
[CV] loss=perceptron ................................................
[CV] ............................... loss=modified_huber, total=   0.0s
[CV] loss=modified_huber ............................................
[CV] loss=modified_huber ............................................
[CV] ............................... loss=squared_hinge, total=   0.1s
[CV] loss=squared_hinge .............................................
[CV] ............................... loss=modified_huber, total=   0.0s
[CV] loss=squared_hinge .............................................
[CV] ................................... loss=perceptron, total=   0.0s
[CV] loss=perceptron ................................................
[CV] ............................... loss=modified_huber, total=   0.0s
[CV] loss=modified_huber ............................................
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] loss=squared_hinge .............................................
[CV] ................................... loss=perceptron, total=   0.0s
[CV] loss=perceptron ................................................
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] ............................... loss=modified_huber, total=   0.0s
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] loss=perceptron ................................................
[CV] loss=squared_loss ..............................................
[CV] loss=huber .....................................................
[CV] ................................... loss=perceptron, total=   0.1s
[CV] ................................... loss=perceptron, total=   0.0s
[CV] loss=epsilon_insensitive .......................................
[CV] loss=squared_loss ..............................................
[CV] ............................... loss=squared_loss, total=   0.1s
[CV] loss=squared_loss ..............................................
[CV] ........................... loss=epsilon_insensitive, total=   0.0s
[CV] loss=epsilon_insensitive .......................................
[CV] ............................... loss=squared_loss, total=   0.0s
[CV] loss=squared_loss ..............................................
[CV] ..................................... loss=huber, total=   0.1s
[CV] loss=huber .....................................................
[CV] ............................... loss=squared_loss, total=   0.0s
[CV] loss=huber .....................................................
[CV] ............................... loss=squared_loss, total=   0.0s
[CV] loss=squared_loss ..............................................
[CV] ........................... loss=epsilon_insensitive, total=   0.1s
[CV] loss=epsilon_insensitive .......................................
[CV] ..................................... loss=huber, total=   0.0s
[CV] loss=huber .....................................................
[CV] ..................................... loss=huber, total=   0.0s
[CV] loss=huber .....................................................
```

```
[CV] ..... loss=epsilon_insensitive, total=   0.0s
[CV] loss=epsilon_insensitive .....................................
[CV] ..... loss=huber, total=   0.0s
[CV] loss=epsilon_insensitive .....................................
[CV] ..... loss=squared_loss, total=   0.1s
[CV] ..... loss=huber, total=   0.0s
[CV] loss=squared_epsilon_insensitive .............................
[CV] loss=squared_epsilon_insensitive .............................
[CV] ..... loss=epsilon_insensitive, total=   0.0s
[CV] ..... loss=epsilon_insensitive, total=   0.0s
[CV] ..... loss=squared_epsilon_insensitive, total=   0.0s
[CV] ..... loss=squared_epsilon_insensitive, total=   0.1s
[CV] loss=squared_epsilon_insensitive .............................
[CV] ..... loss=squared_epsilon_insensitive, total=   0.0s
[CV] loss=squared_epsilon_insensitive .............................
[CV] ..... loss=squared_epsilon_insensitive, total=   0.0s
[CV] loss=squared_epsilon_insensitive .............................
[CV] ..... loss=squared_epsilon_insensitive, total=   0.0s

[Parallel(n_jobs=4)]: Done  45 out of  45 | elapsed:    1.0s finished
```

In [14]:

```
print("Best SGD parameter:", SGD_param)
```

```
Best SGD parameter: modified_huber
```

In [15]:

```
print("kNN classifier's best score:", kNN_clf.best_score_)
print("tree classifier's best score:", tree_clf.best_score_)
print("SGD classifier's best score:", SGD_clf.best_score_)
```

```
kNN classifier's best score: 0.6412956668705564
tree classifier's best score: 0.8410139678158015
SGD classifier's best score: 0.6062338251350011
```

In [16]:

```
print("kNN confidence interval: (", kNN_clf.best_score_ - kNN_clf.cv_results_['std_test_score'][kNN
_clf.best_index_], ",",
      kNN_clf.best_score_ + kNN_clf.cv_results_['std_test_score'][kNN_clf.best_index_], "), length
= ",
     kNN_clf.cv_results_['std_test_score'][kNN_clf.best_index_]*2)
print("tree confidence interval: (", tree_clf.best_score_ - tree_clf.cv_results_['std_test_score'][
tree_clf.best_index_], ",",
      tree_clf.best_score_ + tree_clf.cv_results_['std_test_score'][tree_clf.best_index_], "), leng
th = ",
     tree_clf.cv_results_['std_test_score'][tree_clf.best_index_]*2)
print("SGD confidence interval: (", SGD_clf.best_score_ - SGD_clf.cv_results_['std_test_score'][SGD
_clf.best_index_], ",",
      SGD_clf.best_score_ + SGD_clf.cv_results_['std_test_score'][SGD_clf.best_index_], "), length
= ",
     SGD_clf.cv_results_['std_test_score'][SGD_clf.best_index_]*2)
```

```
kNN confidence interval: ( 0.6306584927837395 , 0.6519328409573732 ), length =
0.021274348173633797
tree confidence interval: ( 0.8396364938444828 , 0.8423914417871202 ), length =
0.0027549479426374974
SGD confidence interval: ( 0.5978416048106572 , 0.6146260454593451 ), length =  0.0167844406486879
```

Таким образом, видим, что наибольшее среднее значение качества показывает DecisionTreeClassifier, в то время как наибольший доверительный интервал демонстрирует SGDClassifier.

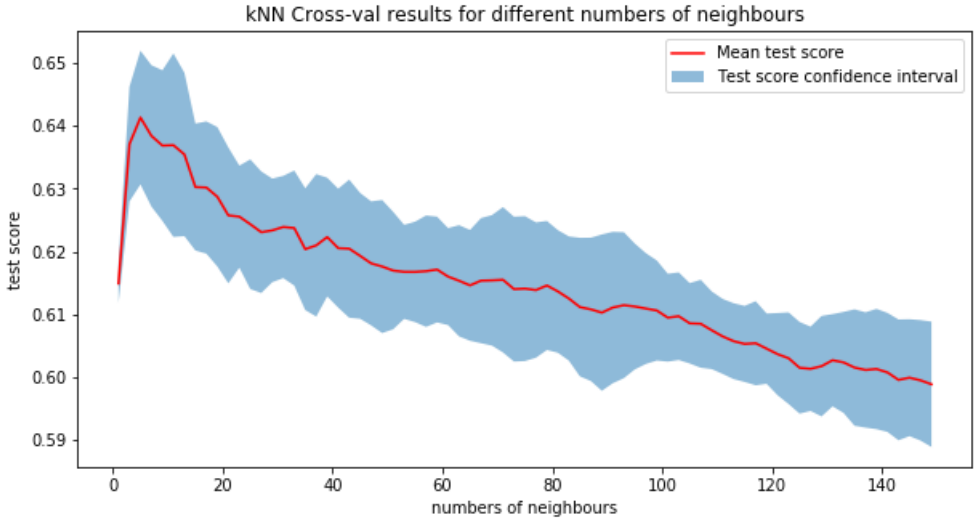
In [19]:

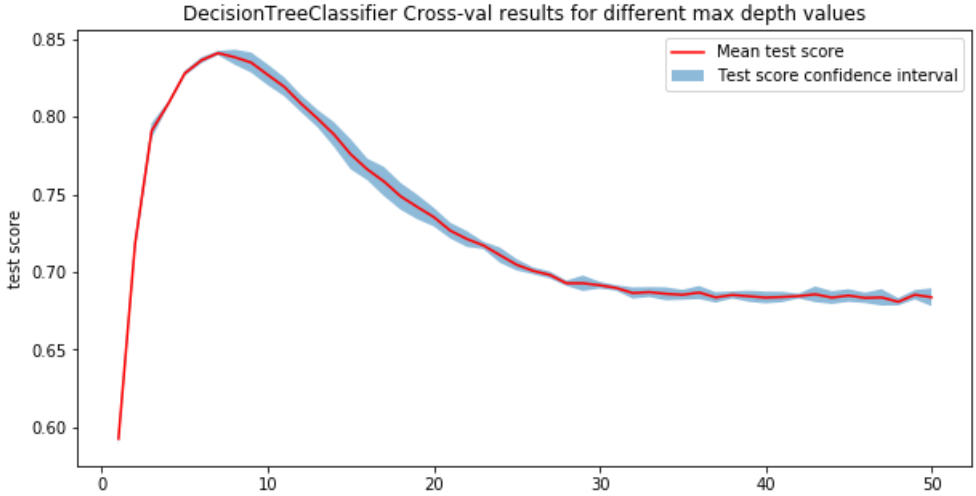
```
%matplotlib inline
import matplotlib.pyplot as plt
```

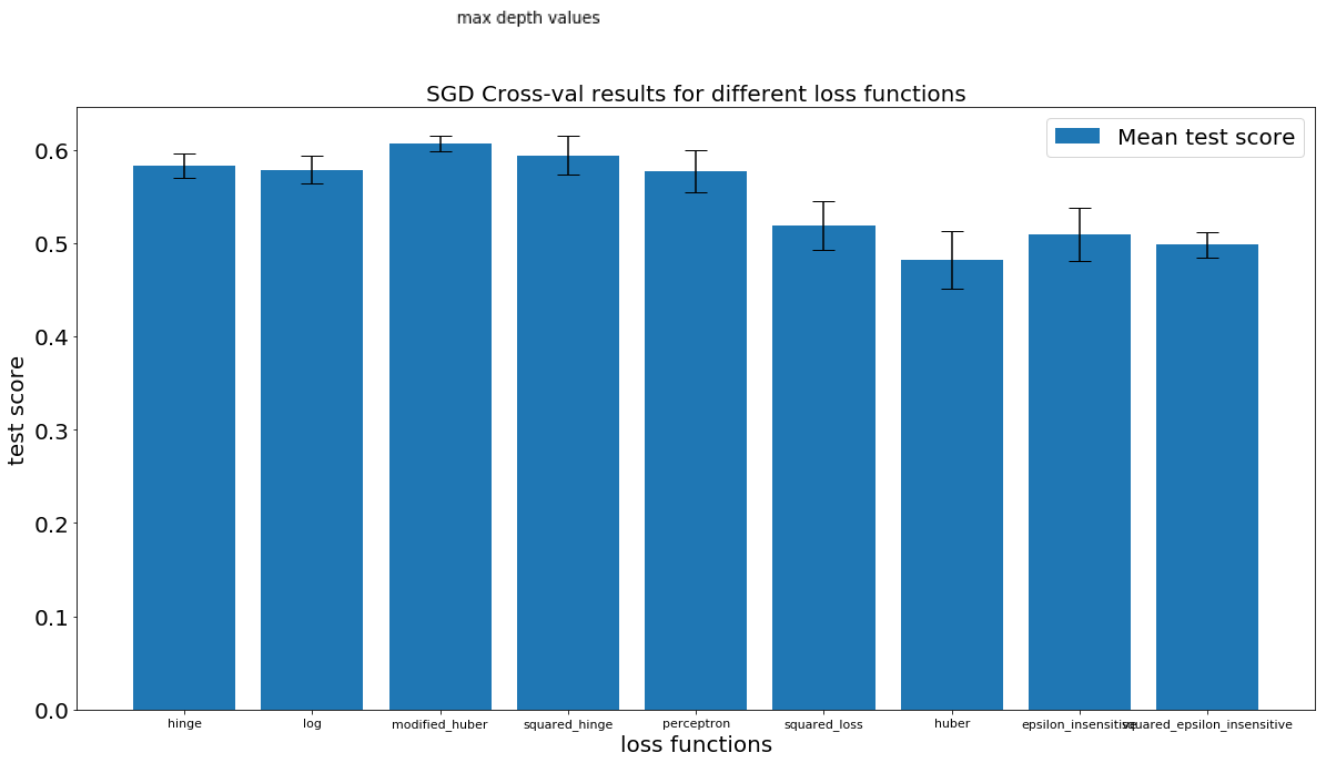
```
def plot_mean_std(clf, name, params):
    mean, std = clf.cv_results_['mean_test_score'], clf.cv_results_['std_test_score']
    if name in {'kNN', 'DecisionTreeClassifier'}:
        plt.figure(figsize=(10, 5))
        plt.title(name + ' Cross-val results for different ' + params)
        if name == 'kNN':
            plt.plot(range(1, 150, 2), mean, c='red', label='Mean test score')
            plt.fill_between(range(1, 150, 2), mean - std, mean + std, label='Test score confidence
interval', alpha=0.5)
        else:
            plt.plot(range(1, 51), mean, c='red', label='Mean test score')
            plt.fill_between(range(1, 51), mean - std, mean + std, label='Test score confidence
interval', alpha=0.5)
        plt.xlabel(params).set_size(10)
        plt.ylabel('test score').set_size(10)
        plt.legend()
    elif name == 'SGD':
        plt.figure(figsize=(20, 10))
        plt.title(name + ' Cross-val results for different ' + params).set_size(20)
        loses = ["hinge", "log", "modified_huber", "squared_hinge",
                         "perceptron", "squared_loss", "huber", "epsilon_insensitive",
                         "squared_epsilon_insensitive"]
        plt.bar(loses, mean, label='Mean test score', yerr=std, capsize=10)
        plt.xlabel(params).set_size(20)
        plt.ylabel('test score').set_size(20)
        plt.yticks(fontsize=20)
        plt.xticks(fontsize=11)
        plt.legend(fontsize=20)
```

In [20]:

```
plot_mean_std(kNN_clf, 'kNN', 'numbers of neighbours')
plot_mean_std(tree_clf, 'DecisionTreeClassifier', 'max depth values')
plot_mean_std(SGD_clf, 'SGD', 'loss functions')
```







(0.5 балл) Задание 3. Теперь подберём число деревьев (*n_estimators*) в алгоритме RandomForest. Как известно, в общем случае Random Forest не переобучается с увеличением количества деревьев. Подберите количество деревьев, начиная с которого качество на кросс-валидации стабилизируется. Обратите внимание, что для проведения этого эксперимента не нужно с нуля обучать много случайных лесов с различными количествами деревьев: обучите один случайный лес с максимальным интересным количеством деревьев, а затем рассмотрите подмножества деревьев разных размеров, состоящие из деревьев построенного леса (поле *estimators_*). В дальнейших экспериментах используйте найденное количество деревьев.

Применить класс *GridSearchCV* в данном задании затруднительно, поэтому предлагается самостоятельно написать цикл по числу деревьев.

Обучим RandomForestClassifier с n_estimators = 500.

In [21]:

```
from tqdm import tqdm

n_estimators = 500
forest = RandomForestClassifier(n_estimators, n_jobs=4)
mean_score = 0
for train_index, test_index in tqdm(kf.split(X)):
    X_train, X_test = X[train_index], X[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]
    forest.fit(X_train, Y_train)
    prediction = forest.predict(X_test)
    mean_score += roc_auc_score(Y_test, prediction)
mean_score /= 5
```

```
5it [00:18,  3.83s/it]
```

In [22]:

```
# Создаём массив средних скоров при разных значениях n_estimators

mean_scores_arr = [mean_score]
```

In [23]:

```
for n in tqdm(range(n_estimators - 1, 0, -1)):
    estimators = np.random.choice(forest.estimators_, n, replace=False)
    frst = forest
```

```
    frst.estimators_ = estimators
    frst.n_estimators = n
    mean_score = 0
    index = 0
    for train_index, test_index in kf.split(X):
        X_train, X_test = X[train_index], X[test_index]
        Y_train, Y_test = Y[train_index], Y[test_index]
        if (index == 4):
            prediction = forest.predict(X_test)
            mean_scores_arr.append(roc_auc_score(Y_test, prediction))
            #mean_scores_arr.append(frst.score(X_test, Y_test))
        index += 1
```

```
100%|██████████| 499/499 [01:50<00:00,  4.51it/s]
```

In [24]:

```
import cufflinks as cf
import plotly
import plotly.offline as py
import plotly.graph_objs as go

cf.go_offline()
py.init_notebook_mode()

mean_scores_arr_plot = pd.DataFrame(np.array(mean_scores_arr[::-1]))
series = mean_scores_arr_plot[0]
series.iplot(kind='scatter', title='RandomForest Cross-val results for different numbers of
estimators',
             yTitle='test score', xTitle='number of estimators')
```

In [25]:

```
forest_n_estimators = 80
```

In [26]:

```
np.array(mean_scores_arr)[n_estimators - forest_n_estimators]
```

Out[26]:

```
0.7019698154254055
```

При обучении алгоритмов стоит обращать внимание не только на их качество, но и каким образом они работают с данными. В этой задаче получилось так, что некоторые из используемых алгоритмов чувствительны к масштабу признаков. Чтобы убедиться, что это могло повлиять на качество, давайте посмотрим на значения самих признаков.

(1 балл) Задание 4. Посмотрите на значения признаков *age*, *fnlwgt*, *capital-gain*. В чем заключается особенность данных? На какие из рассматриваемых алгоритмов это может повлиять? Может ли масштабирование повлиять на работу этих алгоритмов?

In [27]:

```
data.head(20)
```

Out[27]:

	age	workclass	fnlwgt	education	education-num	marital-status	occupation	relationship	race	sex	capital-gain	capital-loss	hours-per-week
0	34	Local-gov	284843	HS-grad	9	Never-married	Farming-fishing	Not-in-family	Black	Male	594	0	60
1	40	Private	190290	Some-college	10	Divorced	Sales	Not-in-family	White	Male	0	0	40
2	36	Local-gov	177858	Bachelors	13	Married-civ-spouse	Prof-specialty	Own-child	White	Male	0	0	40
3	22	Private	184756	Some-college	10	Never-married	Sales	Own-child	White	Female	0	0	30
4	47	Private	149700	Bachelors	13	Married-civ-spouse	Tech-support	Husband	White	Male	15024	0	40
5	18	Private	446771	Some-college	10	Never-married	Adm-clerical	Own-child	White	Male	0	0	25
6	31	Federal-gov	108464	Assoc-acdm	12	Married-civ-spouse	Tech-support	Husband	White	Male	0	0	40
8	25	Private	110138	HS-grad	9	Never-married	Other-service	Not-in-family	White	Male	0	0	40
9	53	Federal-gov	167410	Bachelors	13	Divorced	Tech-support	Not-in-family	Amer-Indian-Eskimo	Male	0	0	40
10	19	Private	131615	HS-grad	9	Never-married	Machine-op-inspct	Own-child	White	Male	0	0	40
11	44	Local-gov	150171	HS-grad	9	Divorced	Adm-clerical	Unmarried	White	Female	0	0	40
12	31	Local-gov	331126	Bachelors	13	Never-married	Protective-serv	Own-child	Black	Male	0	0	48
13	20	Private	191910	HS-grad	9	Never-married	Protective-serv	Own-child	White	Male	0	0	40
14	36	Self-emp-inc	116133	HS-grad	9	Married-civ-spouse	Transport-moving	Husband	White	Male	0	0	57
15	28	Private	139903	Bachelors	13	Never-married	Machine-op-inspct	Unmarried	Black	Female	0	0	40
16	35	Private	107160	12th	8	Separated	Other-service	Not-in-family	White	Female	0	0	30
17	44	Private	121874	Some-college	10	Divorced	Sales	Unmarried	White	Male	0	0	55
18	38	Private	22494	Some-college	10	Divorced	Adm-clerical	Not-in-family	White	Female	7443	0	40
19	30	Private	124020	HS-grad	9	Married-spouse-absent	Adm-clerical	Not-in-family	White	Male	0	0	40
20	37	Local-gov	251396	Assoc-acdm	12	Married-civ-spouse	Prof-specialty	Husband	White	Male	0	0	45

Значения параметра 'fnlwgt' очень большие по модулю, а значения параметра 'capital-gain' имеют очень большую дисперсию/разрежено (возможно, нули по данному параметру означают

имеют очень большую дисперсию/разрежено (возможно, нули по данному параметру означают, что данная информация просто не была предоставлена клиентом). В силу того, что в RandomForestClassifier и в DecisionTreeClassifier вместе с линейным масштабированием параметров столь же линейно изменятся пороги, разделяющие в каждом узле выборку на две части, работа алгоритмов никак не изменится и порожденные группы после разделения в узле будут такими же. Для KNeighborsClassifier масштабирование признаков приведет (скорее всего) к преобразованию пространства, не являющемуся композицией некоторого движения и гомотетии, то есть расстояния между векторами в новом пространстве могут существенно отличаться от исходных. Поэтому масштабирование параметров окажет влияние на kNN и влияние, например, параметра 'fnlwgt' не будет столь существенне влияния параметра 'capital-gain'. Аналогично, на SGDClassifier масштабирование параметров может существенно повлять, снизив переобучение.

Масштабирование признаков можно выполнить, например, одним из следующих способов:

- $x_{new} = \frac{x - \mu}{\sigma}$, где μ, σ — среднее и стандартное отклонение значения признака по всей выборке (см. функцию scale)
- $x_{new} = \frac{x - x_{min}}{x_{max} - x_{min}}$, где $[x_{min}, x_{max}]$ — минимальный интервал значений признака

Похожие схемы масштабирования приведены в классах StandardScaler и MinMaxScaler.

(1 балл) Задание 5. Отмасштабируйте все вещественные признаки одним из указанных выше способов и подберите оптимальные значения гиперпараметров аналогично пункту выше.

Изменилось ли качество некоторых алгоритмов и почему?

In [28]:

```
from sklearn.preprocessing import StandardScaler

scaler = StandardScaler()
scaler.fit(X)
X_normed = scaler.transform(X)

kNN_clf_new = GridSearchCV(kNN, kNN_params, cv=kf, verbose=2, scoring='roc_
auc', n_jobs=4)
tree_clf_new = GridSearchCV(tree, tree_params, cv=kf, verbose=2, scoring='r
oc_auc', n_jobs=4)
SGD_clf_new = GridSearchCV(SGD, SGD_params, cv=kf, verbose=2, scoring='roc_
auc', n_jobs=4)
```

In [29]:

```
kNN_clf_new.fit(X_normed, Y)
knn_param_new = kNN_clf_new.best_params_['n_neighbors']
```

```
Fitting 5 folds for each of 75 candidates, totalling 375 fits
[CV] n_neighbors=1 ...................................................
[CV] n_neighbors=1 ...................................................
[CV] n_neighbors=1 ...................................................
[CV] n_neighbors=1 ...................................................
[CV] ..................................... n_neighbors=1, total=   0.5s
[CV] ..................................... n_neighbors=1, total=   0.5s
[CV] n_neighbors=1 ...................................................
[CV] n_neighbors=3 ...................................................
[CV] ..................................... n_neighbors=1, total=   0.5s
[CV] ..................................... n_neighbors=1, total=   0.4s
[CV] n_neighbors=3 ...................................................
```

```
[CV] n_neighbors=3 ....................................................
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[CV] n_neighbors=15 ...................................................

