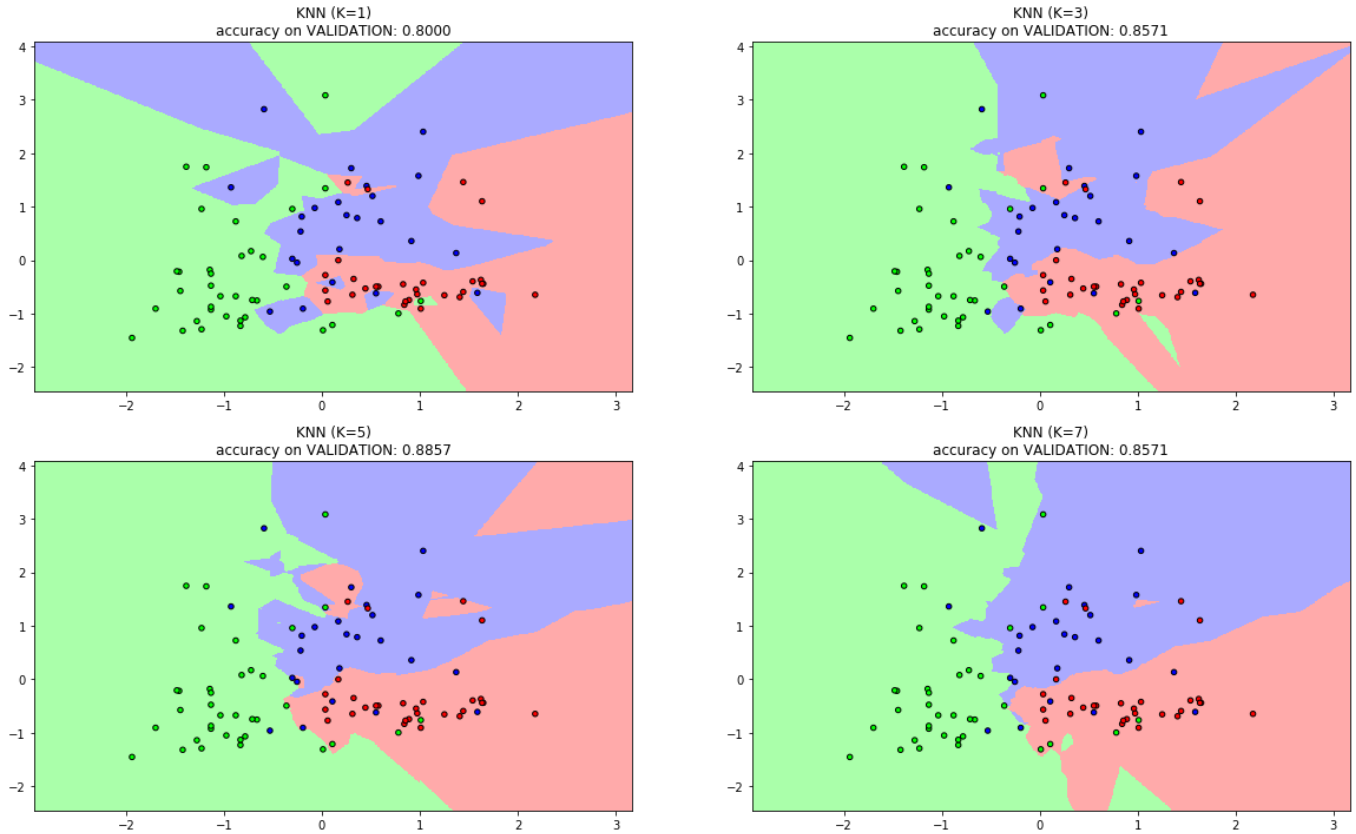
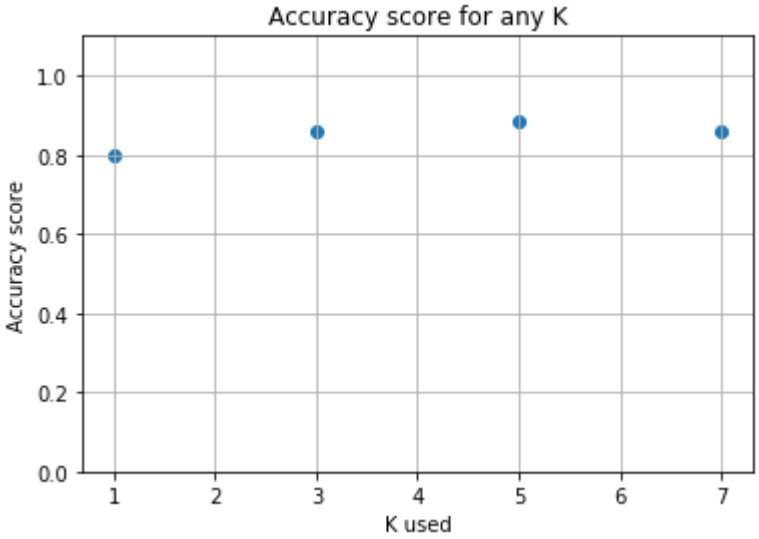
The aim of this homework is to practically test and analyze some of the machine learning algorithms studied during the course.

The data used are futures (two attributes) and labels (that represents three classes) of a wine dataset from scikit learn library. All the following algorithms are `supervised learning models` developed to deal with `classification of multiple classes`: starting from his features the aim is to classify each sample into a class. Samples are split into **train** (50%), that the algorithm will use to build his model, **validation** (20%), that will be used to test the performance and to select the optimal parameters for the model, and **test** (30%), that will be used as effective verification of precision on the model with best parameters trained with both train and validation set. The split is made in such a way that labels have the same distribution in each subset in order to avoid particular cases that would lead to incorrect results. All futures are normalized with a scaler trained with the train and the validation set. Graphs that will be shown represent, through colored background, the spatial classification in the different classes obtained by the algorithm and, through colored points, the train samples (constants). As measure of success the **accuracy score** represents the percentage (from 0 up to 1) of classifications of the validation and test samples successfully made.

K-Nearest Neighbors classifier

The `KNN classifier` assigns a class to a new sample watching the **most recurrent class of the K nearest samples**. The algorithm is iterated for K values {1, 3, 5, 7}.





