Assignments 3

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1 MScBMI 33200 – Machine Learning for Biomedical Informatics

2 Assignment IV

Name: Troy Zhongyi Zhang
Netid: zhongyiz@uchicago.edu

2.0.1 Directions:

1. Fill out below information (tables and methods)
2. Submit this document along with your code in an HTML/PDF format

2.0.2 Section 1: EMR Bots 30-day Readmission study

Using the training datasets, create the following models:
1. Naïve model: This model utilizes only patient characteristics (age, gender and race) to predict 30-day readmission in a logistic regression framework
2. GLM model : This model utilizes patient characteristics and most-recent lab recordings to predict 30-day admissions in a logistic regression framework.
3. ANN model: This model utilizes patient characteristics and most-recent lab recordings to predict 30-day admissions using an artificial neural network. Feature engineering steps include balancing classes using SMOTE as well as data normalization/standardization of continuous variables.

Utilize a five-fold cross-validation technique to build your model.
Calculate AUC on the test dataset. Fill out the following Table.

[1]:
```
import pandas as pd
import numpy as np
from random import seed
seed(1)
```

[2]:
```
r_outcome = pd.read_csv("readmission_outcome.csv")
info = pd.read_csv("encounter_info.csv")
#df1 = pd.merge(info, r_outcome, on = "Encounter_ID")
labs = pd.read_csv("encounter_labs.csv")
```

[3]:
```
labs = labs.groupby(['Encounter_ID']).tail(1)
labs = labs.reset_index(drop=True)
wrong_ids = labs.iloc[:7]
wrong_ids['Encounter_ID'] = pd.DataFrame(wrong_ids['Encounter_ID'
                                                  ]).applymap(lambda x: x.
 ↪replace('1e+05', '100000'))
labs.head()
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/ipykernel_launcher.py:5: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: http://pandas.pydata.org/pandas-
docs/stable/indexing.html#indexing-view-versus-copy
  """
```

[3]:

	Encounter_ID	Lab_DTTM	CBC..ABSOLUTE.LYMPHOCYTES	CBC..ABSOLUTE.NEUTROPHILS	CBC..BASOPHILS	CBC..EOSINOPHILS	CBC..HEMATOCRIT	CBC..HEMOGLOBIN	CBC..PLATELET.COUNT	CBC..RED.BLOOD.CELL.COUNT	CBC..WHITE.BLOOD.CELL.COUNT	METABOLIC..ALBUMIN	METABOLIC..BILI.TOTAL	METABOLIC..BUN	METABOLIC..CALCIUM
0	100000_1	1981-01-08 23:28:24	32.8	76.4	0.0	0.1	35.9	14.8	386.0	4.8	10.7	5.8	0.8	12.6	11.1
1	100000_2	1996-02-06 17:07:30	16.1	77.9	0.2	0.4	49.6	16.2	339.2	5.8	6.4	2.7			
2	100000_3	2002-04-11 00:36:27	23.4	66.2	0.1	0.4	40.4	18.7	408.7	3.2	8.5	3.7			
3	100000_4	2006-11-29 12:01:11	15.7	78.3	0.0	0.2	54.4	18.9	128.6	5.9	7.0	4.0			
4	100000_5	2007-04-27 16:49:40	27.4	62.2	0.1	0.4	45.2	16.8	315.4	4.9	11.8	5.9			

```
1                    0.9            15.6                 8.1
2                    0.3            15.1                 7.9
3                    0.9            24.4                 7.0
4                    0.1            21.4                 7.5

   METABOLIC..CREATININE  METABOLIC..POTASSIUM  METABOLIC..SODIUM
0                    0.9                   4.1              135.5
1                    1.2                   4.7              140.9
2                    0.7                   5.3              150.0
3                    1.1                   4.4              155.0
4                    0.8                   5.6              137.1
```

[4]:
```
read1 = pd.merge(info, labs, on = "Encounter_ID")
read = pd.merge(read1,r_outcome, on = "Encounter_ID")
read['PatientGender'] = read['PatientGender'].replace('Female',1)
read['PatientGender'] = read['PatientGender'].replace('Male',0)
read['PatientGender'] = read['PatientGender'].astype('category').cat.codes

read['PatientRace'] = read['PatientRace'].replace('African American',0)
read['PatientRace'] = read['PatientRace'].replace('White',1)
read['PatientRace'] = read['PatientRace'].replace('Asian',2)
read['PatientRace'] = read['PatientRace'].replace('Unknown',3)
read['PatientRace'] = read['PatientRace'].astype('category').cat.codes

read_train = read[read["AdmissionEndDate"].str[:4].astype(int)<=2004]
read_test = read[read["AdmissionEndDate"].str[:4].astype(int)>2004]
# read_train = read_train.reset_index(drop=True)
# read_test = read_test.reset_index(drop=True)

read_Xtrain1 = read_train[['PatientEncounterAge','PatientGender','PatientRace']]
read_ytrain1 = read_train[['outcome']]
read_Xtest1 = read_test[['PatientEncounterAge','PatientGender','PatientRace']]
read_ytest1 = read_test[['outcome']]
```

3 Naïve model:

3.0.1 readmission - read

[5]:
```
#from sklearn import naive_bayes
from sklearn.naive_bayes import GaussianNB
naive = GaussianNB()
nb = naive.fit(read_Xtrain1, read_ytrain1)
y_pred1 = nb.predict(read_Xtest1)
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
```

```
packages/sklearn/utils/validation.py:724: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

[6]:
```
prob1 = nb.predict_proba(read_Xtest1)
prob1
```

[6]:
```
array([[0.99599489, 0.00400511],
       [0.99527026, 0.00472974],
       [0.99604199, 0.00395801],
       …,
       [0.98164369, 0.01835631],
       [0.99535436, 0.00464564],
       [0.99434525, 0.00565475]])
```

[7]:
```
from sklearn import metrics
nb_matrix1 = metrics.confusion_matrix(read_ytest1, y_pred1)
nb_matrix1
```

[7]:
```
array([[14599,     0],
       [   50,     0]])
```

[8]:
```
target_names1 = ['Not in 30 days', 'Readmitted within 30 days']
from sklearn.metrics import classification_report
print("", classification_report(read_ytest1, y_pred1,␣
 ↪target_names=target_names1))
```

```
                          precision    recall  f1-score   support

           Not in 30 days       1.00      1.00      1.00     14599
Readmitted within 30 days       0.00      0.00      0.00        50