[Parallel(n_jobs=4)]: Done  33 tasks      | elapsed:   12.7s
```

```
[CV] ................................. n_neighbors=13, total=   0.6s
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[CV] ................................. n_neighbors=15, total=   0.5s
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[CV] ................................. n_neighbors=17, total=   0.7s
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[CV] ................................. n_neighbors=23, total=   1.0s
[CV] n_neighbors=25 ..................................................
[CV] ................................. n_neighbors=23, total=   0.9s
[CV] n_neighbors=25 ..................................................
[CV] ................................. n_neighbors=23, total=   0.6s
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[CV] n_neighbors=27
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```
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[CV] ................................... n_neighbors=35, total=   0.8s
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[CV] ................................... n_neighbors=35, total=   1.1s
[CV] n_neighbors=37 ..................................................
[CV] ................................... n_neighbors=35, total=   1.1s
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[Parallel(n_jobs=4)]: Done 154 tasks      | elapsed:  1.8min

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[CV] n_neighbors=119 ..................................................
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[CV] n_neighbors=121 ..................................................
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[CV] n_neighbors=125 ..................................................
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[CV] ................................. n_neighbors=125, total=   1.1s
[CV] n_neighbors=127 ..................................................
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[CV] ................................. n_neighbors=127, total=   1.0s
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[CV] ................................. n_neighbors=127, total=   1.4s
[CV] n_neighbors=129 ..................................................
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[CV] n_neighbors=129 ..................................................
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[CV] n_neighbors=131 ..................................................
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[CV] n_neighbors=133 ..................................................
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[CV] ................................. n_neighbors=131, total=   1.1s
[CV] n_neighbors=133 ..................................................
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[CV] ................................. n_neighbors=135, total=   1.3s
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[CV] ................................. n_neighbors=135, total=   1.2s
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[CV] n_neighbors=137 ..................................................
[CV] ................................. n_neighbors=137, total=   1.1s
[CV] n_neighbors=139 ..................................................
```

```
[CV] ................................. n_neighbors=137, total=   1.1s
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[CV] ................................. n_neighbors=139, total=   1.3s
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[CV] ................................. n_neighbors=139, total=   1.2s
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[CV] n_neighbors=141 .................................................
[CV] ................................. n_neighbors=139, total=   1.1s
[CV] n_neighbors=141 .................................................
[CV] ................................. n_neighbors=141, total=   1.2s
[CV] n_neighbors=141 .................................................
[CV] ................................. n_neighbors=141, total=   1.1s
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[CV] ................................. n_neighbors=141, total=   1.2s
[CV] n_neighbors=143 .................................................
[CV] ................................. n_neighbors=141, total=   1.2s
[CV] n_neighbors=143 .................................................
[CV] ................................. n_neighbors=141, total=   1.2s
[CV] n_neighbors=143 .................................................
[CV] ................................. n_neighbors=143, total=   1.2s
[CV] n_neighbors=143 .................................................
[CV] ................................. n_neighbors=143, total=   1.4s
[CV] n_neighbors=145 .................................................

[Parallel(n_jobs=4)]: Done 357 tasks      | elapsed:  5.5min

[CV] ................................. n_neighbors=143, total=   1.5s
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[CV] ................................. n_neighbors=143, total=   1.2s
[CV] n_neighbors=145 .................................................
[CV] ................................. n_neighbors=143, total=   1.3s
[CV] n_neighbors=145 .................................................
[CV] ................................. n_neighbors=145, total=   1.2s
[CV] n_neighbors=145 .................................................
[CV] ................................. n_neighbors=145, total=   1.2s
[CV] n_neighbors=147 .................................................
[CV] ................................. n_neighbors=145, total=   1.6s
[CV] n_neighbors=147 .................................................
[CV] ................................. n_neighbors=145, total=   1.5s
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[CV] ................................. n_neighbors=147, total=   1.8s
[CV] n_neighbors=147 .................................................
[CV] ................................. n_neighbors=147, total=   1.6s
[CV] n_neighbors=149 .................................................
[CV] ................................. n_neighbors=147, total=   1.5s
[CV] n_neighbors=149 .................................................
[CV] ................................. n_neighbors=147, total=   1.4s
[CV] n_neighbors=149 .................................................
[CV] ................................. n_neighbors=147, total=   1.2s
[CV] n_neighbors=149 .................................................
[CV] ................................. n_neighbors=149, total=   1.2s
[CV] n_neighbors=149 .................................................
```

```
[CV] ..... n_neighbors=149, total=   1.1s
[CV] ..... n_neighbors=149, total=   1.1s
[CV] ..... n_neighbors=149, total=   1.1s
[CV] ..... n_neighbors=149, total=   1.0s

[Parallel(n_jobs=4)]: Done 375 out of 375 | elapsed:  5.9min finished
```

In [30]:

```
print("Best kNN parameter:", knn_param_new)
print("Comparing with old best kNN parameter:", knn_param)
```

```
Best kNN parameter: 55
Comparing with old best kNN parameter: 5
```

In [31]:

```
tree_clf_new.fit(X_normed, Y)
tree_param_new = tree_clf_new.best_params_['max_depth']
```

```
Fitting 5 folds for each of 50 candidates, totalling 250 fits
[CV] max_depth=1 .....................................................
[CV] max_depth=1 .....................................................
[CV] max_depth=1 .....................................................
[CV] max_depth=1 .....................................................
[CV] ..... max_depth=1, total=   0.0s
[CV] ..... max_depth=1, total=   0.0s
[CV] ..... max_depth=1, total=   0.0s
[CV] max_depth=1 .....................................................
[CV] max_depth=2 .....................................................
[CV] ..... max_depth=1, total=   0.0s
[CV] ..... max_depth=1, total=   0.0s
[CV] max_depth=2 .....................................................
[CV] ..... max_depth=2, total=   0.0s
[CV] max_depth=2 .....................................................
[CV] ..... max_depth=2, total=   0.0s
[CV] max_depth=2 .....................................................
[CV] max_depth=3 .....................................................
[CV] max_depth=4 .....................................................
[CV] ..... max_depth=2, total=   0.0s
[CV] ..... max_depth=3, total=   0.0s
[CV] max_depth=5 .....................................................
[CV] max_depth=3 .....................................................
[CV] ..... max_depth=4, total=   0.0s
[CV] max_depth=4 .....................................................
[CV] ..... max_depth=2, total=   0.0s
[CV] max_depth=2 .....................................................
[CV] ..... max_depth=3, total=   0.0s
[CV] max_depth=3 .....................................................
[CV] ..... max_depth=5, total=   0.1s
[CV] ..... max_depth=4, total=   0.0s
[CV] max_depth=4 .....................................................
[CV] max_depth=5 .....................................................
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[CV] max_depth=4 .....................................................
[CV] ..... max_depth=2, total=   0.0s
[CV] max_depth=3 .....................................................
[CV] ..... max_depth=5, total=   0.0s
[CV] max_depth=5 .....................................................
[CV] ..... max_depth=4, total=   0.1s
```

```
[CV] ..................................... max_depth=3, total=   0.0s
[CV] max_depth=4 ......................................................
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[CV] ..................................... max_depth=5, total=   0.1s
[CV] max_depth=6 ......................................................
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[CV] max_depth=6 ......................................................
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[CV] max_depth=6 ......................................................
[CV] ..................................... max_depth=6, total=   0.1s
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[CV] max_depth=7 ......................................................
[CV] ..................................... max_depth=8, total=   0.1s
[CV] max_depth=8 ......................................................
[CV] ..................................... max_depth=6, total=   0.1s
[CV] max_depth=6 ......................................................
[CV] ..................................... max_depth=7, total=   0.0s
[CV] max_depth=7 ......................................................
[CV] ..................................... max_depth=7, total=   0.1s
[CV] max_depth=8 ......................................................
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[CV] ..................................... max_depth=8, total=   0.0s
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[CV] max_depth=9 ......................................................
[CV] ..................................... max_depth=11, total=   0.1s
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[CV] max_depth=11 .....................................................
[CV] ..................................... max_depth=10, total=   0.1s
[CV] max_depth=10
```

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[CV] max_depth=15 .....................................................
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[CV] ..................................... max_depth=17, total=   0.1s
[CV] max_depth=17 .....................................................
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[CV] max_depth=22 .....................................................
[CV] ..................................... max_depth=24, total=   0.1s
[CV] max_depth=24 .....................................................
```

```
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[CV] ..................................... max_depth=24, total=   0.1s

[Parallel(n_jobs=4)]: Done 108 tasks      | elapsed:    2.6s

[CV] max_depth=26 .....................................................
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[CV] ..................................... max_depth=26, total=   0.1s
[CV] max_depth=26 .....................................................
[CV] max_depth=26 .....................................................
[CV] ..................................... max_depth=25, total=   0.1s
[CV] max_depth=25 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=26, total=   0.1s
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[CV] ..................................... max_depth=26, total=   0.1s
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=25, total=   0.1s
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=26, total=   0.1s
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=29 .....................................................
[CV] max_depth=27 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=27, total=   0.1s
[CV] ..................................... max_depth=29, total=   0.1s
[CV] max_depth=29 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
[CV] max_depth=29 .....................................................
[CV] max_depth=28 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=29, total=   0.1s
[CV] ..................................... max_depth=29, total=   0.1s
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[CV] max_depth=29 .....................................................
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
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[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=28, total=   0.1s
[CV] ..................................... max_depth=29, total=   0.1s
[CV] max_depth=29 .....................................................
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=30 .....................................................
[CV] ..................................... max_depth=29, total=   0.1s
[CV] ..................................... max_depth=31, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=30, total=   0.1s
[CV] max_depth=33 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] max_depth=31 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] ..................................... max_depth=33, total=   0.1s
[CV] max_depth=33 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] max_depth=33 .....................................................
[CV] ..................................... max_depth=31, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] ..................................... max_depth=33, total=   0.1s
[CV] ..................................... max_depth=33, total=   0.1s
[CV] max_depth=33 .....................................................
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=32 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=33, total=   0.1s
[CV] ..................................... max_depth=34, total=   0.1s
[CV] max_depth=33 .....................................................
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=32, total=   0.1s
[CV] max_depth=35 .....................................................
[CV] ..................................... max_depth=34, total=   0.1s
[CV] max_depth=34 .....................................................
[CV] ..................................... max_depth=34, total=   0.1s
[CV] ..................................... max_depth=33, total=   0.1s
[CV] max_depth=34 .....................................................
[CV] max_depth=36 .....................................................
[CV] ..................................... max_depth=35, total=   0.1s
[CV] ..................................... max_depth=34, total=   0.1s
[CV] max_depth=35 .....................................................
[CV] max_depth=35 .....................................................
[CV] ..................................... max_depth=34, total=   0.1s
[CV] max_depth=37 .....................................................
[CV]                                      max_depth=36, total=   0.1s
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[CV] ..... max_depth=35, total=   0.1s
[CV] max_depth=36 .....................................................
[CV] max_depth=35 .....................................................
[CV] ..... max_depth=35, total=   0.1s
[CV] max_depth=35 .....................................................
[CV] ..... max_depth=37, total=   0.1s
[CV] max_depth=37 .....................................................
[CV] ..... max_depth=36, total=   0.1s
[CV] max_depth=36 .....................................................
[CV] ..... max_depth=35, total=   0.1s
[CV] max_depth=36 .....................................................
[CV] ..... max_depth=35, total=   0.1s
[CV] max_depth=37 .....................................................
[CV] ..... max_depth=37, total=   0.1s
[CV] max_depth=37 .....................................................
[CV] ..... max_depth=36, total=   0.1s
[CV] max_depth=36 .....................................................
[CV] ..... max_depth=36, total=   0.1s
[CV] max_depth=38 .....................................................
[CV] ..... max_depth=37, total=   0.1s
[CV] max_depth=38 .....................................................
[CV] ..... max_depth=37, total=   0.1s
[CV] max_depth=37 .....................................................
[CV] ..... max_depth=36, total=   0.1s
[CV] ..... max_depth=38, total=   0.1s
[CV] max_depth=38 .....................................................
[CV] max_depth=39 .....................................................
[CV] ..... max_depth=38, total=   0.1s
[CV] max_depth=38 .....................................................
[CV] ..... max_depth=37, total=   0.1s
[CV] ..... max_depth=38, total=   0.1s
[CV] max_depth=40 .....................................................
[CV] ..... max_depth=38, total=   0.1s
[CV] max_depth=39 .....................................................
[CV] max_depth=38 .....................................................
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=39 .....................................................
[CV] ..... max_depth=40, total=   0.1s
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=40 .....................................................
[CV] max_depth=39 .....................................................
[CV] ..... max_depth=38, total=   0.1s
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=39 .....................................................
[CV] max_depth=41 .....................................................
[CV] ..... max_depth=39, total=   0.1s
[CV] ..... max_depth=40, total=   0.1s
[CV] max_depth=40 .....................................................
[CV] ..... max_depth=39, total=   0.1s
[CV] max_depth=41 .....................................................
[CV] max_depth=40 .....................................................
[CV] ..... max_depth=41, total=   0.1s
[CV] max_depth=41 .....................................................
[CV] ..... max_depth=40, total=   0.1s
[CV] ..... max_depth=40, total=   0.1s
[CV] max_depth=40 .....................................................
[CV] max_depth=42 .....................................................
[CV] ..... max_depth=41, total=   0.1s
[CV] max_depth=42 .....................................................
[CV] ..... max_depth=41, total=   0.1s
[CV] max_depth=41 .....................................................
[CV] ..... max depth=40, total=   0.1s
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[CV] ..................................... max_depth=42, total=   0.1s
[CV] max_depth=42 .....................................................
[CV] max_depth=43 .....................................................
[CV] ..................................... max_depth=42, total=   0.1s
[CV] max_depth=42 .....................................................
[CV] ..................................... max_depth=41, total=   0.1s
[CV] max_depth=41 .....................................................
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[CV] max_depth=43 .....................................................
[CV] ..................................... max_depth=42, total=   0.1s
[CV] ..................................... max_depth=42, total=   0.1s
[CV] max_depth=42 .....................................................
[CV] ..................................... max_depth=41, total=   0.1s
[CV] max_depth=44 .....................................................
[CV] max_depth=43 .....................................................
[CV] ..................................... max_depth=42, total=   0.1s
[CV] ..................................... max_depth=43, total=   0.1s
[CV] max_depth=43 .....................................................
[CV] ..................................... max_depth=43, total=   0.1s
[CV] max_depth=43 .....................................................
[CV] max_depth=45 .....................................................
[CV] ..................................... max_depth=44, total=   0.1s
[CV] max_depth=44 .....................................................
[CV] ..................................... max_depth=43, total=   0.1s
[CV] max_depth=44 .....................................................
[CV] ..................................... max_depth=43, total=   0.1s
[CV] max_depth=45 .....................................................
[CV] ..................................... max_depth=45, total=   0.1s
[CV] max_depth=45 .....................................................
[CV] ..................................... max_depth=44, total=   0.1s
[CV] max_depth=44 .....................................................
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[CV] ..................................... max_depth=44, total=   0.1s
[CV] max_depth=46 .....................................................
[CV] ..................................... max_depth=45, total=   0.1s
[CV] max_depth=45 .....................................................
[CV] ..................................... max_depth=44, total=   0.1s
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=44 .....................................................
[CV] max_depth=46 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=46 .....................................................
[CV] ..................................... max_depth=45, total=   0.1s
[CV] max_depth=45 .....................................................
[CV] ..................................... max_depth=44, total=   0.1s
[CV] max_depth=47 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=46 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=47 .....................................................
[CV] ..................................... max_depth=45, total=   0.1s
[CV] max_depth=48 .....................................................
[CV] ..................................... max_depth=46, total=   0.1s
[CV] max_depth=49 .....................................................
[CV] ..................................... max_depth=47, total=   0.1s
[CV] ..................................... max_depth=47, total=   0.1s
[CV] max_depth=47 .....................................................
[CV] max_depth=47 .....................................................
[CV] ..................................... max_depth=48, total=   0.1s
[CV] max_depth=48 .....................................................
[CV] ..................................... max_depth=47, total=   0.1s
```

```
[CV] max_depth=47 ....................................................
[CV] ..................................... max_depth=49, total=   0.1s
[CV] max_depth=49 ....................................................
[CV] ..................................... max_depth=47, total=   0.1s
[CV] max_depth=49 ....................................................
[CV] ..................................... max_depth=48, total=   0.1s
[CV] max_depth=48 ....................................................
[CV] ..................................... max_depth=47, total=   0.1s
[CV] max_depth=48 ....................................................
[CV] ..................................... max_depth=49, total=   0.1s
[CV] max_depth=49 ....................................................
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[CV] max_depth=48 ....................................................
[CV] ..................................... max_depth=48, total=   0.1s
[CV] max_depth=50 ....................................................
[CV] ..................................... max_depth=49, total=   0.1s
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[CV] ..................................... max_depth=50, total=   0.1s
[CV] max_depth=50 ....................................................
[CV] ..................................... max_depth=48, total=   0.1s
[CV] ..................................... max_depth=50, total=   0.1s
[CV] max_depth=50 ....................................................
[CV] ..................................... max_depth=49, total=   0.1s
[CV] ..................................... max_depth=50, total=   0.1s
[CV] max_depth=50 ....................................................
[CV] ..................................... max_depth=50, total=   0.1s
[CV] ..................................... max_depth=50, total=   0.0s

[Parallel(n_jobs=4)]: Done 250 out of 250 | elapsed:    6.3s finished
```

