

CSCI2291 Homework 6

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Problem 1

(a) We will use the following code as a solution:

```
1 higgs_dataset = skd.fetch_openml("higgs", version=1, as_frame=True)
2 data = higgs_dataset.data
3 target = higgs_dataset.target
4
5 imp = Imputer(missing_values=np.nan, strategy='mean')
6 data = imp.fit_transform(data)
7
8 scaler = StandardScaler()
9 data = scaler.fit_transform(data)
10
11 lr = skl.LogisticRegression().fit(data, target)
12 score = lr.score(data, target)
13 print(f"Classification Accuracy: ' :<30){score}")
```

We begin by fetching the **higgs** data set from OpenML. Next, we assign local variables to both the data and target sets. Using the Simple Imputer from **sklearn**, we clean up `np.nan` values by replacing them with mean values. Then we finish our preprocessing by using the **sklearn** class **StandardScaler**, to standardize that attributes to have a zero mean and a variance of 1. Now, we fit a logistic regression to the dataset and target vector. We can see that testing the model over our dataset, we see the following classification accuracy:

```
1 >>> Classification Accuracy: 0.6412340642529322
```

We can see that our model has a 65% fit to the dataset, it can explain much of the variations in the data, but there is still room for improvement.

(b) We will use the following code as a solution:

```
1 higgs_dataset = skd.fetch_openml("higgs", version=1, as_frame=True)
2 data = higgs_dataset.data
3 target = higgs_dataset.target
4
5 imp = Imputer(missing_values=np.nan, strategy='mean')
6 data = imp.fit_transform(data)
7
8 scaler = skp.StandardScaler()
9 data = scaler.fit_transform(data)
10
11 lr = skl.LogisticRegression().fit(data, target)
12 cross_score = cross_val_score(lr, data, target, cv=10)
13 print(f"{'Cross Scores:':<20}{cross_score}")
14 print(f"{'Mean:':<20}{np.mean(cross_score)}")
15 print(f"{'STD Deviation:':<20}{np.std(cross_score)}")
```

We can see that lines 1 – 11 are identical to part **a**. Now, in we use the **cross_val_score** function in **sklearn** to estimate the generalization accuracy of our logistic regression over the dataset.

We will set the number of folds to 10, by specifying the **cv** parameter. We see that we have the following results:

```
1 >>> Cross Scores:      [0.644 0.647 0.638 0.633 0.639 0.645 0.635 0.641 0.646 0.641]
2 >>> Mean:              0.641
3 >>> STD Deviation:     0.004
```

From these results, we can tell that our generally, our model has a score of .64 and is very consistent, as the standard deviation is less than 1%.

(c) We will use the following code as a solution:

```

1  higgs_dataset = skd.fetch_openml("higgs", version=1, as_frame=True)
2  data = higgs_dataset.data
3  target = higgs_dataset.target
4
5  imp = Imputer(missing_values=np.nan, strategy='mean')
6  data = imp.fit_transform(data)
7
8  scaler = skp.StandardScaler()
9  data = scaler.fit_transform(data)
10
11 lr = skl.LogisticRegression().fit(data, target)
12 folds = [2, 4, 8, 16, 32, 64]
13 for num in folds:
14     cross_score = cross_val_score(lr, data, target, cv=num)
15     print(f"-----{num} folds-----")
16     print(f"Mean: ' :<20>{np.mean(cross_score)}")
17     print(f"STD Deviation: ' :<20>{np.std(cross_score)}")

```

Again, we see that lines 1 – 11 are identical to parts **a** and **b**. This time, after fitting our model, we loop over the list `[2, 4, 8, 16, 32, 64]`, and we run **cross_val_scores** with k number of folds for all $k \in [2, 4, 8, 16, 32, 64]$. Printing our results for each iteration, we see that

```

1 >>> Mean: 0.6404385517593065
2 >>> STD Deviation: 0.0001325854156042916
3 >>> -----4 folds-----
4 >>> Mean: 0.6406425368695239
5 >>> STD Deviation: 0.003611404142075488
6 >>> -----8 folds-----
7 >>> Mean: 0.640928017787193
8 >>> STD Deviation: 0.003517847016119673
9 >>> -----16 folds-----
10 >>> Mean: 0.6406832208235512
11 >>> STD Deviation: 0.005178623142595439
12 >>> -----32 folds-----
13 >>> Mean: 0.6407547696450705
14 >>> STD Deviation: 0.0076560042992938875
15 >>> -----64 folds-----
16 >>> Mean: 0.6408055630779084
17 >>> STD Deviation: 0.011903801846240437