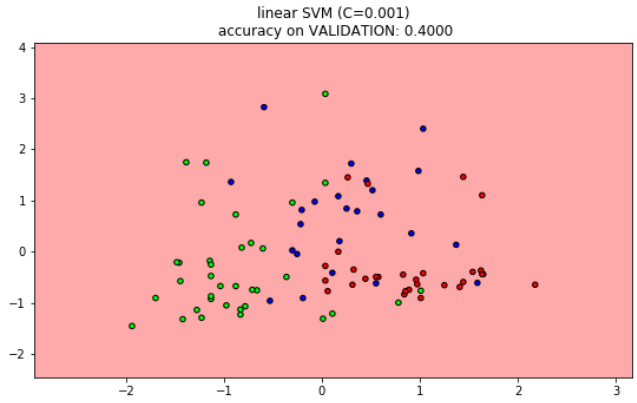

```
Best accuracy on VALIDATION: 0.8857
Best K: 5

Best KNN on TEST (K=5): accuracy: 0.8704
```

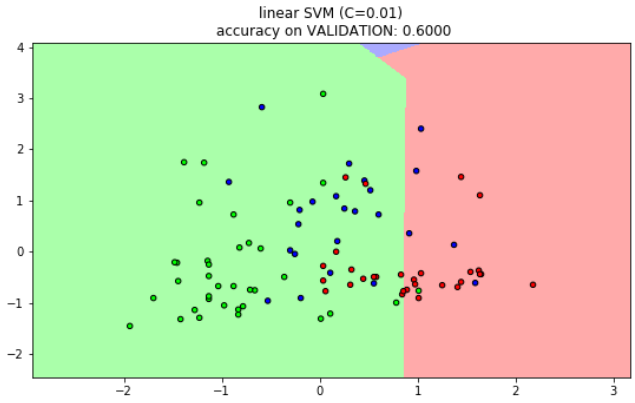
For K values 1 and 3 It is clear that classification areas are more jagged because isolated samples are considered relevant, higer K give more homogeneous separations. Accuracy scores on the validation set are likewise higher than 80%, the best K is 7 and It produces an accuracy score much higher than 80% also on the test set. Although the algorithm is quite onerous for the amount of distances computed, it seems to have excellent performance in classify this dataset.

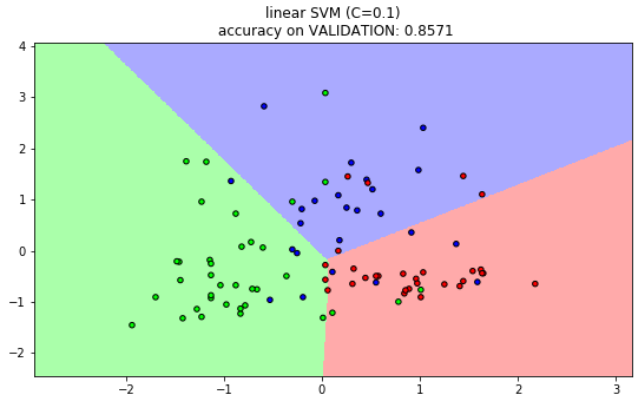
Support-Vector Machine classifier with Linear Kernel

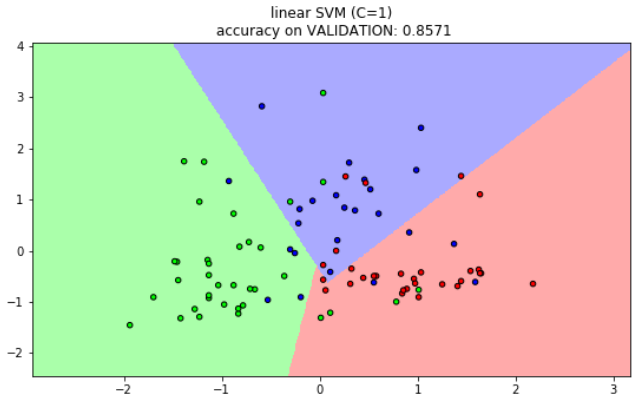
A `SVM classifier` builds a model that separates the space into regions of classification trying to **maximize the distance between samples and the border which separates regions of different classes**.

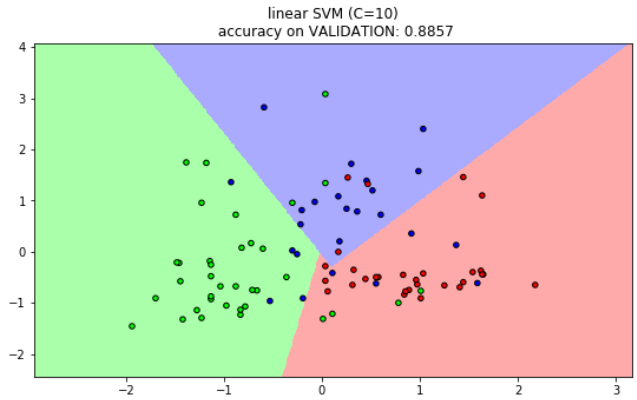
Using a `linear kernel` the **distances are calculated as scalar product** <x, x'> between two samples, consequently the separation between different regions is composed by straight lines. The parameter C represents the measure of avoid misclassification for each training sample: using small C the SVM will separate regions with larger margin but will also misclassify more train samples, on the other hand a large value of C will successfully classify more train samples but the margin will be smaller. The algorithm is iterated for values of C in a range from 0.001 to 1000 in order to select the best one.