In [32]:

```
SGD_clf_new.fit(X_normed, Y)
SGD_param_new = SGD_clf_new.best_params_['loss']
```

```
Fitting 5 folds for each of 9 candidates, totalling 45 fits
[CV] loss=hinge ......................................................
[CV] loss=hinge ......................................................
[CV] loss=hinge ......................................................
[CV] loss=hinge ......................................................
[CV] ..................................... loss=hinge, total=   0.0s
[CV] ..................................... loss=hinge, total=   0.0s
[CV] loss=hinge ......................................................
[CV] ..................................... loss=hinge, total=   0.0s
[CV] ..................................... loss=hinge, total=   0.0s
[CV] loss=log ........................................................
[CV] loss=log ........................................................
[CV] loss=log ........................................................
[CV] ..................................... loss=hinge, total=   0.0s
[CV] ........................................ loss=log, total=   0.0s
[CV] ........................................ loss=log, total=   0.0s
[CV] loss=log ........................................................
[CV] ........................................ loss=log, total=   0.0s
[CV] loss=modified_huber .............................................
[CV] loss=squared_hinge ..............................................
[CV] loss=perceptron .................................................
[CV] ................................ loss=perceptron, total=   0.0s
[CV] loss=perceptron .................................................
[CV] ........................................ loss=log, total=   0.0s
```

```
[CV] ............................. loss=modified_huber, total=   0.0s
[CV] loss=log .....................................................
[CV] loss=modified_huber ..........................................
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] loss=squared_hinge ...........................................
[CV] ............................. loss=modified_huber, total=   0.0s
[CV] loss=modified_huber ..........................................
[CV] ................................ loss=perceptron, total=   0.0s
[CV] loss=perceptron ..............................................
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] ..................................... loss=log, total=   0.0s
[CV] loss=modified_huber ..........................................
[CV] loss=squared_hinge ...........................................
[CV] ............................. loss=modified_huber, total=   0.0s
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] loss=squared_hinge ...........................................
[CV] loss=squared_hinge ...........................................
[CV] ................................ loss=perceptron, total=   0.0s
[CV] loss=perceptron ..............................................
[CV] ............................. loss=modified_huber, total=   0.0s
[CV] loss=modified_huber ..........................................
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] loss=perceptron ..............................................
[CV] ............................... loss=squared_hinge, total=   0.0s
[CV] ................................ loss=perceptron, total=   0.0s
[CV] ............................. loss=modified_huber, total=   0.0s
[CV] loss=squared_loss ............................................
[CV] loss=huber ...................................................
[CV] loss=epsilon_insensitive .....................................
[CV] ................................ loss=perceptron, total=   0.0s
[CV] loss=squared_loss ............................................
[CV] ......................... loss=epsilon_insensitive, total=   0.0s
[CV] ..................................... loss=huber, total=   0.0s
[CV] loss=epsilon_insensitive .....................................
[CV] loss=huber ...................................................
[CV] ................................ loss=squared_loss, total=   0.0s
[CV] ................................ loss=squared_loss, total=   0.0s
[CV] loss=squared_loss ............................................
[CV] loss=squared_loss ............................................
[CV] ..................................... loss=huber, total=   0.0s
[CV] ......................... loss=epsilon_insensitive, total=   0.0s
[CV] ................................ loss=squared_loss, total=   0.0s
[CV] loss=epsilon_insensitive .....................................
[CV] loss=huber ...................................................
[CV] loss=huber ...................................................
[CV] ................................ loss=squared_loss, total=   0.0s
[CV] loss=squared_loss ............................................
[CV] ..................................... loss=huber, total=   0.0s
[CV] ..................................... loss=huber, total=   0.0s
[CV] ......................... loss=epsilon_insensitive, total=   0.0s
[CV] loss=epsilon_insensitive .....................................
[CV] loss=huber ...................................................
[CV] loss=epsilon_insensitive .....................................
[CV] ................................ loss=squared_loss, total=   0.0s
[CV] loss=squared_epsilon_insensitive .............................
[CV] ......................... loss=epsilon_insensitive, total=   0.0s
[CV] loss=squared_epsilon_insensitive .............................
[CV] ..................................... loss=huber, total=   0.0s
[CV] ......................... loss=epsilon_insensitive, total=   0.0s
[CV] ................... loss=squared_epsilon_insensitive, total=   0.0s
[CV] loss=squared_epsilon_insensitive .............................
[CV] ................... loss=squared_epsilon_insensitive, total=   0.0s
```

```
[CV] ................. loss=squared_epsilon_insensitive, total=   0.0s
[CV] loss=squared_epsilon_insensitive ..............................
[CV] ................. loss=squared_epsilon_insensitive, total=   0.0s
[CV] loss=squared_epsilon_insensitive ..............................
[CV] ................. loss=squared_epsilon_insensitive, total=   0.0s
```

```
[Parallel(n_jobs=4)]: Done  45 out of  45 | elapsed:    0.7s finished
```

In [33]:

```
from tqdm import tqdm

n_estimators = 500
forest_new = RandomForestClassifier(n_estimators)
mean_score = 0
for train_index, test_index in tqdm(kf.split(X)):
    X_train, X_test = X_normed[train_index], X_normed[test_index]
    Y_train, Y_test = Y[train_index], Y[test_index]
    forest_new.fit(X_train, Y_train)
    prediction = forest_new.predict(X_test)
    mean_score += roc_auc_score(Y_test, prediction)
mean_score /= 5
print(mean_score)
```

```
5it [00:32,  6.64s/it]
```

```
0.7050976006181567
```

In [34]:

```
mean_scores_arr_new = [mean_score]
```

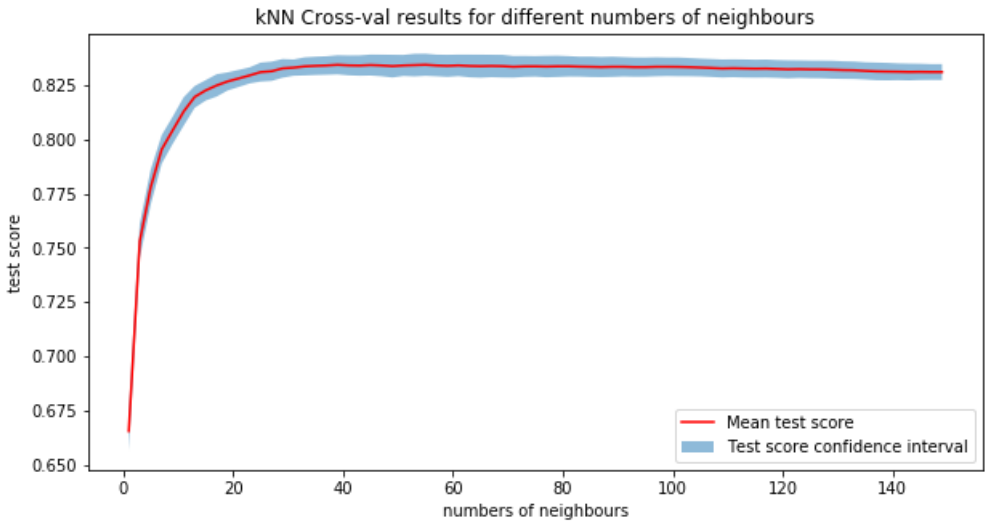
In [35]:

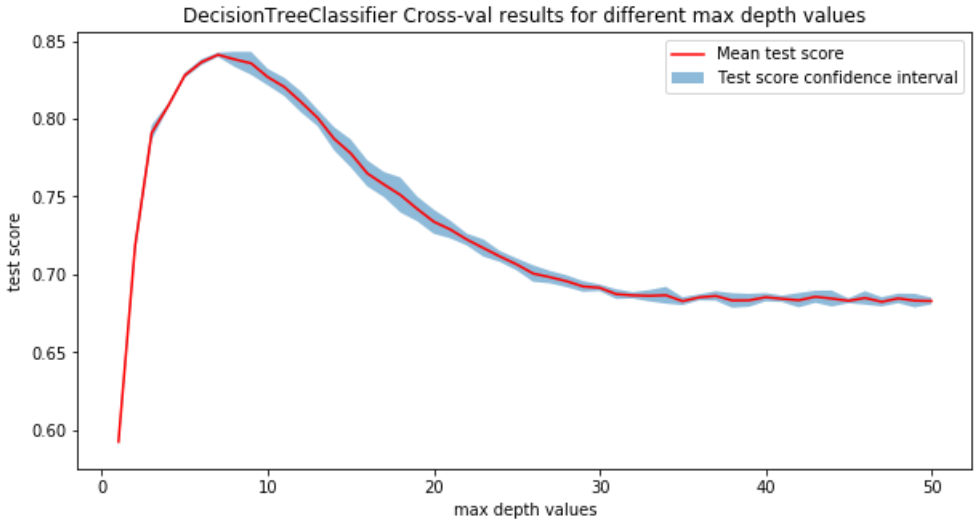
```
for n in tqdm(range(n_estimators - 1, 0, -1)):
    estimators = np.random.choice(forest_new.estimators_, n, replace=False)
    frst = forest_new
    frst.estimators_ = estimators
    frst.n_estimators = n
    mean_score = 0
    index = 0
    for train_index, test_index in kf.split(X):
        X_train, X_test = X_normed[train_index], X_normed[test_index]
        Y_train, Y_test = Y[train_index], Y[test_index]
        if (index == 4):
            prediction = forest_new.predict(X_test)
            mean_scores_arr_new.append(roc_auc_score(Y_test, prediction))
        index += 1
```

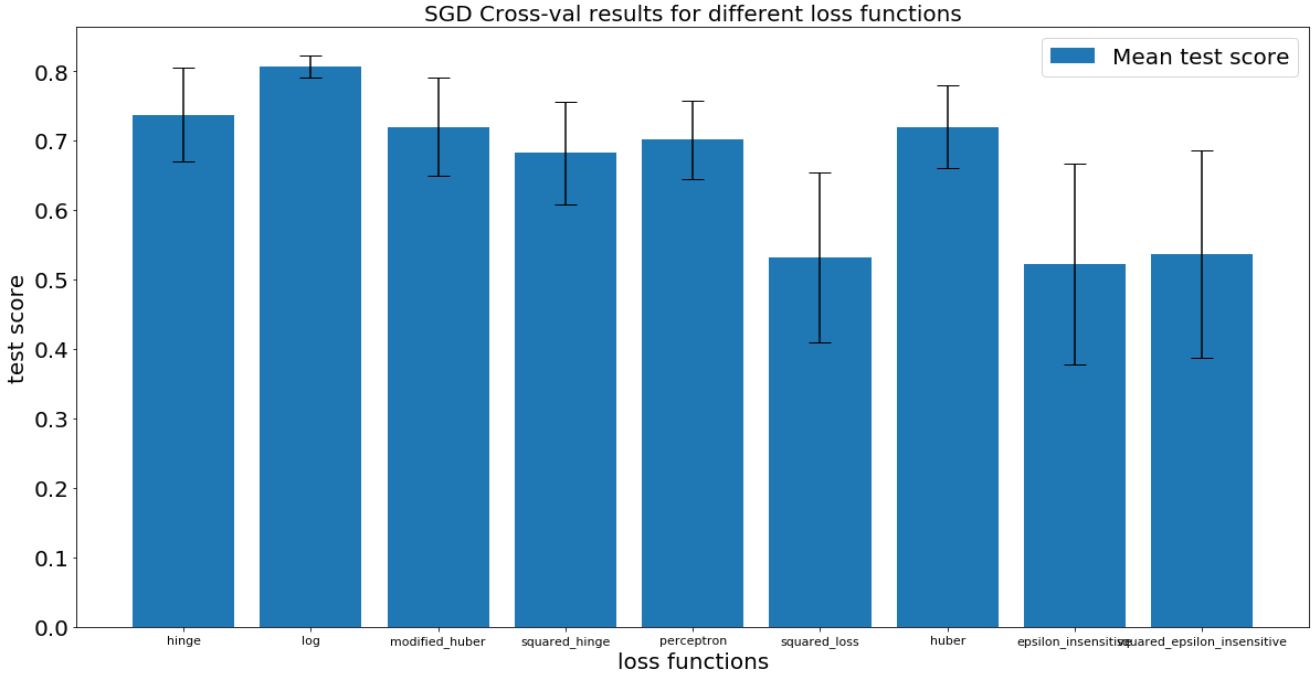
```
100%|██████████| 499/499 [01:29<00:00,  5.55it/s]
```

In [82]:

```
plot_mean_std(kNN_clf_new, 'kNN', 'numbers of neighbours')
plot_mean_std(tree_clf_new, 'DecisionTreeClassifier', 'max depth values')
plot_mean_std(SGD_clf_new, 'SGD', 'loss functions')
```







In [36]:

```
mean_scores_arr_new_plot = pd.DataFrame(np.array(mean_scores_arr_new[::-1]))
series_new = mean_scores_arr_new_plot[0]
series_new.iplot(kind='scatter', title='RandomForest Cross-val results for d
```

```
ifferent numbers of estimators for scaled data',
            yTitle='test score', xTitle='number of estimators')
```

In [37]:

```
forest_n_estimators_new = 54
```

In [38]:

```
print("New results:")
print("kNN classifier's best score:", kNN_clf_new.best_score_)
print("tree classifier's best score:", tree_clf_new.best_score_)
print("SGD classifier's best score:", SGD_clf_new.best_score_)
print("RandomForest classifier's best score:", np.array(mean_scores_arr_new)
[n_estimators - forest_n_estimators_new])
print("\nComparing with old results:")
print("kNN classifier's best score:", kNN_clf.best_score_)
print("tree classifier's best score:", tree_clf.best_score_)
print("SGD classifier's best score:", SGD_clf.best_score_)
print("RandomForest classifier's best score:", np.array(mean_scores_arr)[n_e
stimators - forest_n_estimators])
```

```
New results:
kNN classifier's best score: 0.834390627771687
tree classifier's best score: 0.8411372234302745
SGD classifier's best score: 0.8064773357712638
RandomForest classifier's best score: 0.7112240388864339

Comparing with old results:
kNN classifier's best score: 0.6412956668705564
tree classifier's best score: 0.8410139678158015
SGD classifier's best score: 0.6062338251350011
RandomForest classifier's best score: 0.7019698154254055
```

In [39]:

In [39]:

```
print("New confidence intervals:")
print("kNN confidence interval: (", kNN_clf_new.best_score_ -
      kNN_clf_new.cv_results_['std_test_score'][kNN_clf_new.best_index_], "
,",
      kNN_clf_new.best_score_ + kNN_clf_new.cv_results_['std_test_score'][k
NN_clf_new.best_index_], "), length = ",
     kNN_clf_new.cv_results_['std_test_score'][kNN_clf_new.best_index_]*2)
print("tree confidence interval: (", tree_clf_new.best_score_ -
      tree_clf_new.cv_results_['std_test_score'][tree_clf_new.best_index_],
",",
      tree_clf_new.best_score_ + tree_clf_new.cv_results_['std_test_score']
[tree_clf_new.best_index_], "), length = ",
     tree_clf_new.cv_results_['std_test_score'][tree_clf_new.best_index_]*2
)
print("SGD confidence interval: (", SGD_clf_new.best_score_ -
      SGD_clf_new.cv_results_['std_test_score'][SGD_clf_new.best_index_], "
,",
      SGD_clf_new.best_score_ + SGD_clf_new.cv_results_['std_test_score'][S
GD_clf_new.best_index_], "), length = ",
     SGD_clf_new.cv_results_['std_test_score'][SGD_clf_new.best_index_]*2)
```

```
New confidence intervals:
kNN confidence interval: ( 0.8292865675578219 , 0.8394946879855522 ), length
=  0.010208120427730309
tree confidence interval: ( 0.8397616682870981 , 0.842512778573451 ), length
=  0.0027511102863529333
SGD confidence interval: ( 0.7908490171704153 , 0.8221056543721122 ), length
=  0.031256637201696864
```

Таким образом, видим, что масштабирование параметров практически не повлияло на DecisionTreeCalssifier и на RandomForestClassifier, в то время как качество kNN и SGD существенно повысилось, то есть наши предположения оказались верны.

(1.5 балла) Задание 6. Теперь сделайте перебор нескольких гиперпараметров по сетке и найдите оптимальные комбинации (лучшее среднее значение качества) для каждого алгоритма в данном случае:

- KNN — число соседей (*n_neighbors*) и метрика (*metric*)
- DecisonTree — глубина дерева (*max_depth*) и критерий разбиения (*criterion*)
- RandomForest — критерий разбиения в деревьях (*criterion*) и максимальное число рассматриваемых признаков (*max_features*); используйте найденное ранее каличество деревьев
- SGDClassifier — оптимизируемая функция (*loss*) и *penalty*

Обратите внимание, что эта операция может быть ресурсо- и трудоемкой. Как оптимизировать подбор параметров по сетке сказано в разделе "Подбор гиперпараметров модели".

Какой из алгоритмов имеет наилучшее качество?

In [40]:

```
kNN = KNeighborsClassifier()
tree = DecisionTreeClassifier()
SGD = SGDClassifier()
forest = RandomForestClassifier(n_estimators=forest_n_estimators_new)

kNN_params3 = {'n_neighbors' : np.random.choice(list(range(1, 101, 2)), 20,
replace=False),
               'metric' : ['euclidean', 'manhattan', 'chebyshev',
```

```
                           'minkowski']}
tree_params3 = {'max_depth' : np.random.choice(list(range(1, 51)), 20, repl
ace=False),
                'criterion' : ['gini', 'entropy']}
SGD_params3 = {'loss' : ["hinge", "log", "modified_huber", "squared_hinge",

                         "perceptron", "squared_loss", "huber", "epsilon_ins
ensitive",
                         "squared_epsilon_insensitive"],
               'penalty' : ['none', 'l2', 'l1', 'elasticnet']}
forest_params3 = {'criterion': ['gini', 'entropy'], 'max_features' : list(r
ange(1, 6))}

kNN_clf3 = GridSearchCV(kNN, kNN_params3, cv=kf, verbose=2, scoring='roc_au
c', n_jobs=4)
tree_clf3 = GridSearchCV(tree, tree_params3, cv=kf, verbose=2, scoring='roc
_auc', n_jobs=4)
SGD_clf3 = GridSearchCV(SGD, SGD_params3, cv=kf, verbose=2, scoring='roc_au
c', n_jobs=4)
forest_clf3 = GridSearchCV(forest, forest_params3, cv=kf, verbose=2, scorin
g='roc_auc', n_jobs=4)
```

In [41]:

```
kNN_clf3.fit(X_normed, Y)
```

```
Fitting 5 folds for each of 80 candidates, totalling 400 fits
[CV] metric=euclidean, n_neighbors=37 ................................
[CV] metric=euclidean, n_neighbors=37 ................................
[CV] metric=euclidean, n_neighbors=37 ................................
[CV] metric=euclidean, n_neighbors=37 ................................
[CV] .................. metric=euclidean, n_neighbors=37, total=   0.7s
[CV] metric=euclidean, n_neighbors=37 ................................
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[CV] metric=euclidean, n_neighbors=13 ................................
[CV] .................. metric=euclidean, n_neighbors=13, total=   0.6s
[CV] metric=euclidean, n_neighbors=13 ................................
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[CV] metric=euclidean, n_neighbors=63 ................................
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[CV] metric=euclidean, n_neighbors=63 ................................
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[CV] metric=euclidean, n_neighbors=63 ................................
[CV] .................. metric=euclidean, n_neighbors=63, total=   0.9s
[CV] metric=euclidean, n_neighbors=63 ................................
[CV] .................. metric=euclidean, n_neighbors=63, total=   0.8s
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[CV] .................. metric=euclidean, n_neighbors=63, total=   0.8s
[CV] metric=euclidean, n_neighbors=81 ................................
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[CV] .................. metric=euclidean, n_neighbors=63, total=   0.9s
[CV] metric=euclidean, n_neighbors=81 ................................
```

```
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[CV] metric=euclidean, n_neighbors=21 ..............................
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[Parallel(n_jobs=4)]: Done  33 tasks      | elapsed:   24.2s

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[CV]                  metric=euclidean, n_neighbors=1, total=   0.4s
```

```
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[CV] ................. metric=euclidean, n_neighbors=3, total=   0.5s
```

```
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```

```
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[CV] ................. metric=manhattan, n_neighbors=65, total=   1.1s
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```

```
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[Parallel(n_jobs=4)]: Done 154 tasks      | elapsed:  2.0min

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[CV] metric=chebyshev, n_neighbors=37 ................................
```

```
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[CV] metric=chebyshev, n_neighbors=33 ................................
```

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```

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[CV] ................. metric=minkowski, n_neighbors=13, total=   0.7s
[CV] metric=minkowski, n_neighbors=13 ................................
[CV] ................. metric=minkowski, n_neighbors=13, total=   0.7s
[CV] metric=minkowski, n_neighbors=13 ................................
[CV] ................. metric=minkowski, n_neighbors=37, total=   0.9s
[CV] metric=minkowski, n_neighbors=63 ................................
[CV] ................. metric=minkowski, n_neighbors=13, total=   0.5s
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[CV] ................. metric=minkowski, n_neighbors=13, total=   0.6s
[CV] metric=minkowski, n_neighbors=63 ................................
[CV] ................. metric=minkowski, n_neighbors=13, total=   0.6s
[CV] metric=minkowski, n_neighbors=63 ................................
[CV] ................. metric=minkowski, n_neighbors=63, total=   0.9s
[CV] metric=minkowski, n_neighbors=63 ................................
[CV] ................. metric=minkowski, n_neighbors=63, total=   0.8s
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[CV] ................. metric=minkowski, n_neighbors=63, total=   0.8s
[CV] metric=minkowski, n_neighbors=81 ................................
[CV] ................. metric=minkowski, n_neighbors=81, total=   1.0s
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[CV] ................. metric=minkowski, n_neighbors=81, total=   0.9s
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[CV] metric=minkowski, n_neighbors=21 ................................
[CV] ................. metric=minkowski, n_neighbors=81, total=   0.9s
[CV] metric=minkowski, n_neighbors=21 ................................
[CV] ................. metric=minkowski, n_neighbors=21, total=   0.6s
[CV] ................. metric=minkowski, n_neighbors=21, total=   0.6s
[CV] metric=minkowski, n_neighbors=21 ................................
[CV] metric=minkowski, n_neighbors=21 ................................
[CV] ................. metric=minkowski, n_neighbors=81, total=   1.1s
[CV] metric=minkowski, n_neighbors=85 ................................
[CV] ................. metric=minkowski, n_neighbors=21, total=   0.7s
```

```
[CV] metric=minkowski, n_neighbors=85 ................................
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[CV] ................. metric=minkowski, n_neighbors=33, total=   1.2s
[CV] metric=minkowski, n_neighbors=33 ................................
[CV] ................. metric=minkowski, n_neighbors=85, total=   1.1s
[CV] metric=minkowski, n_neighbors=33 ................................
[CV] ................. metric=minkowski, n_neighbors=33, total=   1.1s
[CV] metric=minkowski, n_neighbors=65 ................................
[CV] ................. metric=minkowski, n_neighbors=33, total=   1.1s
[CV] metric=minkowski, n_neighbors=65 ................................
[CV] ................. metric=minkowski, n_neighbors=33, total=   1.0s
[CV] metric=minkowski, n_neighbors=65 ................................
[CV] ................. metric=minkowski, n_neighbors=33, total=   1.0s
[CV] metric=minkowski, n_neighbors=65 ................................
[CV] ................. metric=minkowski, n_neighbors=65, total=   1.1s
[CV] metric=minkowski, n_neighbors=65 ................................
[CV] ................. metric=minkowski, n_neighbors=65, total=   1.1s
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[CV] ................. metric=minkowski, n_neighbors=65, total=   1.2s
[CV] metric=minkowski, n_neighbors=27 ................................
[CV] ................. metric=minkowski, n_neighbors=65, total=   1.2s
[CV] metric=minkowski, n_neighbors=27 ................................
[CV] ................. metric=minkowski, n_neighbors=27, total=   1.1s
[CV] metric=minkowski, n_neighbors=27 ................................
[CV] ................. metric=minkowski, n_neighbors=65, total=   1.4s
[CV] metric=minkowski, n_neighbors=27 ................................
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[CV] ................. metric=minkowski, n_neighbors=27, total=   0.9s
[CV] metric=minkowski, n_neighbors=1 .................................
[CV] ................. metric=minkowski, n_neighbors=27, total=   1.0s
[CV] metric=minkowski, n_neighbors=1 .................................
[CV] .................. metric=minkowski, n_neighbors=1, total=   0.6s
[CV] metric=minkowski, n_neighbors=1 .................................
[CV] ................. metric=minkowski, n_neighbors=27, total=   1.0s
[CV] .................. metric=minkowski, n_neighbors=1, total=   0.6s
[CV] metric=minkowski, n_neighbors=1 .................................
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[CV] metric=minkowski, n_neighbors=35 ................................
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[CV] metric=minkowski, n_neighbors=35 ................................
[CV] .................. metric=minkowski, n_neighbors=1, total=   0.5s
[CV] metric=minkowski, n_neighbors=35 ................................
[CV] ................. metric=minkowski, n_neighbors=35, total=   0.8s
[CV] metric=minkowski, n_neighbors=35 ................................
[CV] ................. metric=minkowski, n_neighbors=35, total=   0.8s
[CV] metric=minkowski, n_neighbors=31 ................................
[CV] ................. metric=minkowski, n_neighbors=35, total=   1.0s
[CV] metric=minkowski, n_neighbors=31 ................................
[CV] ................. metric=minkowski, n_neighbors=35, total=   1.0s
[CV] metric=minkowski, n_neighbors=31
```

```
[CV] metric=minkowski, n_neighbors=31 .................................
[CV] ................. metric=minkowski, n_neighbors=35, total=   0.7s
[CV] metric=minkowski, n_neighbors=31 .................................
[CV] ................. metric=minkowski, n_neighbors=31, total=   0.7s
[CV] metric=minkowski, n_neighbors=31 .................................
[CV] ................. metric=minkowski, n_neighbors=31, total=   0.7s
[CV] metric=minkowski, n_neighbors=61 .................................