                 accuracy                           1.00     14649
                macro avg       0.50      0.50      0.50     14649
             weighted avg       0.99      1.00      0.99     14649
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/metrics/classification.py:1437: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples.
  'precision', 'predicted', average, warn_for)
```

[9]:
```
from sklearn.metrics import roc_auc_score
nb_probs = nb.predict_proba(read_Xtest1)[:,1]
print(roc_auc_score(read_ytest1, nb_probs))
```

0.49090485649702037

[10]:
```
from sklearn.metrics import accuracy_score
as1 = accuracy_score(read_ytest1, y_pred1)
```

[11]:
```
as1
```

[11]: 0.9965867977336337

[12]:
```
error1 = 1-as1
error1
```

[12]: 0.003413202266366322

[13]:
```
n1 = len(y_pred1)
```

[14]:
```
import math
error1 + 1.96 * math.sqrt((error1 * (1 - error1)) / n1)
```

[14]: 0.004357677685114603

[15]:
```
error1 - 1.96 * math.sqrt((error1 * (1 - error1)) / n1)
```

[15]: 0.0024687268476180405

[16]:
```
import numpy as np, scipy.stats as st
st.t.interval(0.95, len(read_ytest1)-1, loc=np.mean(read_ytest1), scale=st.
 ↪sem(read_ytest1))
```

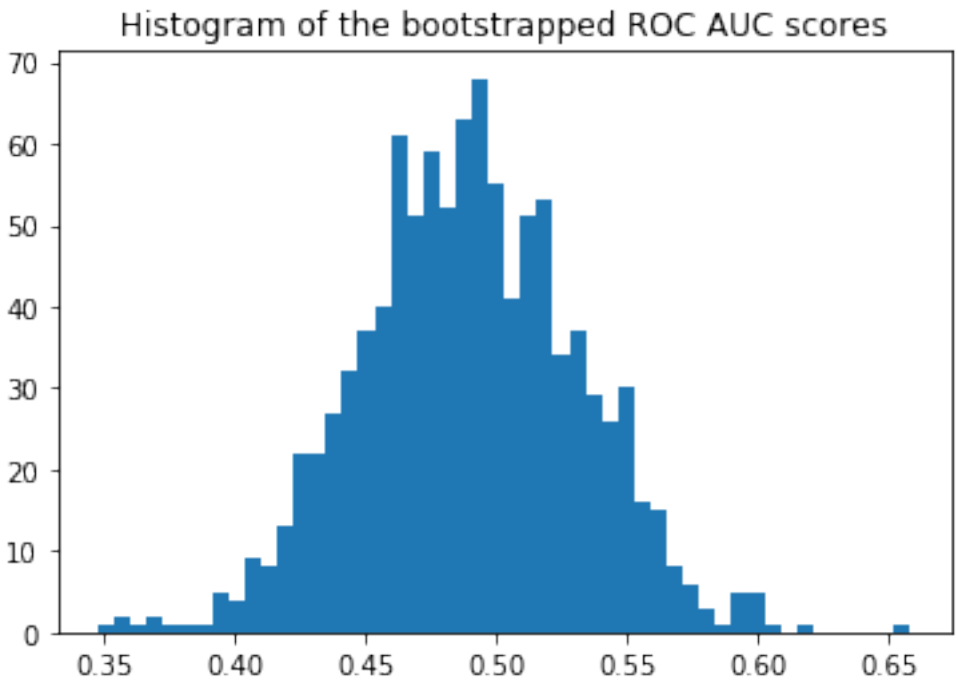
[16]: (array([0.00246863]), array([0.00435777]))

[17]:
```
read_ytest1 = read_ytest1.values
```

[20]:
```
#Calculated the Confidence Interval by bootstrapping
import numpy as np
from scipy.stats import sem
from sklearn.metrics import roc_auc_score

y_pred = nb_probs
y_true = read_ytest1

print("Original ROC area: {:0.4f}".format(roc_auc_score(y_true, y_pred)))

n_bootstraps = 1000
rng_seed = 42  # control reproducibility
bootstrapped_scores = []
```

```
rng = np.random.RandomState(rng_seed)
for i in range(n_bootstraps):
    # bootstrap by sampling with replacement on the prediction indices
    indices = rng.randint(0, len(y_pred), len(y_pred))
    if len(np.unique(y_true[indices])) < 2:
        # We need at least one positive and one negative sample for ROC AUC
        # to be defined: reject the sample
        continue

    score = roc_auc_score(y_true[indices], y_pred[indices])
    bootstrapped_scores.append(score)
    #print("Bootstrap #{} ROC area: {:0.3f}".format(i + 1, score))

import matplotlib.pyplot as plt
plt.hist(bootstrapped_scores, bins=50)
plt.title('Histogram of the bootstrapped ROC AUC scores')
plt.show()

sorted_scores = np.array(bootstrapped_scores)
sorted_scores.sort()

# Computing the lower and upper bound of the 90% confidence interval
# You can change the bounds percentiles to 0.025 and 0.975 to get
# a 95% confidence interval instead.
confidence_lower = sorted_scores[int(0.05 * len(sorted_scores))]
confidence_upper = sorted_scores[int(0.95 * len(sorted_scores))]
print("Confidence interval for the score: [{:0.4f} - {:0.4}]".format(
    confidence_lower, confidence_upper))
```

```
Original ROC area: 0.4909
```




```
Confidence interval for the score: [0.4232 - 0.5578]
```

[21]:
```python
#Transplanted the pROC package from R into Python for CI computation
import numpy as np
import scipy.stats
from scipy import stats

read_ytest1=read_ytest1.reshape((14649,))
# AUC comparison adapted from
# https://github.com/Netflix/vmaf/
def compute_midrank(x):
    """Computes midranks.
    Args:
       x - a 1D numpy array
    Returns:
       array of midranks
    """
    J = np.argsort(x)
    Z = x[J]
    N = len(x)
    T = np.zeros(N, dtype=np.float)
    i = 0
    while i < N:
        j = i
        while j < N and Z[j] == Z[i]:
```

```
            j += 1
        T[i:j] = 0.5*(i + j - 1)
        i = j
    T2 = np.empty(N, dtype=np.float)
    # Note(kazeevn) +1 is due to Python using 0-based indexing
    # instead of 1-based in the AUC formula in the paper
    T2[J] = T + 1
    return T2


def compute_midrank_weight(x, sample_weight):
    """Computes midranks.
    Args:
       x - a 1D numpy array
    Returns:
       array of midranks
    """
    J = np.argsort(x)
    Z = x[J]
    cumulative_weight = np.cumsum(sample_weight[J])
    N = len(x)
    T = np.zeros(N, dtype=np.float)
    i = 0
    while i < N:
        j = i
        while j < N and Z[j] == Z[i]:
            j += 1
        T[i:j] = cumulative_weight[i:j].mean()
        i = j
    T2 = np.empty(N, dtype=np.float)
    T2[J] = T
    return T2


def fastDeLong(predictions_sorted_transposed, label_1_count, sample_weight):
    if sample_weight is None:
        return fastDeLong_no_weights(predictions_sorted_transposed,␣
 ↪label_1_count)
    else:
        return fastDeLong_weights(predictions_sorted_transposed, label_1_count,␣
 ↪sample_weight)


def fastDeLong_weights(predictions_sorted_transposed, label_1_count,␣
 ↪sample_weight):
    """
    The fast version of DeLong's method for computing the covariance of
```