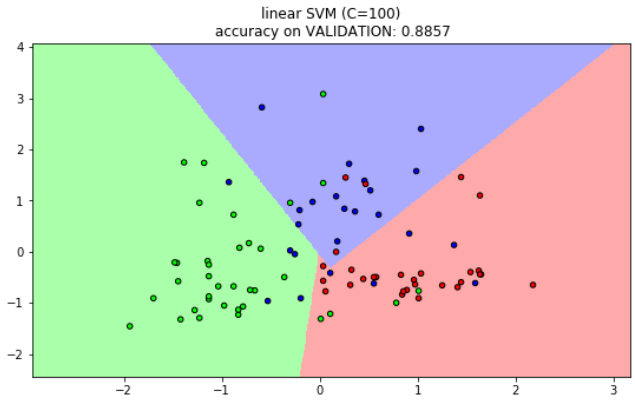

linear SVM (C=0.001)
accuracy on VALIDATION: 0.4000

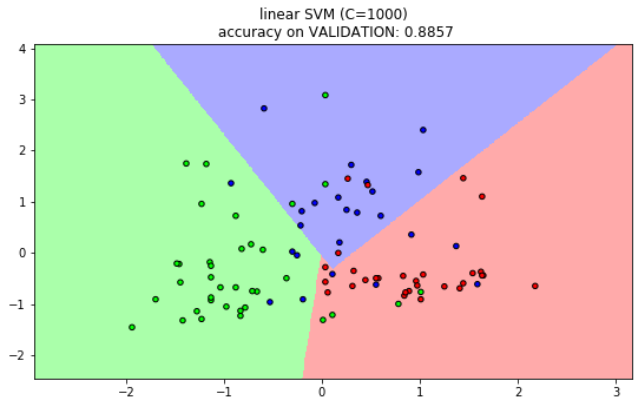

linear SVM (C=0.01)
accuracy on VALIDATION: 0.6000

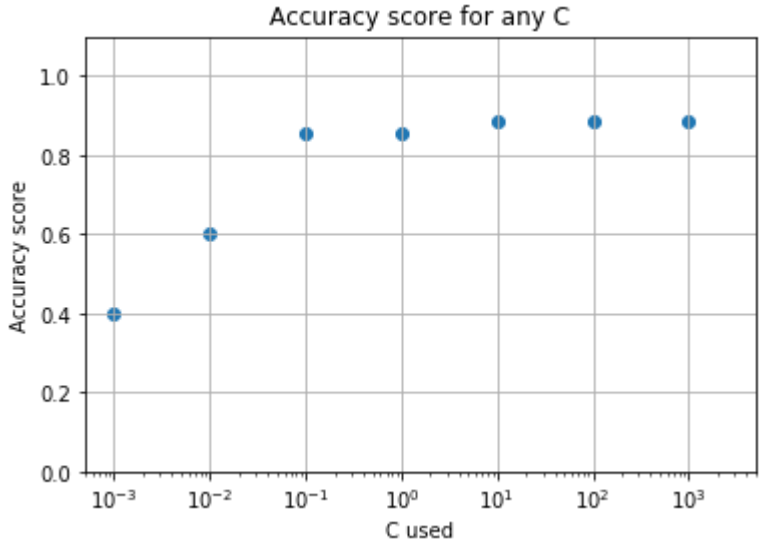

linear SVM (C=0.1)
accuracy on VALIDATION: 0.8571


linear SVM (C=1)
accuracy on VALIDATION: 0.8571


linear SVM (C=10)
accuracy on VALIDATION: 0.8857


linear SVM (C=100)
accuracy on VALIDATION: 0.8857


linear SVM (C=1000)
accuracy on VALIDATION: 0.8857

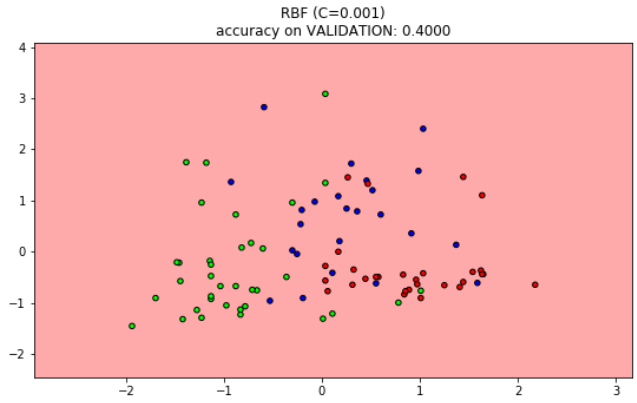


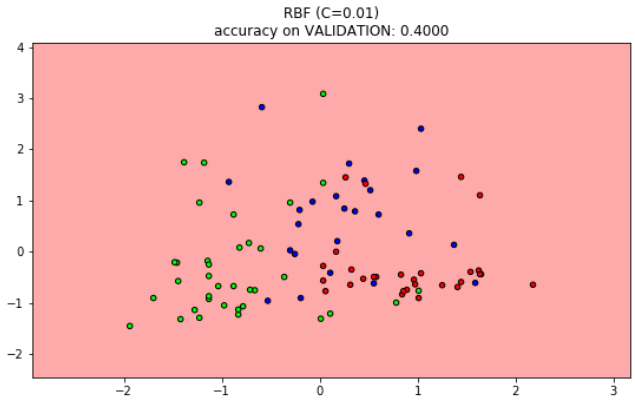

```
Best accuracy on VALIDATION: 0.8857
Best C: 10

Best linear SVM on TEST (C=10): accuracy: 0.7593
```

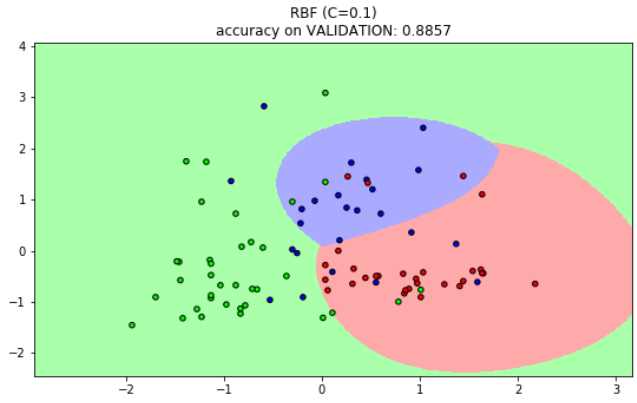
As the first graph shows, tiniest value of C (0.001 and also 0.01) cause the algorithm to diverge classifying the entire space as an unique class or as only two. This happens probably because the dataset is not enought big so that a small C allows to misclassify a huge portion of train samples. Values of C from 0.1 to 1000 produce an accuracy score on the validation set above 80%. In case of having the same score it is better to choose the smaller C in order to reduce misclassification. The best C (10) gives an accuracy on the test set of 75%. The discrepancy of more than 10% between the train-validation and the test accuracy denotes that linear separation doesn't fit excellently with this data.

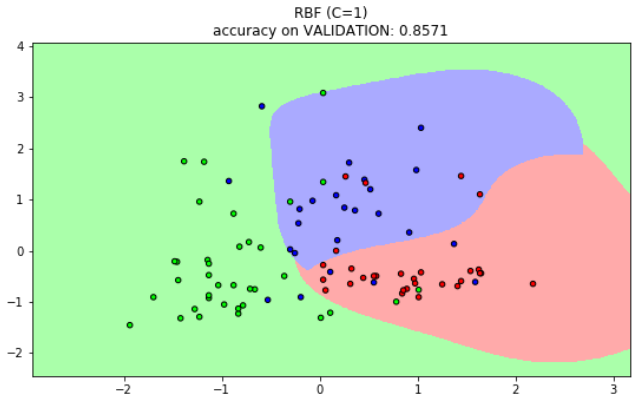
Support-Vector Machine classifier with Radial Basis Function Kernel

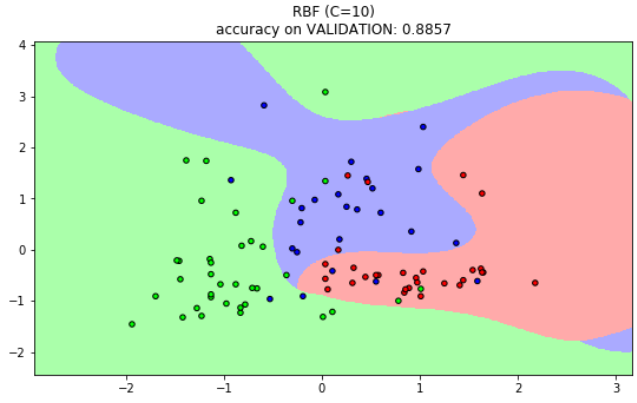
Using a SVM with a `RBF kernel` the **distances are calculated with the Gaussian formula** e^(-gamma*||x - x'||^2) . In this first case the value of gamma is by default chosen automatically.