[Parallel(n_jobs=4)]: Done 357 tasks      | elapsed:  4.6min

[CV] ................. metric=minkowski, n_neighbors=31, total=   0.7s
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[CV] ................. metric=minkowski, n_neighbors=31, total=   1.0s
[CV] metric=minkowski, n_neighbors=61 .................................
[CV] ................. metric=minkowski, n_neighbors=31, total=   1.1s
[CV] metric=minkowski, n_neighbors=61 .................................
[CV] ................. metric=minkowski, n_neighbors=61, total=   1.4s
[CV] metric=minkowski, n_neighbors=61 .................................
[CV] ................. metric=minkowski, n_neighbors=61, total=   1.2s
[CV] metric=minkowski, n_neighbors=87 .................................
[CV] ................. metric=minkowski, n_neighbors=61, total=   0.9s
[CV] metric=minkowski, n_neighbors=87 .................................
[CV] ................. metric=minkowski, n_neighbors=61, total=   0.9s
[CV] metric=minkowski, n_neighbors=87 .................................
[CV] ................. metric=minkowski, n_neighbors=61, total=   1.1s
[CV] metric=minkowski, n_neighbors=87 .................................
[CV] ................. metric=minkowski, n_neighbors=87, total=   1.0s
[CV] metric=minkowski, n_neighbors=87 .................................
[CV] ................. metric=minkowski, n_neighbors=87, total=   1.0s
[CV] metric=minkowski, n_neighbors=25 .................................
[CV] ................. metric=minkowski, n_neighbors=87, total=   1.0s
[CV] metric=minkowski, n_neighbors=25 .................................
[CV] ................. metric=minkowski, n_neighbors=87, total=   1.1s
[CV] metric=minkowski, n_neighbors=25 .................................
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[CV] metric=minkowski, n_neighbors=25 .................................
[CV] ................. metric=minkowski, n_neighbors=25, total=   0.8s
[CV] metric=minkowski, n_neighbors=25 .................................
[CV] ................. metric=minkowski, n_neighbors=25, total=   0.7s
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[CV] metric=minkowski, n_neighbors=3 ..................................
[CV] .................. metric=minkowski, n_neighbors=3, total=   0.7s
[CV] metric=minkowski, n_neighbors=3 ..................................
[CV] ................. metric=minkowski, n_neighbors=25, total=   0.8s
[CV] metric=minkowski, n_neighbors=3 ..................................
[CV] ................. metric=minkowski, n_neighbors=25, total=   0.9s
[CV] metric=minkowski, n_neighbors=3 ..................................
[CV] .................. metric=minkowski, n_neighbors=3, total=   0.5s
[CV] metric=minkowski, n_neighbors=53 .................................
[CV] .................. metric=minkowski, n_neighbors=3, total=   0.5s
[CV] metric=minkowski, n_neighbors=53 .................................
[CV] .................. metric=minkowski, n_neighbors=3, total=   0.6s
[CV] metric=minkowski, n_neighbors=53 .................................
[CV] .................. metric=minkowski, n_neighbors=3, total=   0.5s
[CV] metric=minkowski, n_neighbors=53 .................................
[CV] ................. metric=minkowski, n_neighbors=53, total=   0.7s
[CV] metric=minkowski, n_neighbors=53 .................................
[CV] ................. metric=minkowski, n_neighbors=53, total=   0.7s
[CV] metric=minkowski, n_neighbors=79 .................................
[CV] ................. metric=minkowski, n_neighbors=53, total=   0.8s
[CV] metric=minkowski, n_neighbors=79 .................................
```

```
[CV] ................. metric=minkowski, n_neighbors=53, total=   0.8s
[CV] metric=minkowski, n_neighbors=79 ................................
[CV] ................. metric=minkowski, n_neighbors=53, total=   1.0s
[CV] metric=minkowski, n_neighbors=79 ................................
[CV] ................. metric=minkowski, n_neighbors=79, total=   1.1s
[CV] metric=minkowski, n_neighbors=79 ................................
[CV] ................. metric=minkowski, n_neighbors=79, total=   1.2s
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[CV] metric=minkowski, n_neighbors=45 ................................
[CV] ................. metric=minkowski, n_neighbors=79, total=   0.9s
[CV] metric=minkowski, n_neighbors=45 ................................
[CV] ................. metric=minkowski, n_neighbors=45, total=   0.9s
[CV] metric=minkowski, n_neighbors=45 ................................
[CV] ................. metric=minkowski, n_neighbors=79, total=   0.9s
[CV] metric=minkowski, n_neighbors=45 ................................
[CV] ................. metric=minkowski, n_neighbors=45, total=   0.9s
[CV] metric=minkowski, n_neighbors=93 ................................
[CV] ................. metric=minkowski, n_neighbors=45, total=   0.8s
[CV] metric=minkowski, n_neighbors=93 ................................
[CV] ................. metric=minkowski, n_neighbors=45, total=   0.8s
[CV] metric=minkowski, n_neighbors=93 ................................
[CV] ................. metric=minkowski, n_neighbors=45, total=   0.8s
[CV] metric=minkowski, n_neighbors=93 ................................
[CV] ................. metric=minkowski, n_neighbors=93, total=   1.0s
[CV] metric=minkowski, n_neighbors=93 ................................
[CV] ................. metric=minkowski, n_neighbors=93, total=   1.0s
[CV] ................. metric=minkowski, n_neighbors=93, total=   0.9s
[CV] ................. metric=minkowski, n_neighbors=93, total=   0.9s
[CV] ................. metric=minkowski, n_neighbors=93, total=   1.1s

[Parallel(n_jobs=4)]: Done 400 out of 400 | elapsed:  5.2min finished
```

Out[41]:

```
GridSearchCV(cv=KFold(n_splits=5, random_state=None, shuffle=False),
       error_score='raise',
       estimator=KNeighborsClassifier(algorithm='auto', leaf_size=30, metric
='minkowski',
           metric_params=None, n_jobs=1, n_neighbors=5, p=2,
           weights='uniform'),
       fit_params=None, iid=True, n_jobs=4,
       param_grid={'n_neighbors': array([37, 13, 63, 81, 21, 85, 33, 65, 27,
1, 35, 31, 61, 87, 25,  3, 53,
       79, 45, 93]), 'metric': ['euclidean', 'manhattan', 'chebyshev', 'mink
owski']},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
       scoring='roc_auc', verbose=2)
```

In [42]:

```
tree_clf3.fit(X_normed, Y)
```

```
Fitting 5 folds for each of 40 candidates, totalling 200 fits
[CV] criterion=gini, max_depth=5 .....................................
[CV] criterion=gini, max_depth=5 .....................................
[CV] criterion=gini, max_depth=5 .....................................
[CV] criterion=gini, max_depth=5 .....................................
[CV] ..................... criterion=gini, max_depth=5, total=   0.0s
[CV] ..................... criterion=gini, max_depth=5, total=   0.0s
```

```
[CV] criterion=gini, max_depth=5 .....................................
[CV] ..................... criterion=gini, max_depth=5, total=   0.0s
[CV] criterion=gini, max_depth=49 ....................................
[CV] criterion=gini, max_depth=49 ....................................
[CV] ..................... criterion=gini, max_depth=5, total=   0.0s
[CV] criterion=gini, max_depth=49 ....................................
[CV] ..................... criterion=gini, max_depth=5, total=   0.1s
[CV] criterion=gini, max_depth=49 ....................................
[CV] ..................... criterion=gini, max_depth=49, total=   0.1s
[CV] ..................... criterion=gini, max_depth=49, total=   0.1s
[CV] criterion=gini, max_depth=44 ....................................
[CV] criterion=gini, max_depth=12 ....................................
[CV] ..................... criterion=gini, max_depth=49, total=   0.1s
[CV] criterion=gini, max_depth=16 ....................................
[CV] ..................... criterion=gini, max_depth=49, total=   0.1s
[CV] criterion=gini, max_depth=49 ....................................
[CV] ..................... criterion=gini, max_depth=12, total=   0.1s
[CV] criterion=gini, max_depth=12 ....................................
[CV] ..................... criterion=gini, max_depth=44, total=   0.1s
[CV] criterion=gini, max_depth=44 ....................................
[CV] ..................... criterion=gini, max_depth=16, total=   0.1s
[CV] criterion=gini, max_depth=16 ....................................
[CV] ..................... criterion=gini, max_depth=12, total=   0.1s
[CV] criterion=gini, max_depth=12 ....................................
[CV] ..................... criterion=gini, max_depth=49, total=   0.1s
[CV] criterion=gini, max_depth=44 ....................................
[CV] ..................... criterion=gini, max_depth=44, total=   0.1s
[CV] criterion=gini, max_depth=44 ....................................
[CV] ..................... criterion=gini, max_depth=16, total=   0.1s
[CV] criterion=gini, max_depth=16 ....................................
[CV] ..................... criterion=gini, max_depth=12, total=   0.1s
[CV] criterion=gini, max_depth=12 ....................................
[CV] ..................... criterion=gini, max_depth=44, total=   0.1s
[CV] criterion=gini, max_depth=44 ....................................
[CV] ..................... criterion=gini, max_depth=12, total=   0.1s
[CV] ..................... criterion=gini, max_depth=16, total=   0.1s
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[CV] criterion=gini, max_depth=16 ....................................
[CV] ..................... criterion=gini, max_depth=44, total=   0.1s
[CV] criterion=gini, max_depth=12 ....................................
[CV] ..................... criterion=gini, max_depth=44, total=   0.1s
[CV] criterion=gini, max_depth=23 ....................................
[CV] ..................... criterion=gini, max_depth=12, total=   0.1s
[CV] ..................... criterion=gini, max_depth=16, total=   0.1s
[CV] criterion=gini, max_depth=2 .....................................
[CV] criterion=gini, max_depth=23 ....................................
[CV] ..................... criterion=gini, max_depth=16, total=   0.1s
[CV] criterion=gini, max_depth=22 ....................................
[CV] ..................... criterion=gini, max_depth=2, total=   0.0s
[CV] criterion=gini, max_depth=2 .....................................
[CV] ..................... criterion=gini, max_depth=2, total=   0.0s
[CV] ..................... criterion=gini, max_depth=23, total=   0.1s
[CV] criterion=gini, max_depth=23 ....................................
[CV] criterion=gini, max_depth=2 .....................................
[CV] ..................... criterion=gini, max_depth=23, total=   0.1s
[CV] criterion=gini, max_depth=23 ....................................
[CV] ..................... criterion=gini, max_depth=2, total=   0.0s
[CV] ..................... criterion=gini, max_depth=22, total=   0.1s
[CV] criterion=gini, max_depth=22 ....................................
[CV] criterion=gini, max_depth=22 ....................................
[CV] ..................... criterion=gini, max_depth=23, total=   0.1s
[CV] criterion=gini, max_depth=2 .....................................
[CV] ..................... criterion=gini, max_depth=2, total=   0.0s
```

```
[CV] ..... criterion=gini, max_depth=23, total=   0.1s
[CV] ..... criterion=gini, max_depth=22, total=   0.1s
[CV] criterion=gini, max_depth=23 .....................................
[CV] criterion=gini, max_depth=2 ......................................
[CV] criterion=gini, max_depth=31 .....................................
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[CV] criterion=gini, max_depth=22 .....................................
[CV] ..... criterion=gini, max_depth=2, total=   0.0s
[CV] criterion=gini, max_depth=31 .....................................
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[CV] ..... criterion=gini, max_depth=22, total=   0.1s
[CV] criterion=gini, max_depth=22 .....................................
[CV] criterion=gini, max_depth=20 .....................................
[CV] ..... criterion=gini, max_depth=31, total=   0.1s
[CV] criterion=gini, max_depth=31 .....................................
[CV] ..... criterion=gini, max_depth=31, total=   0.1s
[CV] criterion=gini, max_depth=20 .....................................
[CV] ..... criterion=gini, max_depth=20, total=   0.1s
[CV] criterion=gini, max_depth=20 .....................................
[CV] ..... criterion=gini, max_depth=22, total=   0.2s
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[CV] criterion=gini, max_depth=41 .....................................
[CV] ..... criterion=gini, max_depth=41, total=   0.1s
[CV] criterion=gini, max_depth=41 .....................................
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[CV] ..... criterion=gini, max_depth=41, total=   0.1s
[CV] criterion=gini, max_depth=41 .....................................
[CV] ..... criterion=gini, max_depth=31, total=   0.1s
[CV] criterion=gini, max_depth=39 .....................................
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[CV] criterion=gini, max_depth=33 .....................................
[CV] ..... criterion=gini, max_depth=41, total=   0.1s
[CV] criterion=gini, max_depth=33 .....................................
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[CV] criterion=gini, max_depth=26 .....................................
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[CV] ..... criterion=gini, max_depth=26, total=   0.1s
[CV] criterion=gini, max_depth=26 .....................................
[CV] ..... criterion=gini, max_depth=39, total=   0.1s
```

```
[CV] criterion=gini, max_depth=39 ....................................
[CV] ..................... criterion=gini, max_depth=33, total=   0.1s
[CV] criterion=gini, max_depth=33 ....................................
[CV] ..................... criterion=gini, max_depth=26, total=   0.1s
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[CV] ..................... criterion=gini, max_depth=26, total=   0.1s
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[CV] ..................... criterion=gini, max_depth=39, total=   0.1s
[CV] criterion=gini, max_depth=40 ....................................
[CV] ..................... criterion=gini, max_depth=33, total=   0.1s
[CV] criterion=gini, max_depth=13 ....................................
[CV] ..................... criterion=gini, max_depth=26, total=   0.1s
[CV] criterion=gini, max_depth=27 ....................................
[CV] ..................... criterion=gini, max_depth=40, total=   0.2s
[CV] criterion=gini, max_depth=40 ....................................
[CV] ..................... criterion=gini, max_depth=13, total=   0.1s
[CV] criterion=gini, max_depth=13 ....................................
[CV] ..................... criterion=gini, max_depth=40, total=   0.2s
[CV] criterion=gini, max_depth=40 ....................................
[CV] ..................... criterion=gini, max_depth=27, total=   0.1s
[CV] criterion=gini, max_depth=27 ....................................
[CV] ..................... criterion=gini, max_depth=13, total=   0.1s
[CV] criterion=gini, max_depth=13 ....................................
[CV] ..................... criterion=gini, max_depth=40, total=   0.1s
[CV] criterion=gini, max_depth=27 ....................................
[CV] ..................... criterion=gini, max_depth=40, total=   0.1s
[CV] criterion=gini, max_depth=40 ....................................
[CV] ..................... criterion=gini, max_depth=13, total=   0.1s
[CV] criterion=gini, max_depth=13 ....................................
[CV] ..................... criterion=gini, max_depth=27, total=   0.1s
[CV] criterion=gini, max_depth=27 ....................................
[CV] ..................... criterion=gini, max_depth=27, total=   0.1s
[CV] criterion=gini, max_depth=37 ....................................
[CV] ..................... criterion=gini, max_depth=40, total=   0.1s
[CV] criterion=gini, max_depth=13 ....................................
[CV] ..................... criterion=gini, max_depth=13, total=   0.1s
[CV] criterion=gini, max_depth=37 ....................................
[CV] ..................... criterion=gini, max_depth=27, total=   0.1s
[CV] criterion=gini, max_depth=27 ....................................
[CV] ..................... criterion=gini, max_depth=13, total=   0.1s
[CV] criterion=gini, max_depth=34 ....................................
[CV] ..................... criterion=gini, max_depth=37, total=   0.1s
[CV] criterion=gini, max_depth=37 ....................................
[CV] ..................... criterion=gini, max_depth=37, total=   0.1s
[CV] criterion=gini, max_depth=37 ....................................
[CV] ..................... criterion=gini, max_depth=27, total=   0.1s
[CV] criterion=gini, max_depth=47 ....................................
[CV] ..................... criterion=gini, max_depth=34, total=   0.1s
[CV] criterion=gini, max_depth=34 ....................................
[CV] ..................... criterion=gini, max_depth=37, total=   0.1s
[CV] criterion=gini, max_depth=37 ....................................
[CV] ..................... criterion=gini, max_depth=37, total=   0.1s
[CV] criterion=gini, max_depth=34 ....................................
[CV] ..................... criterion=gini, max_depth=47, total=   0.1s
[CV] criterion=gini, max_depth=47 ....................................
[CV] ..................... criterion=gini, max_depth=34, total=   0.1s
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[CV] ..................... criterion=gini, max_depth=37, total=   0.1s
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[CV] ..................... criterion=entropy, max_depth=5, total=   0.1s
[CV] ..................... criterion=gini, max_depth=34, total=   0.1s
[CV] criterion=entropy, max_depth=5 ..................................
[CV] criterion=gini, max_depth=34
```

```
[CV] criterion=gini, max_depth=34 .....................................
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[CV] ..................... criterion=gini, max_depth=34, total=   0.1s
[CV] criterion=gini, max_depth=47 .....................................
[CV] criterion=gini, max_depth=47 .....................................
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[CV] ................... criterion=entropy, max_depth=5, total=   0.0s
[CV] ..................... criterion=gini, max_depth=34, total=   0.1s
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[CV] criterion=entropy, max_depth=5 ...................................
[CV] ..................... criterion=gini, max_depth=47, total=   0.1s
[CV] ..................... criterion=gini, max_depth=47, total=   0.1s
[CV] criterion=gini, max_depth=47 .....................................
[CV] criterion=entropy, max_depth=49 ..................................
[CV] ................... criterion=entropy, max_depth=5, total=   0.0s
[CV] ................... criterion=entropy, max_depth=5, total=   0.1s
[CV] criterion=entropy, max_depth=44 ..................................
[CV] criterion=entropy, max_depth=49 ..................................
[CV] ..................... criterion=gini, max_depth=47, total=   0.1s
[CV] criterion=entropy, max_depth=12 ..................................
[CV] ................... criterion=entropy, max_depth=49, total=   0.1s
[CV] criterion=entropy, max_depth=49 ..................................
[CV] ................... criterion=entropy, max_depth=49, total=   0.1s
[CV] criterion=entropy, max_depth=49 ..................................
[CV] ................... criterion=entropy, max_depth=44, total=   0.1s
[CV] criterion=entropy, max_depth=44 ..................................
[CV] ................... criterion=entropy, max_depth=12, total=   0.1s
[CV] criterion=entropy, max_depth=12 ..................................
[CV] ................... criterion=entropy, max_depth=49, total=   0.1s
[CV] criterion=entropy, max_depth=44 ..................................
[CV] ................... criterion=entropy, max_depth=12, total=   0.1s
[CV] ................... criterion=entropy, max_depth=49, total=   0.1s
[CV] criterion=entropy, max_depth=49 ..................................
[CV] criterion=entropy, max_depth=12 ..................................
[CV] ................... criterion=entropy, max_depth=44, total=   0.2s
[CV] criterion=entropy, max_depth=44 ..................................
[CV] ................... criterion=entropy, max_depth=12, total=   0.1s
[CV] criterion=entropy, max_depth=12 ..................................
[CV] ................... criterion=entropy, max_depth=44, total=   0.2s
[CV] criterion=entropy, max_depth=44 ..................................
[CV] ................... criterion=entropy, max_depth=49, total=   0.2s
[CV] criterion=entropy, max_depth=16 ..................................
[CV] ................... criterion=entropy, max_depth=44, total=   0.2s
[CV] criterion=entropy, max_depth=12 ..................................
[CV] ................... criterion=entropy, max_depth=12, total=   0.1s
[CV] criterion=entropy, max_depth=16 ..................................
[CV] ................... criterion=entropy, max_depth=12, total=   0.1s
[CV] criterion=entropy, max_depth=23 ..................................
[CV] ................... criterion=entropy, max_depth=44, total=   0.2s
[CV] ................... criterion=entropy, max_depth=16, total=   0.1s
[CV] criterion=entropy, max_depth=2 ...................................
[CV] criterion=entropy, max_depth=16 ..................................