```
    unadjusted AUC.
    Args:
       predictions_sorted_transposed: a 2D numpy.array[n_classifiers,␣
↪n_examples]
          sorted such as the examples with label "1" are first
    Returns:
       (AUC value, DeLong covariance)
    Reference:
     @article{sun2014fast,
       title={Fast Implementation of DeLong's Algorithm for
              Comparing the Areas Under Correlated Receiver Oerating␣
↪Characteristic Curves},
       author={Xu Sun and Weichao Xu},
       journal={IEEE Signal Processing Letters},
       volume={21},
       number={11},
       pages={1389--1393},
       year={2014},
       publisher={IEEE}
     }
    """
    # Short variables are named as they are in the paper
    m = label_1_count
    n = predictions_sorted_transposed.shape[1] - m
    positive_examples = predictions_sorted_transposed[:, :m]
    negative_examples = predictions_sorted_transposed[:, m:]
    k = predictions_sorted_transposed.shape[0]

    tx = np.empty([k, m], dtype=np.float)
    ty = np.empty([k, n], dtype=np.float)
    tz = np.empty([k, m + n], dtype=np.float)
    for r in range(k):
        tx[r, :] = compute_midrank_weight(positive_examples[r, :],␣
↪sample_weight[:m])
        ty[r, :] = compute_midrank_weight(negative_examples[r, :],␣
↪sample_weight[m:])
        tz[r, :] = compute_midrank_weight(predictions_sorted_transposed[r, :],␣
↪sample_weight)
    total_positive_weights = sample_weight[:m].sum()
    total_negative_weights = sample_weight[m:].sum()
    pair_weights = np.dot(sample_weight[:m, np.newaxis], sample_weight[np.
↪newaxis, m:])
    total_pair_weights = pair_weights.sum()
    aucs = (sample_weight[:m]*(tz[:, :m] - tx)).sum(axis=1) / total_pair_weights
    v01 = (tz[:, :m] - tx[:, :]) / total_negative_weights
    v10 = 1. - (tz[:, m:] - ty[:, :]) / total_positive_weights
```

```
    sx = np.cov(v01)
    sy = np.cov(v10)
    delongcov = sx / m + sy / n
    return aucs, delongcov


def fastDeLong_no_weights(predictions_sorted_transposed, label_1_count):
    """
    The fast version of DeLong's method for computing the covariance of
    unadjusted AUC.
    Args:
       predictions_sorted_transposed: a 2D numpy.array[n_classifiers,␣
 ↪n_examples]
          sorted such as the examples with label "1" are first
    Returns:
       (AUC value, DeLong covariance)
    Reference:
     @article{sun2014fast,
       title={Fast Implementation of DeLong's Algorithm for
              Comparing the Areas Under Correlated Receiver Oerating
              Characteristic Curves},
       author={Xu Sun and Weichao Xu},
       journal={IEEE Signal Processing Letters},
       volume={21},
       number={11},
       pages={1389--1393},
       year={2014},
       publisher={IEEE}
     }
    """
    # Short variables are named as they are in the paper
    m = label_1_count
    n = predictions_sorted_transposed.shape[1] - m
    positive_examples = predictions_sorted_transposed[:, :m]
    negative_examples = predictions_sorted_transposed[:, m:]
    k = predictions_sorted_transposed.shape[0]

    tx = np.empty([k, m], dtype=np.float)
    ty = np.empty([k, n], dtype=np.float)
    tz = np.empty([k, m + n], dtype=np.float)
    for r in range(k):
        tx[r, :] = compute_midrank(positive_examples[r, :])
        ty[r, :] = compute_midrank(negative_examples[r, :])
        tz[r, :] = compute_midrank(predictions_sorted_transposed[r, :])
    aucs = tz[:, :m].sum(axis=1) / m / n - float(m + 1.0) / 2.0 / n
    v01 = (tz[:, :m] - tx[:, :]) / n
    v10 = 1.0 - (tz[:, m:] - ty[:, :]) / m
```

```
    sx = np.cov(v01)
    sy = np.cov(v10)
    delongcov = sx / m + sy / n
    return aucs, delongcov


def calc_pvalue(aucs, sigma):
    """Computes log(10) of p-values.
    Args:
       aucs: 1D array of AUCs
       sigma: AUC DeLong covariances
    Returns:
       log10(pvalue)
    """
    l = np.array([[1, -1]])
    z = np.abs(np.diff(aucs)) / np.sqrt(np.dot(np.dot(l, sigma), l.T))
    return np.log10(2) + scipy.stats.norm.logsf(z, loc=0, scale=1) / np.log(10)


def compute_ground_truth_statistics(ground_truth, sample_weight):
    assert np.array_equal(np.unique(ground_truth), [0, 1])
    order = (-ground_truth).argsort()
    label_1_count = int(ground_truth.sum())
    if sample_weight is None:
        ordered_sample_weight = None
    else:
        ordered_sample_weight = sample_weight[order]

    return order, label_1_count, ordered_sample_weight


def delong_roc_variance(ground_truth, predictions, sample_weight=None):
    """
    Computes ROC AUC variance for a single set of predictions
    Args:
       ground_truth: np.array of 0 and 1
       predictions: np.array of floats of the probability of being class 1
    """
    order, label_1_count, ordered_sample_weight =␣
↪compute_ground_truth_statistics(
        ground_truth, sample_weight)
    predictions_sorted_transposed = predictions[np.newaxis, order]
    aucs, delongcov = fastDeLong(predictions_sorted_transposed, label_1_count,␣
↪ordered_sample_weight)
    assert len(aucs) == 1, "There is a bug in the code, please forward this to␣
↪the developers"
    return aucs[0], delongcov
```

```
alpha = .95
y_pred = nb_probs
y_true = read_ytest1

auc, auc_cov = delong_roc_variance(
    y_true,
    y_pred)

auc_std = np.sqrt(auc_cov)
lower_upper_q = np.abs(np.array([0, 1]) - (1 - alpha) / 2)

ci = stats.norm.ppf(
    lower_upper_q,
    loc=auc,
    scale=auc_std)

ci[ci > 1] = 1

print('AUC:', auc)
print('AUC COV:', auc_cov)
print('95% AUC CI:', ci)
```

```
AUC: 0.49090485649702037
AUC COV: 0.0016849429801989745
95% AUC CI: [0.41045214 0.57135757]
```

4 Logistic Regression model

[22]:
```
read_Xtrain2 = read_train.
 ↪drop(["Patient_ID","Encounter_ID","AdmissionStartDate",
                                "AdmissionEndDate","Lab_DTTM",␣
 ↪"outcome"],axis=1)
read_ytrain2 = read_train[['outcome']]
read_Xtest2 = read_test.drop(["Patient_ID","Encounter_ID","AdmissionStartDate",
                              "AdmissionEndDate","Lab_DTTM", "outcome"],axis=1)
read_ytest2 = read_test[['outcome']]
```

[23]:
```
from sklearn.linear_model import LogisticRegression
lg = LogisticRegression(random_state=0,␣
 ↪solver='lbfgs',multi_class='multinomial')
lg = lg.fit(read_Xtrain2, read_ytrain2)
y_pred2 = lg.predict(read_Xtest2)
y_pred2
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/utils/validation.py:724: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/linear_model/logistic.py:947: ConvergenceWarning: lbfgs failed
to converge. Increase the number of iterations.
  "of iterations.", ConvergenceWarning)
```

[23]:
```
array([0, 0, 0, …, 0, 0, 0])
```

[24]:
```
prob2 = lg.predict_proba(read_Xtest2)
prob2
```

[24]:
```
array([[0.98888072, 0.01111928],
       [0.99189012, 0.00810988],
       [0.99457013, 0.00542987],
       …,
       [0.9892227 , 0.0107773 ],
       [0.99568563, 0.00431437],
       [0.99380961, 0.00619039]])
```

[25]:
```
lg_matrix = metrics.confusion_matrix(read_ytest2, y_pred2)
lg_matrix
```

[25]:
```
array([[14599,     0],
       [   50,     0]])
```

[26]:
```
target_names1 = ['Not in 30 days', 'Readmitted within 30 days']
print("", classification_report(read_ytest2, y_pred2,␣
 ↪target_names=target_names1))
```