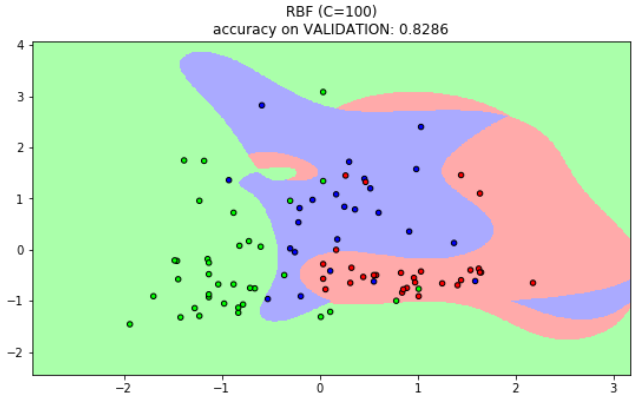

RBF (C=0.001)
accuracy on VALIDATION: 0.4000

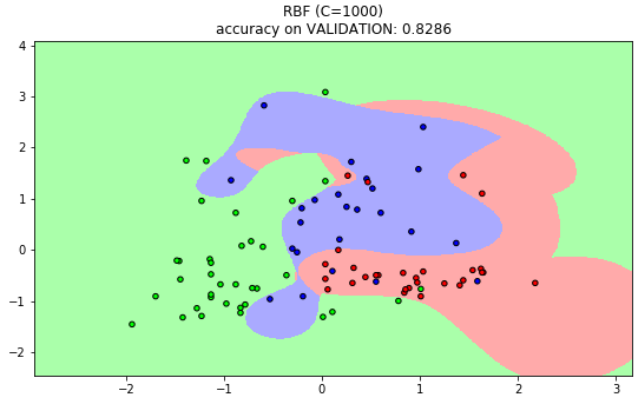

RBF (C=0.01)
accuracy on VALIDATION: 0.4000

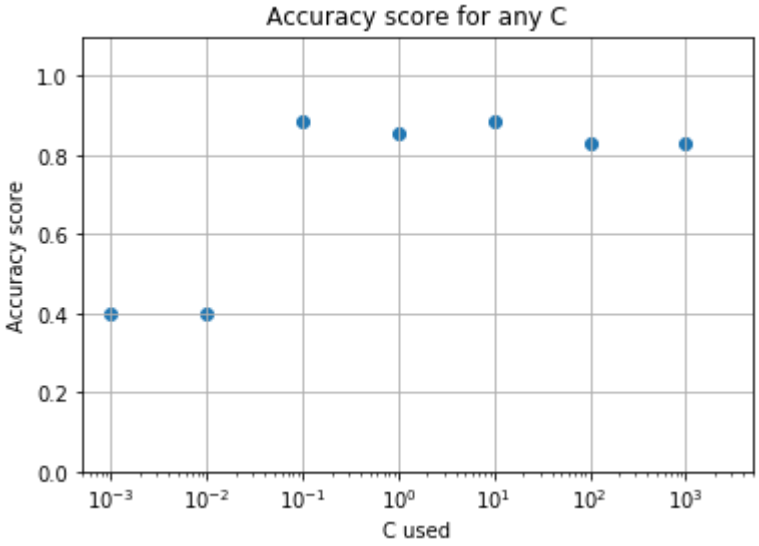

RBF (C=0.1)
accuracy on VALIDATION: 0.8857


RBF (C=1)
accuracy on VALIDATION: 0.8571


RBF (C=10)
accuracy on VALIDATION: 0.8857


RBF (C=100)
accuracy on VALIDATION: 0.8286


RBF (C=1000)
accuracy on VALIDATION: 0.8286




```
Best accuracy on VALIDATION: 0.8857
Best C: 0.1

Best RBF on TEST (C=0.1): accuracy: 0.7593
```

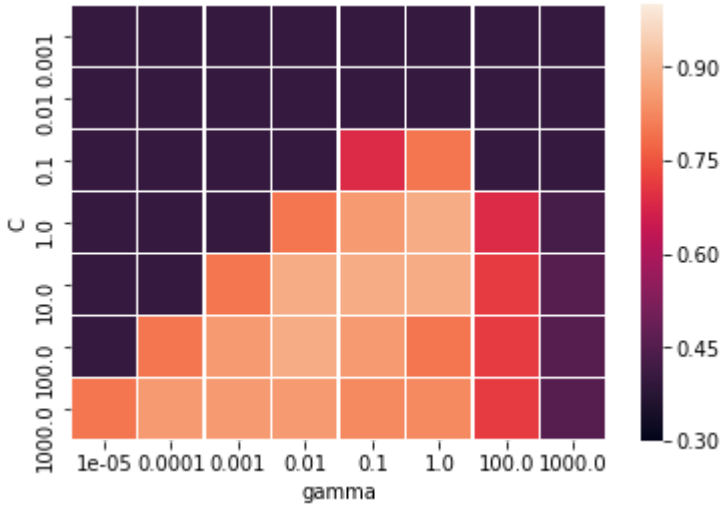
C values are iterated, It appears again that smaller values (up to 0.1) cause the model to degenerate classifying all the space into only one class for the same reasons. Also in this case higher values of C lead to accuracy scores above 80%, the accuracy score of the model applied to the test set with the best C (0.1) is quite less than the expected (~75%). Despite boundaries are clearly different because not linear, accuracy scores on this data seems to be similar as linear kernel SVM.