[Parallel(n_jobs=4)]: Done 108 tasks      | elapsed:    4.1s

[CV] ................... criterion=entropy, max_depth=2, total=   0.0s
[CV] criterion=entropy, max_depth=2 ...................................
[CV] ................... criterion=entropy, max_depth=16, total=   0.2s
[CV] criterion=entropy, max_depth=23 ..................................
[CV] ................... criterion=entropy, max_depth=2, total=   0.0s
[CV] criterion=entropy, max_depth=2 ...................................
```

```
[CV] ..... criterion=entropy, max_depth=2, total=   0.0s
[CV] ..... criterion=entropy, max_depth=23, total=   0.2s
[CV] criterion=entropy, max_depth=22 .....
[CV] criterion=entropy, max_depth=23 .....
[CV] ..... criterion=entropy, max_depth=16, total=   0.1s
[CV] criterion=entropy, max_depth=16 .....
[CV] ..... criterion=entropy, max_depth=23, total=   0.1s
[CV] criterion=entropy, max_depth=23 .....
[CV] ..... criterion=entropy, max_depth=16, total=   0.1s
[CV] criterion=entropy, max_depth=16 .....
[CV] ..... criterion=entropy, max_depth=23, total=   0.1s
[CV] ..... criterion=entropy, max_depth=22, total=   0.1s
[CV] criterion=entropy, max_depth=2 .....
[CV] criterion=entropy, max_depth=22 .....
[CV] ..... criterion=entropy, max_depth=2, total=   0.0s
[CV] criterion=entropy, max_depth=2 .....
[CV] ..... criterion=entropy, max_depth=2, total=   0.0s
[CV] ..... criterion=entropy, max_depth=23, total=   0.2s
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[CV] criterion=entropy, max_depth=31 .....
[CV] ..... criterion=entropy, max_depth=16, total=   0.1s
[CV] criterion=entropy, max_depth=31 .....
[CV] ..... criterion=entropy, max_depth=22, total=   0.1s
[CV] criterion=entropy, max_depth=22 .....
[CV] ..... criterion=entropy, max_depth=23, total=   0.1s
[CV] criterion=entropy, max_depth=20 .....
[CV] ..... criterion=entropy, max_depth=31, total=   0.2s
[CV] ..... criterion=entropy, max_depth=31, total=   0.1s
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[CV] criterion=entropy, max_depth=31 .....
[CV] ..... criterion=entropy, max_depth=22, total=   0.1s
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[CV] ..... criterion=entropy, max_depth=31, total=   0.2s
[CV] ..... criterion=entropy, max_depth=20, total=   0.2s
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[CV] criterion=entropy, max_depth=31 .....
[CV] ..... criterion=entropy, max_depth=22, total=   0.1s
[CV] criterion=entropy, max_depth=22 .....
[CV] ..... criterion=entropy, max_depth=20, total=   0.1s
[CV] criterion=entropy, max_depth=41 .....
[CV] ..... criterion=entropy, max_depth=20, total=   0.1s
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[CV] ..... criterion=entropy, max_depth=22, total=   0.1s
[CV] ..... criterion=entropy, max_depth=31, total=   0.1s
[CV] criterion=entropy, max_depth=31 .....
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[CV] ..... criterion=entropy, max_depth=41, total=   0.1s
[CV] ..... criterion=entropy, max_depth=20, total=   0.1s
[CV] criterion=entropy, max_depth=39 .....
[CV] criterion=entropy, max_depth=41 .....
[CV] ..... criterion=entropy, max_depth=31, total=   0.1s
[CV] criterion=entropy, max_depth=33 .....
[CV] ..... criterion=entropy, max_depth=41, total=   0.1s
[CV] criterion=entropy, max_depth=41 .....
[CV] ..... criterion=entropy, max_depth=41, total=   0.1s
[CV] ..... criterion=entropy, max_depth=39, total=   0.1s
[CV] criterion=entropy, max_depth=39 .....
[CV] ..... criterion=entropy, max_depth=33, total=   0.1s
[CV] criterion=entropy, max_depth=33 .....
[CV] ..... criterion=entropy, max_depth=41, total=   0.1s
```

```
[CV] criterion=entropy, max_depth=41 ..................................
[CV] criterion=entropy, max_depth=33 ..................................
[CV] .................. criterion=entropy, max_depth=39, total=   0.1s
[CV] criterion=entropy, max_depth=39 ..................................
[CV] .................. criterion=entropy, max_depth=33, total=   0.1s
[CV] criterion=entropy, max_depth=33 ..................................
[CV] .................. criterion=entropy, max_depth=33, total=   0.1s
[CV] criterion=entropy, max_depth=26 ..................................
[CV] .................. criterion=entropy, max_depth=41, total=   0.1s
[CV] criterion=entropy, max_depth=39 ..................................
[CV] .................. criterion=entropy, max_depth=39, total=   0.1s
[CV] criterion=entropy, max_depth=39 ..................................
[CV] .................. criterion=entropy, max_depth=26, total=   0.1s
[CV] criterion=entropy, max_depth=26 ..................................
[CV] .................. criterion=entropy, max_depth=33, total=   0.1s
[CV] criterion=entropy, max_depth=33 ..................................
[CV] .................. criterion=entropy, max_depth=39, total=   0.1s
[CV] criterion=entropy, max_depth=26 ..................................
[CV] .................. criterion=entropy, max_depth=39, total=   0.2s
[CV] .................. criterion=entropy, max_depth=26, total=   0.1s
[CV] criterion=entropy, max_depth=26 ..................................
[CV] criterion=entropy, max_depth=40 ..................................
[CV] .................. criterion=entropy, max_depth=33, total=   0.1s
[CV] criterion=entropy, max_depth=13 ..................................
[CV] .................. criterion=entropy, max_depth=26, total=   0.1s
[CV] criterion=entropy, max_depth=26 ..................................
[CV] .................. criterion=entropy, max_depth=13, total=   0.1s
[CV] criterion=entropy, max_depth=13 ..................................
[CV] .................. criterion=entropy, max_depth=26, total=   0.1s
[CV] criterion=entropy, max_depth=27 ..................................
[CV] .................. criterion=entropy, max_depth=40, total=   0.1s
[CV] criterion=entropy, max_depth=40 ..................................
[CV] .................. criterion=entropy, max_depth=26, total=   0.1s
[CV] criterion=entropy, max_depth=40 ..................................
[CV] .................. criterion=entropy, max_depth=13, total=   0.1s
[CV] criterion=entropy, max_depth=13 ..................................
[CV] .................. criterion=entropy, max_depth=27, total=   0.2s
[CV] criterion=entropy, max_depth=27 ..................................
[CV] .................. criterion=entropy, max_depth=40, total=   0.2s
[CV] criterion=entropy, max_depth=40 ..................................
[CV] .................. criterion=entropy, max_depth=13, total=   0.1s
[CV] criterion=entropy, max_depth=13 ..................................
[CV] .................. criterion=entropy, max_depth=40, total=   0.2s
[CV] criterion=entropy, max_depth=40 ..................................
[CV] .................. criterion=entropy, max_depth=27, total=   0.2s
[CV] criterion=entropy, max_depth=27 ..................................
[CV] .................. criterion=entropy, max_depth=40, total=   0.2s
[CV] criterion=entropy, max_depth=13 ..................................
[CV] .................. criterion=entropy, max_depth=13, total=   0.1s
[CV] criterion=entropy, max_depth=27 ..................................
[CV] .................. criterion=entropy, max_depth=40, total=   0.2s
[CV] criterion=entropy, max_depth=37 ..................................
[CV] .................. criterion=entropy, max_depth=27, total=   0.1s
[CV] criterion=entropy, max_depth=27 ..................................
[CV] .................. criterion=entropy, max_depth=13, total=   0.1s
[CV] criterion=entropy, max_depth=34 ..................................
[CV] .................. criterion=entropy, max_depth=27, total=   0.1s
[CV] criterion=entropy, max_depth=37 ..................................
[CV] .................. criterion=entropy, max_depth=37, total=   0.2s
[CV] criterion=entropy, max_depth=37 ..................................
[CV] .................. criterion=entropy, max_depth=27, total=   0.2s
[CV] criterion=entropy, max_depth=47 ..................................
```

```
[CV] ................. criterion=entropy, max_depth=34, total=   0.2s
[CV] criterion=entropy, max_depth=34 ..................................
[CV] ................. criterion=entropy, max_depth=37, total=   0.2s
[CV] criterion=entropy, max_depth=37 ..................................
[CV] ................. criterion=entropy, max_depth=37, total=   0.2s
[CV] criterion=entropy, max_depth=34 ..................................
[CV] ................. criterion=entropy, max_depth=34, total=   0.1s
[CV] criterion=entropy, max_depth=34 ..................................
[CV] ................. criterion=entropy, max_depth=47, total=   0.2s
[CV] criterion=entropy, max_depth=47 ..................................
[CV] ................. criterion=entropy, max_depth=37, total=   0.1s
[CV] criterion=entropy, max_depth=37 ..................................
[CV] ................. criterion=entropy, max_depth=34, total=   0.1s
[CV] criterion=entropy, max_depth=34 ..................................
[CV] ................. criterion=entropy, max_depth=47, total=   0.1s
[CV] ................. criterion=entropy, max_depth=34, total=   0.1s
[CV] criterion=entropy, max_depth=47 ..................................
[CV] criterion=entropy, max_depth=47 ..................................
[CV] ................. criterion=entropy, max_depth=37, total=   0.1s
[CV] ................. criterion=entropy, max_depth=34, total=   0.1s
[CV] ................. criterion=entropy, max_depth=47, total=   0.2s
[CV] ................. criterion=entropy, max_depth=47, total=   0.2s
[CV] criterion=entropy, max_depth=47 ..................................
[CV] ................. criterion=entropy, max_depth=47, total=   0.1s

[Parallel(n_jobs=4)]: Done 200 out of 200 | elapsed:    7.5s finished
```

Out[42]:

```
GridSearchCV(cv=KFold(n_splits=5, random_state=None, shuffle=False),
       error_score='raise',
       estimator=DecisionTreeClassifier(class_weight=None, criterion='gini',
max_depth=None,
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=None,
            splitter='best'),
       fit_params=None, iid=True, n_jobs=4,
       param_grid={'max_depth': array([ 5, 49, 44, 12, 16, 23,  2, 22, 31, 2
0, 41, 39, 33, 26, 40, 13, 27,
       37, 34, 47]), 'criterion': ['gini', 'entropy']},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
       scoring='roc_auc', verbose=2)
```

In [43]:

```
SGD_clf3.fit(X_normed, Y)
```

```
Fitting 5 folds for each of 36 candidates, totalling 180 fits
[CV] loss=hinge, penalty=none .....................................
[CV] loss=hinge, penalty=none .....................................
[CV] loss=hinge, penalty=none .....................................
[CV] loss=hinge, penalty=none .....................................
[CV] ......................... loss=hinge, penalty=none, total=   0.0s
[CV] ......................... loss=hinge, penalty=none, total=   0.0s
[CV] loss=hinge, penalty=none .....................................
[CV] ......................... loss=hinge, penalty=none, total=   0.0s
[CV] ......................... loss=hinge, penalty=none, total=   0.1s
[CV] loss=hinge, penalty=l2 .......................................
[CV] loss=hinge, penalty=l2 .......................................
```

```
[CV] loss=hinge, penalty=l2 ..........................................
[CV] ........................ loss=hinge, penalty=none, total=   0.0s
[CV] loss=hinge, penalty=l2 ..........................................
[CV] ........................... loss=hinge, penalty=l2, total=   0.0s
[CV] loss=hinge, penalty=l1 ..........................................
[CV] ........................... loss=hinge, penalty=l2, total=   0.0s
[CV] loss=hinge, penalty=l2 ..........................................
[CV] ........................... loss=hinge, penalty=l2, total=   0.1s
[CV] loss=hinge, penalty=elasticnet ..................................
[CV] ........................... loss=hinge, penalty=l2, total=   0.1s
[CV] ........................... loss=hinge, penalty=l2, total=   0.0s
[CV] loss=log, penalty=none ..........................................
[CV] loss=hinge, penalty=l1 ..........................................
[CV] ........................... loss=hinge, penalty=l1, total=   0.0s
[CV] loss=hinge, penalty=l1 ..........................................
[CV] ..................... loss=hinge, penalty=elasticnet, total=   0.1s
[CV] ........................... loss=hinge, penalty=l1, total=   0.0s
[CV] loss=hinge, penalty=elasticnet ..................................
[CV] loss=hinge, penalty=l1 ..........................................
[CV] ........................... loss=log, penalty=none, total=   0.0s
[CV] loss=log, penalty=none ..........................................
[CV] ........................... loss=hinge, penalty=l1, total=   0.0s
[CV] loss=hinge, penalty=l1 ..........................................
[CV] ........................... loss=hinge, penalty=l1, total=   0.1s
[CV] ..................... loss=hinge, penalty=elasticnet, total=   0.0s
[CV] ........................... loss=log, penalty=none, total=   0.0s
[CV] loss=log, penalty=none ..........................................
[CV] loss=log, penalty=none ..........................................
[CV] loss=hinge, penalty=elasticnet ..................................
[CV] ........................... loss=log, penalty=none, total=   0.0s
[CV] loss=log, penalty=l2 ............................................
[CV] ........................... loss=log, penalty=none, total=   0.0s
[CV] ........................... loss=hinge, penalty=l1, total=   0.1s
[CV] loss=hinge, penalty=elasticnet ..................................
[CV] loss=log, penalty=none ..........................................
[CV] ..................... loss=hinge, penalty=elasticnet, total=   0.1s
[CV] loss=hinge, penalty=elasticnet ..................................
[CV] ..................... loss=hinge, penalty=elasticnet, total=   0.0s
[CV] loss=log, penalty=l2 ............................................
[CV] ..................... loss=hinge, penalty=elasticnet, total=   0.0s
[CV] loss=log, penalty=l1 ............................................
[CV] ........................... loss=log, penalty=none, total=   0.1s
[CV] loss=log, penalty=elasticnet ....................................
[CV] ............................. loss=log, penalty=l2, total=   0.2s
[CV] loss=log, penalty=l2 ............................................
[CV] ............................. loss=log, penalty=l1, total=   0.0s
[CV] loss=log, penalty=l1 ............................................
[CV] ............................. loss=log, penalty=l2, total=   0.0s
[CV] ............................. loss=log, penalty=l2, total=   0.1s
[CV] loss=log, penalty=l2 ............................................
[CV] loss=log, penalty=l2 ............................................
[CV] ..................... loss=log, penalty=elasticnet, total=   0.1s
[CV] loss=log, penalty=elasticnet ....................................
[CV] ............................. loss=log, penalty=l1, total=   0.1s
[CV] ..................... loss=log, penalty=elasticnet, total=   0.0s
[CV] loss=log, penalty=elasticnet ....................................
[CV] loss=log, penalty=l1 ............................................
[CV] ............................. loss=log, penalty=l2, total=   0.1s
[CV] ............................. loss=log, penalty=l2, total=   0.1s
[CV] loss=log, penalty=l1 ............................................
[CV] loss=modified_huber, penalty=none ...............................
[CV] ................ loss=modified_huber, penalty=none, total=   0.0s
[CV] loss=modified_huber, penalty=none
```

```
[CV] loss=modified_huber, penalty=none ...............................
[CV] ............................ loss=log, penalty=l1, total=   0.0s
[CV] loss=log, penalty=l1 ............................................
[CV] ............................ loss=log, penalty=l1, total=   0.1s
[CV] loss=log, penalty=elasticnet ....................................
[CV] ..................... loss=log, penalty=elasticnet, total=   0.2s
[CV] loss=log, penalty=elasticnet ....................................
[CV] ................ loss=modified_huber, penalty=none, total=   0.1s
[CV] loss=modified_huber, penalty=none ...............................
[CV] ............................ loss=log, penalty=l1, total=   0.1s
[CV] ..................... loss=log, penalty=elasticnet, total=   0.1s
[CV] loss=modified_huber, penalty=none ...............................
[CV] loss=modified_huber, penalty=l2 .................................
[CV] ................ loss=modified_huber, penalty=none, total=   0.0s
[CV] loss=modified_huber, penalty=none ...............................
[CV] ..................... loss=log, penalty=elasticnet, total=   0.1s
[CV] loss=modified_huber, penalty=l1 .................................
[CV] ................ loss=modified_huber, penalty=none, total=   0.0s
[CV] loss=modified_huber, penalty=l2 .................................
[CV] .................. loss=modified_huber, penalty=l1, total=   0.0s
[CV] loss=modified_huber, penalty=l1 .................................
[CV] ................ loss=modified_huber, penalty=none, total=   0.1s
[CV] .................. loss=modified_huber, penalty=l2, total=   0.1s
[CV] loss=modified_huber, penalty=l2 .................................
[CV] loss=modified_huber, penalty=elasticnet .........................
[CV] .................. loss=modified_huber, penalty=l2, total=   0.0s
[CV] loss=modified_huber, penalty=l2 .................................
[CV] .................. loss=modified_huber, penalty=l2, total=   0.0s
[CV] loss=modified_huber, penalty=l1 .................................
[CV] .................. loss=modified_huber, penalty=l2, total=   0.0s
[CV] loss=modified_huber, penalty=l2 .................................
[CV] .................. loss=modified_huber, penalty=l1, total=   0.1s
[CV] loss=modified_huber, penalty=l1 .................................
[CV] .......... loss=modified_huber, penalty=elasticnet, total=   0.1s
[CV] loss=modified_huber, penalty=elasticnet .........................
[CV] .................. loss=modified_huber, penalty=l1, total=   0.0s
[CV] loss=modified_huber, penalty=l1 .................................
[CV] .................. loss=modified_huber, penalty=l2, total=   0.0s
[CV] .................. loss=modified_huber, penalty=l1, total=   0.0s
[CV] loss=squared_hinge, penalty=none ................................
[CV] loss=modified_huber, penalty=elasticnet .........................
[CV] .......... loss=modified_huber, penalty=elasticnet, total=   0.0s
[CV] loss=modified_huber, penalty=elasticnet .........................
[CV] .................. loss=modified_huber, penalty=l1, total=   0.0s
[CV] .......... loss=modified_huber, penalty=elasticnet, total=   0.0s
[CV] loss=squared_hinge, penalty=none ................................
[CV] loss=squared_hinge, penalty=l2 ..................................
[CV] ................ loss=squared_hinge, penalty=none, total=   0.0s
[CV] loss=squared_hinge, penalty=none ................................
[CV] .......... loss=modified_huber, penalty=elasticnet, total=   0.0s
[CV] loss=modified_huber, penalty=elasticnet .........................
[CV] ................ loss=squared_hinge, penalty=none, total=   0.0s
[CV] loss=squared_hinge, penalty=l2 ..................................
[CV] ................ loss=squared_hinge, penalty=none, total=   0.0s
[CV] loss=squared_hinge, penalty=none ................................
[CV] .................. loss=squared_hinge, penalty=l2, total=   0.1s
[CV] loss=squared_hinge, penalty=l2 ..................................
[CV] .......... loss=modified_huber, penalty=elasticnet, total=   0.0s
[CV] loss=squared_hinge, penalty=l1 ..................................
[CV] ................ loss=squared_hinge, penalty=none, total=   0.0s
[CV] .................. loss=squared_hinge, penalty=l2, total=   0.0s
[CV] loss=squared_hinge, penalty=none ................................
[CV] loss=squared_hinge, penalty=l2 ..................................
```