```
                          precision    recall  f1-score   support

           Not in 30 days       1.00      1.00      1.00     14599
Readmitted within 30 days       0.00      0.00      0.00        50

                 accuracy                           1.00     14649
                macro avg       0.50      0.50      0.50     14649
             weighted avg       0.99      1.00      0.99     14649


/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/metrics/classification.py:1437: UndefinedMetricWarning:
Precision and F-score are ill-defined and being set to 0.0 in labels with no
predicted samples.
  'precision', 'predicted', average, warn_for)
```

[27]:
```
lg_probs = lg.predict_proba(read_Xtest2)[:,1]
print(roc_auc_score(read_ytest2, lg_probs))
```

```
0.4787697787519694
```

[28]:
```
import scipy.stats
def mean_confidence_interval(data, confidence=0.95):
    a = 1.0 * np.array(data)
    n = len(a)
    m, se = np.mean(a), scipy.stats.sem(a)
    h = se * scipy.stats.t.ppf((1 + confidence) / 2., n-1)
    return m, m-h, m+h
mean_confidence_interval(read_ytest2, confidence=0.95)
```

[28]:
```
(0.003413202266366305, array([0.00246863]), array([0.00435777]))
```

[29]:
```
import numpy as np, scipy.stats as st
st.t.interval(0.95, len(read_ytest2)-1, loc=np.mean(read_ytest2), scale=st.
 ↪sem(read_ytest2))
```

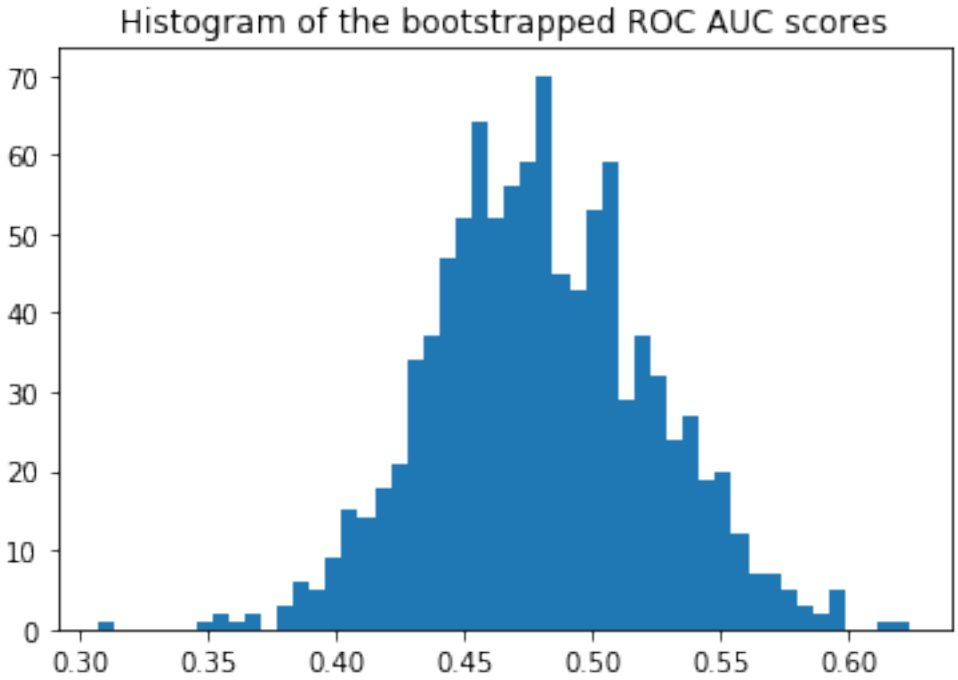
[29]:
```
(array([0.00246863]), array([0.00435777]))
```

[30]:
```
read_ytest2=read_ytest2.values
```

[31]:
```
#Boostrapping calculated 95% CI
y_pred = lg_probs
y_true = read_ytest2

print("Original ROC area: {:0.4f}".format(roc_auc_score(y_true, y_pred)))

n_bootstraps = 1000
rng_seed = 42  # control reproducibility
bootstrapped_scores = []

rng = np.random.RandomState(rng_seed)
for i in range(n_bootstraps):
    # bootstrap by sampling with replacement on the prediction indices
    indices = rng.randint(0, len(y_pred), len(y_pred))
    if len(np.unique(y_true[indices])) < 2:
        # We need at least one positive and one negative sample for ROC AUC
        # to be defined: reject the sample
        continue

    score = roc_auc_score(y_true[indices], y_pred[indices])
    bootstrapped_scores.append(score)
    #print("Bootstrap #{} ROC area: {:0.3f}".format(i + 1, score))
```

```
import matplotlib.pyplot as plt
plt.hist(bootstrapped_scores, bins=50)
plt.title('Histogram of the bootstrapped ROC AUC scores')
plt.show()

sorted_scores = np.array(bootstrapped_scores)
sorted_scores.sort()

# Computing the lower and upper bound of the 90% confidence interval
# You can change the bounds percentiles to 0.025 and 0.975 to get
# a 95% confidence interval instead.
confidence_lower = sorted_scores[int(0.05 * len(sorted_scores))]
confidence_upper = sorted_scores[int(0.95 * len(sorted_scores))]
print("Confidence interval for the score: [{:0.4f} - {:0.4}]".format(
    confidence_lower, confidence_upper))
```

```
Original ROC area: 0.4788
```




```
Confidence interval for the score: [0.4106 - 0.5503]
```

[32]:
```
#pROC calculated 95% CI without bootstrapping
alpha = .95
read_ytest2=read_ytest2.reshape((14649,))
y_pred = lg_probs
y_true = read_ytest2
```

```
auc, auc_cov = delong_roc_variance(
    y_true,
    y_pred)

auc_std = np.sqrt(auc_cov)
lower_upper_q = np.abs(np.array([0, 1]) - (1 - alpha) / 2)

ci = stats.norm.ppf(
    lower_upper_q,
    loc=auc,
    scale=auc_std)

ci[ci > 1] = 1

print('AUC:', auc)
print('AUC COV:', auc_cov)
print('95% AUC CI:', ci)
```

```
AUC: 0.4787697787519693
AUC COV: 0.00188641732159785
95% AUC CI: [0.39364285 0.56389671]
```

[ ]:

5 Artificial Neural Network

5.1 SMOTE First

[33]:
```
# !pip install imblearn
```

[34]:
```
from imblearn.over_sampling import SMOTE
```

```
Using TensorFlow backend.
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorflow/python/framework/dtypes.py:516: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorflow/python/framework/dtypes.py:517: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorflow/python/framework/dtypes.py:518: FutureWarning: Passing
```