SVM classifier with RBF Kernel cycling gamma

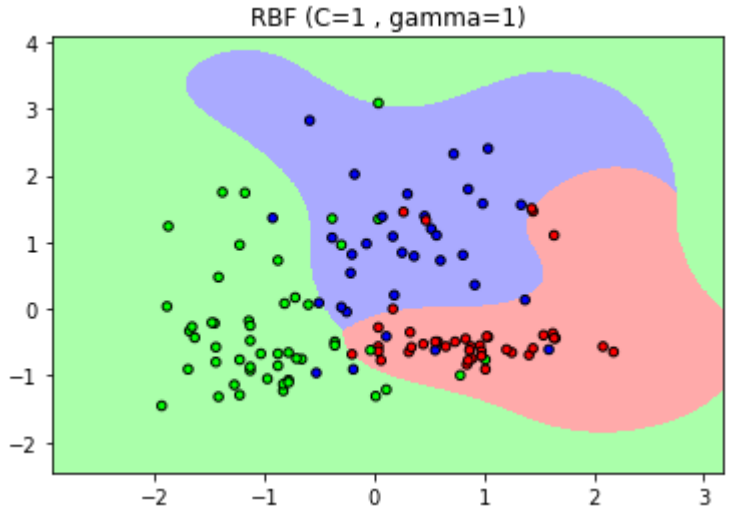
Now the parameter gamma, weight in the RBF exponential calculus of the distance between two samples, is varied in a range from 0.00001 to 1000 together with the C in order to find the better combination of the two parameters. In particular, if gamma is too big each sample influences only himself and the model will be **overfitted** (It will strongly represent the training set but It will not be general enough to fit with new samples), on the other hand if gamma is too small every sample will influence all the other samples including the most distant.

```
RBF on VALIDATION (C=0.001, gamma=1e-05): accuracy score: 0.4000
RBF on VALIDATION (C=0.001, gamma=0.0001): accuracy score: 0.4000
RBF on VALIDATION (C=0.001, gamma=0.001): accuracy score: 0.4000
RBF on VALIDATION (C=0.001, gamma=0.01): accuracy score: 0.4000
RBF on VALIDATION (C=0.001, gamma=0.1): accuracy score: 0.4000
RBF on VALIDATION (C=0.001, gamma=1): accuracy score: 0.4000
RBF on VALIDATION (C=0.001, gamma=100): accuracy score: 0.4000
RBF on VALIDATION (C=0.001, gamma=1000): accuracy score: 0.4000
RBF on VALIDATION (C=0.01, gamma=1e-05): accuracy score: 0.4000
RBF on VALIDATION (C=0.01, gamma=0.0001): accuracy score: 0.4000
RBF on VALIDATION (C=0.01, gamma=0.001): accuracy score: 0.4000
RBF on VALIDATION (C=0.01, gamma=0.01): accuracy score: 0.4000
```

```
RBF on VALIDATION (C=0.01, gamma=0.1): accuracy score: 0.4000
RBF on VALIDATION (C=0.01, gamma=1): accuracy score: 0.4000
RBF on VALIDATION (C=0.01, gamma=100): accuracy score: 0.4000
RBF on VALIDATION (C=0.01, gamma=1000): accuracy score: 0.4000
RBF on VALIDATION (C=0.1, gamma=1e-05): accuracy score: 0.4000
RBF on VALIDATION (C=0.1, gamma=0.0001): accuracy score: 0.4000
RBF on VALIDATION (C=0.1, gamma=0.001): accuracy score: 0.4000
RBF on VALIDATION (C=0.1, gamma=0.01): accuracy score: 0.4000
RBF on VALIDATION (C=0.1, gamma=0.1): accuracy score: 0.6857
RBF on VALIDATION (C=0.1, gamma=1): accuracy score: 0.8000
RBF on VALIDATION (C=0.1, gamma=100): accuracy score: 0.4000
RBF on VALIDATION (C=0.1, gamma=1000): accuracy score: 0.4000
RBF on VALIDATION (C=1, gamma=1e-05): accuracy score: 0.4000
RBF on VALIDATION (C=1, gamma=0.0001): accuracy score: 0.4000
RBF on VALIDATION (C=1, gamma=0.001): accuracy score: 0.4000
RBF on VALIDATION (C=1, gamma=0.01): accuracy score: 0.8000
RBF on VALIDATION (C=1, gamma=0.1): accuracy score: 0.8571
RBF on VALIDATION (C=1, gamma=1): accuracy score: 0.8857
RBF on VALIDATION (C=1, gamma=100): accuracy score: 0.6857
RBF on VALIDATION (C=1, gamma=1000): accuracy score: 0.4286
RBF on VALIDATION (C=10, gamma=1e-05): accuracy score: 0.4000
RBF on VALIDATION (C=10, gamma=0.0001): accuracy score: 0.4000
RBF on VALIDATION (C=10, gamma=0.001): accuracy score: 0.8000
RBF on VALIDATION (C=10, gamma=0.01): accuracy score: 0.8857
RBF on VALIDATION (C=10, gamma=0.1): accuracy score: 0.8857
RBF on VALIDATION (C=10, gamma=1): accuracy score: 0.8857
RBF on VALIDATION (C=10, gamma=100): accuracy score: 0.7143
RBF on VALIDATION (C=10, gamma=1000): accuracy score: 0.4571
RBF on VALIDATION (C=100, gamma=1e-05): accuracy score: 0.4000
RBF on VALIDATION (C=100, gamma=0.0001): accuracy score: 0.8000
RBF on VALIDATION (C=100, gamma=0.001): accuracy score: 0.8571
RBF on VALIDATION (C=100, gamma=0.01): accuracy score: 0.8857
RBF on VALIDATION (C=100, gamma=0.1): accuracy score: 0.8571
RBF on VALIDATION (C=100, gamma=1): accuracy score: 0.8000
RBF on VALIDATION (C=100, gamma=100): accuracy score: 0.7143
RBF on VALIDATION (C=100, gamma=1000): accuracy score: 0.4571
RBF on VALIDATION (C=1000, gamma=1e-05): accuracy score: 0.8000
RBF on VALIDATION (C=1000, gamma=0.0001): accuracy score: 0.8571
RBF on VALIDATION (C=1000, gamma=0.001): accuracy score: 0.8571
RBF on VALIDATION (C=1000, gamma=0.01): accuracy score: 0.8571
RBF on VALIDATION (C=1000, gamma=0.1): accuracy score: 0.8286
RBF on VALIDATION (C=1000, gamma=1): accuracy score: 0.8286
RBF on VALIDATION (C=1000, gamma=100): accuracy score: 0.7143
RBF on VALIDATION (C=1000, gamma=1000): accuracy score: 0.4571
```




```
Best accuracy on VALIDATION: 0.8857
Best C: 1
Best gamma: 1
```




```
Best RBF on TEST (C=1, gamma=1): accuracy: 0.8333
```

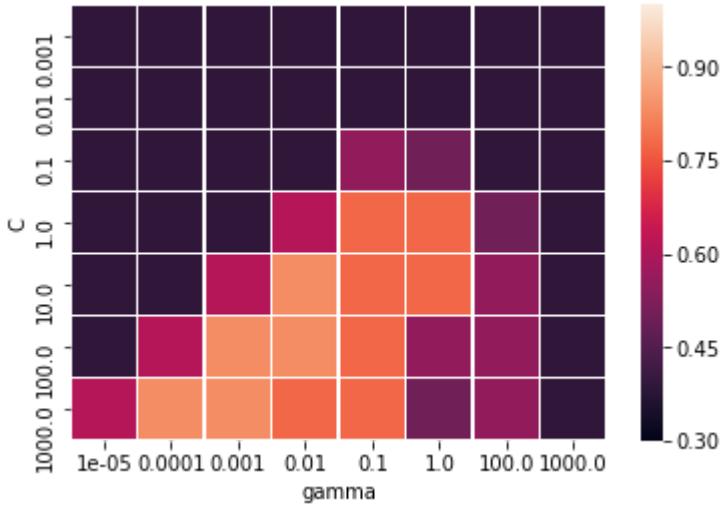
The heatmap represents the accuracy scores optained varying C and gamma, lighter cells shows better scores. The best combination (C=1 and gamma=1) gives an accuracy score slightly lower 90%, the model applied to the test set exceeds 80%. It is evident that cycling both the parameters lead to a better result instead of using the default parameters.

SVM classifier with RBF Kernel cycling gamma with K-Fold Validation

Train set and validation set are now merged to apply a 5-fold validation. The **K-fold validation** is an iteration procedure in which all the data, except the test ones, are randomly splitted K times into train and validation in different ways in order to perform the procedure avoiding special cases of samples distribution.