```
[CV] loss=squared_hinge, penalty=l2 .....................................
[CV] ..... loss=squared_hinge, penalty=l1, total=   0.0s
[CV] loss=squared_hinge, penalty=l1 .....................................
[CV] ..... loss=squared_hinge, penalty=l2, total=   0.1s
[CV] loss=squared_hinge, penalty=l1 .....................................
[CV] ..... loss=squared_hinge, penalty=l2, total=   0.0s
[CV] loss=squared_hinge, penalty=l2 .....................................
[CV] ..... loss=squared_hinge, penalty=l1, total=   0.0s
[CV] loss=squared_hinge, penalty=l1 .....................................
[CV] ..... loss=squared_hinge, penalty=none, total=   0.1s
[CV] ..... loss=squared_hinge, penalty=l1, total=   0.0s
[CV] loss=squared_hinge, penalty=elasticnet .............................
[CV] loss=squared_hinge, penalty=l1 .....................................
[CV] ..... loss=squared_hinge, penalty=l2, total=   0.0s
[CV] loss=perceptron, penalty=none ......................................
[CV] ..... loss=squared_hinge, penalty=l1, total=   0.1s
[CV] loss=squared_hinge, penalty=elasticnet .............................
[CV] ..... loss=squared_hinge, penalty=l1, total=   0.0s
[CV] ..... loss=squared_hinge, penalty=elasticnet, total=   0.0s
[CV] loss=squared_hinge, penalty=elasticnet .............................
[CV] loss=perceptron, penalty=none ......................................
[CV] ..... loss=perceptron, penalty=none, total=   0.0s
[CV] ..... loss=perceptron, penalty=none, total=   0.0s
[CV] loss=perceptron, penalty=none ......................................
[CV] loss=perceptron, penalty=l2 ........................................
[CV] ..... loss=squared_hinge, penalty=elasticnet, total=   0.0s
[CV] loss=squared_hinge, penalty=elasticnet .............................
[CV] ..... loss=squared_hinge, penalty=elasticnet, total=   0.1s
[CV] ..... loss=perceptron, penalty=none, total=   0.0s
[CV] loss=perceptron, penalty=none ......................................
[CV] loss=perceptron, penalty=l2 ........................................
[CV] ..... loss=perceptron, penalty=l2, total=   0.0s
[CV] loss=perceptron, penalty=l2 ........................................
[CV] ..... loss=perceptron, penalty=l2, total=   0.0s
[CV] loss=perceptron, penalty=l2 ........................................
[CV] ..... loss=perceptron, penalty=l2, total=   0.0s
[CV] loss=perceptron, penalty=l2 ........................................
[CV] ..... loss=squared_hinge, penalty=elasticnet, total=   0.1s
[CV] ..... loss=perceptron, penalty=none, total=   0.0s
[CV] loss=squared_hinge, penalty=elasticnet .............................
[CV] loss=perceptron, penalty=none ......................................
[CV] ..... loss=perceptron, penalty=l2, total=   0.0s
[CV] ..... loss=perceptron, penalty=l2, total=   0.0s
[CV] loss=perceptron, penalty=l1 ........................................
[CV] ..... loss=perceptron, penalty=none, total=   0.0s
[CV] ..... loss=squared_hinge, penalty=elasticnet, total=   0.0s
[CV] loss=perceptron, penalty=l1 ........................................
[CV] loss=perceptron, penalty=elasticnet ................................
[CV] loss=squared_loss, penalty=none ....................................
[CV] ..... loss=perceptron, penalty=l1, total=   0.0s
[CV] loss=perceptron, penalty=l1 ........................................
[CV] ..... loss=perceptron, penalty=l1, total=   0.1s
[CV] ..... loss=squared_loss, penalty=none, total=   0.0s
[CV] loss=perceptron, penalty=l1 ........................................
[CV] loss=squared_loss, penalty=none ....................................
[CV] ..... loss=perceptron, penalty=elasticnet, total=   0.0s
[CV] ..... loss=perceptron, penalty=l1, total=   0.0s
[CV] loss=perceptron, penalty=elasticnet ................................
[CV] loss=perceptron, penalty=l1 ........................................
[CV] ..... loss=perceptron, penalty=l1, total=   0.0s
[CV] ..... loss=squared_loss, penalty=none, total=   0.0s
[CV] loss=squared_loss, penalty=none ....................................
[CV] loss=squared_loss, penalty=none ....................................
```

```
[CV] ..... loss=perceptron, penalty=elasticnet, total=   0.0s
[CV] loss=perceptron, penalty=elasticnet .............................
[CV] ..... loss=perceptron, penalty=l1, total=   0.0s
[CV] loss=perceptron, penalty=elasticnet .............................
[CV] ..... loss=perceptron, penalty=elasticnet, total=   0.0s
[CV] ..... loss=squared_loss, penalty=none, total=   0.0s
[CV] loss=squared_loss, penalty=none .................................
[CV] loss=perceptron, penalty=elasticnet .............................
[CV] ..... loss=squared_loss, penalty=none, total=   0.0s
[CV] loss=squared_loss, penalty=l2 ...................................
[CV] ..... loss=perceptron, penalty=elasticnet, total=   0.1s
[CV] loss=squared_loss, penalty=l2 ...................................
[CV] ..... loss=squared_loss, penalty=l2, total=   0.0s
[CV] ..... loss=squared_loss, penalty=none, total=   0.0s
[CV] loss=squared_loss, penalty=l2 ...................................
[CV] loss=squared_loss, penalty=l1 ...................................
[CV] ..... loss=perceptron, penalty=elasticnet, total=   0.0s
[CV] loss=squared_loss, penalty=elasticnet ...........................
[CV] ..... loss=squared_loss, penalty=l1, total=   0.0s
[CV] ..... loss=squared_loss, penalty=l2, total=   0.1s
[CV] ..... loss=squared_loss, penalty=l2, total=   0.0s
[CV] loss=squared_loss, penalty=l1 ...................................
[CV] loss=squared_loss, penalty=l2 ...................................
[CV] loss=squared_loss, penalty=l2 ...................................
[CV] ..... loss=squared_loss, penalty=l1, total=   0.0s
[CV] loss=squared_loss, penalty=l1 ...................................
[CV] ..... loss=squared_loss, penalty=l2, total=   0.0s
[CV] loss=huber, penalty=none ........................................
[CV] ..... loss=squared_loss, penalty=elasticnet, total=   0.1s
[CV] loss=squared_loss, penalty=elasticnet ...........................
[CV] ..... loss=squared_loss, penalty=l2, total=   0.0s
[CV] loss=squared_loss, penalty=l1 ...................................
[CV] ..... loss=huber, penalty=none, total=   0.0s
[CV] loss=huber, penalty=none ........................................
[CV] ..... loss=squared_loss, penalty=l1, total=   0.1s
[CV] loss=squared_loss, penalty=elasticnet ...........................
[CV] ..... loss=squared_loss, penalty=elasticnet, total=   0.0s
[CV] loss=squared_loss, penalty=elasticnet ...........................
[CV] ..... loss=squared_loss, penalty=l1, total=   0.1s
[CV] loss=squared_loss, penalty=l1 ...................................
[CV] ..... loss=huber, penalty=none, total=   0.0s
[CV] loss=huber, penalty=none ........................................
[CV] ..... loss=squared_loss, penalty=elasticnet, total=   0.0s
[CV] loss=huber, penalty=none ........................................
[CV] ..... loss=squared_loss, penalty=l1, total=   0.0s
[CV] ..... loss=squared_loss, penalty=elasticnet, total=   0.1s
[CV] loss=squared_loss, penalty=elasticnet ...........................
[CV] loss=huber, penalty=l2 ..........................................
[CV] ..... loss=huber, penalty=none, total=   0.1s
[CV] ..... loss=huber, penalty=none, total=   0.0s
[CV] loss=huber, penalty=l2 ..........................................
[CV] loss=huber, penalty=none ........................................
[CV] ..... loss=squared_loss, penalty=elasticnet, total=   0.0s
[CV] ..... loss=huber, penalty=l2, total=   0.0s
[CV] loss=huber, penalty=l2 ..........................................

[Parallel(n_jobs=4)]: Done 108 tasks      | elapsed:    2.3s

[CV] loss=huber, penalty=l1 ..........................................
[CV] ..... loss=huber, penalty=l2, total=   0.0s
[CV] ..... loss=huber, penalty=none, total=   0.0s
```

```
[CV] loss=huber, penalty=elasticnet ..................................
[CV] ............................ loss=huber, penalty=l1, total=   0.0s
[CV] loss=huber, penalty=l1 ..........................................
[CV] loss=huber, penalty=l2 ..........................................
[CV] ............................ loss=huber, penalty=l2, total=   0.1s
[CV] ................... loss=huber, penalty=elasticnet, total=   0.0s
[CV] loss=huber, penalty=l1 ..........................................
[CV] ............................ loss=huber, penalty=l2, total=   0.0s
[CV] loss=huber, penalty=l2 ..........................................
[CV] ............................ loss=huber, penalty=l1, total=   0.0s
[CV] loss=huber, penalty=elasticnet ..................................
[CV] loss=huber, penalty=l1 ..........................................
[CV] ............................ loss=huber, penalty=l1, total=   0.0s
[CV] ............................ loss=huber, penalty=l1, total=   0.0s
[CV] loss=huber, penalty=elasticnet ..................................
[CV] loss=huber, penalty=l1 ..........................................
[CV] ............................ loss=huber, penalty=l2, total=   0.0s
[CV] ................... loss=huber, penalty=elasticnet, total=   0.1s
[CV] loss=huber, penalty=elasticnet ..................................
[CV] loss=epsilon_insensitive, penalty=none ..........................
[CV] ............................ loss=huber, penalty=l1, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=none ..........................
[CV] ........... loss=epsilon_insensitive, penalty=none, total=   0.1s
[CV] loss=epsilon_insensitive, penalty=none ..........................
[CV] ................... loss=huber, penalty=elasticnet, total=   0.1s
[CV] ................... loss=huber, penalty=elasticnet, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=l2 ............................
[CV] loss=huber, penalty=elasticnet ..................................
[CV] ........... loss=epsilon_insensitive, penalty=none, total=   0.1s
[CV] loss=epsilon_insensitive, penalty=l2 ............................
[CV] ............. loss=epsilon_insensitive, penalty=l2, total=   0.1s
[CV] ........... loss=epsilon_insensitive, penalty=none, total=   0.1s
[CV] loss=epsilon_insensitive, penalty=l2 ............................
[CV] loss=epsilon_insensitive, penalty=none ..........................
[CV] ................... loss=huber, penalty=elasticnet, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=l1 ............................
[CV] ............. loss=epsilon_insensitive, penalty=l2, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=l2 ............................
[CV] ........... loss=epsilon_insensitive, penalty=none, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=none ..........................
[CV] ........... loss=epsilon_insensitive, penalty=none, total=   0.0s
[CV] ............. loss=epsilon_insensitive, penalty=l2, total=   0.1s
[CV] ............. loss=epsilon_insensitive, penalty=l1, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=l1 ............................
[CV] loss=epsilon_insensitive, penalty=l1 ............................
[CV] ............. loss=epsilon_insensitive, penalty=l2, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=l2 ............................
[CV] loss=epsilon_insensitive, penalty=elasticnet ....................
[CV] ............. loss=epsilon_insensitive, penalty=l2, total=   0.0s
[CV] ..... loss=epsilon_insensitive, penalty=elasticnet, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=elasticnet ....................
[CV] ............. loss=epsilon_insensitive, penalty=l1, total=   0.1s
[CV] loss=epsilon_insensitive, penalty=l1 ............................
[CV] loss=squared_epsilon_insensitive, penalty=none ..................
[CV] ............. loss=epsilon_insensitive, penalty=l1, total=   0.1s
[CV] loss=epsilon_insensitive, penalty=l1 ............................
[CV] ... loss=squared_epsilon_insensitive, penalty=none, total=   0.0s
[CV] ..... loss=epsilon_insensitive, penalty=elasticnet, total=   0.1s
[CV] loss=epsilon_insensitive, penalty=elasticnet ....................
[CV] loss=squared_epsilon_insensitive, penalty=none ..................
[CV] ............. loss=epsilon_insensitive, penalty=l1, total=   0.1s
[CV] loss=squared_epsilon_insensitive, penalty=none ..................
[CV]                loss=epsilon_insensitive, penalty=l1, total=   0.0s
```

```
[CV] ..... loss=epsilon_insensitive, penalty=l1, total=   0.0s
[CV] loss=epsilon_insensitive, penalty=elasticnet ....................
[CV] ... loss=squared_epsilon_insensitive, penalty=none, total=   0.0s
[CV] ..... loss=epsilon_insensitive, penalty=elasticnet, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=none ..................
[CV] loss=epsilon_insensitive, penalty=elasticnet ....................
[CV] ... loss=squared_epsilon_insensitive, penalty=none, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=l2 ....................
[CV] ..... loss=epsilon_insensitive, penalty=elasticnet, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=l2 ....................
[CV] ... loss=squared_epsilon_insensitive, penalty=none, total=   0.0s
[CV] ..... loss=squared_epsilon_insensitive, penalty=l2, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=none ..................
[CV] ..... loss=squared_epsilon_insensitive, penalty=l2, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=l2 ....................
[CV] loss=squared_epsilon_insensitive, penalty=l2 ....................
[CV] ..... loss=epsilon_insensitive, penalty=elasticnet, total=   0.1s
[CV] loss=squared_epsilon_insensitive, penalty=l1 ....................
[CV] ... loss=squared_epsilon_insensitive, penalty=none, total=   0.0s
[CV] ..... loss=squared_epsilon_insensitive, penalty=l2, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=elasticnet ............
[CV] loss=squared_epsilon_insensitive, penalty=l2 ....................
[CV] ..... loss=squared_epsilon_insensitive, penalty=l2, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=l1 ....................
[CV] ..... loss=squared_epsilon_insensitive, penalty=l1, total=   0.1s
[CV] ..... loss=squared_epsilon_insensitive, penalty=l2, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=l1 ....................
[CV] ..... loss=squared_epsilon_insensitive, penalty=l1, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=l1 ....................
[CV]  loss=squared_epsilon_insensitive, penalty=elasticnet, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=elasticnet ............
[CV] ..... loss=squared_epsilon_insensitive, penalty=l1, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=l1 ....................
[CV] ..... loss=squared_epsilon_insensitive, penalty=l1, total=   0.0s
[CV]  loss=squared_epsilon_insensitive, penalty=elasticnet, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=elasticnet ............
[CV] ..... loss=squared_epsilon_insensitive, penalty=l1, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=elasticnet ............
[CV]  loss=squared_epsilon_insensitive, penalty=elasticnet, total=   0.0s
[CV] loss=squared_epsilon_insensitive, penalty=elasticnet ............
[CV]  loss=squared_epsilon_insensitive, penalty=elasticnet, total=   0.0s
[CV]  loss=squared_epsilon_insensitive, penalty=elasticnet, total=   0.0s

[Parallel(n_jobs=4)]: Done 180 out of 180 | elapsed:    3.4s finished
```

Out[43]:

```
GridSearchCV(cv=KFold(n_splits=5, random_state=None, shuffle=False),
       error_score='raise',
       estimator=SGDClassifier(alpha=0.0001, average=False, class_weight=Non
e, epsilon=0.1,
       eta0=0.0, fit_intercept=True, l1_ratio=0.15,
       learning_rate='optimal', loss='hinge', max_iter=None, n_iter=None,
       n_jobs=1, penalty='l2', power_t=0.5, random_state=None,
       shuffle=True, tol=None, verbose=0, warm_start=False),
       fit_params=None, iid=True, n_jobs=4,
       param_grid={'loss': ['hinge', 'log', 'modified_huber', 'squared_hinge
', 'perceptron', 'squared_loss', 'huber', 'epsilon_insensitive', 'squared_ep
silon_insensitive'], 'penalty': ['none', 'l2', 'l1', 'elasticnet']},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
       scoring='roc_auc', verbose=2)
```

In [44]:

```
forest_clf3.fit(X_normed, Y)
```

```
Fitting 5 folds for each of 10 candidates, totalling 50 fits
[CV] criterion=gini, max_features=1 ..................................
[CV] criterion=gini, max_features=1 ..................................
[CV] criterion=gini, max_features=1 ..................................
[CV] criterion=gini, max_features=1 ..................................
[CV] ................... criterion=gini, max_features=1, total=   1.0s
[CV] criterion=gini, max_features=1 ..................................
[CV] ................... criterion=gini, max_features=1, total=   1.0s
[CV] ................... criterion=gini, max_features=1, total=   1.0s
[CV] criterion=gini, max_features=2 ..................................
[CV] ................... criterion=gini, max_features=1, total=   1.0s
[CV] criterion=gini, max_features=2 ..................................
[CV] criterion=gini, max_features=2 ..................................
[CV] ................... criterion=gini, max_features=1, total=   1.1s
[CV] criterion=gini, max_features=2 ..................................
[CV] ................... criterion=gini, max_features=2, total=   1.2s
[CV] criterion=gini, max_features=2 ..................................
[CV] ................... criterion=gini, max_features=2, total=   1.3s
[CV] criterion=gini, max_features=3 ..................................
[CV] ................... criterion=gini, max_features=2, total=   1.3s
[CV] criterion=gini, max_features=3 ..................................
[CV] ................... criterion=gini, max_features=2, total=   1.2s
[CV] criterion=gini, max_features=3 ..................................
[CV] ................... criterion=gini, max_features=2, total=   1.2s
[CV] criterion=gini, max_features=3 ..................................
[CV] ................... criterion=gini, max_features=3, total=   1.5s
[CV] ................... criterion=gini, max_features=3, total=   1.4s
[CV] criterion=gini, max_features=3 ..................................
[CV] criterion=gini, max_features=4 ..................................
[CV] ................... criterion=gini, max_features=3, total=   1.7s
[CV] criterion=gini, max_features=4 ..................................
[CV] ................... criterion=gini, max_features=3, total=   1.7s
[CV] criterion=gini, max_features=4 ..................................
[CV] ................... criterion=gini, max_features=3, total=   1.7s
[CV] criterion=gini, max_features=4 ..................................
[CV] ................... criterion=gini, max_features=4, total=   1.9s
[CV] criterion=gini, max_features=4 ..................................
[CV] ................... criterion=gini, max_features=4, total=   1.8s
[CV] criterion=gini, max_features=5 ..................................
[CV] ................... criterion=gini, max_features=4, total=   1.8s
[CV] criterion=gini, max_features=5 ..................................
[CV] ................... criterion=gini, max_features=4, total=   1.8s
[CV] criterion=gini, max_features=5 ..................................
[CV] ................... criterion=gini, max_features=4, total=   1.8s
[CV] criterion=gini, max_features=5 ..................................
[CV] ................... criterion=gini, max_features=5, total=   2.0s
[CV] criterion=gini, max_features=5 ..................................
[CV] ................... criterion=gini, max_features=5, total=   2.0s
[CV] criterion=entropy, max_features=1 ...............................
[CV] ................... criterion=gini, max_features=5, total=   2.0s
[CV] criterion=entropy, max_features=1 ...............................
[CV] ................... criterion=gini, max_features=5, total=   2.0s
[CV] criterion=entropy, max_features=1 ...............................
[CV] ................ criterion=entropy, max_features=1, total=   1.3s
[CV] criterion=entropy, max_features=1 ...............................
[CV] ................ criterion=entropy, max_features=1, total=   1.4s
[CV] criterion=entropy, max_features=1 ...............................
[CV] ................... criterion=gini, max_features=5, total=   2.3s
```

```
[CV] ..... criterion=entropy, max_features=1, total=   1.4s
[CV] criterion=entropy, max_features=2 ..............................
[CV] criterion=entropy, max_features=2 ..............................
[CV] ..... criterion=entropy, max_features=1, total=   1.7s
[CV] criterion=entropy, max_features=2 ..............................
[CV] ..... criterion=entropy, max_features=1, total=   2.0s
[CV] criterion=entropy, max_features=2 ..............................
[CV] ..... criterion=entropy, max_features=2, total=   2.6s
[CV] criterion=entropy, max_features=2 ..............................
[CV] ..... criterion=entropy, max_features=2, total=   2.7s
[CV] criterion=entropy, max_features=3 ..............................
[CV] ..... criterion=entropy, max_features=2, total=   2.2s
[CV] criterion=entropy, max_features=3 ..............................