```
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorflow/python/framework/dtypes.py:519: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorflow/python/framework/dtypes.py:520: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorflow/python/framework/dtypes.py:525: FutureWarning: Passing
(type, 1) or '1type' as a synonym of type is deprecated; in a future version of
numpy, it will be understood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorboard/compat/tensorflow_stub/dtypes.py:541: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint8 = np.dtype([("qint8", np.int8, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorboard/compat/tensorflow_stub/dtypes.py:542: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint8 = np.dtype([("quint8", np.uint8, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorboard/compat/tensorflow_stub/dtypes.py:543: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint16 = np.dtype([("qint16", np.int16, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorboard/compat/tensorflow_stub/dtypes.py:544: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_quint16 = np.dtype([("quint16", np.uint16, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorboard/compat/tensorflow_stub/dtypes.py:545: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  _np_qint32 = np.dtype([("qint32", np.int32, 1)])
/Users/zhongyizhang/env/lib/python3.7/site-
packages/tensorboard/compat/tensorflow_stub/dtypes.py:550: FutureWarning:
Passing (type, 1) or '1type' as a synonym of type is deprecated; in a future
version of numpy, it will be understood as (type, (1,)) / '(1,)type'.
  np_resource = np.dtype([("resource", np.ubyte, 1)])
```

[35]:
```
smt = SMOTE()
X_train = read_Xtrain2
X_test = read_Xtest2
y_train = read_ytrain2
y_test = read_ytest2
X_train, y_train = smt.fit_sample(X_train, y_train)
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/utils/validation.py:724: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

5.1.1 To test for the SMOTE

[36]:
```
read_ytrain2.shape
```

[36]: (21494, 1)

[37]:
```
read_ytrain2[read_ytrain2['outcome']==0].shape
```

[37]: (21416, 1)

[38]:
```
read_ytrain2[read_ytrain2['outcome']==1].shape
```

[38]: (78, 1)

[39]:
```
X_train.shape
```

[39]: (42832, 19)

[40]:
```
y_train = pd.DataFrame(y_train)
y_train.columns = ['outcome']
y_train[y_train['outcome']==0].shape
```

[40]: (21416, 1)

[41]:
```
y_train[y_train['outcome']==1].shape
```

[41]: (21416, 1)

[42]:
```
X_train.shape
```

[42]: (42832, 19)

5.2 ANN from here

[43]:
```
from sklearn.preprocessing import StandardScaler
scaler = StandardScaler()
# Fit only to the training data
scaler = scaler.fit(X_train)
X_trains = scaler.transform(X_train)
X_tests = scaler.transform(X_test)
# y_train
# y_test
```

[44]:
```
from sklearn.neural_network import MLPClassifier
mlp = MLPClassifier(solver='lbfgs', random_state=1)
mlp = mlp.fit(X_trains, y_train)
ann_pred1 = mlp.predict(X_tests)
ann_pred1
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/neural_network/multilayer_perceptron.py:921:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
```

[44]:
```
array([0, 0, 0, …, 0, 0, 0])
```

[45]:
```
prob3 = mlp.predict_proba(X_tests)
prob3
```

[45]:
```
array([[1.00000000e+00, 3.74902486e-14],
       [1.00000000e+00, 4.31252572e-29],
       [1.00000000e+00, 2.76899710e-40],
       …,
       [1.00000000e+00, 6.38717130e-58],
       [1.00000000e+00, 1.85018221e-22],
       [1.00000000e+00, 4.60875037e-51]])
```

[46]:
```
ann_matrix = metrics.confusion_matrix(y_test, ann_pred1)
ann_matrix
```

[46]:
```
array([[14515,    84],
       [   50,     0]])
```

[47]:
```
target_names1 = ['Not in 30 days', 'Readmitted within 30 days']
print("", classification_report(y_test, ann_pred1,
                                target_names=target_names1))
```

	precision	recall	f1-score	support
Not in 30 days	1.00	0.99	1.00	14599
Readmitted within 30 days	0.00	0.00	0.00	50
accuracy			0.99	14649
macro avg	0.50	0.50	0.50	14649
weighted avg	0.99	0.99	0.99	14649

[48]:
```
ann_probs = mlp.predict_proba(X_tests)[:,1]
print(roc_auc_score(y_test, ann_probs))
```

```
0.505211315843551
```

[49]:
```
mean_confidence_interval(y_test, confidence=0.95)
```

[49]:
```
(0.003413202266366305, 0.0024686339150578173, 0.004357770617674793)
```

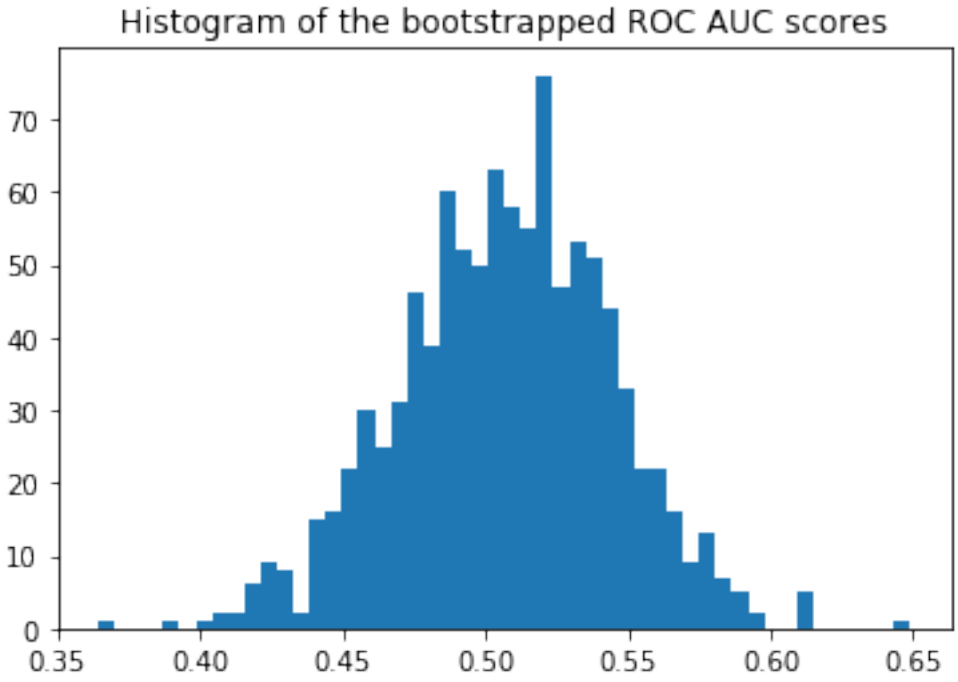
[50]:
```
st.t.interval(0.95, len(y_test)-1,
              loc=np.mean(y_test), scale=st.sem(y_test))
```

[50]:
```
(0.0024686339150578173, 0.004357770617674793)
```

[51]:
```
#Boostrapping calculated 95% CI
y_pred = ann_probs
y_true = y_test

print("Original ROC area: {:0.4f}".format(roc_auc_score(y_true, y_pred)))

n_bootstraps = 1000
rng_seed = 42  # control reproducibility
bootstrapped_scores = []

rng = np.random.RandomState(rng_seed)
for i in range(n_bootstraps):
    # bootstrap by sampling with replacement on the prediction indices
    indices = rng.randint(0, len(y_pred), len(y_pred))
    if len(np.unique(y_true[indices])) < 2:
        # We need at least one positive and one negative sample for ROC AUC
        # to be defined: reject the sample
        continue

    score = roc_auc_score(y_true[indices], y_pred[indices])
    bootstrapped_scores.append(score)
    #print("Bootstrap #{} ROC area: {:0.3f}".format(i + 1, score))

import matplotlib.pyplot as plt
```

```
plt.hist(bootstrapped_scores, bins=50)
plt.title('Histogram of the bootstrapped ROC AUC scores')
plt.show()

sorted_scores = np.array(bootstrapped_scores)
sorted_scores.sort()

# Computing the lower and upper bound of the 90% confidence interval
# You can change the bounds percentiles to 0.025 and 0.975 to get
# a 95% confidence interval instead.
confidence_lower = sorted_scores[int(0.05 * len(sorted_scores))]
confidence_upper = sorted_scores[int(0.95 * len(sorted_scores))]
print("Confidence interval for the score: [{:0.4f} - {:0.4}]".format(
    confidence_lower, confidence_upper))
```

```
Original ROC area: 0.5052
```




```
Confidence interval for the score: [0.4457 - 0.5661]
```