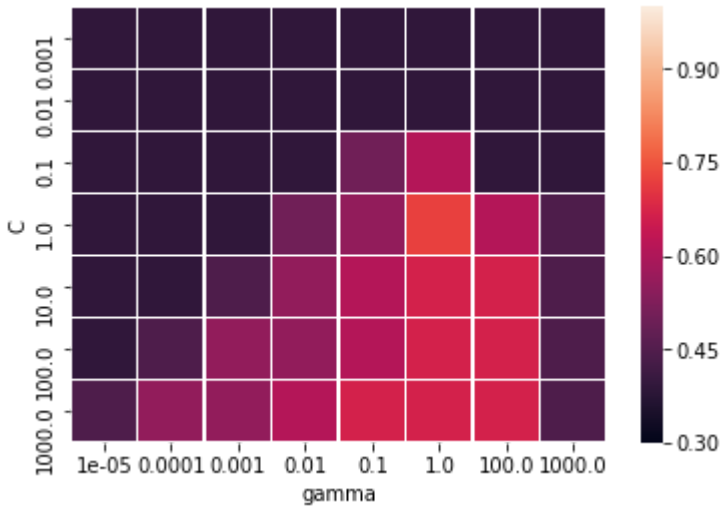
```
RBF on VALIDATION (split 0, C=0.001, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.001, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.001, gamma=0.001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.001, gamma=0.01): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.001, gamma=0.1): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.001, gamma=1): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.001, gamma=100): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.001, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.01, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.01, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.01, gamma=0.001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.01, gamma=0.01): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.01, gamma=0.1): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.01, gamma=1): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.01, gamma=100): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.01, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.1, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.1, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.1, gamma=0.001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.1, gamma=0.01): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.1, gamma=0.1): accuracy score: 0.5556
RBF on VALIDATION (split 0, C=0.1, gamma=1): accuracy score: 0.5000
RBF on VALIDATION (split 0, C=0.1, gamma=100): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=0.1, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=1, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=1, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=1, gamma=0.001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=1, gamma=0.01): accuracy score: 0.6111
RBF on VALIDATION (split 0, C=1, gamma=0.1): accuracy score: 0.7778
RBF on VALIDATION (split 0, C=1, gamma=1): accuracy score: 0.7778
RBF on VALIDATION (split 0, C=1, gamma=100): accuracy score: 0.5000
RBF on VALIDATION (split 0, C=1, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=10, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=10, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=10, gamma=0.001): accuracy score: 0.6111
RBF on VALIDATION (split 0, C=10, gamma=0.01): accuracy score: 0.8333
RBF on VALIDATION (split 0, C=10, gamma=0.1): accuracy score: 0.7778
RBF on VALIDATION (split 0, C=10, gamma=1): accuracy score: 0.7778
RBF on VALIDATION (split 0, C=10, gamma=100): accuracy score: 0.5556
RBF on VALIDATION (split 0, C=10, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=100, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=100, gamma=0.0001): accuracy score: 0.6111
RBF on VALIDATION (split 0, C=100, gamma=0.001): accuracy score: 0.8333
RBF on VALIDATION (split 0, C=100, gamma=0.01): accuracy score: 0.8333
RBF on VALIDATION (split 0, C=100, gamma=0.1): accuracy score: 0.7778
RBF on VALIDATION (split 0, C=100, gamma=1): accuracy score: 0.5556
RBF on VALIDATION (split 0, C=100, gamma=100): accuracy score: 0.5556
RBF on VALIDATION (split 0, C=100, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 0, C=1000, gamma=1e-05): accuracy score: 0.6111
RBF on VALIDATION (split 0, C=1000, gamma=0.0001): accuracy score: 0.8333
```

```
RBF on VALIDATION (split 0, C=1000, gamma=0.001): accuracy score: 0.8333
RBF on VALIDATION (split 0, C=1000, gamma=0.01): accuracy score: 0.7778
RBF on VALIDATION (split 0, C=1000, gamma=0.1): accuracy score: 0.7778
RBF on VALIDATION (split 0, C=1000, gamma=1): accuracy score: 0.5000
RBF on VALIDATION (split 0, C=1000, gamma=100): accuracy score: 0.5556
RBF on VALIDATION (split 0, C=1000, gamma=1000): accuracy score: 0.3889
```



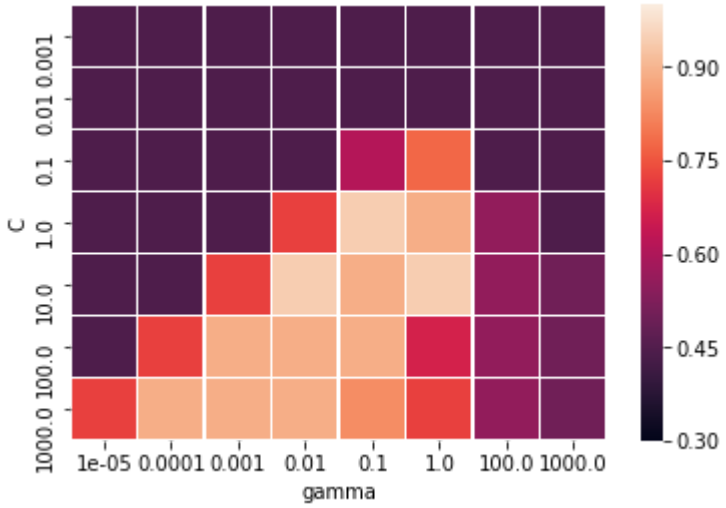

```
RBF on VALIDATION (split 1, C=0.001, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.001, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.001, gamma=0.001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.001, gamma=0.01): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.001, gamma=0.1): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.001, gamma=1): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.001, gamma=100): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.001, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.01, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.01, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.01, gamma=0.001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.01, gamma=0.01): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.01, gamma=0.1): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.01, gamma=1): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.01, gamma=100): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.01, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.1, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.1, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.1, gamma=0.001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.1, gamma=0.01): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.1, gamma=0.1): accuracy score: 0.5000
RBF on VALIDATION (split 1, C=0.1, gamma=1): accuracy score: 0.6111
RBF on VALIDATION (split 1, C=0.1, gamma=100): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=0.1, gamma=1000): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=1, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=1, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=1, gamma=0.001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=1, gamma=0.01): accuracy score: 0.5000
```

```
RBF on VALIDATION (split 1, C=1, gamma=0.1): accuracy score: 0.5556
RBF on VALIDATION (split 1, C=1, gamma=1): accuracy score: 0.7222
RBF on VALIDATION (split 1, C=1, gamma=100): accuracy score: 0.6111
RBF on VALIDATION (split 1, C=1, gamma=1000): accuracy score: 0.4444
RBF on VALIDATION (split 1, C=10, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=10, gamma=0.0001): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=10, gamma=0.001): accuracy score: 0.4444
RBF on VALIDATION (split 1, C=10, gamma=0.01): accuracy score: 0.5556
RBF on VALIDATION (split 1, C=10, gamma=0.1): accuracy score: 0.6111
RBF on VALIDATION (split 1, C=10, gamma=1): accuracy score: 0.6667
RBF on VALIDATION (split 1, C=10, gamma=100): accuracy score: 0.6667
RBF on VALIDATION (split 1, C=10, gamma=1000): accuracy score: 0.4444
RBF on VALIDATION (split 1, C=100, gamma=1e-05): accuracy score: 0.3889
RBF on VALIDATION (split 1, C=100, gamma=0.0001): accuracy score: 0.4444
RBF on VALIDATION (split 1, C=100, gamma=0.001): accuracy score: 0.5556
RBF on VALIDATION (split 1, C=100, gamma=0.01): accuracy score: 0.5556
RBF on VALIDATION (split 1, C=100, gamma=0.1): accuracy score: 0.6111
RBF on VALIDATION (split 1, C=100, gamma=1): accuracy score: 0.6667
RBF on VALIDATION (split 1, C=100, gamma=100): accuracy score: 0.6667
RBF on VALIDATION (split 1, C=100, gamma=1000): accuracy score: 0.4444
RBF on VALIDATION (split 1, C=1000, gamma=1e-05): accuracy score: 0.4444
RBF on VALIDATION (split 1, C=1000, gamma=0.0001): accuracy score: 0.5556
RBF on VALIDATION (split 1, C=1000, gamma=0.001): accuracy score: 0.5556
RBF on VALIDATION (split 1, C=1000, gamma=0.01): accuracy score: 0.6111
RBF on VALIDATION (split 1, C=1000, gamma=0.1): accuracy score: 0.6667
RBF on VALIDATION (split 1, C=1000, gamma=1): accuracy score: 0.6667
RBF on VALIDATION (split 1, C=1000, gamma=100): accuracy score: 0.6667
RBF on VALIDATION (split 1, C=1000, gamma=1000): accuracy score: 0.4444
```