[Parallel(n_jobs=4)]: Done  33 tasks      | elapsed:   16.2s

[CV] ..... criterion=entropy, max_features=2, total=   1.8s
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[CV] ..... criterion=entropy, max_features=5, total=   2.5s
[CV] ..... criterion=entropy, max_features=5, total=   2.2s

[Parallel(n_jobs=4)]: Done  50 out of  50 | elapsed:   26.5s finished
```

Out[44]:

```
GridSearchCV(cv=KFold(n_splits=5, random_state=None, shuffle=False),
       error_score='raise',
       estimator=RandomForestClassifier(bootstrap=True, class_weight=None, c
riterion='gini',
            max_depth=None, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, n_estimators=54, n_jobs=1,
            oob_score=False, random_state=None, verbose=0,
            warm_start=False),
```

```
        warm_start=False),
       fit_params=None, iid=True, n_jobs=4,
       param_grid={'criterion': ['gini', 'entropy'], 'max_features': [1, 2,
3, 4, 5]},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
       scoring='roc_auc', verbose=2)
```

In [45]:

```
print("New results:")
print("kNN classifier's best score:", kNN_clf3.best_score_)
print("tree classifier's best score:", tree_clf3.best_score_)
print("SGD classifier's best score:", SGD_clf3.best_score_)
print("Random Forest classifier's best score:", forest_clf3.best_score_)
print("\nComparing with old results:")
print("kNN classifier's best score:", kNN_clf_new.best_score_)
print("tree classifier's best score:", tree_clf_new.best_score_)
print("SGD classifier's best score:", SGD_clf_new.best_score_)
print("RandomForest classifier's best score:", np.array(mean_scores_arr_new)
[n_estimators - forest_n_estimators_new])
```

```
New results:
kNN classifier's best score: 0.8348833802080656
tree classifier's best score: 0.8281592193876687
SGD classifier's best score: 0.8089039876580952
Random Forest classifier's best score: 0.817443881625561

Comparing with old results:
kNN classifier's best score: 0.834390627771687
tree classifier's best score: 0.8411372234302745
SGD classifier's best score: 0.8064773357712638
RandomForest classifier's best score: 0.7112240388864339
```

In [46]:

```
print("kNN confidence interval: (", kNN_clf3.best_score_ -
      kNN_clf3.cv_results_['std_test_score'][kNN_clf3.best_index_], ",",
      kNN_clf3.best_score_ + kNN_clf3.cv_results_['std_test_score'][kNN_clf
3.best_index_], "), length = ",
     kNN_clf3.cv_results_['std_test_score'][kNN_clf3.best_index_]*2)
print("tree confidence interval: (", tree_clf3.best_score_ -
      tree_clf3.cv_results_['std_test_score'][tree_clf3.best_index_], ",",
      tree_clf3.best_score_ + tree_clf3.cv_results_['std_test_score'][tree_
clf3.best_index_], "), length = ",
     tree_clf3.cv_results_['std_test_score'][tree_clf3.best_index_]*2)
print("SGD confidence interval: (", SGD_clf3.best_score_ -
      SGD_clf3.cv_results_['std_test_score'][SGD_clf3.best_index_], ",",
      SGD_clf3.best_score_ + SGD_clf3.cv_results_['std_test_score'][SGD_clf
3.best_index_], "), length = ",
     SGD_clf3.cv_results_['std_test_score'][SGD_clf3.best_index_]*2)
print("Random forest confidence interval: (", forest_clf3.best_score_ -
      forest_clf3.cv_results_['std_test_score'][forest_clf3.best_index_], "
,",
      forest_clf3.best_score_ + forest_clf3.cv_results_['std_test_score'][f
orest_clf3.best_index_], "), length = ",
     forest_clf3.cv_results_['std_test_score'][forest_clf3.best_index_]*2)
```

```
kNN confidence interval: ( 0.8307983047732368 , 0.8389684556428945 ), length
=  0.008170150869657763
tree confidence interval: ( 0.826504685044864 , 0.8298137537304734 ), length
=  0.0033090686856094126
```

```
SGD confidence interval: ( 0.7992012192496057 , 0.8186067560665847 ), length
=  0.01940553681697905
Random forest confidence interval: ( 0.8136707480918515 , 0.8212170151592706
), length =  0.00754626706741917
```

In [47]:

```
print(kNN_clf3.best_params_)
print(tree_clf3.best_params_)
print(SGD_clf3.best_params_)
print(forest_clf3.best_params_)
```

```
{'metric': 'manhattan', 'n_neighbors': 65}
{'criterion': 'gini', 'max_depth': 5}
{'loss': 'log', 'penalty': 'elasticnet'}
{'criterion': 'entropy', 'max_features': 4}
```

Наилучшее качество показал kNNClassifier, однако, качество других алгоритмов не сильно ему уступает.

(1.5 балла) Задание 7. Постройте для разных алгоритмов графики кривых обучения, изображающие зависимость качества на тестовой и обучающей выборках от количества объектов, на которых обучаются модели. Посмотрите на поведение кривых и ответьте на вопросы:

- Может ли с ростом числа объектов убывать качество на тестовой выборке? А на обучающей? Почему?
- Для каких целей можно использовать знание качества на обучающей части выборки?
- Какой из алгоритмов лучше обучается на меньшем числе объектов?
- Может ли добавление новых объектов значительно повысить качество какого-то из алгоритмов или при существующем наборе данных для всех алгоритмов произошло насыщение?

In [48]:

```
#{'metric': 'manhattan', 'n_neighbors': 65}
#{'criterion': 'gini', 'max_depth': 5}
#{'loss': 'log', 'penalty': 'elasticnet'}
#{'criterion': 'entropy', 'max_features': 4}
kNN4 = KNeighborsClassifier(metric='manhattan', n_neighbors=65)
tree4 = DecisionTreeClassifier(criterion='gini', max_depth=5)
SGD4 = SGDClassifier(loss='log', penalty='elasticnet')
forest4 = RandomForestClassifier(n_estimators=forest_n_estimators_new, crit
erion='entropy', max_features=4)
```

In [49]:

```
%matplotlib inline
from sklearn.model_selection import train_test_split, learning_curve
import matplotlib.pyplot as plt
kNN_train_sizes, kNN_train_scores, kNN_test_scores = learning_curve(
    kNN4, X_normed, Y, cv=kf, train_sizes=np.linspace(.1, 1.0, 50), verbose
=2, scoring='roc_auc', n_jobs=4)
kNN_train_scores_mean = np.mean(kNN_train_scores, axis=1)
kNN_train_scores_std = np.std(kNN_train_scores, axis=1)
kNN_test_scores_mean = np.mean(kNN_test_scores, axis=1)
kNN_test_scores_std = np.std(kNN_test_scores, axis=1)
```

```
[learning curve] Training set sizes: [ 1227  1453  1678  1904  2129  2355  2
```

```
580  2806  3031  3257  3482  3708
  3933  4159  4384  4610  4835  5061  5286  5512  5737  5963  6188  6414
  6639  6865  7090  7316  7541  7767  7992  8218  8443  8669  8894  9120
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[Parallel(n_jobs=4)]: Done 250 out of 250 | elapsed:  2.3min finished
```

In [50]:

```
tree_train_sizes, tree_train_scores, tree_test_scores = learning_curve(
    tree4, X_normed, Y, cv=kf, train_sizes=np.linspace(.1, 1.0, 50), verbos
e=2, scoring='roc_auc', n_jobs=4)
tree_train_scores_mean = np.mean(tree_train_scores, axis=1)
tree_train_scores_std = np.std(tree_train_scores, axis=1)
tree_test_scores_mean = np.mean(tree_test_scores, axis=1)
tree_test_scores_std = np.std(tree_test_scores, axis=1)
```

```
[learning_curve] Training set sizes: [ 1227  1453  1678  1904  2129  2355  2
580  2806  3031  3257  3482  3708
  3933  4159  4384  4610  4835  5061  5286  5512  5737  5963  6188  6414
  6639  6865  7090  7316  7541  7767  7992  8218  8443  8669  8894  9120
  9345  9571  9796 10022 10247 10473 10698 10924 11149 11375 11600 11826
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[Parallel(n_jobs=4)]: Done 125 out of 250 | elapsed:    2.3s remaining:    2
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[Parallel(n_jobs=4)]: Done 250 out of 250 | elapsed:    4.1s finished
```

In [51]:

```
SGD_train_sizes, SGD_train_scores, SGD_test_scores = learning_curve(
    SGD4, X_normed, Y, cv=kf, train_sizes=np.linspace(.1, 1.0, 50), verbose
=2, scoring='roc_auc', n_jobs=4)
SGD_train_scores_mean = np.mean(SGD_train_scores, axis=1)
SGD_train_scores_std = np.std(SGD_train_scores, axis=1)
SGD_test_scores_mean = np.mean(SGD_test_scores, axis=1)
SGD_test_scores_std = np.std(SGD_test_scores, axis=1)
```

```
[learning_curve] Training set sizes: [ 1227  1453  1678  1904  2129  2355  2
580  2806  3031  3257  3482  3708
  3933  4159  4384  4610  4835  5061  5286  5512  5737  5963  6188  6414
  6639  6865  7090  7316  7541  7767  7992  8218  8443  8669  8894  9120
  9345  9571  9796 10022 10247 10473 10698 10924 11149 11375 11600 11826
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[Parallel(n_jobs=4)]: Done 125 out of 250 | elapsed:    1.8s remaining:    1
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[Parallel(n_jobs=4)]: Done 250 out of 250 | elapsed:    3.9s finished
```

In [52]:

```
forest_train_sizes, forest_train_scores, forest_test_scores = learning_curve
(
    forest4, X_normed, Y, cv=kf, train_sizes=np.linspace(.1, 1.0, 10), verb
ose=2, scoring='roc_auc', n_jobs=4)
forest_train_scores_mean = np.mean(forest_train_scores, axis=1)
forest_train_scores_std = np.std(forest_train_scores, axis=1)
forest_test_scores_mean = np.mean(forest_test_scores, axis=1)
forest_test_scores_std = np.std(forest_test_scores, axis=1)
```

```
[learning_curve] Training set sizes: [ 1227  2455  3683  4910  6138  7366  8
593  9821 11049 12277]
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[Parallel(n_jobs=4)]: Done  25 out of  50 | elapsed:    9.2s remaining:    9
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[Parallel(n_jobs=4)]: Done  50 out of  50 | elapsed:   19.3s finished
```
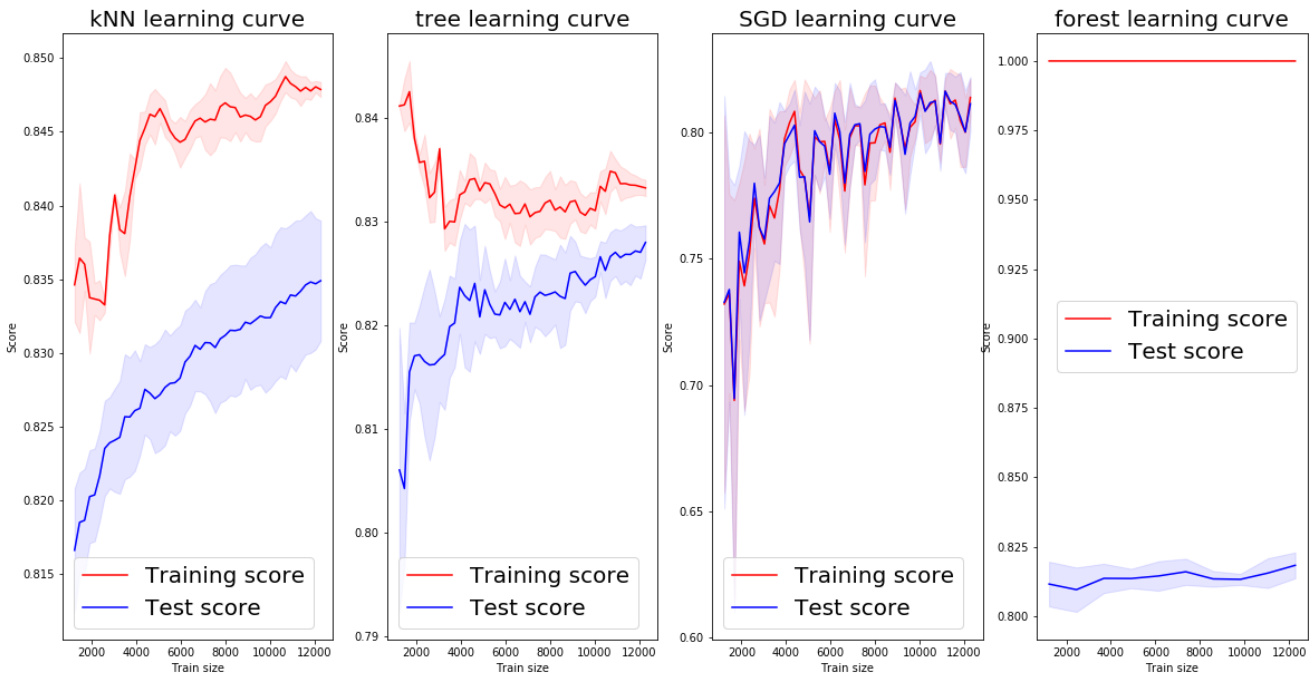

In [53]:

```
plt.figure(figsize=(20, 10))

plt.subplot(1, 4, 1)
plt.plot(kNN_train_sizes, kNN_train_scores_mean, color="red", label="Trainin
g score")
plt.plot(kNN_train_sizes, kNN_test_scores_mean, color="blue", label="Test sc
ore")
plt.fill_between(kNN_train_sizes, kNN_train_scores_mean - kNN_train_scores_s
td,
                 kNN_train_scores_mean + kNN_train_scores_std, alpha=0.
1,
                 color="red")
plt.fill_between(kNN_train_sizes, kNN_test_scores_mean - kNN_test_scores_std
,
                 kNN_test_scores_mean + kNN_test_scores_std, alpha=0.1, col
or="blue")
plt.title("kNN learning curve").set_size(20)
plt.legend(fontsize=20)
plt.xlabel("Train size")
plt.ylabel("Score")

plt.subplot(1, 4, 2)
plt.plot(tree_train_sizes, tree_train_scores_mean, color="red", label="Trai
ning score")
plt.plot(tree_train_sizes, tree_test_scores_mean, color="blue", label="Test
score")
plt.fill_between(tree_train_sizes, tree_train_scores_mean - tree_train_scor
es_std,
                 tree_train_scores_mean + tree_train_scores_std, alpha=
0.1,
                 color="red")
plt.fill_between(tree_train_sizes, tree_test_scores_mean - tree_test_scores
_std,
                 tree_test_scores_mean + tree_test_scores_std, alpha=0.1, c
olor="blue")
plt.title("tree learning curve").set_size(20)
plt.legend(fontsize=20)
plt.xlabel("Train size")
plt.ylabel("Score")

plt.subplot(1, 4, 3)
plt.plot(SGD_train_sizes, SGD_train_scores_mean, color="red", label="Trainin
g score")
plt.plot(SGD_train_sizes, SGD_test_scores_mean, color="blue", label="Test sc
ore")
plt.fill_between(SGD_train_sizes, SGD_train_scores_mean - SGD_train_scores_s
td,
                 SGD_train_scores_mean + SGD_train_scores_std, alpha=0.
1,
                 color="red")
plt.fill_between(SGD_train_sizes, SGD_test_scores_mean - SGD_test_scores_std
,
                 SGD_test_scores_mean + SGD_test_scores_std, alpha=0.1, col
or="blue")
plt.title("SGD learning curve").set_size(20)
```

```
plt.title("SGD learning curve").set_size(20)
plt.legend(fontsize=20)
plt.xlabel("Train size")
plt.ylabel("Score")

plt.subplot(1, 4, 4)
plt.plot(forest_train_sizes, forest_train_scores_mean, color="red", label="T
raining score")
plt.plot(forest_train_sizes, forest_test_scores_mean, color="blue", label="T
est score")
plt.fill_between(forest_train_sizes, forest_train_scores_mean - forest_train
_scores_std,
                 forest_train_scores_mean + forest_train_scores_std, al
pha=0.1,
                 color="red")
plt.fill_between(forest_train_sizes, forest_test_scores_mean - forest_test_s
cores_std,
                 forest_test_scores_mean + forest_test_scores_std, alpha=0.
1, color="blue")
plt.title("forest learning curve").set_size(20)
plt.legend(fontsize=20)
plt.xlabel("Train size")
plt.ylabel("Score")
```

Out[53]:

```
Text(0,0.5,'Score')
```



Может ли с ростом числа объектов убывать качество на тестовой выборке? А на обучающей? Почему? Для каких целей можно использовать знание качества на обучающей части выборки? Какой из алгоритмов лучше обучается на меньшем числе объектов? Может ли добавление новых объектов значительно повысить качество какого-то из алгоритмов или при существующем наборе данных для всех алгоритмов произошло насыщение? 1) В kNN качество как на обучающей, так и на тестовой выборке, в целом, растёт. В DecisionTreeClassifier качество на обучающей выборке падает, в то время как качество на тестовой выборке растёт. Это логично, поскольку у нас есть ограничение на глубину дерева, а значит с увеличением количества элементов в обучающей выборке обоющающая способность растет, но число ошибок на обучающей выборке может при это увеличиваться. Для SGD наблюдаются значительные скачки качества, однако, в среднем, и на обучающей выборке, и на тестовой, качество растёт. Что же касается RandomForestClassifier, кривые и на обучающей, и на тестовой выборке почти константны. Кривая для обучающей выборки почти тождественно

тестовой выборке почти константны. Кривая для обучающей выборки почти тождественно равна 1, что может быть признаком переобучения (но в случае RandomForestClassifier это скорее просто особенность классификатора, который полностью подгоняется под обучающую выборку при отсутствии жестких ограничений на глубину).

2) Знание качества на обучающей выборке при сравнении его с качеством на тестовой выборке может быть показателем того, имеет ли смысл добавлять новые объекты в выборки. Если кривые сошлись друг к другу, то произошло насыщение и добавление новых объектов вряд ли существенно увеличит качество классификатора.

3) Возможно, на меньшем числе объектов лучше обучается SGD, однако, из кривой обучения это неочевидно.

4) Исходя из графиков, возможно, при добавлении новых объектов будет повышено качество классификаторов kNN и DecisionTree.

(2 балла) Добавление категориальных признаков в модели

Пока мы не использовали нечисловые признаки, которые есть в датасете. Давайте посмотрим, правильно ли мы сделали и увеличится ли качество моделей после добавлениях этих признаков.

(0.5 балла) Задание 8. Преобразуйте все категориальные признаки с помощью метода one-hot-encoding (например, это можно сделать с помощью функции pandas.get_dummies или DictVectorizer / OneHotEncoder из sklearn).

In [54]:

```
X_big = np.array(data)

data1 = pd.get_dummies(data.drop(columns=['age','fnlwgt','education-num',
                                          'capital-gain','capital-loss','ho
urs-per-week']))
```

Так как после кодирования признаков получилось достаточно много, в этой работе мы не будем подбирать заново оптимальные гиперпараметры для моделей с учетом новых признаков (хотя правильнее было бы это сделать).

(1.5 балла) Задание 9. Добавьте к масштабированным вещественным признакам закодированные категориальные и обучите алгоритмы с наилучшими гиперпараметрами, найденными ранее. Дало ли добавление новых признаков прирост качества? Измеряйте качество, как и раньше, используя 5-Fold CV. Для этого удобно воспользоваться функцией cross_val_score.

Отличается ли теперь наилучший классификатор от наилучшего в предыдущем пункте?

In [55]:

```
from sklearn.model_selection import cross_val_score


#{'metric': 'manhattan', 'n_neighbors': 65}
#{'criterion': 'gini', 'max_depth': 5}
#{'loss': 'log', 'penalty': 'elasticnet'}
#{'criterion': 'entropy', 'max_features': 4}
X_big = np.concatenate((X_normed, np.array(data1)), axis=1)
kNN5 = KNeighborsClassifier(metric='manhattan', n_neighbors=65)
tree5 = DecisionTreeClassifier(criterion='gini', max_depth=5)
SGD5 = SGDClassifier(loss='log', penalty='elasticnet')
forest5 = RandomForestClassifier(n_estimators=forest_n_estimators_new, crit
erion='entropy', max_features=4)
```

In [56]:

```
kNN5_cross_val_score = cross_val_score(kNN5, X_big, Y, cv=5, verbose=2, sco
ring='roc_auc')
kNN5_score = np.mean(kNN5_cross_val_score)
kNN5_std = np.std(kNN5_cross_val_score)
```

```
[CV]  ................................................................
[CV] ................................................ , total=   5.7s
[CV]  ................................................................
```

```
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    5.7s remaining:    0
.0s
```

```
[CV] ................................................ , total=   6.3s
[CV]  ................................................................
[CV] ................................................ , total=   6.1s
[CV]  ................................................................
[CV] ................................................ , total=   5.5s
[CV]  ................................................................
[CV] ................................................ , total=   5.7s
```

```
[Parallel(n_jobs=1)]: Done   5 out of   5 | elapsed:   29.3s finished
```

In [57]:

```
tree5_cross_val_score = cross_val_score(tree5, X_big, Y, cv=5, verbose=2, s
coring='roc_auc')
tree5_score = np.mean(tree5_cross_val_score)
tree5_std = np.std(tree5_cross_val_score)
```

```
[CV]  ................................................................
[CV] ................................................ , total=   0.1s
[CV]  ................................................................
[CV] ................................................ , total=   0.1s
[CV]  ................................................................
```

```
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.1s remaining:    0
.0s
```

```
[CV] ................................................ , total=   0.1s
[CV]  ................................................................
[CV] ................................................ , total=   0.1s
[CV]  ................................................................
[CV] ................................................ , total=   0.1s
```

```
[Parallel(n_jobs=1)]: Done   5 out of   5 | elapsed:    0.4s finished
```

In [58]:

```
SGD5_cross_val_score = cross_val_score(SGD5, X_big, Y, cv=5, verbose=2, sco
ring='roc_auc')
SGD5_score = np.mean(SGD5_cross_val_score)
SGD5_std = np.std(SGD5_cross_val_score)
```

```
[CV]  ................................................................
```

```
[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.1s remaining:    0
.0s

[CV] ................................................ , total=   0.1s
[CV]  ................................................................
[CV] ................................................ , total=   0.1s
[CV]  ................................................................
[CV] ................................................ , total=   0.1s
[CV]  ................................................................
[CV] ................................................ , total=   0.1s
[CV]  ................................................................
[CV] ................................................ , total=   0.1s

[Parallel(n_jobs=1)]: Done   5 out of   5 | elapsed:    0.4s finished
```

In [59]:

```
forest5_cross_val_score = cross_val_score(forest5, X_big, Y, cv=5, verbose=
2, scoring='roc_auc')
forest5_score = np.mean(forest5_cross_val_score)
forest5_std = np.std(forest5_cross_val_score)
```

```
[CV]  ................................................................
[CV] ................................................ , total=   0.8s
[CV]  ................................................................