[52]:
```
#pROC calculated 95% CI without bootstrapping
alpha = .95
y_pred = ann_probs
y_true = y_test

auc, auc_cov = delong_roc_variance(
```

```
    y_true,
    y_pred)

auc_std = np.sqrt(auc_cov)
lower_upper_q = np.abs(np.array([0, 1]) - (1 - alpha) / 2)

ci = stats.norm.ppf(
    lower_upper_q,
    loc=auc,
    scale=auc_std)

ci[ci > 1] = 1

print('AUC:', auc)
print('AUC COV:', auc_cov)
print('95% AUC CI:', ci)
```

```
AUC: 0.505211315843551
AUC COV: 0.0014218917463916226
95% AUC CI: [0.43130503 0.5791176 ]
```

[ ]:

---

6 Section 2: Gusto Study

6.0.1 Using the training datasets, create the following models:

1. GLM model : This model utilizes all features to predict 30-day mortality in a logistic regression framework.
2. Ridge Regression model : This model utilizes all features to predict 30-day mortality in a logistic regression framework with regularization. Utilize a 5 fold cross validation to build the parameters for your model.

7 Gusto

[53]:
```
gusto = pd.read_csv("gusto_data.csv")
gusto['GROUP'] = gusto['GROUP'].replace('west',0)
gusto['GROUP'] = gusto['GROUP'].replace('sample2',1)
gusto['GROUP'] = gusto['GROUP'].replace('sample4',2)
gusto['GROUP'] = gusto['GROUP'].replace('sample5',3)
gusto['GROUP'] = gusto['GROUP'].astype('category').cat.codes
```

[54]:
```
gu_train = gusto.loc[(gusto['GROUP'] == 1
                      ) | (gusto['GROUP'] == 2
                          ) | (gusto['GROUP'] == 3)]
gu_test = gusto[gusto['GROUP']==0]

gu_Xtrain = gu_train.drop("DAY30",axis=1)
gu_ytrain = gu_train[['DAY30']]
gu_Xtest = gu_test.drop("DAY30",axis=1)
gu_ytest = gu_test[['DAY30']]
```

8 GLM Model

[55]:
```
lg2 = LogisticRegression()
lg2= lg2.fit(gu_Xtrain, gu_ytrain)
gu_y_pred = lg2.predict(gu_Xtest)
gu_y_pred
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/linear_model/logistic.py:432: FutureWarning: Default solver
will be changed to 'lbfgs' in 0.22. Specify a solver to silence this warning.
  FutureWarning)
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/utils/validation.py:724: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

[55]:
```
array([0, 0, 0, …, 0, 0, 0])
```

[56]:
```
gu_y_pred.shape
```

[56]:
```
(2188,)
```

[57]:
```
prob4 = lg2.predict_proba(gu_Xtest)
prob4
```

[57]:
```
array([[0.90879031, 0.09120969],
       [0.96328343, 0.03671657],
       [0.96116893, 0.03883107],
       …,
       [0.9623824 , 0.0376176 ],
       [0.89408582, 0.10591418],
       [0.97521901, 0.02478099]])
```

[58]:
```
lg_matrix2 = metrics.confusion_matrix(gu_ytest, gu_y_pred)
lg_matrix2
```

[58]:
```
array([[2037,   16],
       [ 114,   21]])
```

[59]:
```
target_names2 = ['Still alive at 30 day', 'Died in 30 days']
print("", classification_report(gu_ytest, gu_y_pred,␣
 ↪target_names=target_names2))
```

```
                      precision    recall  f1-score   support

Still alive at 30 day       0.95      0.99      0.97      2053
      Died in 30 days       0.57      0.16      0.24       135

             accuracy                           0.94      2188
            macro avg       0.76      0.57      0.61      2188
         weighted avg       0.92      0.94      0.92      2188
```

[60]:
```
lg2_probs = lg2.predict_proba(gu_Xtest)[:,1]
print(roc_auc_score(gu_ytest, lg2_probs))
```

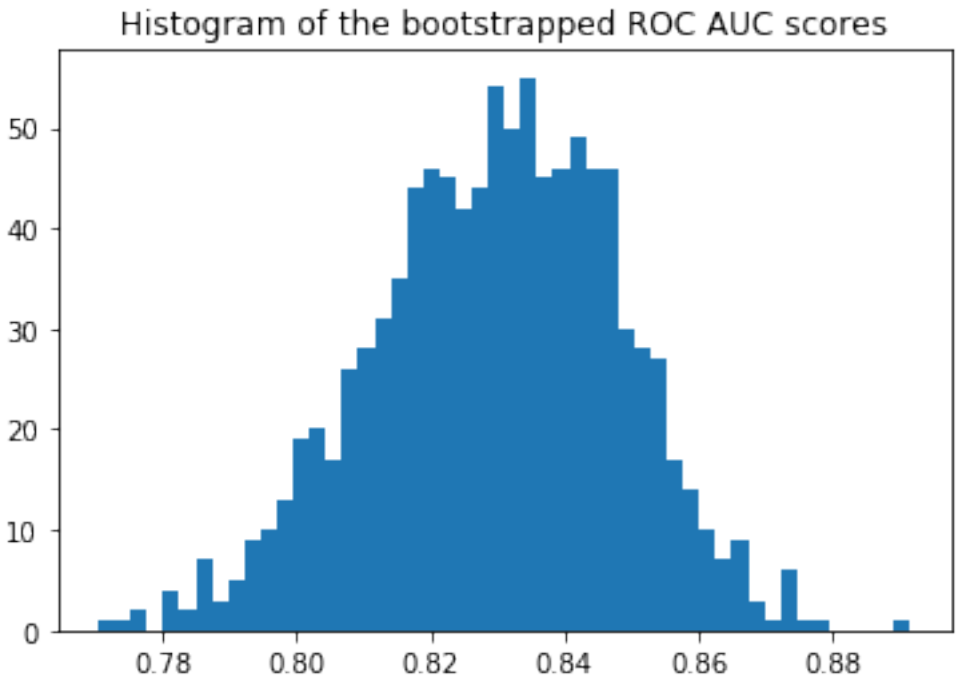
```
0.8284606086846712
```

[61]:
```
gu_ytest=gu_ytest.values
```

[62]:
```
#Boostrapping calculated 95% CI
y_pred = lg2_probs
y_true = gu_ytest

print("Original ROC area: {:0.4f}".format(roc_auc_score(y_true, y_pred)))

n_bootstraps = 1000
rng_seed = 42  # control reproducibility
bootstrapped_scores = []

rng = np.random.RandomState(rng_seed)
for i in range(n_bootstraps):
    # bootstrap by sampling with replacement on the prediction indices
    indices = rng.randint(0, len(y_pred), len(y_pred))
    if len(np.unique(y_true[indices])) < 2:
        # We need at least one positive and one negative sample for ROC AUC
        # to be defined: reject the sample
        continue

    score = roc_auc_score(y_true[indices], y_pred[indices])
```

```
    bootstrapped_scores.append(score)
    #print("Bootstrap #{} ROC area: {:0.3f}".format(i + 1, score))

import matplotlib.pyplot as plt
plt.hist(bootstrapped_scores, bins=50)
plt.title('Histogram of the bootstrapped ROC AUC scores')
plt.show()

sorted_scores = np.array(bootstrapped_scores)
sorted_scores.sort()