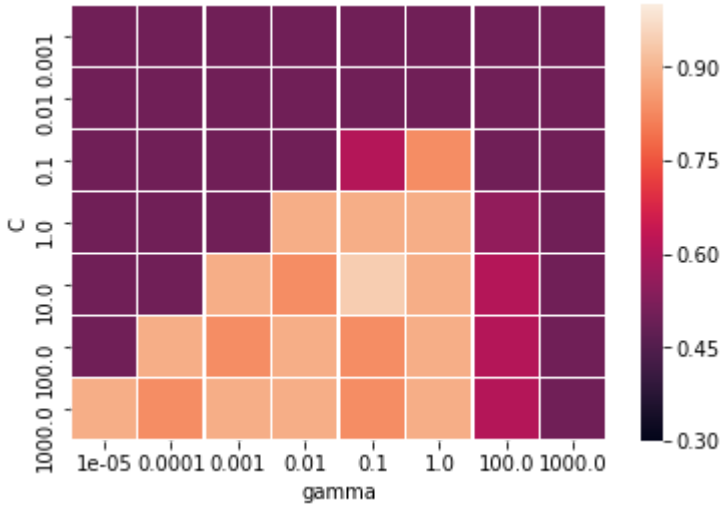

```
RBF on VALIDATION (split 2, C=0.001, gamma=1e-05): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.001, gamma=0.0001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.001, gamma=0.001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.001, gamma=0.01): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.001, gamma=0.1): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.001, gamma=1): accuracy score: 0.4444
```

```
RBF on VALIDATION (split 2, C=0.001, gamma=100): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.001, gamma=1000): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.01, gamma=1e-05): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.01, gamma=0.0001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.01, gamma=0.001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.01, gamma=0.01): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.01, gamma=0.1): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.01, gamma=1): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.01, gamma=100): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.01, gamma=1000): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.1, gamma=1e-05): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.1, gamma=0.0001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.1, gamma=0.001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.1, gamma=0.01): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.1, gamma=0.1): accuracy score: 0.6111
RBF on VALIDATION (split 2, C=0.1, gamma=1): accuracy score: 0.7778
RBF on VALIDATION (split 2, C=0.1, gamma=100): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=0.1, gamma=1000): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=1, gamma=1e-05): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=1, gamma=0.0001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=1, gamma=0.001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=1, gamma=0.01): accuracy score: 0.7222
RBF on VALIDATION (split 2, C=1, gamma=0.1): accuracy score: 0.9444
RBF on VALIDATION (split 2, C=1, gamma=1): accuracy score: 0.8889
RBF on VALIDATION (split 2, C=1, gamma=100): accuracy score: 0.5556
RBF on VALIDATION (split 2, C=1, gamma=1000): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=10, gamma=1e-05): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=10, gamma=0.0001): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=10, gamma=0.001): accuracy score: 0.7222
RBF on VALIDATION (split 2, C=10, gamma=0.01): accuracy score: 0.9444
RBF on VALIDATION (split 2, C=10, gamma=0.1): accuracy score: 0.8889
RBF on VALIDATION (split 2, C=10, gamma=1): accuracy score: 0.9444
RBF on VALIDATION (split 2, C=10, gamma=100): accuracy score: 0.5556
RBF on VALIDATION (split 2, C=10, gamma=1000): accuracy score: 0.5000
RBF on VALIDATION (split 2, C=100, gamma=1e-05): accuracy score: 0.4444
RBF on VALIDATION (split 2, C=100, gamma=0.0001): accuracy score: 0.7222
RBF on VALIDATION (split 2, C=100, gamma=0.001): accuracy score: 0.8889
RBF on VALIDATION (split 2, C=100, gamma=0.01): accuracy score: 0.8889
RBF on VALIDATION (split 2, C=100, gamma=0.1): accuracy score: 0.8889
RBF on VALIDATION (split 2, C=100, gamma=1): accuracy score: 0.6667
RBF on VALIDATION (split 2, C=100, gamma=100): accuracy score: 0.5556
RBF on VALIDATION (split 2, C=100, gamma=1000): accuracy score: 0.5000
RBF on VALIDATION (split 2, C=1000, gamma=1e-05): accuracy score: 0.7222
RBF on VALIDATION (split 2, C=1000, gamma=0.0001): accuracy score: 0.8889
RBF on VALIDATION (split 2, C=1000, gamma=0.001): accuracy score: 0.8889
RBF on VALIDATION (split 2, C=1000, gamma=0.01): accuracy score: 0.8889
RBF on VALIDATION (split 2, C=1000, gamma=0.1): accuracy score: 0.8333
RBF on VALIDATION (split 2, C=1000, gamma=1): accuracy score: 0.7222
RBF on VALIDATION (split 2, C=1000, gamma=100): accuracy score: 0.5556
RBF on VALIDATION (split 2, C=1000, gamma=1000): accuracy score: 0.5000
```



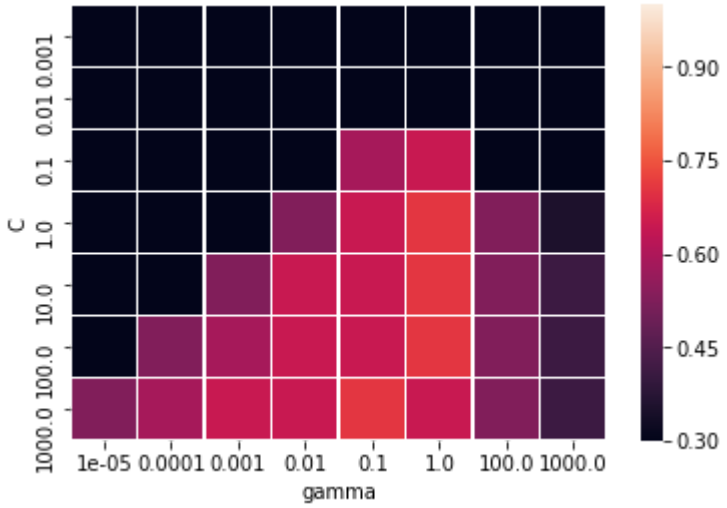

```
RBF on VALIDATION (split 3, C=0.001, gamma=1e-05): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.001, gamma=0.0001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.001, gamma=0.001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.001, gamma=0.01): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.001, gamma=0.1): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.001, gamma=1): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.001, gamma=100): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.001, gamma=1000): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.01, gamma=1e-05): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.01, gamma=0.0001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.01, gamma=0.001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.01, gamma=0.01): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.01, gamma=0.1): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.01, gamma=1): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.01, gamma=100): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.01, gamma=1000): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.1, gamma=1e-05): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.1, gamma=0.0001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.1, gamma=0.001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.1, gamma=0.01): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.1, gamma=0.1): accuracy score: 0.6111
RBF on VALIDATION (split 3, C=0.1, gamma=1): accuracy score: 0.8333
RBF on VALIDATION (split 3, C=0.1, gamma=100): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=0.1, gamma=1000): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=1, gamma=1e-05): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=1, gamma=0.0001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=1, gamma=0.001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=1, gamma=0.01): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=1, gamma=0.1): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=1, gamma=1): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=1, gamma=100): accuracy score: 0.5556
RBF on VALIDATION (split 3, C=1, gamma=1000): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=10, gamma=1e-05): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=10, gamma=0.0001): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=10, gamma=0.001): accuracy score: 0.8889
```

```
RBF on VALIDATION (split 3, C=10, gamma=0.01): accuracy score: 0.8333
RBF on VALIDATION (split 3, C=10, gamma=0.1): accuracy score: 0.9444
RBF on VALIDATION (split 3, C=10, gamma=1): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=10, gamma=100): accuracy score: 0.6111
RBF on VALIDATION (split 3, C=10, gamma=1000): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=100, gamma=1e-05): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=100, gamma=0.0001): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=100, gamma=0.001): accuracy score: 0.8333
RBF on VALIDATION (split 3, C=100, gamma=0.01): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=100, gamma=0.1): accuracy score: 0.8333
RBF on VALIDATION (split 3, C=100, gamma=1): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=100, gamma=100): accuracy score: 0.6111
RBF on VALIDATION (split 3, C=100, gamma=1000): accuracy score: 0.5000
RBF on VALIDATION (split 3, C=1000, gamma=1e-05): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=1000, gamma=0.0001): accuracy score: 0.8333
RBF on VALIDATION (split 3, C=1000, gamma=0.001): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=1000, gamma=0.01): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=1000, gamma=0.1): accuracy score: 0.8333
RBF on VALIDATION (split 3, C=1000, gamma=1): accuracy score: 0.8889
RBF on VALIDATION (split 3, C=1000, gamma=100): accuracy score: 0.6111
RBF on VALIDATION (split 3, C=1000, gamma=1000): accuracy score: 0.5000
```

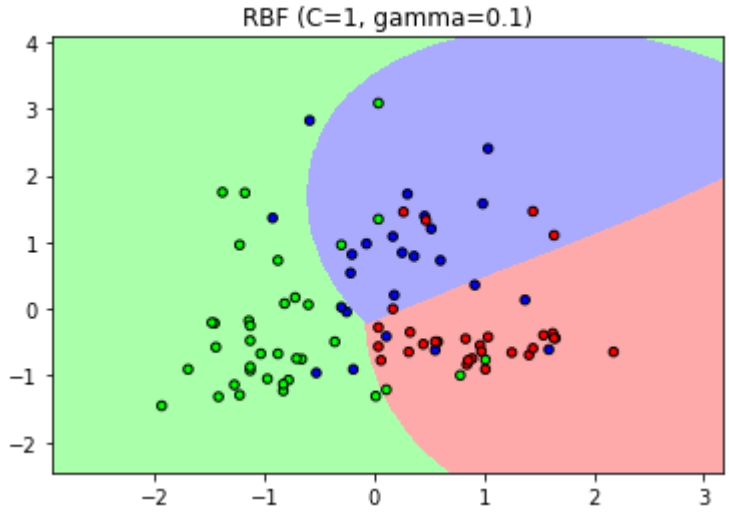



```
RBF on VALIDATION (split 4, C=0.001, gamma=1e-05): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.001, gamma=0.0001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.001, gamma=0.001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.001, gamma=0.01): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.001, gamma=0.1): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.001, gamma=1): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.001, gamma=100): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.001, gamma=1000): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.01, gamma=1e-05): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.01, gamma=0.0001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.01, gamma=0.001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.01, gamma=0.01): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.01, gamma=0.1): accuracy score: 0.2941
```

```
RBF on VALIDATION (split 4, C=0.01, gamma=1): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.01, gamma=100): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.01, gamma=1000): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.1, gamma=1e-05): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.1, gamma=0.0001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.1, gamma=0.001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.1, gamma=0.01): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.1, gamma=0.1): accuracy score: 0.5882
RBF on VALIDATION (split 4, C=0.1, gamma=1): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=0.1, gamma=100): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=0.1, gamma=1000): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=1, gamma=1e-05): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=1, gamma=0.0001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=1, gamma=0.001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=1, gamma=0.01): accuracy score: 0.5294
RBF on VALIDATION (split 4, C=1, gamma=0.1): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=1, gamma=1): accuracy score: 0.7059
RBF on VALIDATION (split 4, C=1, gamma=100): accuracy score: 0.5294
RBF on VALIDATION (split 4, C=1, gamma=1000): accuracy score: 0.3529
RBF on VALIDATION (split 4, C=10, gamma=1e-05): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=10, gamma=0.0001): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=10, gamma=0.001): accuracy score: 0.5294
RBF on VALIDATION (split 4, C=10, gamma=0.01): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=10, gamma=0.1): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=10, gamma=1): accuracy score: 0.7059
RBF on VALIDATION (split 4, C=10, gamma=100): accuracy score: 0.5294
RBF on VALIDATION (split 4, C=10, gamma=1000): accuracy score: 0.4118
RBF on VALIDATION (split 4, C=100, gamma=1e-05): accuracy score: 0.2941
RBF on VALIDATION (split 4, C=100, gamma=0.0001): accuracy score: 0.5294
RBF on VALIDATION (split 4, C=100, gamma=0.001): accuracy score: 0.5882
RBF on VALIDATION (split 4, C=100, gamma=0.01): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=100, gamma=0.1): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=100, gamma=1): accuracy score: 0.7059
RBF on VALIDATION (split 4, C=100, gamma=100): accuracy score: 0.5294
RBF on VALIDATION (split 4, C=100, gamma=1000): accuracy score: 0.4118
RBF on VALIDATION (split 4, C=1000, gamma=1e-05): accuracy score: 0.5294
RBF on VALIDATION (split 4, C=1000, gamma=0.0001): accuracy score: 0.5882
RBF on VALIDATION (split 4, C=1000, gamma=0.001): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=1000, gamma=0.01): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=1000, gamma=0.1): accuracy score: 0.7059
RBF on VALIDATION (split 4, C=1000, gamma=1): accuracy score: 0.6471
RBF on VALIDATION (split 4, C=1000, gamma=100): accuracy score: 0.5294
RBF on VALIDATION (split 4, C=1000, gamma=1000): accuracy score: 0.4118
```




```
Best accuracy on VALIDATION: 0.9444 (split 2)
Best C: 1
Best gamma: 0.1
```




```
Best RBF on TEST (C=1, gamma=0.1): accuracy: 0.7963
```

The procedure of train and validation is performed cycling C and gamma for each of the 5 different splits, the heatmaps show that for each split the results are similar in reference to parameters but each time quite better or worse. The best C and gamma are selected, though the best accuracy score on one of the the validations is 94%, the model on test set scores less than 80%. This denotes that, in this case and with this dataset, K-fold did not bring to a better result.