[Parallel(n_jobs=1)]: Done   1 out of   1 | elapsed:    0.8s remaining:    0
.0s

[CV] ................................................ , total=   1.0s
[CV]  ................................................................
[CV] ................................................ , total=   0.9s
[CV]  ................................................................
[CV] ................................................ , total=   0.7s
[CV]  ................................................................
[CV] ................................................ , total=   0.8s

[Parallel(n_jobs=1)]: Done   5 out of   5 | elapsed:    4.3s finished
```

In [60]:

```
print("New results:")
print("kNN classifier's best score:", kNN5_score)
print("tree classifier's best score:", tree5_score)
print("SGD classifier's best score:", SGD5_score)
print("Random Forest classifier's best score:", forest5_score)
print("\nComparing with old results:")
print("New results:")
print("kNN classifier's best score:", kNN_clf3.best_score_)
print("tree classifier's best score:", tree_clf3.best_score_)
print("SGD classifier's best score:", SGD_clf3.best_score_)
print("Random Forest classifier's best score:", forest_clf3.best_score_)
```

```
New results:
kNN classifier's best score: 0.8905809080206858
tree classifier's best score: 0.8820430311595473
```

```
SGD classifier's best score: 0.8838140547684559
Random Forest classifier's best score: 0.8940079715316347

Comparing with old results:
New results:
kNN classifier's best score: 0.8348833802080656
tree classifier's best score: 0.8281592193876687
SGD classifier's best score: 0.8089039876580952
Random Forest classifier's best score: 0.817443881625561
```

Видим, что качество всех классификаторов повысилось. При этом, теперь лучшим является RandomForestClassifier.

(3 балла) Смешивание моделей (blending)

Во всех предыдущих пунктах мы получили много сильных моделей, которые могут быть достаточно разными по своей природе (например, метод ближайших соседей и случайный лес). Часто на практике оказывается возможным увеличить качество предсказания путем смешивания разных моделей. Давайте посмотрим, действительно ли такой подход дает прирост в качестве.

Выберете из построенных моделей двух предыдущих пунктов две, которые дали наибольшее качество на кросс-валидации (обозначим их clf_1 и clf_2). Далее постройте новый классификатор, ответ которого на некотором объекте x будет выглядеть следующим образом:

$$result(x) = clf_1(x) * \alpha + clf_2(x) * (1 - \alpha)$$

где α — гиперпараметр нового классификатора.

(2 балла) Задание 10. При реализации своих моделей хорошей практикой является создание sklearn-совместимых классов. Во-первых, такая реализация будет иметь стандартный интерфейс и позволит другим людям безболезненно обучать реализованные вами модели. Во-вторых, появляется возможность использовать любой функционал пакета sklearn, принимающий на вход модель, например, класс *GridSearchCV*, *learning_curve* и другие.

Создайте классификатор, который инициализируется двумя произвольными классификаторами и параметром α. Во время обучения такой классификатор должен обучать обе базовые модели, а на этапе предсказания замешивать предсказания базовых моделей по формуле, указанной выше.

Для создания пользовательского классификатора необходимо отнаследоваться от базовых классов *BaseEstimator*, *ClassifierMixin* и реализовать методы *__init__, fit, predict и predict_proba*. Пример sklearn-совместимого классификатора с комментариями можно найти здесь

In [61]:

```
from sklearn.base import BaseEstimator, ClassifierMixin
from sklearn.utils.validation import check_X_y, check_array, check_is_fitted
from sklearn.utils.multiclass import unique_labels
class MyClassifier(BaseEstimator, ClassifierMixin):
    def __init__(self, first_clf, second_clf, alpha=0.5):
        self.first_clf = first_clf
        self.second_clf = second_clf
        self.alpha = alpha

    def fit(self, X, y):
        X, y = check_X_y(X, y)
        self.classes_ = unique_labels(y)
        self.X_ = X
        self.y_ = y
```

```
        self.classes_, y = np.unique(y, return_inverse=True)
        self.first_clf.fit(X, y)
        self.second_clf.fit(X, y)
        return self

    def predict(self, X):
        check_is_fitted(self, ['X_', 'y_'])
        X = check_array(X)
        return self.classes_[np.argmax(self.first_clf.predict_proba(X) * se
lf.alpha +
                                       self.second_clf.predict_proba(X) * (
1 - self.alpha), axis=1)]

    def predict_proba(self, X):
        check_is_fitted(self, ['X_', 'y_'])
        X = check_array(X)
        return (self.first_clf.predict_proba(X) * self.alpha +
                                self.second_clf.predict_proba(X) * (1 - self.
alpha))
```

(1 балл) Задание 11. Подберите по сетке от 0 до 1 значение α для этого классификатора. Если класс реализован правильно, то вы сможете использовать *GridSearchCV*, как в случае с обычными классификаторами.

Изобразите на графике среднее качество по фолдам и доверительный интервал в зависимости от α.

Дал ли этот подход прирост к качеству по сравнению с моделями, обученными по-отдельности? Поясните, почему даже простой блендинг моделей может влять на итоговое качество?

In [62]:

```
clf = MyClassifier(RandomForestClassifier(n_estimators=forest_n_estimators_
new, criterion='entropy', max_features=4),
                           KNeighborsClassifier(metric='manhattan', n_neighb
ors=65))
my_clf = GridSearchCV(clf, {'alpha' : np.linspace(.01, 1.0, 10)}, cv=kf, ve
rbose=2, n_jobs=4, scoring='roc_auc')
```

In [63]:

```
my_clf.fit(X_big, Y)
```

```
Fitting 5 folds for each of 10 candidates, totalling 50 fits
[CV] alpha=0.01 ......................................................
[CV] alpha=0.01 ......................................................
[CV] alpha=0.01 ......................................................
[CV] alpha=0.01 ......................................................
[CV] ..................................... alpha=0.01, total=  13.4s
[CV] alpha=0.01 ......................................................
[CV] ..................................... alpha=0.01, total=  13.5s
[CV] alpha=0.12 ......................................................
[CV] ..................................... alpha=0.01, total=  13.4s
[CV] alpha=0.12 ......................................................
[CV] ..................................... alpha=0.01, total=  13.7s
[CV] alpha=0.12 ......................................................
[CV] ..................................... alpha=0.01, total=  12.6s
[CV] alpha=0.12 ......................................................
[CV] ..................................... alpha=0.12, total=  12.3s
[CV] alpha=0.12 ......................................................
```

```
[CV] ..................................... alpha=0.12, total=  12.4s
[CV] alpha=0.23 .......................................................
[CV] ..................................... alpha=0.12, total=  12.8s
[CV] alpha=0.23 .......................................................
[CV] ..................................... alpha=0.12, total=  13.0s
[CV] alpha=0.23 .......................................................
[CV] ..................................... alpha=0.12, total=  12.8s
[CV] alpha=0.23 .......................................................
[CV] ..................................... alpha=0.23, total=  12.9s
[CV] alpha=0.23 .......................................................
[CV] ..................................... alpha=0.23, total=  13.2s
[CV] alpha=0.34 .......................................................
[CV] ..................................... alpha=0.23, total=  12.8s
[CV] alpha=0.34 .......................................................
[CV] ..................................... alpha=0.23, total=  12.9s
[CV] alpha=0.34 .......................................................
[CV] ..................................... alpha=0.23, total=  12.6s
[CV] alpha=0.34 .......................................................
[CV] ..................................... alpha=0.34, total=  12.7s
[CV] alpha=0.34 .......................................................
[CV] ..................................... alpha=0.34, total=  12.5s
[CV] alpha=0.45 .......................................................
[CV] ..................................... alpha=0.34, total=  12.5s
[CV] alpha=0.45 .......................................................
[CV] ..................................... alpha=0.34, total=  12.5s
[CV] alpha=0.45 .......................................................
[CV] ..................................... alpha=0.34, total=  12.4s
[CV] alpha=0.45 .......................................................
[CV] ..................................... alpha=0.45, total=  13.9s
[CV] alpha=0.45 .......................................................
[CV] ..................................... alpha=0.45, total=  14.0s
[CV] alpha=0.56 .......................................................
[CV] ..................................... alpha=0.45, total=  13.8s
[CV] alpha=0.56 .......................................................
[CV] ..................................... alpha=0.45, total=  13.8s
[CV] alpha=0.56 .......................................................
[CV] ..................................... alpha=0.45, total=  13.1s
[CV] alpha=0.56 .......................................................
[CV] ..................................... alpha=0.56, total=  13.1s
[CV] alpha=0.56 .......................................................
[CV] ..................................... alpha=0.56, total=  13.1s
[CV] alpha=0.67 .......................................................
[CV] ..................................... alpha=0.56, total=  13.3s
[CV] alpha=0.67 .......................................................
[CV] ..................................... alpha=0.56, total=  12.6s
[CV] alpha=0.67 .......................................................
[CV] ..................................... alpha=0.56, total=  13.2s
[CV] alpha=0.67 .......................................................
[CV] ..................................... alpha=0.67, total=  13.1s
[CV] ..................................... alpha=0.67, total=  13.1s
[CV] alpha=0.67 .......................................................
[CV] alpha=0.78 .......................................................
[CV] ..................................... alpha=0.67, total=  12.5s
[CV] alpha=0.78 .......................................................

[Parallel(n_jobs=4)]: Done  33 tasks      | elapsed: 11.9min

[CV] ..................................... alpha=0.67, total=  12.7s
[CV] alpha=0.78 .......................................................
[CV] ..................................... alpha=0.67, total=  12.6s
[CV] alpha=0.78 .......................................................
```

```
[CV] ..................................... alpha=0.78, total=  12.5s
[CV] alpha=0.78 .......................................................
[CV] ..................................... alpha=0.78, total=  12.5s
[CV] alpha=0.89 .......................................................
[CV] ..................................... alpha=0.78, total=  12.8s
[CV] alpha=0.89 .......................................................
[CV] ..................................... alpha=0.78, total=  12.9s
[CV] alpha=0.89 .......................................................
[CV] ..................................... alpha=0.78, total=  13.0s
[CV] alpha=0.89 .......................................................
[CV] ..................................... alpha=0.89, total=  12.5s
[CV] alpha=0.89 .......................................................
[CV] ..................................... alpha=0.89, total=  12.6s
[CV] alpha=1.0 ........................................................
[CV] ..................................... alpha=0.89, total=  12.7s
[CV] alpha=1.0 ........................................................
[CV] ..................................... alpha=0.89, total=  12.6s
[CV] alpha=1.0 ........................................................
[CV] ..................................... alpha=0.89, total=  12.3s
[CV] alpha=1.0 ........................................................
[CV] ..................................... alpha=1.0, total=  12.5s
[CV] alpha=1.0 ........................................................
[CV] ..................................... alpha=1.0, total=  12.5s
[CV] ..................................... alpha=1.0, total=  12.5s
[CV] ..................................... alpha=1.0, total=   8.6s
[CV] ..................................... alpha=1.0, total=   7.6s
```

```
[Parallel(n_jobs=4)]: Done  50 out of  50 | elapsed: 15.3min finished
```

Out[63]:

```
GridSearchCV(cv=KFold(n_splits=5, random_state=None, shuffle=False),
       error_score='raise',
       estimator=MyClassifier(alpha=0.5,
       first_clf=RandomForestClassifier(bootstrap=True, class_weight=None, c
riterion='entropy',
            max_depth=None, max_features=4, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_sampl...attan',
           metric_params=None, n_jobs=1, n_neighbors=65, p=2,
           weights='uniform')),
       fit_params=None, iid=True, n_jobs=4,
       param_grid={'alpha': array([0.01, 0.12, 0.23, 0.34, 0.45, 0.56, 0.67,
0.78, 0.89, 1.  ])},
       pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
       scoring='roc_auc', verbose=2)
```

In [64]:

```
print(my_clf.best_params_, my_clf.best_score_)
```

```
{'alpha': 0.45} 0.902388238071557
```

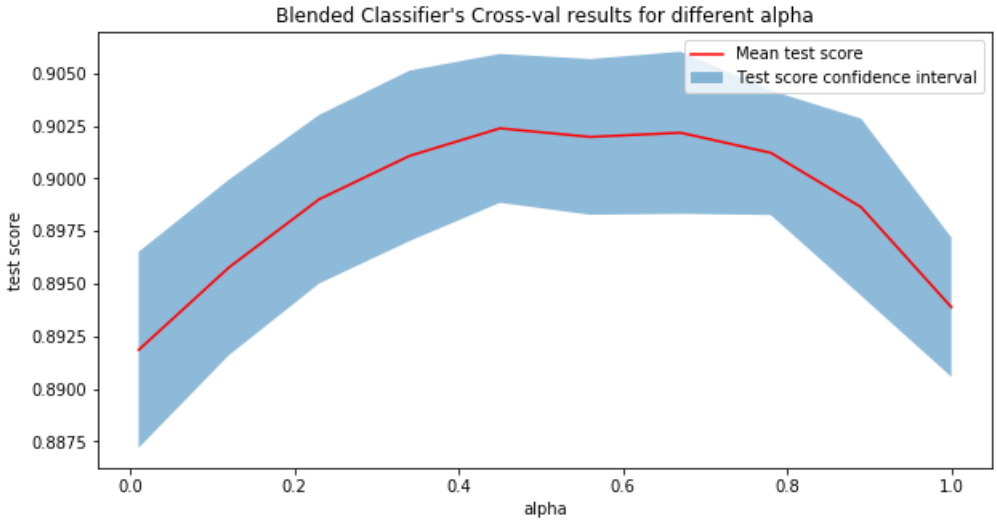
In [85]:

```
mean, std = my_clf.cv_results_['mean_test_score'], my_clf.cv_results_['std_
test_score']
plt.figure(figsize=(10, 5))
plt.title("Blended Classifier's Cross-val results for different alpha")
plt.plot(np.linspace(.01, 1.0, 10), mean, c='red', label='Mean test score')
```

```
plt.fill_between(np.linspace(.01, 1.0, 10), mean - std, mean + std, label='
Test score confidence interval', alpha=0.5)
plt.xlabel('alpha').set_size(10)
plt.ylabel('test score').set_size(10)
plt.legend()
```

Out[85]:

```
<matplotlib.legend.Legend at 0x1a2c1a4e10>
```



Новый классификатор дал score 0.902388238071557, в то время как модели, обученные по-отдельности, имели score: kNN - 0.8905809080206858, Random Forest - 0.8940079715316347. Блендинг модели позволяет делать следующее: в случае, когда более сильный классификатор уверен в ответе, решающее значение имеет он. Однако, когда он ошибается и не очень уверен в ответе, более слабый классификатор может не ошибаться и своей уверенностью перевесить показания более сильного классификатора.

(2 балла) Сравнение построенных моделей

MODEL	GOLF	DUET	SAVILE	ELITE	SOLO	TRAVELER	MINI
SRP	$129	$149	$350	$149	$99	$89	$49
CANOPY SIZE (arc-diameter)	62" Massive - Our largest	55" Large enough for two	55" Large enough for two	50" Spacious for one	43" Classic individual-sized	40" Compact for travel	38" Ultra-compact
CLOSED LENGTH	40" Full-length shaft	14.75" Foldable shaft	37" Full-length shaft	34" Full-length shaft	11.75" Foldable shaft	9" Foldable shaft	7" Foldable shaft
OPEN/CLOSE	Auto-open	Auto-open & close	Manual open/close	Auto-open	Auto-open & close	Auto-open & close	Manual open/close
COLORS	Black Black/Royale Blue Black/Deep Red Black/Sport Green Black/Sport Yellow	Black Black/Cranberry Red	Black Midnight Blue Hunter	Black Navy Blue Copper	Black Black/Pale Blue Black/Wasabi Green Black/Sport Yellow	Black Classic Red Royal Blue Yellow Kiwi Green Fuchsia Pink	Black Red Yellow Turquoise
USE	For golf or if you need ultimate coverage	For larger-sized men Golf-size canopy, but collapsible	For the purist, our most elegant	For an upscale, classic look	Ideal for standard-sized individuals Our most popular model	Fits in any bag If portability & travel is a high priority	Fits in any pocket Keep it with you always

После того как было построено много моделей правильным продолжением является сравнение их между собой. На семинаре по визуализации вам было показано как строить "ящик с усами" (диаграмму размаха). Воспользуемся ей для сравнения алгоритмов между собой.

(2 балла) Задание 12. Для каждого типа классификатора (kNN, DecisionTree, RandomForest, SGD classifier), а так же смешанной модели, выберете тот, которых давал наилучшее качество на кросс-валидации и постройте диаграмму размаха. Все классификаторы должны быть изображены на одном графике.

Сделайте общие итоговые выводы о классификаторах с точки зрения их работы с признаками и сложности самой модели (какие гиперпараметры есть у модели, сильно ли изменение значения гиперпараметра влияет на качество модели).

In [66]:

```
my_clf_score = my_clf.best_score_
means = [kNN5_score, tree5_score, forest5_score, SGD5_score, my_clf_score]
stds = [kNN5_std, tree5_std, forest5_std, SGD5_std, my_clf.cv_results_['std
_test_score'][my_clf.best_index_]]
```

In [81]:

```
plt_data = [go.Bar(
            x=['kNN', 'DecisionTree', 'RandomForest', 'SGD', 'Blended'],
            y=means, error_y=dict(type='data', array=stds, visible=True))]
layout = go.Layout(
    title='Best Cross-val results for different classificators',
    yaxis=dict(type='log', title='test score', titlefont=dict(size=16), tic
kfont=dict(size=14)),
    xaxis=dict(title='Classifiers', titlefont=dict(size=16), tickfont=dict(
size=14)))

fig = go.Figure(data=plt_data, layout=layout)
py.iplot(fig)
```

1) kNN Classifier показывает плохие результаты на не масштабированных данных: best 'n_neighbors': 5, best score: 0.6412956668705564. При этом качество классификатора не очень существенно зависит от гиперпараметра 'n_estimators'. После масштабирования результаты значительно улучшаются: best 'n_neighbors': 55, best score: 0.834390627771687. При этом качество классификатора достаточно

'n_neighbors': 35, best score: 0.8345906277771687. При этом качество классификатора достаточно существенно зависит от гиперпараметра 'n_estimators' на достаточно малых его значениях, однако потом наступает некоторое "насыщение" и качество практически перестаёт меняться. Это достаточно простая модель, в ней даже нет как такового "обучения". При подборе двух гиперпараметров, 'n_estimators' и 'metric', качество практически не изменяется: best score: 0.8348833802080656. Добавление категориальных признаков с one-hot кодированием повышает размерность пространства признаков и качество классификатора: best score: 0.8905809080206858.

2) DecisionTreeClassifier показывает хорошие результаты как на не масштабированных данных - best 'max_depth': 7, best score: 0.8410139678158015 - так и на масштабированных данных - best 'max_depth': 7, best score: 0.8411372234302745. Как уже было сказано, это вызвано тем, что качество DecisionTreeClassifier не зависит от масштабирования параметров. При этом качество классификатора достаточно существенно зависит от гиперпараметра 'max_depth', возрастая до определенного момента, а потом достаточно сильно снижаясь при больших значениях. При подборе двух гиперпараметров, 'max_depth' и 'criterion', качество практически не изменяется: best score: 0.8281592193876687. Добавление категориальных признаков с one-hot кодированием повышает качество классификатора: best score: 0.8820430311595473 - что может быть вызвано увеличением числа возможных условий в узлах дерева.

3) SGD Classifier показывает плохие результаты на не масштабированных данных: best 'loss': modified_huber, best score: 0.6062338251350011. Это может быть вызвано тем, что данная модель - линейная, и признаки с большой дисперсией могут оказаться доминирующими, в то время как остальные признаки почти не будут учитываться. После масштабирования результаты значительно улучшаются: best 'loss': 'log', best score: 0.8064773357712638. При этом качество классификатора достаточно сильно разнится при различных значения гиперпараметра 'loss' (логично, что всё будет сильно зависеть от того, какую функцию мы минимизируем). При подборе двух гиперпараметров, 'loss' и 'penalty', качество практически не изменяется: best score: 0.8089039876580952. Добавление категориальных признаков с one-hot кодированием повышает качество классификатора: best score: 0.8838140547684559.

4) RandomForestClassifier показывает средние результаты как на не масштабированных данных - best 'n_estimators' = 80, best score: 0.7019698154254055 - так и на масштабированных данных - best 'n_estimators' = 54, best score: 0.7112240388864339. При этом качество классификатора достаточно существенно зависит от гиперпараметра 'n_estimators' на достаточно малых его значениях, однако потом наступает некоторое "насыщение" и качество практически перестаёт меняться. Как и в случае DecisionTreeClassifier, было показано, что качество RandomForestClassifier не зависит от масштабирования параметров. При подборе двух гиперпараметров, 'criterion' и 'max_features' (и фиксированным значением)'n_estimators', качество существенно возрастает: best 'criterion': 'entropy', best 'max_features': 4, best score: 0.817443881625561. Гиперпараметр 'criterion' указывает функцию, которая меряет качество разбиения в дереве, поэтому логично, что её подбор существенно влияет на качество. Добавление категориальных признаков с one-hot кодированием повышает качество классификатора: best score: 0.8940079715316347.

5) BlendedClassifier улучшает качество двух лучших классификаторов: best score: 0.902388238071557. Как уже было сказано, блендинг модели позволяет делать следующее: в случае, когда более сильный классификатор уверен в ответе, решающее значение имеет он. Однако, когда он ошибается и не очень уверен в ответе, более слабый классификатор может не ошибаться и своей уверенностью перевесить показания более сильного классификатора.