# Computing the lower and upper bound of the 90% confidence interval
# You can change the bounds percentiles to 0.025 and 0.975 to get
# a 95% confidence interval instead.
confidence_lower = sorted_scores[int(0.05 * len(sorted_scores))]
confidence_upper = sorted_scores[int(0.95 * len(sorted_scores))]
print("Confidence interval for the score: [{:0.4f} - {:0.4}]".format(
    confidence_lower, confidence_upper))
```

```
Original ROC area: 0.8285
```




```
Confidence interval for the score: [0.7985 - 0.8585]
```

[63]:
```
#pROC calculated 95% CI without bootstrapping
alpha = .95
gu_ytest = gu_ytest.reshape((2188,))
y_pred = lg2_probs
y_true = gu_ytest

auc, auc_cov = delong_roc_variance(
    y_true,
    y_pred)

auc_std = np.sqrt(auc_cov)
lower_upper_q = np.abs(np.array([0, 1]) - (1 - alpha) / 2)

ci = stats.norm.ppf(
    lower_upper_q,
    loc=auc,
    scale=auc_std)

ci[ci > 1] = 1

print('AUC:', auc)
print('AUC COV:', auc_cov)
print('95% AUC CI:', ci)
```

```
AUC: 0.8284606086846711
AUC COV: 0.0003479545222665671
95% AUC CI: [0.79190034 0.86502087]
```

[ ]:
```

```

9 Ridge Regression Model

[64]:
```
from sklearn.linear_model import Ridge
ridge_model = Ridge(alpha = 1, solver='cholesky')
# ridge_model = RidgeClassifier(alpha = 1)

ridge_model.fit(gu_Xtrain, gu_ytrain)
gu_regul = ridge_model.predict(gu_Xtest)
auc = roc_auc_score(gu_ytest, gu_regul)
auc
```

[64]: 0.8271436560769245

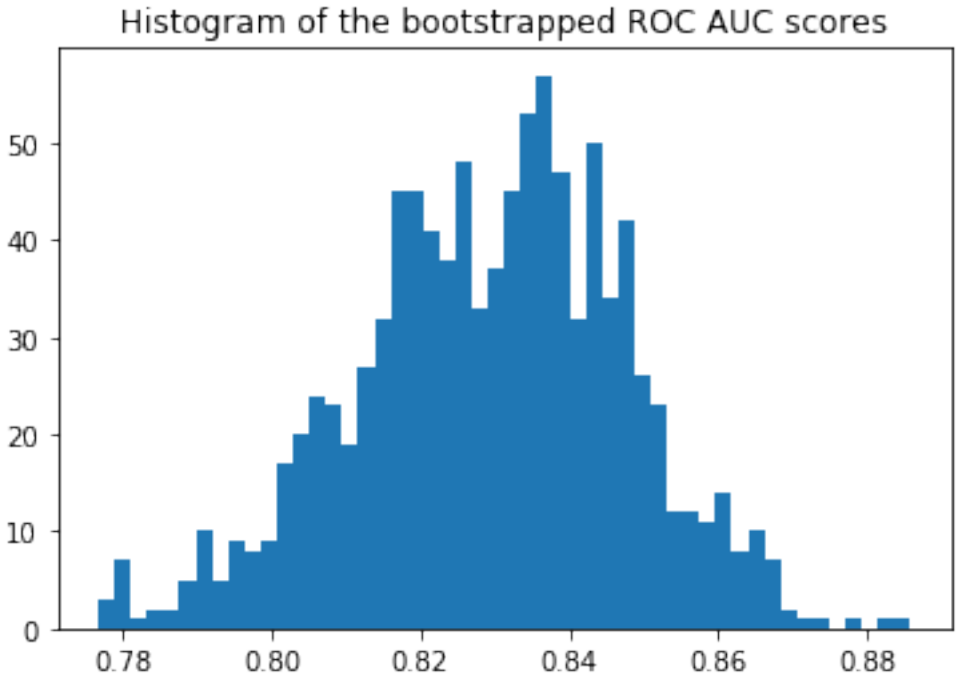
[65]:
```
from sklearn.linear_model import RidgeCV
```

```
ridgecv = RidgeCV(alphas=[1e-3, 1e-2, 1e-1, 1, 10], cv=5, fit_intercept=True,␣
↪scoring=None, normalize=False)
ridgecv=ridgecv.fit(gu_Xtrain,gu_ytrain)
gu_ridgecv = ridgecv.predict(gu_Xtest)
roc_auc_score(gu_ytest, gu_ridgecv)
```

[65]: 0.8279590842669263

[66]:
```
#Boostrapping calculated 95% CI
y_pred = gu_ridgecv
y_true = gu_ytest

print("Original ROC area: {:0.4f}".format(roc_auc_score(y_true, y_pred)))

n_bootstraps = 1000
rng_seed = 42  # control reproducibility
bootstrapped_scores = []

rng = np.random.RandomState(rng_seed)
for i in range(n_bootstraps):
    # bootstrap by sampling with replacement on the prediction indices
    indices = rng.randint(0, len(y_pred), len(y_pred))
    if len(np.unique(y_true[indices])) < 2:
        # We need at least one positive and one negative sample for ROC AUC
        # to be defined: reject the sample
        continue

    score = roc_auc_score(y_true[indices], y_pred[indices])
    bootstrapped_scores.append(score)
    #print("Bootstrap #{} ROC area: {:0.3f}".format(i + 1, score))

import matplotlib.pyplot as plt
plt.hist(bootstrapped_scores, bins=50)
plt.title('Histogram of the bootstrapped ROC AUC scores')
plt.show()

sorted_scores = np.array(bootstrapped_scores)
sorted_scores.sort()

# Computing the lower and upper bound of the 90% confidence interval
# You can change the bounds percentiles to 0.025 and 0.975 to get
# a 95% confidence interval instead.
confidence_lower = sorted_scores[int(0.05 * len(sorted_scores))]
confidence_upper = sorted_scores[int(0.95 * len(sorted_scores))]
print("Confidence interval for the score: [{:0.4f} - {:0.4}]".format(
    confidence_lower, confidence_upper))
```

```
Original ROC area: 0.8280
```




```
Confidence interval for the score: [0.7982 - 0.8586]
```

[67]:
```
#pROC calculated 95% CI without bootstrapping
alpha = .95
gu_ridgecv = gu_ridgecv.reshape((2188,))
y_pred = gu_ridgecv
y_true = gu_ytest

auc, auc_cov = delong_roc_variance(
    y_true,
    y_pred)

auc_std = np.sqrt(auc_cov)
lower_upper_q = np.abs(np.array([0, 1]) - (1 - alpha) / 2)

ci = stats.norm.ppf(
    lower_upper_q,
    loc=auc,
    scale=auc_std)

ci[ci > 1] = 1

print('AUC:', auc)
```

```
print('AUC COV:', auc_cov)
print('95% AUC CI:', ci)
```

```
AUC: 0.8279590842669264
AUC COV: 0.0003523557006508896
95% AUC CI: [0.79116833 0.86474984]
```

[ ]:

10 Artificial Neural Network

[68]:
```
scaler = StandardScaler()
# Fit only to the training data
scaler = scaler.fit(gu_Xtrain)
gu_Xtrains = scaler.transform(gu_Xtrain)
gu_Xtests = scaler.transform(gu_Xtest)
```

[69]:
```
mlp2 = MLPClassifier(solver='lbfgs', random_state=1)
mlp2 = mlp2.fit(gu_Xtrains, gu_ytrain)
ann_pred2 = mlp2.predict(gu_Xtests)
ann_pred2
```