```

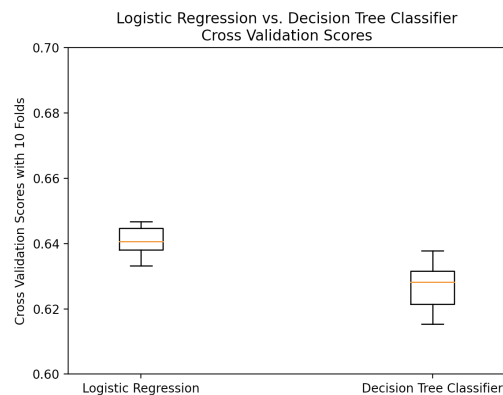
From this experiment, we can see that our mean value stays consistent for any number of folds. However, The standard deviation of our accuracy scores increase as we increase the number of folds. This is likely due to the fact that as we increase number of "folds" (divisions of the dataset) each of these smaller folds will be smaller and thus more "random". This will increase the chance that the models performance will decrease, because the "training set" is smaller and thus more random. This results in more deviation among all the individual tests, but the mean score remains steady.

Problem 2

(a) We will use the following code as a solution:

```
1  higgs_dataset = skd.fetch_openml("higgs", version=1, as_frame=True)
2  data = higgs_dataset.data
3  target = higgs_dataset.target
4
5  imp = Imputer(missing_values=np.nan, strategy='mean')
6  data = imp.fit_transform(data)
7
8  scaler = StandardScaler()
9  data = scaler.fit_transform(data)
10
11 lr = LogisticRegression().fit(data, target)
12 dtc = DecisionTreeClassifier().fit(data, target)
13 lr_score = cross_val_score(lr, data, target, cv=10)
14 dtc_score = cross_val_score(dtc, data, target, cv=10)
15
16 plt.boxplot([lr_score, dtc_score], positions=[-1, 1],
17             labels=["Logistic Regression", "Decision Tree Classifier"])
18 plt.ylim([.6, .7])
19 plt.ylabel("Cross Validation Scores with 10 Folds")
20 plt.title("Logistic Regression vs. Decision Tree Classifier\nCross Validation Scores")
21 plt.show()
```

Again, lines 1 – 11 are identical to problem 1. Then, we additionally fit a **DecisionTreeClassifier** model to the dataset and cross validate each model using **cross_val_score** with 10 folds. We then create a boxplots for each of our sets of 10 scores. After applying the appropriate labels and scaling, we see



This boxplot helps provide very useful insight into our results. We can clearly see that the mean of the Logistic Regression is slightly higher,

but only by a difference of approximately 1% or so. However, we can tell the the height of the Decision Tree Classifier is greater, which tells us that the Decision Tree Classifier has a higher standard deviation. This suggests that any given Decision Tree Classifier model is more likely to have be less accurate than any single Logistic Regression model. This is likely due to the methods used to create the models. Namely, the method used to generate the Decision Tree model enhances the specific noise of the training set, more so than the Logistic Regression models.

(b) We will use the following code as solution:

```
1 higgs_dataset = skd.fetch_openml("higgs", version=1, as_frame=True)
2 data = higgs_dataset.data
3 target = higgs_dataset.target
4
5 imp = Imputer(missing_values=np.nan, strategy='mean')
6 data = imp.fit_transform(data)
7
8 scaler = StandardScaler()
9 data = scaler.fit_transform(data)
10
11 lr = LogisticRegression().fit(data, target)
12 dtc = DecisionTreeClassifier().fit(data, target)
13 lr_score = cross_val_score(lr, data, target, cv=10)
14 dtc_score = cross_val_score(dtc, data, target, cv=10)
15
16 lr_score_stand = scaler.fit_transform(lr_score.reshape(-1, 1))[:, 0]
17 dtc_score_stand = scaler.fit_transform(dtc_score.reshape(-1, 1))[:, 0]
18
19 test_stand = ttest_ind(lr_score_stand, dtc_score, equal_var=True)
20 print(f"{'t-statistic:':<20}{test_stand[0]}")
21 print(f"{'p-value:':<20}{test_stand[1]}")
```

Again, lines 1 – 11 are the same as above. We next calculate the **cross_val_score** for each model. Then, we standardize the scores using the standard scaler. The arrays must be reshaped to 2D arrays to use the scaler, and then we take the column vector to pass to our test.

We can use a independent t-test, to calculate weather the variations in the means between the two scoresets are due to random chance. Printing our results we see that

```
1 >>> t-statistic:      -1.8796393366850002
2 >>> p-value:         0.07644491368115493
```

We can see that the p-value is very close to 0. Thus, this tells us that there is a very low probability that the variations in the means of the two sets are due to random chance. From this test we can conclude that the difference in means of the **cross_cal_scores** sets is unlikely to be a result of random chance.

Problem 3

- (a) We can set up 3 independent trials. The probability of success is $p = 0.2$, while the probability failure is 0.8. Let X_i be the event that the i^{th} trial is a success. Since these, trials are independent, we know that

$$\begin{aligned} P(X_1 \cap X_2 \cap X_3) &= P(X_1) \cdot P(X_2) \cdot P(X_3) \\ &= 0.2 \cdot 0.2 \cdot 0.2 = 0.2^3 = 0.008 \end{aligned}$$

So, we conclude that the probability of the model correctly predicting all three class labels is 0.008.

- (b) Let X be the number of correct predictions that the model makes in 10 trials. Then we state that

$$X \sim \text{Binom}(n, p)$$

where $n = 10$ and $p = 0.2$. Then, we can compute the probability that it will make 7 correct classifications:

$$\begin{aligned} P(x = 7) &= \binom{10}{7} p^7 (p - 1)^3 \\ &= (120)(0.2)^7 (0.8)^3 \\ &= (120)(0.0000128)(0.512) \\ &= (120)(0.0000065536) \\ &= (0.000786432) \end{aligned}$$

So we see that probability of the model will make 7 correct predictions in a set of 10 classifications is 0.079%

Problem 4

- (a) The current performance of AI-based algorithms still needs improvement. As stated in the article, "Given that automatic screening tools are actively being developed in research^{19,20,21,22,23} and have been shown to match specialist performance¹⁶, underdiagnosis in AI-based diagnostic algorithms can be a crucial concern if used in the clinical pipeline for patient triage." It is clear that progress has been made in the effort to utilize AI in the medical world, however, there is still a concern over the accuracy of the algorithms at this time, and their current rate of underdiagnosis could cause problems.
- (b) Misdiagnosis is when a patient is diagnosed with a condition, but it is labeled as less severe than it actually is. Conversely, underdiagnosis is when a patient is deemed to be healthy, when really they need medical attention. As stated in the paper, underdiagnosis is far more troubling as "underdiagnosis is potentially worse than misdiagnosis, because in the latter case, the patient still receives clinical care, and the clinician can use other symptoms and data sources to clarify the mistake".
- (c) As described in the paper, the term false-positive rate, is the rate at which the algorithms incorrectly assign the "no finding" label to patients. In other words, the **FPR** measures the rate at which patients are underdiagnosed by AI algorithms.
- (d) Gender, age, race, and socio-economic status all played a role in the underdiagnosis rates of the algorithms. According to **Fig.2a**, which shows the results for false-positive rates sorted by various status traits, the FPR for males was approximately 20%, while it was closer to 25% for females. Additionally, patients in the age range of 0 – 20 years old had an FPR of approximately 45%. The false-positive rate for blacks and hispanics was around 10% higher than for other races. And, finally, those on medicaid had approximately a 10% higher FPR, than patients on private insurance policies.
- (e) The article makes it quite clear that much of the bias that is present in the dataset and then amplified by the algorithms, stems from the

original diagnoses from which the dataset was created. This is likely a result of the inaccessability of healthcare ot underserved groups: "Patients with low socioeconomic status may have fewer interactions with the healthcare system, or they may be more likely to visit a teaching or research clinic where clinical reasoning or treatment plans may be different".

Additionally, looking at the table summary of all statistics, we see that the proportions of race present in the dataset, do not correspond to the ratial distribution of the 2020 US census:

Race	Data Set	US Census
Asian	3.2 %	5.9%
Black	18.6 %	12.1%
Hispanic	6.4 %	18.7%
Native	0.3 %	0.2%
White	67.6 %	57.8 %
Other	3.8 %	0.5%

We can see that Whites and Blacks are over represented relative to the population, while Asians and Hispanics are under represented in the data set used for the AI algorithms. This definetley can lead to a bias in the model, when it is used on the entire population, because the model may be skewed to better diagnosis a white patient, rather than a patient of another race.