```
/Library/Frameworks/Python.framework/Versions/3.7/lib/python3.7/site-
packages/sklearn/neural_network/multilayer_perceptron.py:921:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
```

[69]:
```
array([0, 0, 0, …, 0, 0, 0])
```

[70]:
```
prob5 = mlp2.predict_proba(gu_Xtests)
prob5
```

[70]:
```
array([[1.00000000e+00, 4.92987998e-92],
       [1.00000000e+00, 3.30660487e-78],
       [1.00000000e+00, 5.34809233e-83],
       …,
       [1.00000000e+00, 1.21594736e-30],
       [1.00000000e+00, 8.23828743e-48],
       [1.00000000e+00, 8.12154336e-39]])
```

[71]:
```
ann_matrix2 = metrics.confusion_matrix(gu_ytest, ann_pred2)
ann_matrix2
```

[71]:
```
array([[1947,  106],
       [  93,   42]])
```

[72]:
```
target_names2 = ['Still alive at 30 day', 'Died in 30 days']
print("", classification_report(gu_ytest, ann_pred2,␣
 ↪target_names=target_names2))
```

```
                        precision    recall  f1-score   support

Still alive at 30 day       0.95      0.95      0.95      2053
      Died in 30 days       0.28      0.31      0.30       135

             accuracy                           0.91      2188
            macro avg       0.62      0.63      0.62      2188
         weighted avg       0.91      0.91      0.91      2188
```

[73]:
```
ann_probs2 = mlp2.predict_proba(gu_Xtests)[:,1]
print(roc_auc_score(gu_ytest, ann_probs2))
```

```
0.759576771120853
```

[74]:
```
mean_confidence_interval(gu_ytest, confidence=0.95)
```

[74]:
```
(0.06170018281535649, 0.051610485002938786, 0.0717898806277742)
```

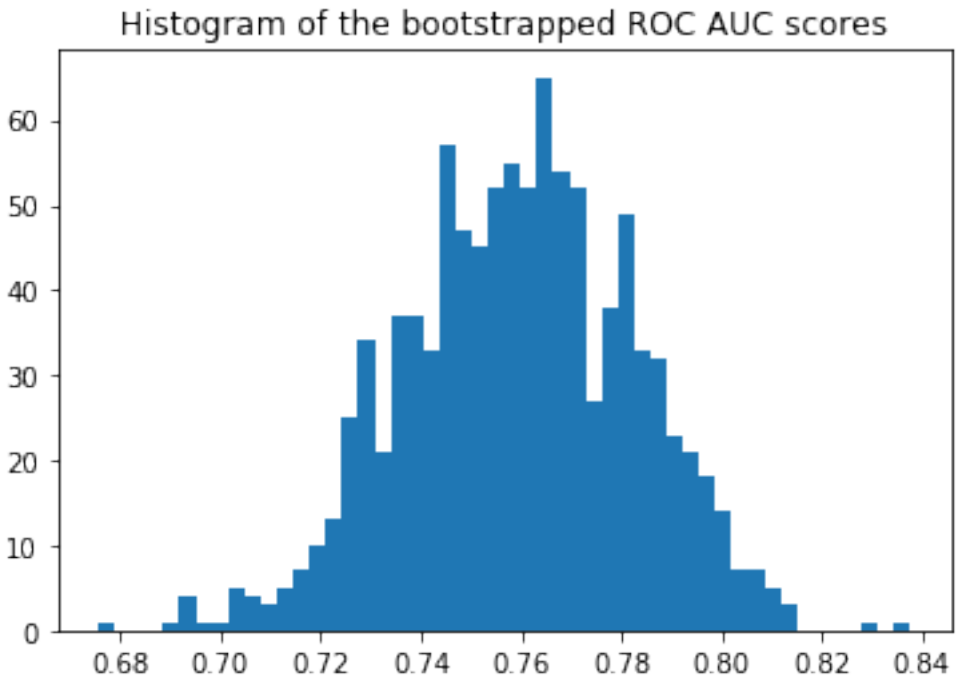
[75]:
```
st.t.interval(0.95, len(gu_ytest)-1,
              loc=np.mean(gu_ytest), scale=st.sem(gu_ytest))
```

[75]:
```
(0.051610485002938786, 0.0717898806277742)
```

[76]:
```
#Boostrapping calculated 95% CI
y_pred = ann_probs2
y_true = gu_ytest

print("Original ROC area: {:0.4f}".format(roc_auc_score(y_true, y_pred)))

n_bootstraps = 1000
rng_seed = 42  # control reproducibility
bootstrapped_scores = []

rng = np.random.RandomState(rng_seed)
for i in range(n_bootstraps):
    # bootstrap by sampling with replacement on the prediction indices
    indices = rng.randint(0, len(y_pred), len(y_pred))
    if len(np.unique(y_true[indices])) < 2:
        # We need at least one positive and one negative sample for ROC AUC
```

```
        # to be defined: reject the sample
        continue

    score = roc_auc_score(y_true[indices], y_pred[indices])
    bootstrapped_scores.append(score)
    #print("Bootstrap #{} ROC area: {:0.3f}".format(i + 1, score))

import matplotlib.pyplot as plt
plt.hist(bootstrapped_scores, bins=50)
plt.title('Histogram of the bootstrapped ROC AUC scores')
plt.show()

sorted_scores = np.array(bootstrapped_scores)
sorted_scores.sort()

# Computing the lower and upper bound of the 90% confidence interval
# You can change the bounds percentiles to 0.025 and 0.975 to get
# a 95% confidence interval instead.
confidence_lower = sorted_scores[int(0.05 * len(sorted_scores))]
confidence_upper = sorted_scores[int(0.95 * len(sorted_scores))]
print("Confidence interval for the score: [{:0.4f} - {:0.4}]".format(
    confidence_lower, confidence_upper))
```

```
Original ROC area: 0.7596
```



```
Confidence interval for the score: [0.7232 - 0.7963]
```

[77]:
```
#pROC calculated 95% CI without bootstrapping
alpha = .95
y_pred = ann_probs2
y_true = gu_ytest

auc, auc_cov = delong_roc_variance(
    y_true,
    y_pred)

auc_std = np.sqrt(auc_cov)
lower_upper_q = np.abs(np.array([0, 1]) - (1 - alpha) / 2)

ci = stats.norm.ppf(
    lower_upper_q,
    loc=auc,
    scale=auc_std)

ci[ci > 1] = 1

print('AUC:', auc)
print('AUC COV:', auc_cov)
print('95% AUC CI:', ci)
```

```
AUC: 0.759576771120853
AUC COV: 0.0005295762772071846
95% AUC CI: [0.71447305 0.80468049]
```

[ ]:

[ ]:

[ ]: